



THE
COLOMBO
CONFERENCE

First International Conference on

**UNIVERSITY-INDUSTRY COLLABORATIONS
FOR SUSTAINABLE DEVELOPMENT
(ICSD)- 2024**

PROCEEDINGS BOOK

Editors

Prof. Ranjith Dissanayake

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The 1st International Conference on
University-Industry Collaborations for Sustainable Development – 2024
Colombo, Sri Lanka – 15th – 17th March 2024



**Proceedings of the 1st International Conference on University-Industry
Collaborations for Sustainable Development (ICSD 2024)**

15th – 17th March 2024, Colombo 07, Sri Lanka

Vision

To create a global platform that inspires and empowers University-Industry collaborations, driving sustainable solutions, innovative technologies, and entrepreneurial strategies for sustainable development

Mission

To facilitate dialogue, knowledge exchange, and partnerships among academia, industry, and policymakers. By integrating cutting-edge research, practical insights, and visionary thinking, the conference seeks to enhance university curricula, strengthen business links, and catalyze the development of innovative sustainable solutions that promote environmental and socio-economic growth

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PREFACE

Welcome to the First International Conference on University-Industry Collaborations for Sustainable Development (ICSD 2024), also known as The Colombo Conference. This distinguished gathering catalyzes the exchange of cutting-edge ideas, innovative technologies, and entrepreneurial strategies within the realm of agro-industries. With a commitment to fostering sustainability, the conference aims to propel university curricula into new dimensions, fortify business ties, and cultivate a fertile ground for invention, innovation, and entrepreneurship. Contained within this book are the full papers of research work spanning various sub-specialties, evidence of the diverse and impactful contributions made by scholars and practitioners alike. These papers are scheduled for presentation at parallel sessions from March 16th to 17th, 2024 at the gapHQ, Colombo 07, Sri Lanka. We extend our deepest appreciation to our esteemed keynote speakers, whose valuable insights have played a pivotal role in shaping the discourse on University-Industry Collaborations for Sustainable Development. The richness of this compilation is grateful much to the dedication and caliber of the contributing authors, who have presented research papers of exceptional quality. Each full paper featured in this book has undergone rigorous scrutiny by a panel of academic and professional experts, individuals distinguished in their respective fields. We express our sincere gratitude to these reviewers for their tireless efforts, which have elevated the scholarly standard of this collection. Acknowledgment is also due to the unwavering support and guidance provided by the local and international advisory committees, as well as the diligent members of the co-chairs committee. Their valuable input has been instrumental in arranging the success of this significant event. We extend our heartfelt thanks to all volunteers who have generously offered their time and expertise, contributing to the seamless execution of the conference. Moreover, we gratefully acknowledge the financial sponsorship generously provided by numerous organizations, whose support has been instrumental in ensuring the achievement of this international conference. It is our earnest hope, as editors, that this full paper book will serve as a valuable resource for the global research community engaged in studies related to University-Industry Collaborations for Sustainable Development. May the insights shared within these pages inspire and guide future endeavors toward a more sustainable and collaborative future.

Editors

Prof. Ranjith Dissanayake

Dr. Pradeep Gajanayake

The First International Conference on University-Industry Collaborations for Sustainable Development (ICSD 2024)

15th to 17th March 2024, gapHQ, Colombo 07, Sri Lanka

Message from the Conference Co-Chairs

It is with great pleasure that we extend a warm welcome to all participants of the Colombo Conference – the First International Conference on University-Industry Collaborations for Sustainable Development (ICSD 2024) in the vibrant city of Colombo, Sri Lanka. The chosen theme, "University-Industry Collaborations for Sustainable Development," resonates deeply with the global imperative for fostering innovative and sustainable research to shape a brighter future. In organizing this conference, our vision is to create a dynamic convergence point for talents, knowledge, and dedication. We believe that this platform will serve as a crucible for the generation of groundbreaking ideas and the exchange of expertise among participants dedicated to the cause of sustainable global development. Our conference explores diverse sub-topics within the sphere of sustainable development, focusing on the intricate interplay of academia and industry. We anticipate discussions spanning a wide range of subjects, each contributing to the overarching goal of advancing sustainable research practices for the benefit of future generations. The selected, leading full papers of the Colombo Conference (ICSD 2024) will be published by Springer Nature under the book series Proceedings in Technology Transfer. All other accepted papers will be published in a special volume of proceedings with an international standard book number (ISSN). The choice of Colombo as our host city holds significance, as it is a city steeped in rich heritage, unique architecture, cultural diversity, and natural beauty. We hope that amidst the intellectually stimulating sessions, you find moments to relish the distinctive charm and climate of Colombo. Our heartfelt gratitude goes out to our distinguished guests, keynote speakers, authors, members of the international advisory committee, and the dedicated editorial committee. We extend sincere appreciation to our sponsors and all those who have generously volunteered their time and efforts to ensure the success of this pivotal event. As conference co-chairs, we are honored to be part of this collaborative journey towards sustainable development. We look forward to witnessing the flourishing exchange of ideas and forging lasting connections during this memorable event.

Prof. Ranjith Dissanayke
Prof. G. Yugantha Jayasinghe
Prof. Sujeeva Setunga
Prof. Dilanthi Amaratunga
Prof. Lasith Gunawardena
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**AGROINDUSTRY'S TRENDS, PATTERNS, AND DEVELOPMENTAL
IMPACTS**

ICSD 024

THE EFFECT OF FRONT OF FRONT-OF-PACK LABEL INTENTION ON PURCHASE INTENTION OF BISCUITS: A CASE OF TRAFFIC LIGHT SYSTEM

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Abstract: Since June 2019, Sri Lanka has implemented the front-of-pack traffic light system, guiding consumers towards healthier and sustainable food choices. This study aims to assess the current status of the traffic light system on biscuit products and find out the impact of the front-of-pack label, with special concern on traffic light system on purchase intention of biscuits. Study utilized five different biscuit types; crackers, cream biscuits, wafers, Marie, and puff-type from different brands available in the local market. Fifty biscuits from different brands were considered. A database of biscuit labels was created using the photographs of front-of-pack and back-of-pack labels and label analysis was performed to understand the current status of the biscuit labels. Primary data collection tools were interviewer-administered, pretested, structured questionnaire and focus group discussions with retailers were instrumental, and stratified random sampling was used to select respondents from various retail forms; grocery stores, and supermarkets. A total of 200 respondents, encompassing 9 provinces of the country were used. Data analysis involved descriptive statistics, correlation, and multiple regression. Results indicated that the traffic light system was available on all biscuit products, but lacked consistency in label placement and size. Traffic lights were used to indicate the sugar, salt, and fat. Crackers were the only biscuit type in which all products met the green colour code for sugar content. Of the sample, 42% of respondents stated that they consider the traffic light system when purchasing biscuits and 64% of them were supermarket customers. Consumers recommend displaying the average sugar, salt, and fat content per serving on the front-of-pack label. 25% of parents stated, they often prioritize children's preferences over health-related factors when choosing biscuits. The price, taste, brand, family income, and Traffic-Light-system have a significant impact on the consumer biscuit purchase intention. Retailers reported that health-conscious consumers, women who could allocate more time to grocery shopping, actively seek nutritional information on product labels.

Keywords: Biscuit; Consumer; Purchase intention; Traffic-light system

1. Introduction

Nutritional labels play an important role in making healthier and sustainable food choices. With the emergence of non-communicable diet-related diseases, countries use nutrition labeling as a strategy that can be used to address the concern of unhealthy diets and that increases the awareness of the consumers about the nutritional properties of the food which can aid the purchase decisions of the consumers. (WHO, Nutrition Labeling: Policy Brief, 2020). Nutrition labeling includes ingredient lists, nutrient declarations, supplementary nutrition information, and nutrition and health claims (WHO, Nutrition Labeling: Policy Brief, 2020). Among them, supplementary nutrition information provides an overall summary score about the nutrient level and reflects the healthfulness of the product to the consumers. Front-of-pack labeling systems provide supplementary nutrition information and they are presented in front of food packages.

In 2019 Sri Lanka implemented the traffic light scheme, which is one of the front-of-pack labeling schemes and which indicates the sugar, salt, and fat content of the packaged food product. Red, Amber, and green colors are used to indicate the level of sugar, salt, and fat contents in the product. The biscuit stands as a versatile snack in the food industry, valued for its extended shelf life, diverse flavors, textures, and broad consumption. (Arepally, Reddy and Goswami,2020) Biscuits are a widely consumed snack in Sri Lanka. There are a large number of biscuit manufacturers in Sri Lanka with a large number of biscuit consumers. As biscuits are usually rich in sugar, fat, and salt, the front-of-pack traffic light system was introduced to empower individuals to make informed dietary decisions.

This research assesses the compliance and consistency of the traffic light system of the biscuit products and answers the question of do consumers actually consider the front of the pack label with the traffic light system when purchasing biscuits. This study is significant as most of the existing research mainly focused on the effect of traffic light systems on beverage purchases rather than snack products such as biscuits. Biscuits are a widely enjoyed snack among the people of Sri Lanka. This study provides valuable insights for refining and augmenting labeling strategies, thereby empowering consumers to make informed and health-conscious biscuit purchases.

The objectives of this study are to identify the current status of the traffic light system on the front-pack label of different biscuit products available in Sri Lanka, identify the consumer awareness of the traffic light system, and find out the impact of the front-of-pack label, special concern on traffic light system on purchase intention of biscuits. Consumer awareness of the front-of-pack traffic light system plays a major role in making healthy dietary choices.

2. Conceptual Framework

According to the consumer behavior theory, the consumer decision-making process is shaped by a number of factors. According to the Engel, Blackwell, and Minard model of consumer behavior, determinants of the consumer decision-making process are categorized into three broad categories. individual differences encompassing consumer resources, knowledge, attitudes, motives, personality values, and lifestyle; environmental influences such as culture, social class, personal influences, family, and situation; psychological processes include the steps of the consumer decision-making process. This study mainly focuses on the impact of the front-of-pack traffic light system among the various factors influencing consumers' biscuit purchase intentions.

The factors impacting consumer biscuit purchase intention can be categorized into three main categories based on consumer behaviour theory: the socio-economics of the consumer, product attributes, and shop factors. This study's conceptual framework (Figure 1) visually illustrates the interrelationships among these key variables. Biscuit purchase intention serves as the dependent variable, influenced by a range of independent variables. These encompass socio-economic factors, including age, gender, educational

level, occupation, income, and family size; product attributes like brand, price, taste, nutritional profile, the traffic light system, expiry date, and packaging; and shop-related aspects such as accessibility, parking facilities, customer service, and product placement on shelves.

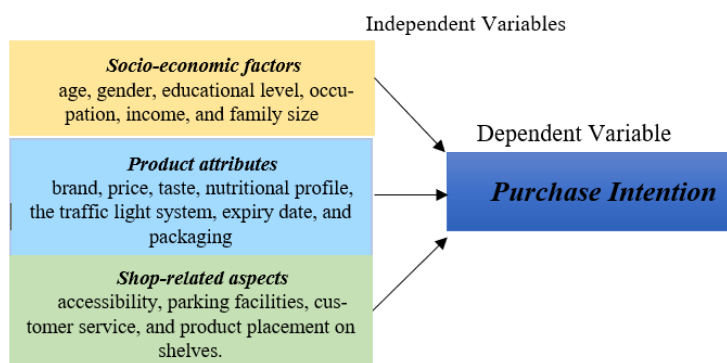


Figure 1: Conceptual framework of the study.

3. Methodology

3.1 Research Location, Sample, Sampling Method, and Data Collection Tools

This research consists of two sections. The first section aims to identify the current status of the traffic light system on biscuit products. For this purpose, the study utilized five different biscuit types: crackers, cream biscuits, wafers, Marie, and puff-type from various brands available in the local market. A total of fifty biscuit types from different brands were considered. Photographs of the front-of-pack, back-of-pack, and side views of the labels were taken by visiting several retail outlets, and data was analysed by creating a database.

Table 1: Biscuit type and the number of biscuit labels

<i>Biscuit Type and the number of biscuit labels</i>	
<i>Type of the Biscuit</i>	<i>Number of biscuit labels obtained</i>
<i>Crackers</i>	12
<i>Cream biscuits</i>	9
<i>wafers</i>	7
<i>Marie</i>	11
<i>Puff-type</i>	11

The next section of this research involved conducting a consumer survey and focused group discussions with retailers specifically aimed at assessing consumer awareness regarding the traffic light system on biscuit products and examining the influence of the front-of-pack traffic light system on biscuit purchase intentions. The consumer survey targeted the demographic of biscuit consumers in Sri Lanka. To achieve a representative sample, the stratified random sampling technique was applied within the country's nine provinces. The population of biscuit consumers was stratified into two distinct categories: those who visit supermarkets and those who frequent local grocery outlets. By specifically targeting both supermarket and local grocery outlet consumers within each province, ensured a proper representation of varying consumer preferences and purchasing habits. Through this approach, a total of 200 respondents were selected, with distribution across provinces as follows: Southern Province (30), Western Province (30), Sabaragamuwa Province (20), Uva Province (20), Central Province (20), Northern

Province (20), Eastern Province (20), North Central Province (20), and North Western Province (20). In each province, an equal division of respondents was maintained between supermarkets and grocery outlets. Interviews were conducted with the respondents after obtaining permission from the respective outlets, ensuring a balanced representation. To minimize potential biases, interviews were conducted by using every third consumer, facilitating a more varied and random selection of respondents.

3.2 An Overview of the Sample Profile

As mentioned above, the sample composition (Table 2) comprises respondents from diverse geographical regions, with a proper representation across Southern, Western, Sabaragamuwa, Uva, Central, Northern, Eastern, North-Central, and North-Western provinces. Gender distribution is relatively balanced, with 47.5% male and 52.5% female participants. The age distribution is varied, with the majority falling between 21 to 40 years old, primarily within the 21-30 and 31-40 age brackets, contributing 41.5% and 25.5%, respectively. The income distribution spans various categories, notably with 25% of respondents earning between Rs 60,000 to Rs 100,000, followed by 24% within the Rs 30,000 - Rs 60,000 category. Educationally, a significant portion has completed university education (61.5%), while 30.5% have studied up to the Advanced Level. Regarding parental status, 53% are parents, and 46% are not in the parental status. Occupation-wise, participants are diverse, with 31% in Government/Retired roles, 19.5% in Mid-level/Supervisory positions, and 13.5% in Senior-level/Managerial positions. The sample presents a wide representation across various demographics, reflecting a heterogeneous mix of backgrounds and characteristics.

Table 2: Sample profile

Sample profile		Fre- quency	Percentage %
Location	<i>Southern</i>	30	15
	<i>Western</i>	30	15
	<i>Sabaragamuwa</i>	20	10
	<i>Uva</i>	20	10
	<i>Central</i>	20	10
	<i>Northern</i>	20	10
	<i>Eastern</i>	20	10
	<i>North - Central</i>	20	10
	<i>North - Western</i>	20	10
Gender	<i>Male</i>	95	47.5
	<i>Female</i>	105	52.5
Age	<i>Below 21</i>	11	5.5
	<i>21 – 30</i>	83	41.5
	<i>31 – 40</i>	51	25.5
	<i>41 – 50</i>	25	12.5
	<i>51 – 60</i>	19	9.5
	<i>61 – 70</i>	10	5.0
	<i>Above 70</i>	1	0.5
Income (Family)	<i>Below Rs 10000</i>	26	13
	<i>Rs 10000 – 30000</i>	32	16
	<i>Rs 30000 – 60000</i>	48	24
	<i>Rs 60000 – 100000</i>	50	25
	<i>Rs 100000 – 150000</i>	20	10
	<i>Rs 150000 – 200000</i>	14	7
	<i>Above Rs 200000</i>	10	5
Level of Educa- tion	<i>Studied up to grade 5</i>	1	0.5
	<i>Studied up to Ordinary Level</i>	6	3
	<i>Studied up to Advanced Level</i>	61	30.5

	<i>Graduated from university/ higher education institution</i>	123	61.5
	<i>Completed master's degree / Ph.D.</i>	9	4.5
Parental Status	<i>Yes</i>	106	53
	<i>No</i>	93	46
Occupation	<i>Government/ Retired</i>	62	31
	<i>Mid-level/Supervisory</i>	39	19.5
	<i>Senior-level/Managerial</i>	27	13.5
	<i>Executive/Top management</i>	12	6
	<i>Entrepreneur</i>	20	10
	<i>Other/Unemployed</i>	40	20

3.3 Data Collection Tools

As Primary data collection tools interviewer-administered pretested structured questionnaire and focus group discussions with retailers were instrumental. The structured questionnaire was designed with a combination of closed-ended and open-ended questions. It comprised three key sections: socio-economic data, product attributes (with a particular focus on the traffic light system), and shop-related data. Each section aimed to gather specific information from the respondents. Two focused group discussions (FGD) were conducted with retailers for the same two strata; Supermarkets and grocery outlets using online platforms due to the limited time and resources. The focus group discussions were centered on gathering detailed insights into several aspects, including shifts in consumer preferences, the utilization of nutritional information and traffic light systems in biscuit purchases, emerging consumer trends, and the identification of customer segments exhibiting higher interest in seeking nutritional and health-related information during biscuit purchases.

3.4 Data Analysis Method

The analysis involved various statistical methods such as descriptive statistics, correlation, and multiple regression. The IBM SPSS-25 Statistical Package and MS Excel 2016 were employed for this purpose. The creation and analysis of the biscuit label database were accomplished using the MS Excel 2016 software package. Descriptive statistics and crosstabulation aided in identifying frequencies and percentages within the consumer survey dataset. Prior to conducting multiple linear regression, correlation analysis was performed to ascertain the strength and nature of relationships between the dependent and independent variables. Subsequently, multiple linear regression was employed to explore the linear relationships between these variables, with a specific focus on the front-of-pack traffic light system.

4. Results and Discussion

4.1 Current status of the Traffic Light System

The first objective of this study is to identify the current status of the traffic light system on biscuits. Analysis of the database reveals that this traffic light system utilizes red, amber, and green color codes to indicate the sugar, salt, and fat content in each product. Front – of – pack traffic light system appears on every biscuit label, but it lacks consistency in placement and size. (Figure 2) Analysis of various biscuit types revealed distinct patterns in color-coded labeling. Crackers stood out as the sole category where all products consistently met the green color code for sugar content (100%). Conversely, Marie biscuits consistently aligned with the amber color code for sugar content while cream biscuits, wafers, and puff-type biscuits displayed the red color code (100%) for sugar content (Figure 3). Regarding salt content, the majority of biscuits generally fell within the amber color code, with all Marie and puff-type biscuits consistently classified under this category (100%). (Figure 4) Notably, none of the biscuit products achieved a green color code for fat content (0%). (Figure 5)



Figure: 2 Placement of the Traffic Light System.

Table :3 Analysis of the traffic light system

Analysis of the Traffic Light system on the label									
	Sugar %			Salt %			Fat %		
	Red	Amber	Green	Red	Amber	Green	Red	Amber	Green
Crackers	0	0	100	50	50	0	16.66	83.33	0
Cream Biscuits	100	0	0	0	88.88	11.11	66.66	33.33	0
Marie	0	100	0	0	100	0	0	100	0
Wafers	100	0	0	14.28	57.14	28.57	28.57	71.42	0
Puff-Type	100	0	0	0	100	0	10	1	0

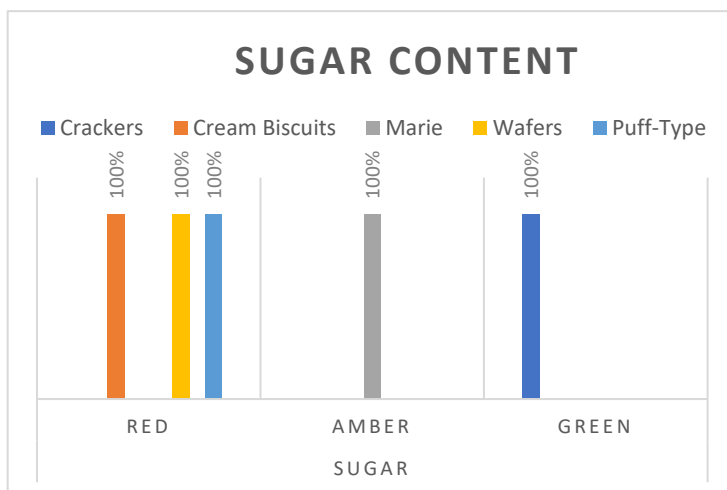


Figure:3 Sugar content result.

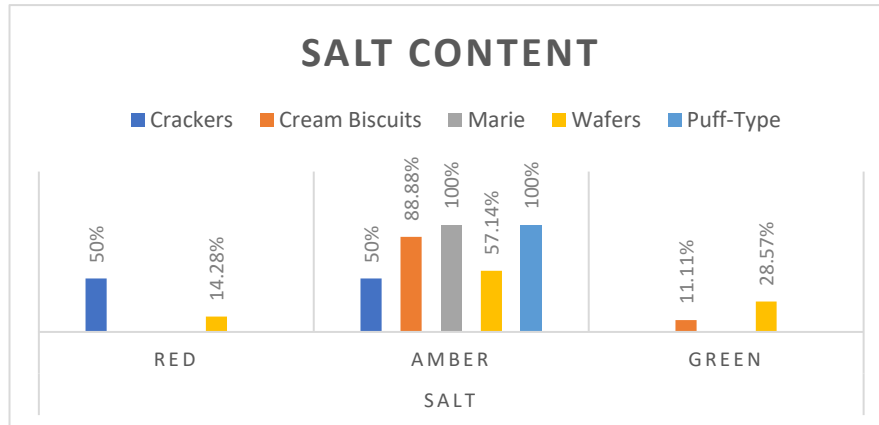


Figure:4 Salt content result.

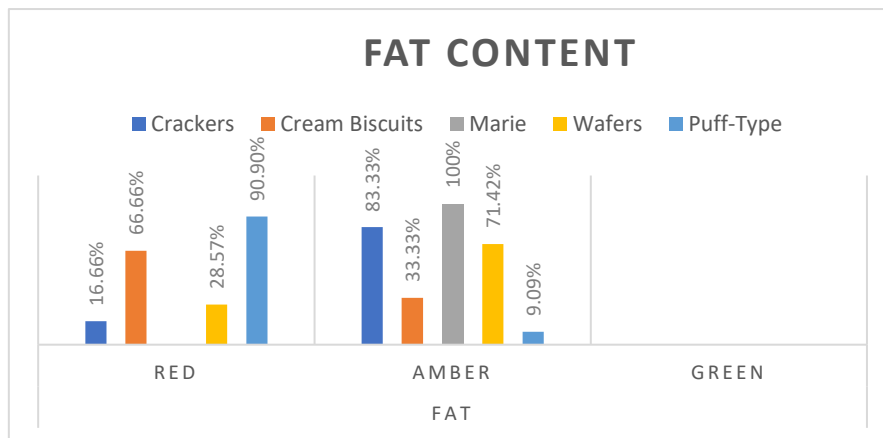


Figure:5 Fat content result.

4.2 Consumer awareness of the front-of-pack traffic light system

The results of the descriptive analysis indicated that 75.5% of respondents were aware of the traffic light system and found it easy to understand (Table 4). 42% of consumers consider the traffic light system when making the purchase decision and 64% of them are supermarket customers (Table 5 and 6). Of the sample, 53% are parents and 50.9% of them consider the traffic light system. (Table 7) 25% among them stated that despite their preference for healthier dietary choices, often found themselves acquiring biscuits based on their children without giving significant consideration to health-related factors. (Figure 6)

Table:4 Descriptive analysis of consumer awareness of Traffic Light System

		Fre- quency	Percentage	Valid Percentage	Cumulative Percentage
<i>Awareness of the front-of-pack traffic light system and find it easy to understand</i>	No	49	24.5	24.5	24.5
	Yes	151	75.5	75.5	100.0
	Total	200	100.0	100.0	

Table:5 Descriptive analysis for consideration of Traffic Light System

		Fre- quency	Per- centage	Valid Per- centage	Cumulative Percentage
<i>Consideration of the color of the traffic light when purchasing biscuits</i>	Yes	84	42.0	42.0	42.0
	No	116	58.0	58.0	100.0
	Total	200	100.0	100.0	

Table :6 Crosstabulation between retail type and the consideration of the Traffic Light System

Crosstabulation between retail type and the consideration of the Traffic Light System				
		<i>Consideration of Traffic Light System</i>		Total
		No	Yes	
<i>Retail Type</i>	Supermarkets	48	52	100
	Local grocery outlets	68	32	100
Total		116	84	200

Table :7 Crosstabulation between parental status and the consideration of the Traffic Light System

Crosstabulation between parental status and the consideration of the Traffic Light System				
		<i>Consideration of Traffic Light System</i>		Total
		No	Yes	
<i>Pa- rental Status</i>	Yes	52	54	106
	No	64	30	94
Total		116	84	200

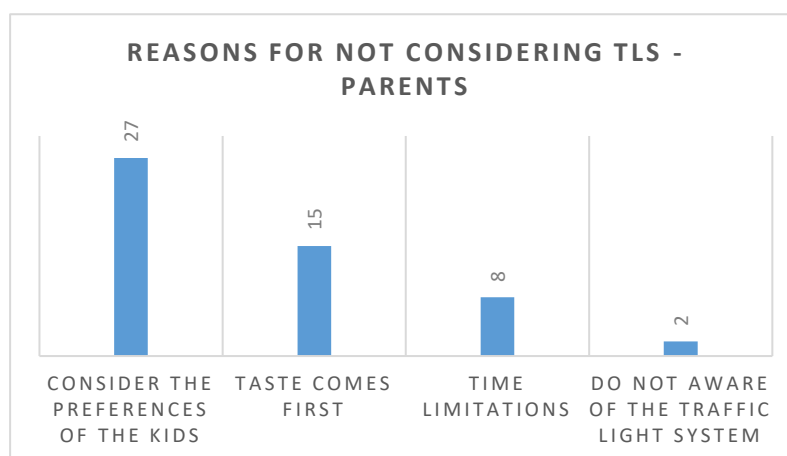


Figure:6 Descriptive analysis for consideration of Traffic Light System.

4.3 Retailers' Perspective

Retailers highlighted that there is a shift toward healthier dietary habits among consumers. They identified specific segments, including individuals with diet-related diseases, health-conscious individuals, and women with ample time for grocery shopping, who prioritize nutritional aspects when deciding on purchases. Local grocery retailers emphasized a predominant focus on pricing among their consumers. Those more price-conscious consumers showed less tendency to seek nutritional information, such as the traffic light system, when buying biscuits. Supermarket retailers stated that their product arrangement facilitates the consumer to search labeling information including front-of-pack and make their purchase decisions.

4.4 Impact of front-of-pack traffic light System on consumer biscuit purchase intention

As discussed under the conceptualization, there are a number of factors that can influence consumer decision-making processes. This study mainly focused on the socio-economic factors, product attributes, and shop factors that can affect the biscuit purchase decision of consumers. Correlation analysis serves to identify the strength and direction of relationships between variable pairs. Multiple Linear Regression (MLR) is a methodology employed to uncover the linear relationship between dependent and independent variables. Prior to conducting the multiple regression analysis in this study, correlation analysis was employed to identify the strength and direction of relationships between the dependent variable, the consumer's biscuit purchase intention, and the independent variables. The independent variables encompass various socio-economic factors such as gender, age, level of education, family size, monthly family income, and parental status; product attributes including price, brand, taste, package, traffic light system, and nutritional table; and shop-related factors like accessibility, customer service, and shop ambiance.

4.4.1 Correlation

Among all independent variables, brand, taste, monthly family income, taste, traffic light system, accessibility, customer service, and the shop ambiance indicated a significant correlation with the consumers' biscuit purchase intention. (Table 8) Results indicated there is a strong positive correlation observed between taste and purchase intention ($r = 0.634$, $p < 0.01$). Similarly, monthly family income shows a positive correlation with purchase intention ($r = 0.543$, $p < 0.01$). Notably, brand ($r = 0.451$, $p < 0.01$), traffic light system ($r = 0.368$, $p < 0.01$), and accessibility ($r = 0.412$, $p < 0.01$) also demonstrate significant positive correlations with purchase intention. In contrast, price displays a negative correlation ($r = -0.224$, $p < 0.01$), implying an inverse relationship with purchase intention. Customer service exhibits a moderately significant correlation ($r = 0.443$, $p = 0.009$), while shop ambiance shows a moderate positive correlation ($r = 0.298$, $p < 0.01$).

Table:8 Results of the correlation analysis

		Brand	Price	Monthl y Fam- ily In- come	Taste	Traffic Light System	Acces- sibility	Cus- tomer Service	Shop Ambi- ence
Purchase Intention	Pearson Correlation	.451**	-. 0.224**	.543**	.634**	0.368**	0.412**	0.443**	0.297**
	Sig. (2- tailed)	.000	0.001	.000	.000	.000	.000	.009	.000
	Sample Size	200	200	200	200	200	200	200	200
**. Correlation is significant at the 0.01 level (2-tailed).									

4.4.2 Multiple Regression

In this study, multiple linear regression (MLR) was used to identify the significant linear relationships between the dependent variable and the independent variables. The model exhibits a solid fit, indicated by a significant R-squared of 0.630. This value implies that approximately 63% of the variation in the dependent variable, Purchase Intention, can be explained by the included independent variables. Moreover, the adjusted R-squared, a crucial measure that accounts for the number of predictors in the model, stands at 0.589, indicating a well-balanced model complexity. The overall model shows statistical significance with an F-value of 15.259 and a corresponding p-value of .000, emphasizing that at least one of the independent variables has a significant relationship with the dependent variable. These results solidify the reliability of the model in uncovering the factors that impact Purchase Intention within this study.

The multiple regression analysis revealed significant relationships between several independent variables and the dependent variable of consumer's biscuit purchase intention. (Table 9) Among the independent variables, Taste (Beta = 0.440, $p < 0.01$) and monthly family income (Beta = 0.528, $p < 0.05$) demonstrated the highest impact, suggesting a substantial influence on purchase intention. Following those variables, the Brand also displayed a notable impact (Beta = 0.322, $p < 0.01$), indicating its importance in consumers' purchase decisions. Accessibility (Beta = 0.194, $p < 0.01$) and Traffic Light System (Beta = 0.153, $p = 0.01$) showed smaller yet still significant effects, while price exhibited a negative relationship with the purchase intention. (Beta = -0.128, $p < 0.05$). Even though in the correlation step, customer service and the shop ambiance indicated a significant correlation with the purchase intention, results indicated that they didn't exhibit a significant linear relationship with the purchase intention.

Table:9 Coefficient table of the multiple regression analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.189	.455		2.614	.010
	Accessibility	.174	.054	.194	3.230	.001
	Price	-.113	.056	-.128	-2.030	.044
	Traffic Light System	.126	.049	.153	2.589	.010
	Brand	.242	.041	.322	5.889	.000
	Taste	.420	.057	.440	7.344	.000
	Monthly Family Income	.486	.214	.528	2.267	.025

4.5 Discussion

The database compiled with labels of the biscuits in this study provides crucial insights into Sri Lanka's food industry. It highlights the effective implementation of the color-coded system by various biscuit brands in adherence to regulations. However, despite this successful integration, a concerning factor emerges. The majority of biscuit categories and brands do not align with the favorable sugar, fat, or salt criteria outlined by these indicators. While the traffic light system serves as a guide to product healthiness, it highlights the significant shortage of healthy biscuit options in Sri Lanka's food market.

The majority of the sample is aware of this traffic light system and finds it easy to understand. Of the sample, 42% stated that they consider the traffic light system when purchasing biscuits. Previous studies found that households in non-rural areas have a tendency to use nutritional information on the labels.

(Drichoutis, Lazaridis & Nayga, Jr., 2006). This study found that respondents who consider the traffic light system on the front-of-pack label are supermarket consumers (62%), rather than those who visit local grocery shops the majority of them are supermarket customers. Previous studies stated that parents who have young children actively seek nutrition information from the labels. (Drichoutis, Lazaridis & Nayga, Jr., 2006) In this study, 23% of parents stated that they allow their kids to have their preferred biscuits, despite the parents' preferences for healthy dietary choices. According to previous research, there are specific consumer groups who frequently seek nutritional information on the product label. Such as people who are on a special diet, organic buyers, and those aware of the diet-disease relation. Retailers stated that there is a tendency for most consumers to have healthy dietary choices. And that health-conscious consumers and women who could allocate more time to grocery shopping, actively seek nutritional information on product labels.

According to the previous research, consumer consideration of price surpasses other label factors, indicating that the front-of-pack traffic light system minimally influences purchasing behavior (Madhusanka, Rathnayake & Mahaliyanaarachchi, 2021). In contrast to these findings, this analysis employing multiple regression techniques revealed a significant impact of the traffic light system (Beta = 0.153, $p = 0.01$) on consumer biscuit purchase intention. This influence was observed alongside other influential factors such as price, brand, taste, monthly family income, and accessibility.

5. Conclusion and Recommendations

This study was focused on a front-pack traffic light system on biscuit products and the effect of it on consumer biscuit purchase intention. This research has two main sections. The first section involved the creation of a database by including photographs of front-of-pack, back-of-pack, and side views of fifty biscuit products under five main categories; crackers, cream biscuits, wafers, Marie, puff-type biscuits. In the second section consumer survey was conducted with 200 respondents covering 9 provinces, in Sri Lanka, with a special concern on socio-economic factors, product attributes, especially traffic light systems, and shop factors. The data was analyzed using descriptive statistics, correlation, and multiple regression. Results indicated that the traffic light system was available on all biscuit types with a lack of consistency in placement and size. Despite having the traffic light system on the label, most of the biscuit categories didn't meet healthy sugar, salt, and fat content. The majority of the sample were aware of the traffic light system and found it easy to understand. Of the sample, 42% of consumers consider the traffic light system when making purchase decisions. The regression analysis found that there is a significant impact of the traffic light system along with other factors such as price, brand, taste, monthly family income, and accessibility.

According to the suggestions made by respondents, they value having information regarding sugar, salt, and fat content per serving, on the front-of-pack, instead of having per 100 grams. While the traffic light system significantly influences consumer biscuit purchase intention by indicating product healthiness, it's insufficient on its own. The Sri Lankan food industry must prioritize innovation, developing products that balance consumer satisfaction while ensuring healthier levels of sugar, salt, fat, and other key ingredients.

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ICSD 039

THE IMPACT OF FRESH MEAT VALUE CHAINS ON URBAN AND PERI-URBAN FOOD NUTRITION SECURITY: A CASE STUDY OF FRESH MEAT VALUE CHAIN

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Abstract: Fresh meat value chains play a critical role in urban and peri-urban food and nutrition security. This research aims to identify the structure of the fresh meat value chains and find out the role of the fresh meat value chains in urban and peri-urban food nutrition security. Value chain mapping is key to the study from farm to fork and understanding the structure. The research methodology employs a combination of qualitative (Porter's value chain model) and quantitative methods. The data was collected by using in-depth interviews with key players of meat value chains involving 16 meat producers (10 poultry producers, 4 pork producers, and 3 beef producers), 5 transport service providers, 10 wholesalers, 4 processors, 44 retailers (25 local meat shops, 5 supermarkets, 10 meat shops in the market fair, and 4 branded meat retailers), and a stratified random sample of 200 consumers. As part of the secondary data analysis, relevant legislative frameworks were considered, including the Butchers' Ordinance of 1893, Animal Act No. 29 of 1958, and Food Act No. 26 of 1980. The findings reveal the key actors within the fresh meat value chains, including producers, transporters, wholesalers, processors, retailers, and consumers, and the institution landscape comprised with Ministry of Livestock Development, and government service providers such as veterinarians, and PHI (Public Health Inspectors). The study suggests that fresh meat availability, access, and quantity of buying have a significant impact on consumer satisfaction with fresh meat. Significant correlation (0.01) between household income, affordability, quantity of buying, and buying frequency of meat. Of the sample (73%) of consumers express a preference for purchasing fresh meat through loose-scale transactions, indicating a choice for buying by weight, as opposed to packaged alternatives. Findings highlight significant barriers and challenges, such as limited availability and access to beef due to strict regulations on slaughtering and transportation. High costs associated with animal husbandry, such as the cost of poultry feeds and transportation, have led to farm closures.

Keywords: Accessibility; Affordability; Availability; Food nutrition security; Fresh meat value chains

1. Introduction

The role of fresh meat value chains, serving as pivotal conduits that shape the availability, affordability, and access to fresh meat in urban and peri-urban settings, is crucial. The functioning of fresh meat value chains encompasses the processes involved in producing, transporting, wholesaling, processing, retailing, and consuming fresh meat, making it a key determinant of the availability and accessibility of fresh meat in urban and peri-urban areas. Recent statistics from the National Livestock Statistics reveal a 6.3% decrease in poultry numbers in 2022 compared to 2021, while the quantity of pigs increased by approximately 5.3%, and cattle showed a notable rise of approximately 12.6%. The districts with the maximum cattle population are Kurunegala and Anuradhapura, while Gampaha and Puttalam have the highest pig population. Jaffna and Anuradhapura lead in goat population, and Kurunegala and Puttalam have the maximum chicken population. (National Livestock Statistics 2017 - 2022: Department of Census and Statistics, n.d.)

The per capita chicken availability in Sri Lanka was 10.23 kg/year, goat availability was 0.14 kg/year, and pork availability was 0.43 kg/year in 2022. (Livestock Statistics: Department of Animal Production & Health, 2023). The significance of this research lies in its potential to contribute to a better understanding of the role of fresh meat value chains in ensuring food and nutrition security for urban and peri-urban populations. Specifically, the research examines the value chains associated with chicken, pork, beef, and mutton, strategically dissecting the fresh meat value chain into key nodes, including producers, transporters, wholesalers, processors, retailers, and consumers. The study zooms into distinct poultry farms, pig farms, cattle farms, and goat farms, acknowledging the diversity in meat sources and production practices.

Furthermore, the examination of retailers is bifurcated into local meat shops, supermarkets, and meat fairs, recognizing the varying dynamics and influences that different retail channels exert on the accessibility, affordability, and availability of fresh meat in urban and peri-urban settings. Understanding the roles played by diverse retail outlets is crucial for comprehending consumer choices and nutritional outcomes. The title implicitly underscores the importance of fresh meat value chains in the context of urban and peri-urban food and nutrition security. It addresses a critical knowledge gap by bringing attention to the specific dynamics of fresh meat, in densely populated areas. Understanding these dynamics is imperative for crafting targeted strategies that ensure not only the availability of fresh meat but also its accessibility and affordability, ultimately impacting the nutritional well-being of urban residents.

As urban centers become epicenters of demographic and economic shifts, the need to decipher the complexities of fresh meat value chains becomes urgent. The title serves as a clarion call, indicating that this research is a pragmatic response to the evolving challenges faced by urban and peri-urban communities in securing adequate and nutritious food. By unraveling the intricacies of fresh meat value chains, this research aspires to provide actionable insights that can inform policy decisions, industry practices, and community initiatives.

In essence, the research title acts as a beacon, guiding attention to the heart of the matter — the transformative potential of understanding and optimizing fresh meat value chains in the quest for urban and peri-urban food and nutrition security. In light of these considerations, the objectives of this research are to identify the structure of fresh meat value chains and understand their role in urban and peri-urban food nutrition security. This will be achieved through a combination of qualitative and quantitative methods, providing valuable insights that can inform policy and interventions aimed at improving the availability and accessibility of fresh meat in urban and peri-urban areas. Overall, this research seeks to contribute to a better understanding of the impact of fresh meat value chains on urban and peri-urban food nutrition security, with the ultimate goal of improving the well-being of urban and peri-urban populations.

2. Conceptualization

This framework is derived from the synthesis of seminal theories in food security and builds on the premise that ensuring food security involves a nuanced understanding of the accessibility, availability, and affordability of essential food items, particularly fresh meat in urban and peri-urban settings.

The concept of food security, as defined by the World Food Summit of 1996, encompasses not only the availability and access to food but also its affordability. Drawing on this foundation, our conceptual framework positions food security as the dependent variable, influenced by the independent variables of access, availability, and affordability.

Figure 1 discusses the Examining spatial dynamics and market proximity, access to fresh meat focuses on individual reach. Availability, represented by loose scale and packaged options, considers traditional and formal supply chains, while variety encompasses poultry, pork, beef, and mutton. Affordability assesses how pricing influences overall food security, streamlining the analysis to key factors of availability, access, and affordability.

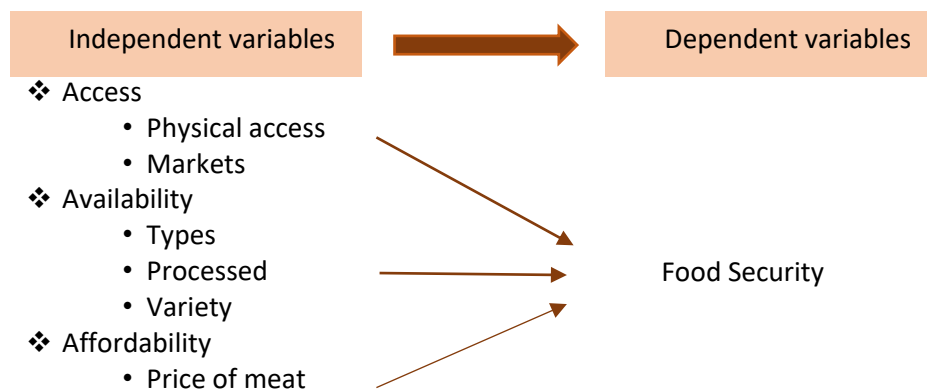


Figure 1: Conceptual Framework.

3. Methodology

This study was conducted across several key locations in Sri Lanka, including Colombo, Galle, Kurunegala, Kalutara, Anuradhapura, and Gampaha. These areas were strategically chosen to provide a comprehensive understanding of the meat value chains and associated practices within different regions.

In this research, a meticulous approach was employed in selecting respondents to ensure the representation of various stakeholders in the meat value chain. The snowball sampling method was utilized as the primary strategy, initiating with 16 meat producers (comprising 10 poultry producers, 4 pork producers, and 3 beef producers). Subsequently, this initial contact facilitated connections with other essential actors in the value chain, such as transport service providers, wholesalers, processors, and retailers, as well as secondary actors in the value chain, including public health inspectors (PHI), veterinarians, and livestock inspectors.

For the consumer segment, a stratified random sampling technique was applied. Every 3rd consumer purchasing meat from specific retail shops was selected to create a diverse and representative sample. Table 1 discusses the research involved a diverse sample of participants, including 16 meat producers, 5 transport service providers, 10 wholesalers, 4 processors, 44 retailers (comprising 25 local meat shops, 5 supermarkets, 10 meat shops in the market fair, and 4 branded meat retailers), and a stratified random sample of 200 consumers.

Table 1: Profile of the Sample

Segment	Sample Size	Sampling Technique
Meat Producers	16	Snowball Sampling
Transport Service	5	Snowball Sampling
Wholesalers	10	Snowball Sampling
Processors	4	Snowball Sampling
Retailers	44	Snowball Sampling
Consumers	200	Stratified Random Sampling

The choice of stratified random sampling for consumers was motivated by the clear division of the population into strata based on their purchasing patterns. This method allowed for the selection of a representative sample from each stratum, ensuring a more nuanced understanding of consumer behavior.

The snowball sampling method for other stakeholders in the value chain was deemed appropriate due to the interconnectivity of these actors. Initiating contact with meat producers and progressively branching out to other value chain participants enabled a comprehensive exploration of the intricacies within the meat industry. The chosen sampling methods were aimed for a well-rounded and insightful analysis of the meat value chains in the selected regions.

4. Data Collection

Utilizing a structured questionnaire incorporating both open-ended and close-ended questions, this method efficiently gathered primary data, ensuring standardized responses for quantitative analysis at each value chain node. In-depth interviews were conducted, employing a mix of telephone and physical visits with producers, transporters, processors, and secondary actors. The application of descriptive statistics allowed for the summarization and presentation of key features within the data, providing insights into central tendencies, variability, and distribution. This approach was aligned with the objective of comprehensively understanding the roles and linkages within the fresh meat value chain. When engaging with producers, the research sought to gather crucial insights into their production practices, challenges faced, and perspectives on the dynamics of the value chain. The involvement of transporters and processors facilitated a detailed exploration of the transportation and processing phases, revealing key challenges and opportunities within these crucial links of the value chain. Additionally, the inclusion of secondary actors, such as public health inspectors, veterinarians, and livestock inspectors, was imperative for grasping their pivotal roles in ensuring food safety within the value chain.

Sources of secondary data: As an integral component of secondary data analysis, turned attention to pertinent legislative frameworks that profoundly influence the fresh meat value chain. Specifically, examined the Butchers' Ordinance of 1893, the Animal Act No. 29 of 1958, and the Food Act No. 26 of 1980. These legislative instruments provide a historical and regulatory backdrop, offering insights into the evolving governance of meat-related practices. Additionally, exploration delved into the statistical landscape through the examination of the National Livestock Statistics spanning the years 2017 to 2022, sourced from the Department of Census and Statistics. These statistics serve as a valuable repository of quantitative information.

5. Results and Discussion

The identification of the fresh meat value chain structure reveals a dynamic network of actors and intricate linkages that collectively contribute to the production, distribution, and consumption of fresh meat products. At the primary stage, the value chain typically encompasses producers such as farmers

and ranchers who are engaged in livestock rearing. These producers play a pivotal role in initiating the chain, ensuring the quality and health of the animals. Moving forward, the processing and packaging stage involves various actors, including transporters, slaughterhouses, wholesalers, meat processors, and retailers. Distribution channels involve actors such as transporters, wholesalers, retailers, and logistics providers, facilitating the movement of fresh meat from production centers to end consumers. Additionally, government and service providers, regulatory authorities, and quality control agencies are integral actors, ensuring compliance with health and safety standards at every stage. The linkages within this value chain are multifaceted, encompassing financial transactions, information flow, and collaborative relationships that collectively shape the trajectory of fresh meat from farm to fork.

Figure 2 is to elucidate the intricate dynamics of the fresh meat value chain according to Porter’s value chain model, a comprehensive map has been crafted, serving as a visual representation within the results and discussion of this study. This illustrative tool highlights the key actors, linkages, and the flow of production from initial stages to end consumers. Arrows and nodes on the map emphasize the directional flow, capturing the movement of fresh meat from its origin through transportation, processing, distribution, and ultimately reaching the consumers.

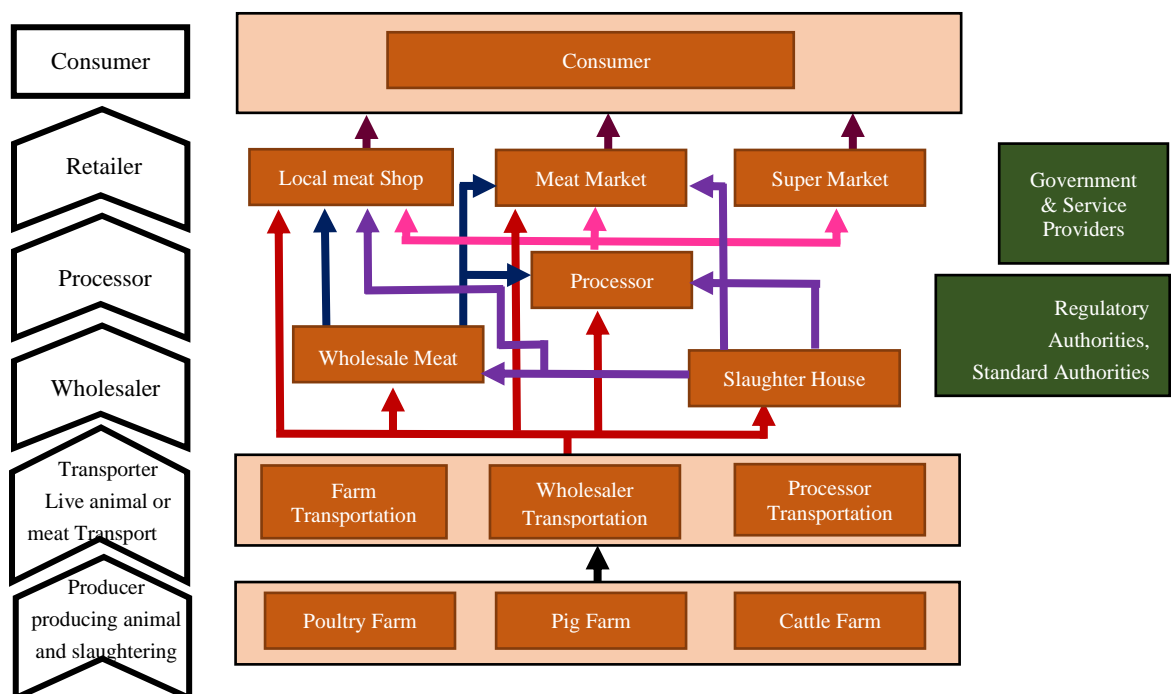


Figure 2: Fresh meat value chain flow according to Porter's value chain model.

5.1 Producer

The findings from our study reveal a diverse landscape among fresh meat producers, characterized by variations in the duration and scale of operations spanning poultry, pigs, and cattle farming, ranging from 1 to over 20 years. Livestock management practices display a spectrum of approaches, with producers adopting intensive, free-range, and conventional methods. Notably, intensive farming is employed in poultry farming by producers with more than 500 chicks in their farm.



(a)



(b)



(c)

Figure 3: (a) Free range poultry farming (b) Intensive poultry farming (c) Commercial poultry farming.



Figure 4: Commercial pig farming.



Figure 5: Commercial cattle farming.

Sales strategies vary, with some poultry producers affiliated with processing companies earning Rs.500 profit per chicken, while others set prices at Rs.800 – Rs.1200 per kilogram or per chicken. Pig and cattle producers adopt a per-kilogram pricing strategy, ranging from Rs.800 – Rs.1400 for pigs and exceeding 1 lakh for cattle.

In Sri Lanka, regulations, such as The Animals Act, No. 29 of 1958, and related regulations, restrict the transportation of cattle between districts. A transport permit, obtained from the Divisional Secretary of the area where the cattle are kept, is required for such transportation. This legal framework is in place to manage and control the movement of cattle, addressing considerations related to disease control, animal welfare, and food safety. (Lanka, Department of Animal Production and Health, 2023)

To ensure equitable access to fresh meat, transporters may adopt a strategy that balances delivery to both urban and rural areas. This involves optimizing routes, considering the diverse needs of different regions, and potentially collaborating with local distributors. By addressing unique challenges in each area, transporters contribute to a more inclusive distribution of fresh meat products.

5.3 Slaughterhouse

Slaughterhouses serve the purpose of humanely slaughtering animals for consumption. Establishing a slaughterhouse without a valid permit from the appropriate authority is prohibited. Regulations govern the slaughtering process, particularly for cattle, with stricter restrictions currently in place. These regulations include mandatory inspections by a veterinarian and a public health inspector, a 12-hour quarantine period for cattle prior to slaughter, and pre- and post-mortem examinations by a veterinarian. Upon satisfactory post-mortem inspection, the veterinarian issues an official certificate authorizing the distribution of the carcass for human consumption.



Figure 9: Post mortem of cattle by PHI.



Figure 10: Quarantine time of 12 hours' cattle

5.4 Wholesaler

Fresh meat wholesalers revealed a diverse range of animal and meat products in their inventories, including poultry, pork, beef, and mutton. In this research, shops selling more than 100kg of poultry per day were considered as wholesalers. These wholesalers demonstrated a commitment to ensuring a consistent supply of fresh meat to meet market demands through robust value chain management. They supply meat to various outlets, including local meat shops, meat fairs, processors, restaurants, and hotels, in large quantities.

Quality control measures were reported to be in place, encompassing stringent checks and processes to maintain the freshness and overall quality of the meat. The strategies employed for determining fair pricing were multifaceted, considering market dynamics, production costs, and customer expectations. Furthermore, wholesalers emphasized a dedication to balancing affordability and quality, implementing cost-effective measures without compromising on the freshness or integrity of their products. Collaborations and partnerships with producers and transporters were identified as integral components of their operations, enhancing both the availability and affordability of fresh meat. Agreements with partners were established to facilitate these collaborations. Initiatives were reported to ensure accessibility to a diverse consumer base, reflecting a commitment to inclusivity and market reach. Addressing challenges related to storage, inventory management, and wastage issues emerged as a focal point. Overall, the research underscores the complexity of fresh meat supply chains and the multifaceted approaches adopted by wholesalers to meet consumer needs while navigating various operational challenges.

5.5 Processor

In this study, fresh meat processors operate integrated farms under their brand, ensuring a continuous supply of meat for their production. They source poultry from their farms, receiving 30,000 to 45,000 kg daily, and pigs at a weekly rate of 5,000 kg. For poultry, 70% is processed as fresh meat, while the remaining 30% is allocated for meat products. For pork, 90% is designated for fresh meat, with the remaining 10% utilized in meat product manufacturing. Employing advanced technologies and stringent quality control measures, processors prioritize hygiene and sanitation practices throughout the production chain. The study identifies challenges faced by processors, including limitations in processing capacity and the imperative to maintain consistent quality standards. Processors actively address these challenges by investing in advanced processing technologies and optimizing production efficiency. Robust quality control measures, encompassing real-time monitoring and corrective actions, are implemented to ensure that meat products consistently meet consumer expectations.

Acknowledging affordability concerns, processors implement strategies to mitigate costs. Findings indicate a focus on minimizing expenses through efficient supply chain management, supplier negotiation, and adopting cost-effective packaging solutions. These initiatives aim to strike a balance between maintaining quality and enhancing the economic accessibility of fresh meat products to a broader consumer base. Value-added products and packaging innovations play a pivotal role as key strategies among fresh meat processors. Report successful implementation of value-added products, such as pre-marinated cuts and ready-to-cook options. Packaging innovations, including eco-friendly and portion-controlled solutions, contribute not only to sustainability but also cater to evolving consumer preferences. Food safety remains a paramount concern for fresh meat processors. The study reveals adherence to rigorous food safety protocols, including HACCP, with processors staying abreast of regulatory requirements. Continuous staff training programs, regular inspections, and investments in traceability technologies contribute to a robust food safety framework throughout the processing chain.

5.6 Retailer

The analysis of the collected data from various meat retailers provides valuable insights into the meat industry in the surveyed areas. The majority of the retailers focus on offering chicken and pork, with variations in the types and cuts available. The processing methods vary, including tray packing, vacuum packing, and loose scaling, reflecting the diverse preferences of customers. It is noteworthy that most retailers strive to accommodate specific customer requests, emphasizing a customer-centric approach.



Figure 11: Local retail shops.

Local sourcing is a common practice among these retailers, with an emphasis on natural processes and the absence of additives. This aligns with the growing consumer trend towards locally sourced and minimally processed meats. Additionally, the retailers exhibit a commitment to quality by selecting suppliers based on specific criteria, such as no added hormones or antibiotics. Promotional strategies are evident in the market, with some retailers offering discounts on fresh meat to enhance affordability for customers. The frequency of restocking fresh meat varies, with daily restocking being a common practice among retailers, ensuring a consistent supply to meet customer demand.

The analysis also reveals variations in the number of suppliers each retailer engages with, ranging from one to six. Notable suppliers include Prima, CIC, Anthony's, and local sources, contributing to the diversity of meat products offered. Furthermore, specific retailers, such as Cargills, have adopted a tray and vacuum-packed approach, indicating a focus on quality packaging to preserve freshness. The sales patterns highlight that weekends, particularly Sundays, and before the poya day are peak selling days for most retailers. In terms of inventory management, the number of refrigerators in each shop ranges from two to four, reflecting the capacity required to store and preserve the various meat products. Overall, this comprehensive analysis provides a nuanced understanding of the meat retail landscape, shedding light on key practices, trends, and strategies employed by retailers in the surveyed areas.

Figure 12 showing the pie chart illustrates the distribution of monthly electricity costs among meat retailers in the surveyed areas. The majority of retailers, comprising 57.1%, fall within the Rs. 25,000 to Rs. 30,000 range, indicating a significant portion with moderate to higher electricity expenses. A substantial segment of 35.7% reports costs in the Rs. 20,000 to Rs. 25,000 range, suggesting a sizable proportion with slightly lower monthly expenditures. A smaller but notable group, constituting 7.1% of retailers, falls within the Rs. 15,000 to Rs. 20,000 categories, reflecting those with relatively lower monthly electricity costs. This breakdown provides a comprehensive overview of the diverse cost structures in the electricity expenses of meat retailers.

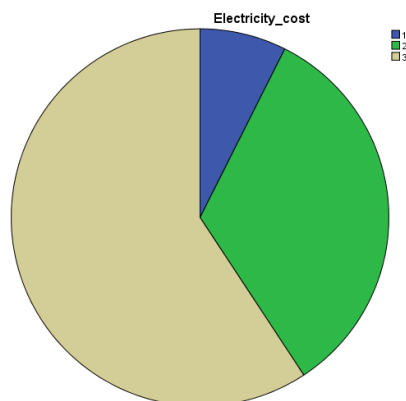


Figure 12: Electricity cost of retailers.

5.7 Consumers

As we transition from theoretical frameworks to tangible outcomes, the analysis of consumer data takes center stage. The objectives set forth at the initiation of this study find their manifestation in the rich tapestry of consumer responses, shedding light on the intricate interplay between our research hypotheses and the real-world experiences of those we aim to understand. The results of the study indicate that fresh meat availability, accessibility, and quality of fresh meat have a significant positive impact on consumer satisfaction with fresh meat. As shown in Table 3, the unstandardized coefficient for availability is 0.456, indicating that a one-unit increase in availability is associated with a 0.456-unit increase in satisfaction. The standardized coefficient for availability is 0.477, suggesting that availability has a moderate to strong effect on satisfaction.

Similarly, the unstandardized coefficient for accessibility is 0.327, indicating that a one-unit increase in accessibility is associated with a 0.327-unit increase in satisfaction. The standardized coefficient for accessibility is 0.359, suggesting that accessibility has a moderate effect on satisfaction. Finally, the unstandardized coefficient for quality is 0.120, indicating that a one-unit increase in quality is associated with a 0.120-unit increase in satisfaction. The standardized coefficient for quality is 0.141, suggesting that quality has a weak to moderate effect on satisfaction. Overall, the findings of this study suggest that fresh meat retailers should focus on improving availability, accessibility, and quality to enhance consumer satisfaction with fresh meat.

The standardized coefficients (Beta) allow for a comparison of the relative importance of each variable in explaining the variance in the dependent variable. In this case, availability has the highest standardized coefficient, suggesting it has the largest impact on consumer satisfaction compared to the other variables.

Table 2: Significant impact on consumer satisfaction with fresh meat

<i>Coefficients^a</i>						
	<i>Model</i>	Unstandardized Coefficients		Standardized Coefficients	<i>t</i>	<i>Sig.</i>
		B	Std. Error	Beta		
<i>I</i>	(Constant)	.469	.238		1.976	.050
	Availability	.456	.062	.477	7.299	.000
	Accessibility	.327	.059	.359	5.502	.000
	Quality	.120	.038	.141	3.121	.002

a. Dependent Variable: Satisfaction

Table 3: Fresh meat consumption consumers table

Fresh meat consumption	Consumption consumers	Consumption percentage
Chicken	198	99%
Pork	66	33%
Beef	59	29.5%
Mutton	24	12%

Figure 13 displays the chart of consumption of fresh meat types by consumers, with the percentages.

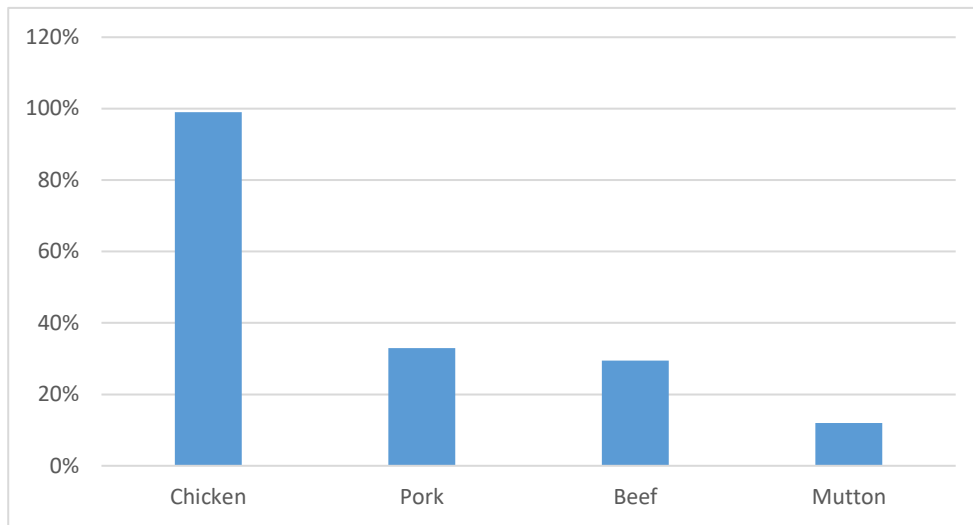


Figure 13: Fresh meat consumption consumers chart.

There is a significant correlation (0.01) between household income, affordability, quantity of buying, and buying frequency of meat. The correlation matrix in Table 5 shows that there are significant positive correlations between household income and affordability, quantity of buying, and buying frequency of meat. This means that as household income increases, affordability, quantity of buying, and buying frequency of meat also increase. The correlation coefficients between household income and affordability, quantity of buying, and buying frequency of meat are 0.805, -0.118, and -0.738, respectively. These correlation coefficients are all statistically significant at the 0.01 level. There is also a significant negative correlation between household income and buying frequency of meat. This means that as household income increases, buying frequency of meat decreases. The correlation coefficient between household income and buying frequency of meat is -0.738. This correlation coefficient is statistically significant at the 0.01 level.

There are also significant positive correlations between affordability and quantity of buying, and buying frequency of meat. This means that as affordability increases, quantity of buying, and buying frequency of meat also increase. The correlation coefficients between affordability and quantity of buying, and buying frequency of meat are 0.239, and -0.693, respectively. These correlation coefficients are all statistically significant at the 0.01 level. There is also a significant negative correlation between affordability and buying frequency of meat. This means that as affordability increases, buying frequency of meat decreases. The correlation coefficient between affordability and buying frequency of meat is -0.693. This correlation coefficient is statistically significant at the 0.01 level. There is also a significant positive correlation between quantity of buying and buying frequency of meat. This means that as quantity of buying increases, buying frequency of meat also increases. The correlation coefficient between quantity of buying and buying frequency of meat is 0.502. This correlation coefficient is statistically significant at the 0.01 level.

Table 4: Significant correlation

<i>Correlations</i>					
		Income	Affordability	Quantity	Buying Frequency
<i>Income</i>	Pearson Correlation	1	.682**	.306**	.066
	Sig. (2-tailed)		.000	.000	.351
	N	200	200	200	200
<i>Affordability</i>	Pearson Correlation	.682**	1	.232**	.061
	Sig. (2-tailed)	.000		.001	.387
	N	200	200	200	200
<i>Quantity</i>	Pearson Correlation	.306**	.232**	1	.088
	Sig. (2-tailed)	.000	.001		.214
	N	200	200	200	200
<i>Buying Frequency</i>	Pearson Correlation	.066	.061	.088	1
	Sig. (2-tailed)	.351	.387	.214	
	N	200	200	200	200

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 14 is showing 73% of consumers prefer for purchasing fresh meat through loose-scale transactions, indicating a preference for buying by weight rather than opting for packaged alternatives Within the sample.

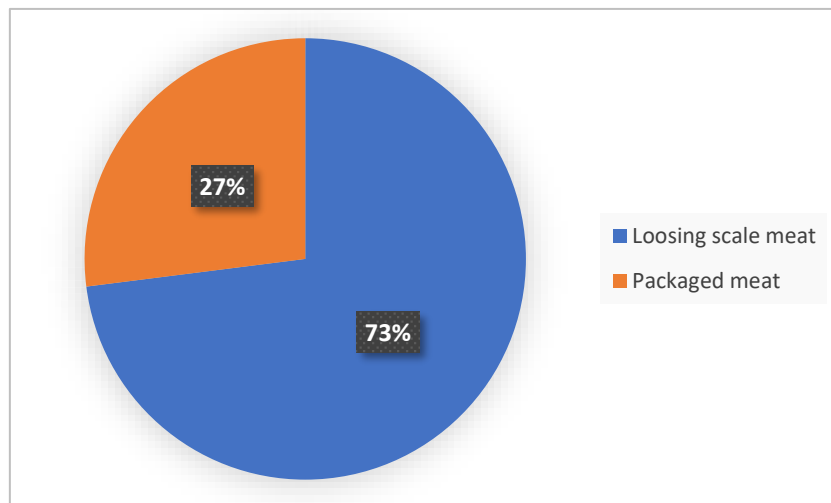


Figure 14: Method of buying fresh meat.

In culmination, this research illuminates the intricate web of relationships within the fresh meat value chain, offering a comprehensive understanding of the challenges, strategies, and interdependencies that shape the industry. As navigate the complexities revealed in this study, the insights gained pave the way for informed decision-making, fostering a more resilient and sustainable future for all stakeholders involved in the dynamic landscape of fresh meat production, distribution, and consumption.

6. Discussion

The identification of the fresh meat value chain structure elucidates a network of actors and linkages that play crucial roles in the production, processing, distribution, and consumption of fresh meat products. The involvement of diverse stakeholders, including producers, transporters, slaughterhouses, wholesalers, processors, retailers, and consumers, highlights the multifaceted nature of the value chain. This comprehensive understanding is essential for developing targeted interventions and strategies to enhance the availability, access, efficiency, resilience, and sustainability of the fresh meat supply chain. The study also highlights the diverse practices and challenges faced by fresh meat producers, ranging from poultry to pig and cattle farming. Variations in production methods, sales strategies, and economic pressures underscore the need for tailored support mechanisms to bolster the resilience of producers, particularly in the face of fluctuating market conditions and rising input costs. Moreover, the reliance on self-sustainability due to limited government subsidies underscores the importance of empowering producers with access to resources, training, and market linkages to enhance their competitiveness and viability.

Transportation emerges as a critical link in the fresh meat value chain, facilitating the movement of live animals and slaughtered meat from production centers to end consumers. The challenges associated with transportation, including regulatory constraints, logistical issues, and the need for temperature-controlled transport, underscore the importance of efficient route planning, real-time tracking, and collaboration among stakeholders to ensure the timely and safe delivery of fresh meat products. Moreover, efforts to optimize delivery routes and expand access to both urban and rural areas contribute to enhancing food accessibility and nutrition security.

Slaughterhouses, processors, and retailers prioritize quality control measures to maintain the safety, freshness, and integrity of fresh meat products. Advanced technologies, hygiene practices, and quality assurance protocols contribute to ensuring consumer satisfaction and trust. Consumer preferences, as reflected in the preference for loose-scale transactions by 73% of consumers, underscore the importance of catering to diverse preferences and market demands. The statistical values related to consumer satisfaction coefficients and correlations between household income, affordability, quantity of buying, and buying frequency of meat provide quantitative evidence of the factors influencing consumer behavior and market dynamics. These insights are instrumental in guiding strategic decisions to enhance product quality, affordability, and accessibility, ultimately fostering consumer satisfaction and loyalty.

7. Conclusion and Recommendations

The study provides a comprehensive examination of the fresh meat value chains and their crucial role in urban and peri-urban food and nutrition security. Through a combination of qualitative and quantitative methods, the research identifies key actors within the value chains, including producers, transporters, wholesalers, processors, retailers, and consumers, as well as relevant institutional frameworks. The findings highlight the significance of fresh meat availability, access, and purchasing behavior in influencing consumer satisfaction. Moreover, the research uncovers significant correlations between household income, affordability, quantity of buying, and buying frequency of meat, indicating the complex interplay of economic factors in consumer decision-making. Notably, consumer preferences favor loose-scale transactions, underscoring a preference for purchasing fresh meat by weight over packaged alternatives. The study also illuminates notable challenges within the value chains, such as limited availability and access to beef due to stringent regulations on slaughtering and transportation, as well as the economic pressures faced by producers, leading to farm closures.

As the recommendations, Policymakers should consider revising existing legislative frameworks, such as the Butchers' Ordinance of 1893, Animal Act No. 29 of 1958, and Food Act No. 26 of 1980, to address barriers and challenges within the fresh meat value chains. Flexibility and adaptation to current market dynamics and consumer preferences are crucial to ensure the sustainability and resilience of the industry. In the existing Butchers' Ordinance legislation, the focus primarily revolves around cattle

slaughtering for human consumption. However, there is a need to include legislation for pigs and other animals slaughtered for human consumption as well.

Initiatives should have aimed at supporting small-scale fresh meat producers, particularly in poultry, pork, and beef farming, are essential to mitigate economic pressures and prevent farm closures. Access to financial resources, training programs, and market linkages can enhance the competitiveness and viability of small-scale producers, contributing to a more diverse and resilient supply chain.

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ICSD 047

THE IMPACT OF BRAND AMBASSADORS ON CONSUMER PURCHASING INTENTION: A COMPARATIVE STUDY BETWEEN TWO LEADING BRANDS OF INSTANT NOODLES IN SRI LANKA BY ANALYZING THE PRESENCE AND ABSENCE OF BRAND AMBASSADORS

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Abstract: In the present day highly competitive and dynamic marketplace, brand ambassadors have become a crucial aspect for companies to promote their products and influence consumer purchasing intention. This study aims to compare the consumer purchasing intention towards instant noodles with the presence and absence of brand ambassadors and to assess the role of brand ambassadors in building brand loyalty towards instant noodles. To achieve these objectives two leading brands of instant noodles in Sri Lanka were selected. Among these two, “Brand A” has updated brand ambassadors who are popular singers in Sri Lanka, and “Brand B” doesn’t have any updated brand ambassadors. The data used in this research is primary data using a questionnaire with a sample of 200 consumers from 09 provinces in Sri Lanka. Respondents were selected using a stratified random sampling method. The data was analyzed using descriptive statistics, multiple regression and correlation. The findings suggest that 73% of consumers' purchasing intentions are positively influenced by the presence of brand ambassadors. Consumers reported that they were influenced to buy “Brand A” mainly by seeing TV commercials and social media posts featuring the performance of brand ambassadors. Consumers reported that the presence of brand ambassadors had a positive impact on brand recall and memorability. The absence of brand ambassadors negatively affects the purchasing decisions of 48% of consumers, primarily because they face difficulties in remembering or recalling the “Brand B”. The results also indicate that the price, taste and availability of brand ambassadors have a significant impact on consumer purchasing intention. Consumers reported that 56% of them are loyal to “Brand A” and the presence of brand ambassadors are a reason for building brand loyalty for "Brand A", while the absence of brand ambassadors makes "Brand B" less trustworthy. And 40% of consumers are not loyal to “Brand B”. Consumers reported that having updated brand ambassadors for a brand is an effective marketing strategy for instant noodles.

Keywords: Brand ambassador; Brand loyalty; Consumer; Instant noodles; Purchase intention

1.Introduction

In today's competitive market, brands are constantly seeking ways to differentiate themselves and gain a competitive advantage. One popular strategy employed by many companies is the use of brand ambassadors to promote their products and create a positive image in the minds of consumers. Brand ambassadors are individuals who are hired by a company to represent and promote their brand, often through various marketing and advertising initiatives. According to Doucett (2008) in his book says that a brand ambassador is someone who has passion for the brand, wants to introduce it, and even voluntarily provides information about the brand. The role of the perfect brand ambassador is to set trends and create influence over the products that the company offers. Brand ambassadors will help create a stronger emotional connection between a brand/company and consumers so that it will indirectly build a product image that has an impact on purchasing decisions and product usage (Royan, 2004: 8).

According to a study by Duffett (2015), the use of brand ambassadors can have a significant impact on consumer purchasing behavior. The study found that consumers are more likely to purchase a product if it is endorsed by a celebrity or public figure they admire. This is because consumers often associate the qualities and values of the ambassador with the brand, leading to increased trust and loyalty towards the product. In addition to influencing purchasing behavior, brand ambassadors also play a crucial role in building brand awareness and creating a positive brand image. A study by Erdogan (1999) found that brand ambassadors can help to enhance brand recall and recognition, as well as create a sense of authenticity and credibility for the brand.

This is particularly important in today's digital age, where consumers are inundated with marketing messages and are increasingly skeptical of traditional advertising tactics. The use of brand ambassadors has also been shown to have a positive impact on brand loyalty. A study by Till et al. (2008) found that consumers who have a strong emotional connection with a brand ambassador are more likely to exhibit brand loyalty and engage in repeat purchases.

The purpose of this research is to conduct a comparative study between two leading instant noodles brands in Sri Lanka, namely brand A and brand B. Brand A has recently updated its brand ambassadors, who are popular singers in Sri Lanka, while brand B does not have updated brand ambassadors. The study aims to investigate the impact of the presence and absence of brand ambassadors on consumer purchasing intention and brand loyalty toward instant noodles.

Consumer purchasing intention is the likelihood or probability that a consumer will purchase a particular product or service. It is a key factor in marketing decisions, as it helps marketers understand how consumers make decisions about their purchases. There are many factors that can influence consumer purchasing intention, including product quality, price, brand image, and marketing efforts. Studies have shown that brand ambassadors can have a significant impact on consumer purchasing intention. However, it is important to choose brand ambassadors who are a good fit for the brand and who will resonate with the target audience. Additionally, it is important to use brand ambassadors in a way that is authentic and believable. When used effectively, brand ambassadors can help to increase brand awareness, improve brand image, and build trust with consumers, all of which can lead to increased sales and brand loyalty.

Brand loyalty is the devotion and commitment that a customer has to a particular brand. It is the result of positive customer experiences, strong brand relationships, and a belief that the brand consistently delivers high-quality products or services (Dibb et al., 2006; Chailan et al., 2016). Brand loyalty is essential for businesses because it leads to repeat purchases, positive word-of-mouth, and increased customer lifetime value (Lavidge & Steiner, 1961; Anderson & Mittal, 2000). According to a study by Atwal and Williams (2009), brand ambassadors contribute to brand loyalty by creating a sense of trust and credibility among consumers. When a brand ambassador is a well-known and respected figure, consumers are more likely to trust the brand, leading to increased loyalty. In the context of the food industry,

a research article by Wiedmann, Hennigs, and Siebels (2007) suggests that the use of celebrities as brand ambassadors positively affects consumers' emotional attachment to the brand. Emotions are powerful drivers of brand loyalty, and the presence of a relatable and likeable ambassador can evoke positive emotions towards the brand.

Instant noodles are a popular and convenient food product in Sri Lanka. In recent years, the instant noodles market has become increasingly competitive, with brands investing heavily in marketing campaigns to attract and retain consumers. Brand ambassadors are a common marketing tool used to promote products and services. However, there is limited research on the impact of brand ambassadors on consumer purchasing intention and brand loyalty, particularly in the context of instant noodles. This study will address this gap in the literature and provide valuable insights for marketers in the instant noodles industry.

1.1 Significance of this study

Recognizing the influence of brand ambassadors on consumers' purchase intentions is crucial for businesses trying to negotiate the complex landscape of the competitive marketplace. The goal of this study is to add significant understanding to the body of research on consumer behavior and marketing, especially as it relates to Sri Lanka's instant noodle sector. The study efforts to provide a detailed knowledge of the role that brand ambassadors play in influencing consumer preferences by comparing the response of consumers to instant noodles by analyzing the presence and absence of brand ambassadors.

1.2 Objectives of this study

The primary goal of this study is to compare the consumer purchasing intention towards instant noodles with the presence and absence of brand ambassadors. And other aim is to assess the role of brand ambassadors in building brand loyalty towards instant noodles. To achieve these objectives two leading instant noodle brands in Sri Lanka were selected. Between these, "Brand A" has updated brand ambassadors who are popular singers in Sri Lanka, and "Brand B" doesn't have any updated brand ambassadors.

2. Conceptual Framework

In the realm of marketing, the conceptualization of brand ambassadors as influential figures aligns with the principles of celebrity endorsements and their impact on consumer perceptions and behaviors. Drawing from communication theories, particularly the source credibility model and social impact theory, one can establish the theoretical groundwork for understanding how brand ambassadors, as persuasive sources, can significantly affect consumer attitudes and purchasing decisions. Moreover, consumer behavior theories, such as the Theory of Planned Behavior by Icek Ajzen, can provide insights into the interplay between individual attitudes, subjective norms, perceived behavioral control, and their influence on purchasing intention.

The conceptual framework derived from the theoretical foundations which provides a lens through which to understand the impact of brand ambassadors on consumer purchasing intention, with a focus on instant noodles in Sri Lanka. The study will consider the presence and absence of brand ambassadors as the main independent variable, while the dependent variable will be consumer purchasing intention. The conceptual framework took as sub-independent variables which are sociodemographic factors (such as age, gender, income, and education level), product attributes (such as brand, price, taste, quality, and packaging), shop factors (such as accessibility, customer service, product placement on shelves, parking facility, shop layout).

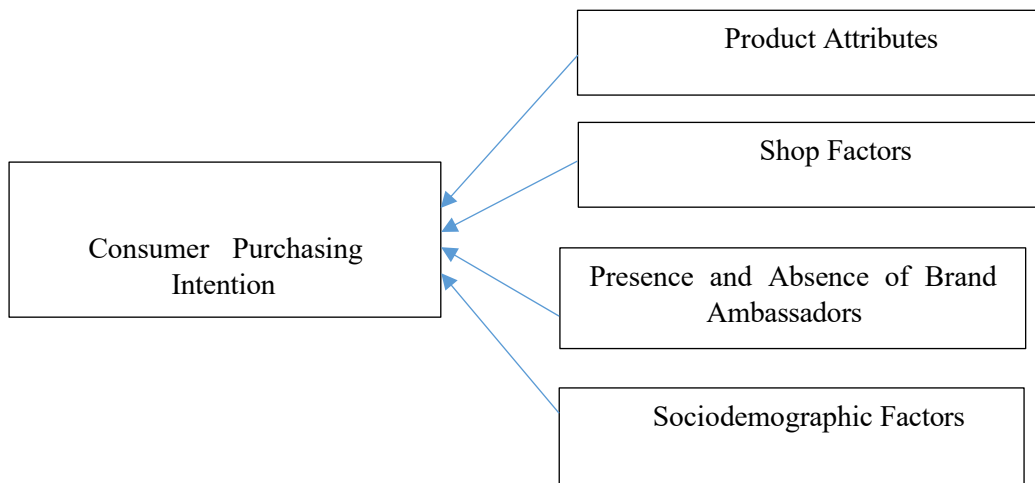


Figure 1: Conceptual Framework.

3. Research Methodology

The impact of brand ambassadors on consumer purchasing intention and brand loyalty towards instant noodles in Sri Lanka was compared using a quantitative research approach. A stratified random sampling technique was employed to select 200 respondents from 09 provinces in Sri Lanka, ensuring a diverse representation of the consumer population. Stratified random sampling is a technique that involves dividing the population into subgroups, or strata, based on certain characteristics that are relevant to the research. In your case, the population of noodle consumers in Sri Lanka can be divided into different provinces, which represent distinct regions with their unique consumer behaviors and preferences. By using stratified random sampling, you ensure that your sample includes representation from each of these provinces, thereby increasing the generalizability of your findings to the entire population of noodle consumers in Sri Lanka.

A structured questionnaire was utilized as the data collection tool to gather standardized data on consumer purchasing intention, brand loyalty, and the influence of brand ambassadors. The questionnaire included items related to consumer purchasing intention, brand loyalty, and the influence of brand ambassadors on these variables. The selection of this data collection tool is justified by its effectiveness in capturing the attitudes and perceptions of consumers towards instant noodles and brand ambassadors.

Data was collected from supermarkets and groceries, where potential buyers of instant noodles were likely to be found, increasing the relevance and reliability of the data. This approach ensured that the sample comprises actual consumers who are potential buyers of instant noodles. Descriptive statistics, multiple regression, and correlation analysis were used as analytical tools to examine the relationship between the presence of brand ambassadors and consumer purchasing intention, as well as brand loyalty toward instant noodles. Descriptive statistics summarized the characteristics of the sample, while multiple regression identified the impact of brand ambassadors on consumer purchasing intention and brand loyalty. Additionally, correlation analysis explored the strength and direction of the relationships between variables. Methodology enabled a comprehensive examination of the impact of brand ambassadors on consumer behavior towards instant noodles in Sri Lanka, providing valuable insights for marketers and brand managers in the food industry.

4. Results and Discussion

Respondent Characteristics

Below are the characteristics of the respondents based on the questionnaires that were distributed.

Table 1: Respondent Characteristics

Characteristics of Respondents		Total	Percentage %
Gender	Male	77	38.50
	Female	123	61.50
Age	18-24	62	31.00
	25-34	81	40.50
	35-44	26	13.00
	45-54	17	8.50
	55<	14	7.00
Civil Status	Single	129	64.50
	Married	71	35.50
Occupation	Student	80	40.00
	Employed	85	42.50
	Self Employed	15	7.50
	Unemployed	12	6.00
	Retired	8	4.00
Monthly Household Income	Below 30,000	45	22.50
	30,000 - 60,000	62	31.00
	60,000 - 90,000	43	21.50
	90,000 - 120,000	27	13.50
	120,000 and above	23	11.50

Relationship between Gender and Brand Ambassador Endorsement:

The table shows that there is a considerable difference in brand ambassador endorsement between males and females, with females being more likely to endorse brand ambassadors (61.5%). This suggests that females may be more influenced by brand ambassadors when making purchasing decisions.

Relationship between Age and Brand Ambassador Endorsement:

The table shows that there is a relationship between age and brand ambassador endorsement, with younger consumers being more likely to endorse brand ambassadors (31.0% for 18-24, 40.5% for 25-34). This suggests that brand ambassadors may be more effective at reaching younger consumers.

Relationship between Occupation and Brand Ambassador Endorsement:

The table shows that there is a relationship between occupation and brand ambassador endorsement, the majority of respondents who endorsed brand ambassadors were employed (42.5%). However, a significant number of students (40.0%) also endorsed brand ambassadors. This suggests that brand ambassadors can be an effective way to reach both employed and student consumers.

Relationship between Monthly Household Income and Brand Ambassador Endorsement:

The table shows that there is a relationship between monthly household income and brand ambassador endorsement, it is evident that brand ambassadors are particularly effective in influencing purchasing decisions among consumers with a monthly household income ranging from 30,000 to 60,000 Sri Lankan rupees. This income segment exhibits the highest endorsement rate, with 31.0% of respondents endorsing brand ambassadors.

Comparing the Presence and Absence of Brand Ambassadors on Consumer Purchasing Intention

Brand A: The Presence of Brand Ambassadors on Consumer Purchasing Intention

The table below shows the results of a survey on the effect of brand ambassadors on purchasing intention. The survey was conducted with 200 respondents, and 146 of them (73%) said that the presence of brand ambassadors positively affects their purchasing intention. This means that a majority of respondents are more likely to purchase a product if they see a brand ambassador endorsing it.

Q: Do you believe that the presence of brand ambassadors positively affects your purchasing intention towards “Brand A”?

Table 2: The Presence of Brand Ambassadors on Consumer Purchasing Intention

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Yes	146	73.0	73.0	73.0
No	54	27.0	27.0	100.0
Total	200	100.0	100.0	

Correlation between purchase intention and the presence of brand ambassadors:

The table shows the correlation between the presence of brand ambassadors and the purchase intention of consumers. The results indicated that there is a strong positive correlation between the presence of brand ambassadors and the purchase intention of consumers. ($r = 0.653$, $p < 0.01$)

Table 3: Correlations

		Purchase_Intention	The presence of Brand Ambassadors
Purchase_Intention	Pearson Correlation	1	.653***
	Sig. (2-tailed)		.004
	N	200	200
The presence of Brand Ambassadors	Pearson Correlation	.653***	1
	Sig. (2-tailed)	.004	
	N	200	200

**. Correlation is significant at the 0.01 level (2-tailed).

Consumers reported that they were influenced to buy “Brand A” mainly by seeing TV commercials and social media posts featuring the performance of brand ambassadors.

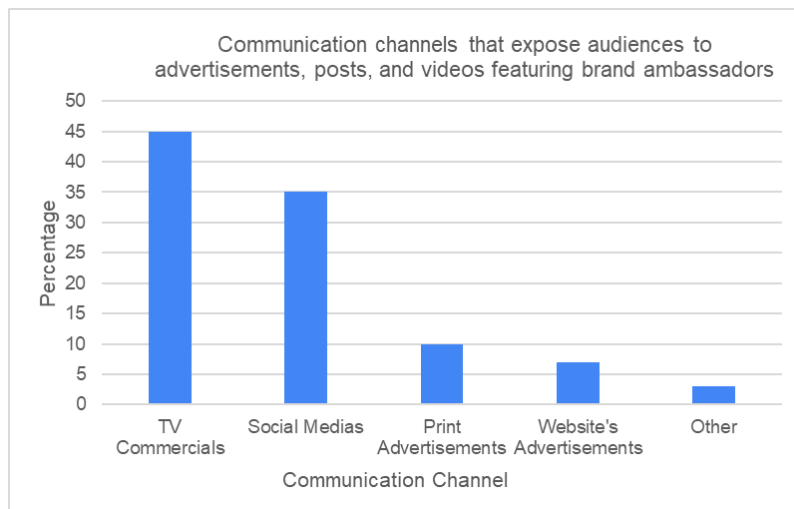


Figure 2: Communication Channels.

Consumers reported that the presence of brand ambassadors had a positive impact on brand recall and memorability.



Figure 3: Reasons that positively affects consumer's purchasing intention towards "Brand A".

Brand B: The Absence of Brand Ambassadors on Consumer Purchasing Intention

The table you provided shows the results of a survey on the effect of brand ambassadors on purchasing intention. The survey was conducted with 200 respondents, and 96 of them (48%) said that the absence of brand ambassadors negatively affects their purchasing intention 104 of them (52%) said that the absence of brand ambassadors does not negatively affect their purchasing intention. This indicates that considerable respondents are unlikely to purchase a product in the absence of a brand ambassador endorsement.

Q. Do you believe that the absence of brand ambassadors negatively affects your purchasing intention towards "Brand B"?

Table 4: The Absence of brand ambassadors on Consumer Purchasing Intention

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Yes	96	48.0	48.0	48.0
No	104	52.0	52.0	100.0
Total	200	100.0	100.0	

Correlation between purchase intention and the absence of brand ambassadors:

The table shows the correlation between the absence of brand ambassadors and the absence of purchase intention. The results indicated that there is a moderate negative correlation between the absence of brand ambassadors and the purchase intention of consumers.

($r = -0.324$, $p < 0.01$)

Table 5: Correlations

Correlations

		Purchase Intention	The absence of Brand Ambassadors
Purchase Intention	Pearson Correlation	1	-.324**
	Sig. (2-tailed)		.004
	N	200	200
The absence of Brand Ambassadors	Pearson Correlation	-.324**	1
	Sig. (2-tailed)	.004	
	N	200	200

Correlation is significant at the 0.01 level (2-tailed)

Consumers reported that because of the absence of brand ambassadors, primarily they face difficulties in remembering or recalling "Brand B".

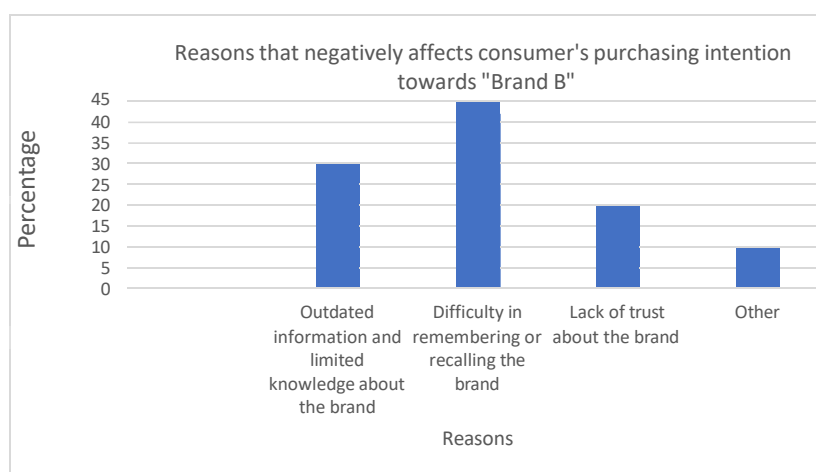


Figure 4: Reasons that negatively influence consumer's purchasing intention towards "Brand B"

Multiple Regression

Table 6: Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.722 ^a	.521	.495	.346

- a. Predictors: (Constant), Brand, Occupation, Availability of Brand Ambassadors, Taste, Monthly Income, Age, Gender, Accessibility, Level of Education, Price

Table 7: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.464	10	2.446	20.431	.000 ^b
	Residual	22.511	188	.120		
	Total	46.975	198			

- a. Dependent Variable: Purchasing_Intention
 b. Predictors: (Constant), Brand, Occupation, Availability of Brand Ambassadors, Taste, Monthly Income, Age, Gender, Accessibility, Level of Education, Price

Table 8: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.875	.243		7.705	.000
	Age	-.071	.022	-.173	-3.288	.001
	Gender	-.023	.053	-.023	-.437	.663
	Level of Education	-.050	.025	-.122	-2.030	.044
	Occupation	.004	.020	.011	.182	.856
	Monthly Income	.055	.023	.127	2.427	.016
	Availability of Brand Ambassadors	.089	.034	.135	2.601	.010
	Price	-.280	.038	-.684	-7.423	.000
	Accessibility	-.006	.021	-.016	-.282	.778
	Taste	.086	.037	.126	2.307	.022
	Brand	.010	.037	.024	.264	.792

- a. Dependent Variable: Purchasing_Intention

The R value of 0.722 and the R square value of 0.521 in the table indicate a strong positive relationship between the independent variables and the dependent variable. This means that the independent variables are able to explain a significant portion of the variance in the dependent variable. The R value is a correlation coefficient that measures the strength and direction of the linear relationship between two

variables. In this case, the R value is 0.722, which indicates a strong positive relationship between the independent variables and the dependent variable. This means that as the values of the independent variables increase, the values of the dependent variable also tend to increase. The R square value is the square of the R value, and it represents the proportion of the variance in the dependent variable that can be explained by the independent variables. In this case, the R square value is 0.521, which means that 52.1% of the variance in the dependent variable can be explained by the independent variables.

The results of the multiple regression analysis indicated significant associations between several independent variables and the dependent variable measuring the influence of brand ambassadors on consumer purchasing intention. Notably, factors such as Taste ($B = 0.086, p < 0.05$) and monthly income ($B = 0.055, p < 0.05$) emerged as the most influential variables, suggesting a substantial impact on consumers' intention to purchase. Additionally, age was identified as a significant factor ($B = -0.071, p < 0.01$) in shaping consumer purchase decisions. While the presence of brand ambassadors ($B = 0.089, p = 0.01$) demonstrated a moderate impact, the relationship with price was negative, indicating that price had a detracting effect on purchase intention ($B = -0.280, p < 0.01$).

Brand loyalty towards “Brand A” & “Brand B”

Table 9: Brand loyalty towards “Brand A”

Brand loyalty towards “Brand A”:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not loyal at all	19	9.5	9.5	9.5
	Slightly loyal	11	5.5	5.5	15.0
	Neutral	58	29.0	29.0	44.0
	Loyal	70	35.0	35.0	79.0
	Very loyal	42	21.0	21.0	100.0
	Total	200	100.0	100.0	

The table shows that most consumers are loyal to brand A because of the presence of brand ambassadors. Specifically, 79% of consumers are loyal to brand A, and 35% of consumers say that brand ambassadors are a major factor in their loyalty. This suggests that brand ambassadors are an effective way for brand A to build and maintain customer loyalty.

Table 10: Brand loyalty towards “Brand B”

Brand loyalty towards “Brand B”:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not loyal at all	50	25.0	25.0	25.0
	Slightly loyal	57	28.5	28.5	53.5
	Neutral	55	27.5	27.5	81.0
	Loyal	24	12.0	12.0	93.0
	Very loyal	14	7.0	7.0	100.0
	Total	200	100.0	100.0	

The table shows that most consumers are not loyal to brand B because they don't have brand ambassadors. 54% of consumers are not loyal to brand B. This suggests that the absence of brand ambassadors has a considerable negative impact on building brand loyalty toward Brand B”.

5. Discussion:

Objective 01: To compare the consumer purchasing intention towards instant noodles with the presence and absence of brand ambassadors

The presence of brand ambassadors has a significant impact on consumer purchasing intention towards instant noodles, particularly for "Brand A." When brand ambassadors are present, consumers are more likely to have a positive purchasing intention due to the impact of brand recall and memorability. This is because brand ambassadors help create a strong association between the product and the personality of the ambassador, leading to increased brand recognition and a positive perception among consumers. Consumers are often exposed to brand ambassadors through various channels such as TV commercials, social media posts, and advertisements. The visibility of brand ambassadors on these platforms helps to reinforce the brand's image and message, leading to a higher purchasing intention among consumers. In addition to the presence of brand ambassadors, other factors such as price, taste, age, and monthly income also play a significant role in influencing consumer purchasing intention towards instant noodles. However, the presence of brand ambassadors acts as a catalyst in shaping consumer perceptions and influencing their decision-making process. On the other hand, the absence of brand ambassadors has a negative impact on consumer purchasing intention, particularly for "Brand B." Without brand ambassadors, there is difficulty in remembering and recalling the brand, leading to limited knowledge and trust about the product. This lack of trust and familiarity can result in a lower purchasing intention among consumers.

Objective 02: To assess the role of brand ambassadors in building brand loyalty toward instant noodles

The role of brand ambassadors in building brand loyalty towards instant noodles is significant, particularly for "Brand A." Consumers are more likely to exhibit brand loyalty towards "Brand A" due to the presence of brand ambassadors. This is because brand ambassadors help create a strong association between the product and the personality of the ambassador, leading to increased brand recognition and a positive perception among consumers.

Brand ambassadors act as a catalyst in shaping consumer perceptions and influencing their decision-making process, leading to a higher level of trust and familiarity with the brand. The visibility of brand ambassadors in various channels such as TV commercials, social media posts, and advertisements reinforces the brand's image and message, further enhancing brand loyalty among consumers.

On the other hand, "Brand B," which lacks brand ambassadors, struggles to build brand loyalty among consumers. Without brand ambassadors, there is difficulty in remembering and recalling the brand, leading to limited knowledge and trust about the product. This lack of trust and familiarity can result in lower brand loyalty among consumers. Overall, the presence of brand ambassadors plays a crucial role in building brand loyalty towards instant noodles. The strong association created between the product and the personality of the ambassador enhances brand recognition, creates a favorable brand image, and ultimately leads to higher levels of brand loyalty among consumers. This highlights the importance of utilizing brand ambassadors as part of the marketing strategy for instant noodle products to build and maintain brand loyalty.

6. Conclusion

In conclusion, this comparative study between two leading brands of instant noodles in Sri Lanka has revealed the significant impact of brand ambassadors on consumer purchasing intention and brand loyalty. As per 1st objective, the presence of brand ambassadors significantly influences consumer

purchasing intention towards instant noodles. Consumers are more likely to exhibit brand loyalty towards a brand with brand ambassadors, such as "Brand A," compared to a brand without brand ambassadors, such as "Brand B." This highlights the importance of utilizing brand ambassadors as part of the marketing strategy for instant noodle products to increase consumer purchasing intention. As per 2nd objective, brand ambassadors play a crucial role in building brand loyalty towards instant noodles. The strong association created between the product and the personality of the ambassador enhances brand recognition, creates a favorable brand image, and ultimately leads to higher levels of brand loyalty among consumers. This emphasizes the significance of brand ambassadors in shaping consumer perceptions and influencing their decision-making process.

Recommendations: Based on the findings, it is recommended that instant noodle brands, particularly in the food industry, consider utilizing brand ambassadors as an effective marketing strategy to increase consumer purchasing intention and build brand loyalty. By incorporating brand ambassadors into their marketing efforts, brands can enhance their visibility, create a strong association with their products, and ultimately foster greater trust and familiarity among consumers. Additionally, brands should consider selecting brand ambassadors who align with their target audience and can effectively communicate the brand's message to further strengthen their marketing efforts.

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ICSD 055

POST EVALUATION OF OPERATIONAL PERFORMANCE OF COMPOST PROJECTS OF LOCAL AUTHORITIES

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Abstract: In comparison to other Asian countries in the region, Sri Lanka has a moderately high percentage of organic waste generation, characterized by its higher moisture content and low calorific value. Given the composition of the waste and prevailing socio-economic conditions, composting emerges as the most viable technology for managing organic waste with high moisture content. Numerous projects have been launched in the country to address solid waste management and move towards achieving zero waste by 2030; recognizing the need and suitability of composting, the Pilisar National Solid Waste Management Project extends financial and technical support to local authorities seeking to implement compost projects for sustainable waste management. This study sets out to assess the effectiveness of compost projects in Southern and Western Sri Lanka. Data and information were gathered through field visits, questionnaire surveys, formal and informal discussions, and expert interviews. The analysis revealed that among the 20 selected sites, 7 sites exhibited a performance level exceeding 75%, while 8 sites performed at a level between 75% and 50%. Only 5 sites demonstrated a performance level below 50%. The findings indicated that site failures stemmed from various factors, including inadequate financial assistance and technical expertise, shortcomings in site selection and design, limited institutional commitment and community involvement, production of low-quality compost, and irregular monitoring of the composting process and compost quality. Moreover, by scrutinizing existing solid waste management practices conducted by local authorities, significant gaps were identified. This study proposes practical measures that local authorities can adopt to address these gaps and enhance their waste management practices.

Keywords: Waste management; waste; composting; compost quality; local authorities

1. Introduction

As global populations swell, technological advancements surge, economies expand rapidly, and income-induced lifestyle changes take hold, the volume of waste produced escalates correspondingly. This surge in waste generation presents one of the gravest management challenges facing the world today. In Sri Lanka, a nation still on the developmental trajectory, the sources of solid waste are manifold, encompassing residential, commercial, industrial, biomedical, institutional, agricultural, construction, and demolition waste. The country has recorded an alarming 80% organic waste generation (Pandyaswargo & Premakumara, 2014), which is the highest reported percentage within this category. A further cause for concern is the higher-than-average per capita waste production, which stands at 0.9 kg/day-person. This surge in waste is attributed to the migration of populations from rural to urban settings and an escalation in consumerism (Chiemchaisri et al., 2007). Breaking down the composition of the waste generated in Sri Lanka, 57% is identified as short-term biodegradable waste, while a smaller fraction, 6%, is considered long-term biodegradable waste (Jayasinghe-Mudalige & Udugama, 2011). When examined in specific terms, the waste categories include 76.4% food waste, 10.6% waste from paper and cardboard, 5.7% from plastics, 1.3% metal waste, 1.3% glass waste, and 4.7% attributed to other waste forms. Comparatively negligible amounts are contributed by wood waste, textiles, disposable diapers, and waste from rubber and leather products (Pipatti et al., 2006). Furthermore, the waste's moisture content is distinctively high, while the average calorific value is relatively low, ranging from 600 to 1000 kcal/kg and accounting for 70% - 80% of the waste by weight (Bandara, 2008). The waste management situation in Sri Lanka, therefore, underscores a pressing need for sustainable and practical solutions that can address the multifaceted challenges presented by this varied and voluminous waste spectrum.

Sri Lanka has undertaken numerous initiatives to advance sustainable waste management practices, striving to mitigate the environmental impact of escalating waste volumes. Nationally and internationally sponsored programs such as the "Pilisar" Project, assistance from the Japan International Cooperation Agency (JICA), and support from the Korea International Cooperation Agency (KOICA) highlight the collaborative efforts to tackle the complex challenges of waste management. Progress in this arena has been mixed. While specific projects have successfully implemented and sustained waste management practices, others have continued operations due to an array of emergent difficulties during their execution. Data from the Solid Waste Management Supporting Centre (2019) sheds light on the situation: Sri Lanka generates approximately 8,700 tons of municipal solid waste per day, yet only about 4,480 tons are collected. The Western province, as the prime waste-producing region, contributes to a significant 32% of the nation's total waste generation, contrasted by the Southern province, which accounts for just 8%. A considerable gap exists in local authority services, where about half are unable to collect the entirety of waste produced in their jurisdictions, and around 50% of the total local authorities gather more than half of their waste. It is anticipated that the daily generation of municipal solid waste will increase to around 15,320 tons by 2025. Per capita waste generation is expected to reach 4 kilograms, with organic waste constituting up to 76% of the overall waste composition. Concurrently, increments in paper, plastic, glass, metal, and other waste categories are predicted to rise to 5%, 6%, 1%, 1%, and 5%, respectively (Hoornweg & Bhada, 2012). Organic waste in developing countries, such as Sri Lanka, typically features high density and moisture content paired with a low calorific value. These characteristics make it more appropriate for biological treatment methods rather than thermal treatment options (Pandyaswargo & Premakumara, 2014; Rand et al., 2000). The ongoing challenges suggest a critical need for adaptable, efficient, and sustainable waste management solutions that can effectively address current and future environmental needs.

Among the biological treatment options for waste, specifically aerobic composting and anaerobic digestion, it is observed that anaerobic digestion systems have not seen widespread success in many Asian countries, including Sri Lanka. Hurdles such as high capital investment, ongoing

maintenance costs, and the expertise required for their operation have impacted their viability (Pandyaswargo & Premakumara, 2014; Mazumdar, 2012). Composting, which is an aerobic process, holds potential as a recycling method by converting waste into compost and reintroducing it into the environment for use as a soil amendment or fertilizer. Beyond the contribution to waste reduction, composting offers multifaceted benefits: environmental, agricultural, social, and economic. As such, when contrasted with other management strategies for biodegradable waste, composting emerges as a particularly significant and practical option for Sri Lanka, where the prevalent waste characteristics render incineration unsuitable. Based on data from the Pilisaru project, facilities capable of processing compost handle about 1,341 tons per day, which equates to roughly 40% of the total degradable waste of 3,349 tons per day. These statistics reveal a substantial gap in composting capability, with another 60% of degradable waste requiring processing.

In Sri Lanka, composting operations vary in scale. Most local authority-managed sites are small-scale compost yards with capacities of less than 5 tons per day. A limited number of cluster-based and medium-scale yards also exist. The choice of composting technology spans from high-cost, high-tech solutions to more economical, low-tech options, generally determined by both affordability and the availability of technical expertise. Specifically, the Pilisaru project has implemented the turning windrow composting method, wherein the organic fraction of sorted waste is assembled into windrows. The practicality of utilizing a broad spectrum of feedstock, coupled with low operational costs and ease of management, has made the windrow composting method popular across various regions of the country. The primary aim of the research is to define the factors influencing the operational performance of composting sites, to critically assess the efficacy of local authority composting initiatives, to identify discrepancies between current operational conditions and optimal standards, and to recommend best practices that will foster sustainable and eco-friendly improvements in the management of compost yards.

The Pilisaru Project, established with the aim of mitigating the mounting waste management challenges, has implemented the highest number of composting projects in the Western and Southern provinces of Sri Lanka. These initiatives were established in response to the significant waste generated in these areas and at the behest of the respective local authorities (LAs). The Southern province, spanning an area of 5,650 km², is situated in the lower section of the island and comprises three principal districts: Galle, Matara, and Hambantota. This region is home to 2,477,288 inhabitants, constituting 12% of the total population of Sri Lanka, and is characterized by a population density of 460 individuals/km² (Department of Census and Statistics, 2012). Here, waste generation reportedly amounts to approximately 696 tons daily (NSWMS, 2019), with waste collection figures reaching 335 tons per day. This province is organized into 49 local authorities, which include 03 Municipal Councils (MC), 04 Urban Councils (UC), and 42 Pradeshiya Sabhas (PS). Conversely, the Western province is comprised of a smaller area of 3,575 km² yet holds a significant demographic and waste management profile. It includes the districts of Colombo, Gampaha, and Kalutara. The population in this region is the highest in Sri Lanka, representing 28.7% of the country's population, with a considerably greater density of 1,621 persons/km². The magnitude of waste management here is distinctly evident with the generation of 2,780 tons of waste per day, of which 1,919 tons are collected (NSWMS, 2019). Governed by 48 local authorities, the Western province includes 07 Municipal Councils (MC), 14 Urban Councils (UC), and 27 Pradeshiya Sabhas (PS). These statistics underline the pressing need for effective waste management strategies in both provinces. Through the Pilisaru Project's interventions, particularly in composting, there is a critical move towards addressing the environmental challenges posed by waste while supporting sustainable development in these densely populated regions of Sri Lanka.

2. Methodology

The current status of municipal solid waste management in the country was referred to through a literature review, reports published by the government, expert interviews, ongoing projects on waste management, field visits, and formal and informal interviews of the personnel who are engaged in waste management activities. A questionnaire was designed to evaluate the performance of existing compost projects, and gathered data was analyzed to evaluate the operational performance of each selected site. Specific field inspections were carried out to verify data. The questionnaire included all aspects of the composting process, from waste generation to final disposal of residue and marketability of produced compost, by mainly focusing on questions related to operational aspects. Out of 341 LAs in Sri Lanka, 137 LAs have Pilisaru project-funded compost sites, including 24 compost sites for the Western Province and 28 compost sites for the Southern Province. Compost plants implemented by the Pilisaru project were selected through a stratified random sampling method depending on their capacity and geographical location. Based on these criteria, this study covered 20 composting sites, which represent small-scale compost sites in Western and Southern Provinces and their operation under the supervision of relevant LAs. Compost yards having a capacity of less than or equal to 5 ton/day of solid waste are considered small-scale compost yards.

A set of indicators covering waste generation to final disposal of municipal solid waste have been selected to assess the overall performance and efficiency of selected sites. All the criteria were evaluated for selected compost site and the overall operational performance of each compost yard was determined based on waste segregation, feed-stock preparation (shredding, mixing, applying additives), pile identification, maintaining optimum levels and monitoring parameters (temperature, moisture, C:N ratio, particle size), turning compost piles, sieving produced compost, inspection of quality of produced compost, odor, fly density, leachate handling (reuse/dispose of after proper treatment), final disposal of residue, stormwater handling, process failures, optimum utilization of the compost yard, sales of compost, local authority/institutional contribution, rate of waste reduction, potential reduction of waste disposal, Environmental Protection License (EPL) for the waste management site, use of personnel protective equipment (PPE). Priority of each indicator was designed depending on their importance, and those criteria were identified based on a literature review, expert interviews, and on-site inspections.

3. Results and discussion

This research encompassed an analysis of 20 small-scale compost sites that employ the turning windrow composting method, accounting for 40% of the sites established under the Pilisaru Project. Of these, 16 sites, translating to 80%, were found to be operational, while the remaining 4 sites, or 20%, were non-operational. Some sites initially operated successfully but later experienced operational difficulties for various reasons. The efficacy of waste segregation was a key focus during field inspections. Approximately 75% of the examined sites practiced source segregation, whereas about 25% were still accumulating mixed waste and conducting segregation at the waste management facility itself. Only those who engaged in source-segregated waste collection expressed an intent to adopt the practice in the future. Nevertheless, even among LAs that did implement source segregation, there was a necessity for additional segregation due to improper source separation practices. The segregated organic fraction was then directly sent for piling, indicating a positive approach toward waste segregation.

The extent of waste segregation could be assessed by the presence of non-degradable materials in the compost piles. Of the sites surveyed, 50% demonstrated a high level of segregation, 39% exhibited a moderate level, and 11% had a poor segregation standard. Common non-compostable contaminants such as polythene, metals, and glass were observed within the compost piles during inspections. On-site feedstock preparation was a rare activity, with mixing before piling preparation being the most common practice observed across all operational sites. Only 12.5% of the sites included shredding and additive application in their processes. The dimensions of

compost piles varied, with most sites opting for trapezoidal configurations while others prepared rectangular-shaped piles. Some sites encountered challenges with overcapacity and were compelled to increase their pile sizes to utilize the available space efficiently. Furthermore, pile identification was an overlooked aspect among the LAs, with only a quarter of the sites utilizing visible boards that featured identifying details like pile number, preparation date, and scheduled turning dates for easy on-site management. The implementation of such identification methods is a simple yet effective practice for enhancing the organization and monitoring of composting activities.

Based on observations conducted during site visits, a variety of methods for turning compost piles were documented. Sixty percent of the sites employed manual turning with shovels, while 20% utilized mechanical turning with equipment such as bobcats. This data analysis suggests a correlation between the capacity of the compost site and the choice of turning method, indicating that more extensive facilities tend to opt for mechanical means. The frequency with which compost piles were turned also varied across the surveyed sites; 75% of the facilities performed turning once a week. In contrast, a tiny fraction, 5%, turned their piles once every two weeks or less. Twenty percent of the sites were not operational at the time of assessment. The duration required to complete the composting process ranged from two to five months. Interestingly, no direct link was found between turning frequency and the time taken to produce compost, mainly because many sites needed to take into account the stability and maturity of the compost instead of adhering to predetermined timeframes. Generally, active composting takes anywhere from four to sixteen weeks. However, this can extend to months depending on variables such as feedstock type, composting technology, feedstock preparation, climatic conditions, and operational efficiency. The sites in this study reported compost production cycles lasting from eight to twenty weeks.

Approximately half of the facilities actively monitored temperature and moisture levels within their compost piles. Different practices were observed for managing these parameters; for example, the temperature of the compost pile was regulated by turning the pile when it exceeded optimal levels or by increasing the pile size to raise the temperature when it was too low. Concerning the management of leachate, which is a by-product of the early stages of composting, most LAs have implemented an effective drainage system to collect it. Typically, two leachate collection tanks were installed, allowing for the leachate to flow into them by gravity. The collected leachate would then be reused by diluting it and adding it back into the compost piles during the initial stages. However, this practice was not applied during the curing stage due to the risk of introducing harmful microorganisms into the compost. For the disposal of leachate, we observed that 55% of the facilities reused it for composting purposes, 5% disposed of the leachate into the environment following rudimentary treatment, and 10% released the leachate directly into the environment without any treatment, leading to potential pollution of nearby surface and groundwater sources.

During site inspections, it was noted that odors from compost operations could pervade surrounding areas, causing a public nuisance. The extent of the odor's reach varied, with some sites emitting odors over more considerable distances. In contrast, others were confined to more localized areas, which was especially problematic when residential vicinities were nearby. Post-maturation, the compost underwent a sieving process, with only 10% of the examined sites using manual methods. Surprisingly, despite being small in scale, 71% of the sites opted for mechanical sieving, utilizing machines that enhanced the efficiency of their operations. The residual matter post-sieving comprised partially degraded organics such as yard and market waste, as well as non-biodegradable materials. This final residue was collected for separate disposal. Sieved compost was then stored, awaiting packaging, which occurred at different intervals across the sites, ranging from one week to several months post-sieving. Disposal practices of this final residue varied, showing a dependency on available land, technology, and technical

considerations. The predominant approach, at 41% of sites, was open or controlled dumping, with only 36% of selected sites employing an alternative final disposal method, such as repurposing for cultivation or reintroducing into new compost piles.

Only 37% of the sites performed quality checks on the finished compost, while the majority, 63%, did not engage in quality control. When quality was assessed, it was not a routine procedure, often carried out at the Department of Agriculture in Gannoruwa upon request from the waste management authority in the western province. Worker safety protocols were observed, noting that while all personnel wore gloves, the adherence to other PPE was less consistent. Seventy-five percent of workers used boots, 15% wore uniforms, and 35% wore masks, yet none utilized safety helmets. Regarding environmental compliance, 40% of the sites held active EPLs for the operation. In contrast, 30% had not secured an EPL from the CEA, and 20% had previously held licenses that were either suspended due to regulation breaches or had expired, with a small portion in the process of renewal. The level of waste management engagement varied among the responsible LAs and institutions. Forty-five percent demonstrated strong commitment within their capacities, whereas 40% showed a moderate engagement with room for improvement. A mere 15% exhibited minimal involvement in advancing their waste management practices. Community involvement mirrored a similar pattern, with only 5% of communities highly engaged in waste practices, 80% showing moderate engagement, and 15% exhibiting low participation levels. In terms of yard utilization for composting, discrepancies were evident across sites with similar design capacities. Of the 20 sites, 4 were non-operational. Only 3 sites managed waste in alignment with their designed capacity, thereby optimizing yard usage. Six sites exceeded their capacity, highlighting a need for expansion, while another six needed to be more utilized in their facilities.

Within the scope of this study, which included 20 composting facilities, 11 sites reported a robust demand for their produced compost, with over half of their output being utilized for various applications. On the other hand, 3 sites experienced a lower demand, which could be attributed to the lower quality of the compost they produced or a need for more public awareness regarding the benefits and usage of compost. It was noted that many composting sites maintain designated agricultural areas on their premises where the compost produced is applied to support farming activities. The compost utilization ratio, calculated based on the average amount of compost sold monthly against the input of waste by wet weight, indicated that demand for compost varied significantly across different sites. A handful of sites saw high demand, whereas the majority experienced lower demand levels. Specifically, demand for compost in the Western province was dampened by the limited scope of agricultural activities within the region. Meanwhile, in rural areas of the Southern Province, a preference for chemical fertilizers over compost among farmers was hypothesized to impact demand negatively. The study affirmed the role of composting in diminishing the flow of waste to landfills or other final disposal methods. This assertion hinges on the volume of waste processed into compost and the resulting quantity of compost produced. A notable number of sites demonstrated a high rate of waste reduction by weight, confirming the effectiveness of composting in cutting down waste volumes. Upon synthesizing all collected data, a clear discrepancy emerged between the anticipated outcomes of the composting process and the realized performance levels at the composting sites. This gap underscores the need for enhancements in operations and public engagement to elevate the efficiency and efficacy of composting practices.

4. Gap identification and recommendations

The promotion of the 3R concept among the public is critical for reducing solid waste generation. Efforts to enhance the reuse and recycling potential through material collection centers are vital, including the establishment of a waste collection network and value-addition systems that engage both public and private institutions. A country must take necessary actions to adapt prod-

uct and packaging designs to be more eco-friendly, encourage smart shopping, avoid unnecessary items, share among communities, and raise awareness about waste reduction. Despite these efforts, a considerable challenge remains with the solid waste management projects carried out by LAs, often stemming from a need for more expertise in designing, implementing, and managing integrated solid waste management plans. Failures in some cases have been attributed to improper site selection, proximity to sensitive areas, and the revocation of EPLs by CEA. The design of compost yards varies, with earlier designs incorporating both undercover piling areas and open-to-sky areas. However, it was noted that this effort was not suitable for wet zone areas due to high rainfall, prompting a shift in design towards fully covered yards. Space constraints have also been a challenge for LAs, particularly concerning final disposal, even when composting processes are appropriately conducted.

Compost yards are traditionally designed to anticipate future waste generation for a set period. However, many LAs find themselves over capacity within just a few years. Issues of overcapacity, poor management, and failure to estimate future waste generation significantly affect the operational performance of these yards. The design capacity directly correlates with optimum yard performance, as deviations from this capacity can impede efficiency. Source separation is practiced to varying degrees across different LAs, with some engaging well, thus simplifying treatment processes, and others still handling mixed waste, necessitating extra effort and time for separation at the site. A lack of segregation is evident, as non-biodegradable or recyclable materials are often found within compost piles, affecting the quality of the final product. Continuous awareness programs and firm actions against collecting mixed waste are critical. Other operational challenges include odor control, leachate management, and inefficient waste collection due to a lack of resources. The preparation of feedstock before piling is often inadequate, as activities such as shredding and adding bulking materials to balance the carbon-to-nitrogen ratio are not consistently applied, leading to issues in final product quality. Regular monitoring of parameters such as temperature, moisture, pH level, and oxygen concentration is essential for maintaining optimal composting conditions and managing changes that may require corrective actions. Leachate management has been suboptimal in many sites, with insufficient tanks and treatment facilities leading to environmental pollution. The uncertainty in the quality and demand for the final compost product hinders the financial sustainability of composting operations. Limited financial support often needs to be improved on quality assurance measures. Centralizing compost marketing could alleviate some of these problems by ensuring consistent quality control and value addition suited to local needs.

Inadequate human resources often compound operational and management challenges. The labor force's performance is crucial, yet the high turnover rates, the contract nature of jobs, and the lack of incentives contribute to operational inefficiencies. Training and capacity-building programs are vital to improve worker effectiveness, alongside better employment conditions and facilities. The utilization of equipment is another area of concern, as affordability and maintenance capacity of LAs fall short, affecting service continuity. Data collection for waste management needs to be improved, with no national database or regular updating mechanism undermining effective strategy development. Public protests and social factors frequently stem from operational nuisances like odors and leachate runoff, underscoring the need for better control mechanisms and community engagement. Facilities often lack essential infrastructure, affecting worker morale and highlighting the need for financial allocation conducive to sustainable waste management practices. Ultimately, the success of solid waste management facilities relies on adequate monitoring and evaluation, which needs to be improved. Introducing waste management models tailored to institutional systems and implementing separate financial mechanisms like the Polluter Pays Principle and Extended Producer Responsibility could foster accountability. Public awareness remains a cornerstone for change, using media and community programs to highlight responsible waste practices. A Public-Private Partnership (PPP) could bring much-needed capacity where LAs fall short, ensuring that waste management projects

meet environmental and economic needs efficiently. The involvement of a third-party institution could provide oversight and balance, ensuring the management of solid waste is upheld to benefit all stakeholders involved.

5. Conclusions

This research sheds light on the varying degrees of operational efficacy across composting sites in Sri Lanka, with 07 sites demonstrating over 75% performance, 08 sites ranging from 75% to 50% performance, and 5 sites falling below the 50% threshold. The findings suggest that a majority of LAs in Sri Lanka need more capacity to establish and maintain sustainable and environmentally friendly waste management centers. Moreover, they need to acquire skills and expertise in several facets of waste management, including the knowledge necessary for cost recovery and marketing the produced compost, to ensure efficient operations and quality output that align with established standards within their regions.

LAs face challenges in handling waste management issues due to a multitude of factors, including improper selection of sites, failures in design considerations, inadequate financial assistance, and insufficient technical acumen. Other notable issues include deficits in the workforce, with gaps in carder positions related to waste management activities, the absence of essential resources, utility facilities, and a robust regulatory framework. A critical impediment to the success of these composting sites is the lack of an efficient compost process monitoring system, which is a frequent cause of failure among compost projects financed by the Pilisaru Project. To resolve these failures, promoting the 3R concept is essential. Strategies such as allocating separate funds for waste management, establishing a centralized database, adopting the Extended Producer Responsibility and Polluter Pays Principle, enhancing the value addition of produced compost, and improving marketing strategies are recommended to elevate the progress and performance of waste management processes. The role of individuals and institutions in charge of waste management cannot be overstated. Their commitment and motivation, bolstered by leadership and political support, are crucial. Moreover, community backing and partnerships with private entities further influence the successful operation of composting sites and waste management units. Addressing the identified gaps with appropriate preventive and corrective actions pertaining to waste management issues could significantly enhance the public's perception of the waste sector, leading to better engagement and outcomes.

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ICSD 072

A REVIEW ON CLIMATE RESILIENT BIODEGRADABLE RAIN COVERS AS A CLIMATE ADAPTATION STRATEGY FOR VEGETABLE PRODUCTION

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Abstract: Climate change threatens food production with rising temperatures, erratic weather, and extreme events disrupting agriculture, impacting crop yields and food security. Heavy rainfall, intensified by climate change, challenges crop production, leading to increased demand and market uncertainty. The review has conducted (a) to assess climate resilient biodegradable rain covers as a climate adaptation strategy for vegetable production and (b) to suggest eco-friendly sustainable solution for soil erosion and crop protection. This review considers the peer reviewed articles published between 2002 and 2022 in the Science direct. In recent years, innovative proactive climate adaptation measures have emerged as essential strategies for stabilize agricultural production and foster a more secure and predictable market for crops. As a climate adaptation innovative strategy, biodegradable rain covers have found which is climate resilient that can be placed above plants during heavy rainfall, shielding them from excessive water and potential damage. The aims of biodegradable rain cover for crop protection include shielding crops from heavy rainfall to prevent waterlogging and erosion, regulating soil moisture for optimal growth, contributing to environmental sustainability, reducing plastic pollution, and supporting overall soil health through enhanced microbial activity. These align with environmentally conscious agricultural practices. The assessment achieved several outcomes as farmers benefited from vegetable production during heavy rainfall season by using the biodegradable rain covers and farmers were able to conserve the soil by erosion, assessing how effectively these rain covers protect the vegetables from severe weather conditions, the environmental benefits, investigating how well these coatings adapt to different climatic conditions, assessment of possible unintended consequences or long-term effects on soil health, biodiversity, suggestions for improvements. The review emphasis the climate-resilient biodegradable rain covers offer a promising strategy for enhancing vegetable production in the face of climate change.

Keywords: Adaptation; Biodegradable covers; Climate resilience; Crop protection

1. Introduction

Major global climate changes will affect plant production and agriculture as a whole. This affects the world's food supply. Climate change is not necessarily bad, but it can cause problems because it is very difficult to predict, such as the flow of rain and the fluctuation of highs and lows. As a result, product productivity will decrease. Vegetables tend to be tastier and more sensitive to climate change. Increased rainfall due to climate change will restrict crop production, increase demand and increase market uncertainty. During the rainy season, crop yields are low, so prices of various vegetables remain high. This is due to high soil moisture and high drainage.

In some cases, the risk of diseases, insects and pathogens increases, which significantly reduces yields. And also, fertilization is low because rainfall leaches nitrogen and potassium from the root zone. These conditions can be achieved through the use of protective structures like rain covers such as rain shelters and small tunnel. Using these structures, several vegetables have a great demand in the market such as tomatoes, eggplants, peppers, peppers, broccoli, cabbage, cauliflower, radishes, carrots, spinach, cilantro, lettuce, cucumbers, bottle gourds and bitter gourds. (Sahu *et al.*, 2020)

Vegetable production under protected covers reduces the effects of diseases caused by pests, diseases and yield losses by heavy rains and results in higher productivity and returns. Farmers can also produce vegetables even in the off-season, improving the availability of fresh produce when vegetables are scarce. Vegetable prices are higher in the off-season, so farmers can make more profit. (Srinivasan, 2011)

Plastic films made of low density polyethylene (LDPE) are commonly used in agriculture as coverings in order to increase yield and quality. To increase the sustainability of agriculture and overcome the problem of disposal of conventional plastics, films on bio-based and renewable agricultural resources are available these days. At the end of its useful life, the biodegradable film can be disposed of directly on the ground or in a composting plant and in the general organic waste stream. It seems to be a good solution for plastic films. Biodegradable plastics should not create toxic residues in the soil (Environ, 2008)

This review examines to assess climate resilient biodegradable rain covers as a climate adaptation strategy for vegetable production in order to increase the yield during rainy season and to suggests eco-friendly sustainable solution for soil erosion and crop protection by reviewing the biodegradable films for the use of rain covers.

2. Methodology

A systematic review of articles was conducted through PRISMA (Preferred Reporting Items for Systematic Meta-Analytics), as shown in Figure 1. Studies related to the research objectives were searched in Google Scholar using the following keywords: Adaptation, Biodegradable Covers, Climate Resilience and crop protection. In addition, searches were conducted between 2002 and 2022. Eighty papers were analyzed, 15 were considered relevant, and the results are presented here.

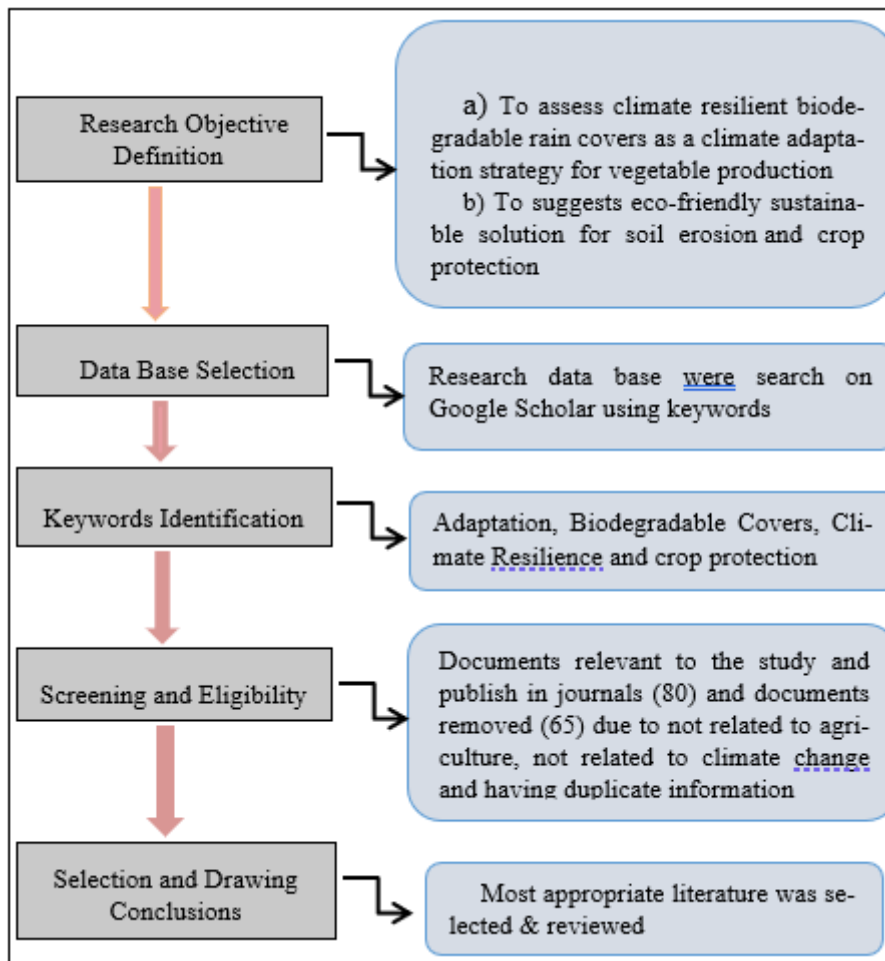


Figure 1: Method for selection of research papers for review and analysis.

3. Results and Discussion

3.1. Rain covers as a climate adaptation strategy

In order to strengthen the system's ability to respond to diverse climate-related disturbances, climate resilient agriculture integrates adaptation, mitigation, and other activities. This allows the system to resist or tolerate damage and recover fast (Bulletin of the Indian Society of Soil Science, 2018). In vegetable production, using rain covers as a climate adaptation strategy is a proactive way to protect crops against the damaging impacts of increasingly unpredictable and severe weather patterns, particularly excessive rainfall that are linked to climate change. These covers, which are usually composed of specialty fabrics or high-grade plastics, are intended to form a protective barrier over the crops, reducing the possibility of physical harm, soil erosion, and the spread of pests and illnesses that are transmitted through water and can be aggravated by excessive wetness. Rain covers typically consist of a structural frame with screens on the sides and ends and a polyethylene film or rigid plastic panels covering the top of the structure. They often lack electricity and active heating and cooling systems, although they do have access to an irrigation source. The most popular materials for framing are metal and lumber. Furthermore, locally accessible materials like bamboo and guava as well as plastics like PVC tubing have been utilized as framing components (Kratky, 2006).

Protected structures can be crucial in reducing the effects of temperature swings, excessive or insufficient precipitation, varying sun exposure hours, and pest and disease infestation. In order to counteract the unpredictable weather patterns and new problems in vegetable production, farmers are progressively

implementing various protective structures. During the wet season, the most popular structure for growing vegetable seedlings was the poly-tunnel. Farmers are also beginning to favor crop production inside agro-shade nets and seedlings growing in pro-trays. The poly-house proved to be the most effective construction under field conditions, despite the poly-tunnel being the most often used design. These protective covers aid in lowering soil runoff and erosion, regulating soil temperature, and reducing evaporation. Vegetables like tomatoes experience yield losses from heavy rainfall during the hot rainy season. Tomato yields are improved when simple clear plastic rain shelters are used to stop water logging caused by flooding and rain impact damage to growing tomatoes (Spaldon, 2015). Farmers are far less dependent on rainfall thanks to polyhouse farming, which also makes optimal use of limited water supplies and land. (Bulletin of the Indian Society of Soil Science, 2018)

3.2. Polyethylene Rain covers

Three primary characteristics of a plastic film utilized in agriculture are mechanical, optical, and thermal. Tensile strength, elongation, impact strength, and tear propagation are examples of mechanical qualities. Color, total light transmission, diffused light transmission, transmitted light spectrum, and reflected light spectrum are examples of optical qualities. Thermicity and heat flexion temperature are two of the polyethylene rain cover's thermal characteristics (Mormile et al. 2017).

By definition, the rain cover system is the most advanced method for combining plastic materials to raise production quality and quantity in a completely regulated manner. Many plastic solutions, like covering films, must survive a long time in order to be used as rain covers. Additionally, some plastic trash, like irrigation tubes, may be readily collected and disposed of because they are not overly contaminated after they reach the end of their useful lives (Guerrini et al. 2017).

3.2.1. Types of Rain Covers Resistant to Climate Change

Low-level tunnel

Another name for these is "miniature greenhouses." This kind of construction is also referred to as "row cover" since it covers plant rows. The low wire hoops (arcs up to 1.0 m high) are covered with clean plastic or nets to protect plants, particularly from wind, insects, and heavy rain. In order to improve plant growth in an open field during the winter months when temperatures are very low, 8°C or below, plastic low tunnels are flexible, translucent covers that are placed over one or more rows of vegetables (Jayasurya, 2021).

Net house with shade

A shade house is a low-cost, covered structure with holes for the necessary air, sunshine, and moisture to flow through that is surrounded by shade nets or any other woven material. It produces a suitable microclimate that is thought to be highly favorable to plant growth. The frame and cladding material are the two main parts of a shadow house structure. The frame of the shade house protects against crop load, wind, and rain while supporting the cladding material. A shade net home should last a maximum of five years, depending on the climate and the type of structural material used. (Jayasurya, 2021)

A walking tunnel

A walk-in tunnel is a transient building composed of bamboo or GI pipes that is coated in a variety of cladding materials based on the projected growing season. (Jayasurya, 2021)

3.2.2. Advantages of Polyethylene Rain covers

The purpose of the rain covers is to shield against crop weight, wind, and rain. Rain covers have a maximum lifespan of five years, depending on the climate and the type of structural material used. The airflow and partial shade lower interior temperatures, creating a favorable environment for crop growth. The structures shield the crop from insect damage as well. Insects and diseases are contained to a spe-

cific structure when smaller, individual rain covers are used, preventing them from spreading throughout a bigger, multi-unit building. The structures can also be used to raise winter vegetable seedlings for open-field gardening in the early season. It is possible to maximize the yield of a number of vegetable crops at high altitudes. Under shade net conditions, fruit quality can be improved in addition to yield.

3.2.3. Limitations of Polyethylene Rain covers

A number of building supplies, including as GI pipes and polyethylene sheet, are occasionally unavailable in the local market and must be imported at a substantial cost, which includes freight and customs duties. Because many plants depend on insects or air movement for pollination and because enclosed screens shorten the time the plants are exposed to insects and disease, there may be poor pollination in rain shelters with screens. Skilled laborers are occasionally needed for installation, monitoring, and supervision; however, these people are not always readily accessible in rural locations. As the procedures for growing various vegetable crops throughout the year have not been standardized, recommendations from one location may not apply to another. Large-scale cultivation is hampered by farmers' ignorance of the potential for producing protected vegetables.

3.3. Biodegradable Rain covers

Novel Biodegradable and Eco-Friendly Thermoplastic Films

Scientific research has been concentrating on biodegradable materials based on polymers produced from renewable sources as a viable substitute for oil-derived polymers in packaging and agricultural applications in an effort to counteract the detrimental environmental effects of petroleum-based plastics. When biodegradable polymers are disposed of in bioactive environments, bacteria, fungi, and algae can break them down enzymatically and produce biomass, carbon dioxide, water, or methane, depending on whether the environment is aerobic or anaerobic throughout the degradation process. Therefore, when biodegradable films reach the end of their useful life, they can be buried or left on the soil, where bacteria will initiate the process of biodegradation. Alternatively, they can be combined with other organic materials to create compost that is rich in carbon (Santagata et al. 2017).

A material is said to be truly biodegradable if it is either mineralized, bio assimilated, or destroyed by soil microbes. Although starch-based polymers have demonstrated improved biodegradability, they are still too costly and occasionally too heavy for use in agricultural settings. Since biodegradable plastics are made to break down in natural environments or in facilities that treat biological waste from industry and municipalities, they have allowed for new perspectives on waste management techniques. The renewable polymers are inherently biodegradable, reasonably priced, and environmentally benign (Kasirajan and Ngouajio, 2012).

When compared to crops grown in an open field, plants grown beneath polypropylene nonwoven fleece typically yield higher yields. When butterhead lettuce was covered in biodegradable nonwovens, the same outcome was seen. Leeks beneath the biodegradable covers produced larger yields even if there was some cover tearing over the winter. The marketable yield for both tested Biodegradable covers in the 2008–09 season was substantially higher than the control. (Siwe et al. 2013). There are established mechanical design specifications for both conventional and low tunnel completely biodegradable films. These specifications are essential for determining the lowest permissible thickness of thin biodegradable films and for assessing the suitability of The cost difference between biodegradable and cheaper PE materials is still the primary obstacle. When the waste manager's costs for removal and disposal are taken into account, the total cost is reduced. Even so, the cost-benefit ratio with PE varies depending on the particular PE mulch utilized in each area. Goods must become more competitive and get past some of the current barriers, like the low biobased content of commercial materials, the limited transparency, and the weakness of clear films. They also need to improve permeability to gases targeted at particular applications, lengthen the film's duration for crops that will last a long time, and stay out of the way of competition with the food production industry.

The inadequate training given to users is a second obstacle to the field's adoption of biodegradable materials. It is necessary to have training in applying the films, learn about the materials' breakdown, and understand how in-soil biodegradation occurs under various crop and environmental circumstances. The third hurdle is the accessibility of biodegradable materials in the market. The situation has steadily improved in this regard over time, in terms of the variety of materials as well as their distribution and conversion. (Closas et al. 2017)

Although biobased plastics are not a panacea for all of the world's issues, they will eventually run out of fossil fuels, in which case plastics will need to be produced from other, most likely agricultural, sources. Although there are still certain obstacles to be solved, such as the high cost, inferior mechanical qualities when compared to plastics derived from fossil fuels, the scarcity of agricultural land, etc., the future of biobased plastics is bright. However, there are just a few uses for biodegradable plastics, which were formerly believed to offer a solution to the problems of landfills and littering. They won't help because making a material biodegradable won't address the societal issue of littering. Littering is a problem. Only specific circumstances and periods of time may allow biological agents to biodegrade biodegradable polymers; nevertheless, these prerequisites must be satisfied for plastic material to completely benefit from its biodegradability(Sokele and Plipović, 2017). Biodegradable polymers derived from renewable sources have some drawbacks, despite showing encouraging trends for application: low mechanical properties, a fast rate of degradation, a high hydrophilic capacity, and occasionally, poor mechanical properties, particularly in humid environments, which makes their use impractical (Rosseto et al. 2019).

In order to increase crop resilience against climatic variability and boost yields and produce quality, the usage of rain covers as a climate adaptation method in vegetable production is covered in this research. Climate-resilient agriculture mixes adaptation, mitigation, and other practices to improve the system's capacity to adjust to various climate-related shocks. In vegetable production, protective structures like rain covers—such as rain shelters and small tunnels—are essential. These structures increase productivity and yield by shielding plants from pest-related illnesses, infections, and yield losses brought on by severe rains. Furthermore, farmers are able to grow vegetables even during the off-season, which increases the availability of fresh produce during a time when veggies are in short supply and enables them to profit from higher off-season prices.

Utilizing biodegradable rain covers as a climate adaptation tactic provides a sustainable and environmentally beneficial way to prevent soil erosion and safeguard crops. As an alternative to traditional plastics, biodegradable films created from sustainable agricultural resources have the benefit of being easily disposed of when their useful lives are coming to an end without leaving harmful residues in the land. The report discusses many types of climate change-resistant rain covers, such as pedestrian tunnels, net dwellings with shade, and low-level tunnels. By shielding from wind, bugs, intense rain, and high temperatures, these structures improve overall productivity by fostering a microclimate that is ideal for plant growth. Even though biodegradable polymers made from renewable resources are showing encouraging trends for use in rain covers, they do have several disadvantages, including low mechanical qualities, a quick rate of disintegration, a high hydrophilic capacity, and occasionally poor mechanical qualities in humid conditions. Despite these difficulties, it is thought that using rain covers to grow vegetables is an affordable and sustainable approach to modify farming methods in response to climate change, promoting food security and maintaining the stability of local economies.

4. Conclusion

In conclusion, this review paper emphasizes the importance of using climate-resilient biodegradable rain covers as a strategic approach to increase vegetable production in the face of challenges such as climate change. By providing a protective barrier against adverse weather changes and unpredictable rainfall patterns, these covers offer a functional solution to mitigating the effects of climate change on crop yield and quality. The use of biodegradable materials promotes sustainability in agriculture and

also contributes to eco-friendly practices by reducing plastic waste and soil pollution. Overall, integrating and introducing climate-resilient technologies such as biodegradable rain covers into vegetable production systems offers a promising avenue for ensuring food security, enhancing market stability, and building resilience in the face of evolving climate conditions.

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ICSD 099

**RIDGE AND FURROW RAINWATER HARVESTING SYSTEM WITH
DURABLE PLASTIC FILM FOR GROUNDNUT PRODUCTION IN DRY AREAS
OF SRI LANKA: A SYSTEMATIC LITERATURE REVIEW**

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Abstract: Groundnuts are grown in Highlands of Sri Lanka during the rainy Maha season (September-March) and on irrigated paddy fields in the dry and intermediate zones during the Yala season (May-August). Rainfall conditions in the dry areas of Sri Lanka is less than the other areas. When Groundnut grows in these dry areas; collected water in the field cannot be saved due to the high evapotranspiration. Saving rainwater is highly essential to provide irrigation to groundnut during the rainless conditions. Plastic covered ridge and furrow system is a solution for this problem when it connects to a Groundwater collection storage that was established in the field. The purposes of this study were (a) to assess the effectiveness of plastic covered ridge and furrow rainfall harvesting system, (b) to investigate the applicability of this system in dry zone of Sri Lanka and (c) to conserve the rainwater that collected in available time and to increase the Groundnut production with appropriate amount of water. This review was conducted by reviewing 36 research articles in google scholar, from 2008 to 2023. In this study Groundnut was cultivated in ridges of ridge and furrow system. HDPE (High Density Polyethylene) is used as a durable plastic film to cover ridges as a mulch, and it covers furrow area to collect the rainwater in this system. Collected rainwater was transported to an underground cement tank with the help of a water pipe system. As a result, this method could be used in areas dominated by light rainfall patterns of low intensity where crops fail their growth due to the water stress conditions. The plastic covered ridge and furrow rainwater harvesting system had the potential to optimize groundnut yield and produce greater economic benefits. This method helps to reduce evaporation and improve the soil quality and conditions over time. Furthermore, applying mulch in the furrow increase the effectiveness of harvested rainwater. Under this technique these harvesting rainwater can be used in the dry seasons for the groundnut cultivation. Therefore, this method could be used in areas dominated by light rainfall patterns of low intensity where crops fail their growth due to the water stress conditions.

Keywords: Dry zone agriculture; Mulch; Rainwater harvesting; Ridge and furrow

1. Introduction

a. Groundnut production in dry areas of Sri Lanka

Groundnut (*Arachis hypogaea* L.) is an important oil seed crop that contain carbohydrates, vitamins, minerals, oils, protein and some other nutrients. Though groundnut is an oil crop, in Sri Lanka it is demanded as snacks and confectionaries (P.Wigesinghe et al., 2019). In Sri Lanka, Groundnut are mainly cultivated in Hambantota, Puttalam like dry areas as supplementary food crop under irrigated conditions during Yala (May-August) season (Ravichandran and Geretharan, 2015). In Yala season of 2018, total Groundnut production was 8104 MT and the extent of cultivation was 3,605ha. In Maha season of 2018/19, total Groundnut production was 18,008 MT and the extent of cultivation was 10,247ha (Department of Census and Statistics, 2018).

b. Ridge and furrow rainwater harvesting system

The ridge and furrow rainwater harvesting system (RFRH) with mulch is very effective method to promote the crop growth by increasing water availability (Xiao-Yan Li et al., 2002). As per the studies of researchers about this RFRH system, they have conducted feild study to determine the effect of RFRH system on increase water use efficiency of crops in a semi humid climate. They showed that this method is very effective for drought stress conditions during crop growth (Yang Wu et al., 2015). RFRH system with durable plastic film-mulching is most suitable and effective practice to conserve the rainwater that collected in rainy season and to increase the crop yield and growth during water stress conditions by supplying appropriate amount of water. In this system (HDPE) High Density Polyethylene film is use to cover ridges as a mulch. It has great potential to reduce evaporation, prolong the moisture availability period, and improve soil moisture storage and other soil qualities. Additionally, the mulch in the furrow increase the effectiveness of harvested rainwater. It also evidence by some of research. RFRH system with polyethylene mulch increases the crop yield by increasing soil temperature and reducing soil erosion (Kornecki et al., 2005).

1.3 Plastic ridge and furrow rainwater harvesting system for Groundnut production in dry areas of Sri Lanka

Rainfall in dry areas is less than other areas in Sri Lanka. Dry zone areas receive less than 1750mm annual rainfall, 1700-1900mm annual evaporation and there is high solar radiation condition when compare with the wet zone (Department of Meteorology, 2019). As per the studies of researchers about climate change in Sri Lanka, they have analysed rainfall variations and identified that during the recent past average temperature has been increased with increasing trend. According to their analysis annual rainfall has significantly decreased and rainfall variability has increased in last few decades. This rainfall variability is high in dry zone than other parts of the country (K.H.M.S.Premalal, 2009). However, rainfall received from North East Monsoon is decreased last few decades in dry zone due to climate change. Therefore, during dry period soil moisture deficit and it determines the irrigation requirement for Groundnut and other field crops (C.Shanthi De Silva, 2009). When Groundnut grows in dry areas, low crop yield and crop failure happened during the rainless conditions. Because most of the harvested rainwater is losses due to the high evapotranspiration. Therefore farmers have to pay their attention to water saving methods (C.Shanthi De Silva, 2009). It is necessary to have more effective practices not only for saving rainwater, but also prevent surface runoff and storing that water to provide irrigation to Groundnut during the rainless period. Plastic covered ridge and furrow rainwater harvesting (PRFRH) method could be used in areas dominated by light rainfall patterns of low intensity where crops fail their growth due to the water stress conditions.

This review highlights few number of studies that have taken in recent years. According to the above considerations, the aim of this review is to provide data and evidence of research articles

published in academic journals in recent years and determine the effectiveness and applicability of PRFRH system in dry zone of Sri Lanka to increase the Groundnut production.

2. Methods and materials

Several procedures were followed to ensure the efficiency of the plastic-covered ridge and furrow rainwater harvesting system for groundnut under the light rain conditions in dry areas. The method began with thoroughly observing 36 research articles in well-known scientific and academic database named Google Scholar. This substantial search used some relevant keywords; dry zone agriculture, mulch, rainwater harvesting, ridge and furrow to let out a various article, papers, studies that provide a deep insight in to the topic. In the period of 2008-2023, published research articles in Google Scholar used to reveal legality and correctness of data observed. Then, this review was conducted by existing literature on ridge and furrow rainwater harvesting system with plastic cover, including its design principles, implementation strategies, and performance evaluation. Data were gathered on selected plastic-covered ridge and furrow rainwater harvesting system including design specifications, installation details, operation performance, maintenance records and user(farmer) feedbacks. Some details about site visits on this rainwater harvesting systems for groundnut and other crops, assess their physical conditions and some interviews with farmers(surveys) were collected by searching research papers in relevant source. The performance evaluation conducted by evaluating the performance of this system based on predefined metrics such as water collection efficiency, storage capacity utilization, maintenance issues, increment of yields in Groundnut under this system and suitability of the system for the dry zone. Performance and effectiveness of the system were compared with other rainwater harvesting systems against the established criteria to identify strengths, weaknesses, opportunities and threats. After this data observation by different research articles on Google Scholar, some recommendations were provided to optimize the design, operation, and maintenance of this system as well as some suggestions were provided for the improvement of policies and future research directions about this system especially for the dry zone Groundnut cultivation. Finally, all findings of review were compiled into a comprehensive report including executive summaries, methodology details, analysis of data, discussion, conclusion and recommendations with supportive evidence and references.

3. Results and discussion

a. Rainfall and runoff characteristics

It has been estimated that the success or failure of groundnut is intimately related to the water supply of groundnut cultivation. When considering rainfall, the rainfall should be distributed well during the flowering and pegging stages of crop. The total amount of rainfall needed for pre-sowing operations (preparatory cultivation) is 100 mm, for sowing 150mm, and for flowering and pod development an evenly distributed rainfall of 400-500 mm (Iksan et al., 2024). Groundnut is an important crop of the semi-arid regions where potential yields are frequently reduced by water stress. Studies on occurrence and intensity of the drought during crop growing season revealed the effect of water stress on the groundnut yields in the dry areas. The studies have highlighted Groundnut plant contains about 80% of water on fresh weight basis and reduction of the plant water status much below this level causes wilting and affects the rate of several plant functions. Though different stages have different sensitivity to water deficit, none of these can proceed normally growing below some minimum water conditions (Singh et al., 2013)

In Sri Lanka Groundnut production is done in two seasons yala and maha. The researchers found that, Maha season production always exceeds the Yala season production. Groundnut cultivation

is mainly carried out using rainfed irrigation in dry areas. Only a smaller number of farmers cultivate groundnut using artificial irrigation. Groundnut cultivation is influenced by a variety of limiting factors, among that water stress is mostly impact to groundnut production in dry areas of Sr Lanka. In particular, due to erratic rainfall and frequent drought conditions experienced during the groundnut growth period, groundnut yields are generally low and unstable (John et al., 2011). Water stress during reproductive stages like flowering and pod filling, is crucial for yield of groundnut. But this reduction of crop yield depends on groundnut varieties. Some tolerant genotypes are able to give better yields considerably, due to physiological and biochemical changes that were triggered during water stress (Ramachandran et al., 2021).

b. Harvest Rainfall with plastic covered mulch in ridge and furrow system

For that that less rainfall conditions farmers think to modified rainfall conditions with using mulch conditions. the study that of many researchers mentioned about the need of mulching for groundnut with harvesting rainwater in ridges and furrow groundnut cultivation. During rainy seasons heavy rainfalls happen. During less rainy seasons, Land configuration is the alternation of shape of cultivation bed and land surface which helps in infiltration of rainfall, to the soil, with minimizing erosion, preventing runoff, facilitates drainage and ultimately improves water use efficiency. Land configuration can be considered as one of the most important management practices which increases water use efficiency and groundnut production.

Ridge-furrow rainwater harvesting with plastic film-mulching has been shown to be an easy and efficient method to harvest rainwater and improve crop yield in arid and semi-arid regions (. The Research found in the soil water content in dry periods at the beginning of the of dry period was significantly high. However, in later dry periods, the soil water content was not significantly enough for growth of groundnut. Because of that in high rainy seasons the rainwater was flow through the furrows to water harvesting tanks and store for use to dry water stress seasons. These findings are shown the effectiveness of ridge and furrow rainwater harvesting with plastic mulch. And also, This soil water content dynamic can be explained by the finding that black color mulches can decrease evaporation losses of soil water by 50% to 80% but increase transpiration by 10% to 30% (Battikhi and Hill, 1986; Ghavwi amd Battikhi, 1986; Haddadin and Ghawi, 1983). As a result plastic mulch not only used to harvest rainwater, it also used for reduce evaporation loses of soil

Mulching covers the soil to make more favorable conditions for production of groundnut. Mulching can be used mainly to prevent loss of water by evaporation. Different mulching methods provide better environment to the plant. When compared to other mulches plastic mulch plays a positive role in water conservation by cultivating a completely impermeable to water mainly due to prevention of direct evaporation of water from the soil limiting the water losses and soil erosion over the surface. Researchers found Groundnut can be grown under different land configuration methods like flatbed method, broad bed furrow, ridges and furrows like methods. Among that ridge and furrow and mulched with plastic mulching is a better management practice to enhance the growth and yield of groundnut.

c. Growth conditions

When considering growth parameters of groundnut, Growth parameters like plant height and number of branches had a significant effect on the plant production (Table 1). At harvest stage, highest of plant (40.2 cm) and number of branches (5.8) were observed in groundnut grown under ridge and furrow system than plant height of (36.5 cm) in broad bed furrow. Among the various mulching practices highest plant height (41.2 cm) and number of branches (6.5) were observed with plastic mulching while non-mulch plot resulted lowest plant height (36.8 cm) and branches (5.0).

The interaction effect of land configuration and mulching was significantly affect on plant height and number of branches of groundnut. Higher plant height (43.4 cm) and number of branches (6.7) were observed when groundnut grown under ridge and furrow system along with plastic film mulching over the other treatment combinations. Adoption of ridge and furrow found superior for groundnut as the water content was periodically maintained in the root zone and minimized run off (Vekariya et al., 2015) while plastic mulching created a suitable condition for growth of groundnut by influencing soil temperature, moisture retention, and improved soil texture (Ghosh et al., 2006).

Table 1. Effect of land configuration and mulching on the growth and yield parameters of groundnut (Pooled data of 3 years)

Treatments	Plant height (cm)				Number of branches/plant				Number of pods/plant				100 kernel weight (g)			
	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
L ₁	37.5	37.4	39.8	38.2	4.7	5.3	6.3	5.4	11.4	10.4	13.5	11.8	31.5	34	36.9	34.1
L ₂	35.0	35.4	39.0	36.5	4.9	5.2	6.3	5.5	13.5	15.2	19.3	16.0	31.8	33.9	37.0	34.2
L ₃	37.8	38.3	42.4	39.5	5.0	5.5	6.5	5.7	13.8	14.1	17.9	15.3	31.6	34.5	37.9	34.7
L ₄	36.9	40.5	43.4	40.3	5.2	5.6	6.7	5.8	15.2	15.7	17.7	16.2	32.0	34.7	38.6	35.1
Mean	36.8	37.9	41.2		5.0	5.4	6.5		13.5	13.9	17.1		31.7	34.3	37.6	
	S. Em±		C. D. (P=0.05)		S. Em±		C. D. (P=0.05)		S. Em±		C. D. (P=0.05)		S. Em±		C. D. (P=0.05)	
Main plot (L)	0.42		1.46		0.06		0.22		0.23		0.81		0.08		NS	
Sub plot (M)	0.75		2.23		0.06		0.16		0.15		0.44		0.08		NS	
M at L	1.49		4.47		0.11		0.32		0.3		0.89		0.16		NS	
L at M	1.29		3.93		0.11		0.34		0.33		1.09		0.16		NS	

NS : Not Significant; L1: Flatbed method; L2: Broad bed furrow; L3: Raised bed and furrows; L4:Ridge and furrow; M1: Control (no mulch); M2: Organic mulch (paddy straw @ 5 t/ha); and M3: Plastic mulch

d. Yield attributes

The yield parameters of groundnut like number of pods per plant, 100 kernel weight, and shelling percentage observed significant influence at harvesting stage of the crop (Tables 1 and 2). The studies found higher number of pods (16.2) were produced when groundnut was grown under ridge and furrow system and lower number of pods (11.8) were observed at flatbed method. Regarding the various mulching practices, higher number of pods observed at plastic mulching (17.1) and lower in non-mulch plot (13.5). This may be due to enhanced earlier pod penetrations by plastic mulching which prevented the late set peg from penetrating into the soil and extracting the nutrients of earlier pods (Bhanudas, 2011).

Table 2. Effect of land configuration and mulching on the yield attributes of groundnut, yield and economics of the groundnut (Pooled data of 3 years)

Treatments	Shelling percentage (%)				Biomass production (g/plant)				Pod yield (kg/ha)				ECR			
	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
L ₁	69.7	70.3	71.4	70.5	30.7	31.5	35.7	32.6	1820	1763	1942	1842	1.75	1.57	1.74	1.69
L ₂	69.4	69.9	71.7	70.3	33.1	35.5	41.7	36.8	1915	1944	2409	2089	1.87	1.77	2.16	1.93
L ₃	69.6	70.7	72.1	70.8	35.0	39.0	37.9	37.3	1946	1986	2407	2113	1.89	1.79	2.23	1.97
L ₄	70.8	71.0	71.9	71.2	40.1	32.8	40.7	37.9	1966	2006	2481	2151	1.92	1.8	2.25	1.99
Mean	69.9	70.5	71.8		34.7	34.7	39.0		1912	1925	2310		1.86	1.73	2.10	
	S. Em±		C. D. (P=0.05)		S. Em±		C. D. (P=0.05)		S. Em±		C. D. (P=0.05)		-		-	
Main plot (L)	0.25		NS		0.51		1.75		13.10		45.35		-		-	
Sub plot (M)	0.15		0.45		0.74		2.20		22.31		66.88		-		-	
M at L	0.35		0.90		1.47		4.00		44.63		133.77		-		-	
L at M	0.30		NS		1.30		4.41		38.72		118.13		-		-	

L1: Flatbed method; L2: Broad bed furrow (1m width and 50 cm furrow); L3: Raised bed and furrows; L4: Ridge and furrow; M1: Control (no mulch); M2: Organic mulch (paddy straw @ 5 t/ha); and M3: Plastic mulch

The interaction effect of land configuration and mulching was significantly influenced on the number of groundnut pods. Higher number of pods was observed when groundnut cultivated in ridge and furrow with plastic mulching. The combination of ridge and furrow and plastic mulching recorded higher pod yield of 2481 kg/ha. This may be due to the plastic mulching which created a favorable micro-climatic condition for groundnut and moreover, reduced the crop-weed competition due to complete cover of the field (Ghosh et al., 2006)

3.5 Applications of the Ridge and furrow rainwater harvesting system with, durable plastic film in dry areas

The PRFRH system accommodates various benefits in dry areas according to the many research papers. The PRFRH system is more potent of harvesting rainwater and abbreviate evaporation from the soil, in addition to enhancing the soil's thermal condition. This assisting to maintaining more persistence hydrothermal conditions within the root zone, encouraging consistent soil moisture and temperature levels (Liu et al., 2016, Tang et al., 2019, Liao et al., 2022). And also the PRFRH system can be attribute to the effectively incrementing rainwater collection through the reduction of surface runoff, abbreviating water loss from the soil through evaporation, and facilitating the infiltration of rainwater into the soil. (Ramakrishna et al., 2006, Zhao et al., 2012, Hou and Li, 2019). Mulching is promoting temperature shifts in soil have been widely reported in the literature (Wang et al., 2015, Mo et al., 2017b). For an example, soil temperature was greatly influenced by mulching methods (Zheng et al. (2021)

Previous researchers have discovered that the effect of mulching on both the yield and water productivity (WP) of potatoes is more appreciable when the average air temperature ranges between 15 to 20°C throughout the growing season when use the PRFRH system (Q. Li et al., 2018). Apart from that the use of plastic film mulching can manipulate to raised temperatures during the peak of summer, probably causing heat stress in potato crops. (Zhao et al., 2012, Zhao et al., 2014). Certainly, Ridge-furrow plastic film mulching technique aid to conserve soil moisture, abbreviate water evaporation from the soil, stimulates the utilization of deep-water resources, and increments the soil temperature (Qin et al., 2018), substantially enhancing the yield of crop grains as well (Xiong et al., 2020). furthermore, the ridge and furrow design increments aeration and sun-light exposure, one study found that can potentially increase daylight radiation by 10-90% (Wang et al., 1998).

4. Conclusion

As a conclusion this research highlights the potential of the ridge and furrow rainwater harvesting system with, durable plastic film for groundnut production in dry areas of Sri Lanka. This system is a systematic Rainwater harvesting technique that benefits for aggravates runoff, increments the moisture content in soil, reduces the consumption of soil water, and improves the efficiency of water use. This technique has the potential to significant enhance crop yields in areas where light rainfall is prevalent. The PRFRH system could be widely adopted in the dry areas like monaragala in Sri Lanka, helping to alleviate crop failure caused by insufficient water availability.

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PROCESSED FRUIT AND VEGETABLE INDUSTRY IN SRI LANKA: POTENTIALS, CHALLENGES, AND PROSPECTS

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Abstract: Sri Lanka has the potential to produce processed fruit and vegetable products for both domestic and export markets since we are blessed with an abundance of highly diverse and delectable tropical fruit and vegetable varieties. The main objective of this study was to analyze the present situation, processing potentials, and constraints for the locally processed fruit and vegetable sector. Both primary and secondary data were collected. Purposive sampling was employed and a pre-tested structured questionnaire was used to interview the selected processors and traders in the Colombo, Gampaha, and Kandy districts. Key informant interviews and case studies were also conducted. Descriptive analysis, compound growth rate analysis, instability analysis, and constraint-facing index were applied in the data analysis. Processed fruit and vegetable exports in the country have shown positive growth from 2011 to 2021. A majority (93.33%) of the sample processors are willing to expand their production capacity in future. Regular customer base, high demand for special products, regular supply of quality raw materials by producers, and skilled labour force were identified as key strengths. Most of the sample processors (57%) send their products to both the local and export markets. The local markets provide about 110 international and 172 local brands of fruits and vegetables. Dehydrated fruit and vegetable products have the highest potential in both domestic and export markets. The Middle East, Europe, America, Oceania, and Asia are the most potential export regions for Sri Lankan processed fruit and vegetable exports. According to the constraint-facing index results, issues pertaining to the production process rank highest among the challenges faced by fruit and vegetable processors. In order to enable processors to access either the domestic or export markets, it is necessary for the administrative and institutional infrastructures, together with the legal framework, to be continuously developed.

Keywords: Barriers; Compound annual growth rate analysis; Constraint-Facing index; Export market; Tropical fruits and vegetables

1. Introduction

Fruit and vegetable (F&V) processing sector is one of the core segments under food processing in Sri Lanka. Development of F&V processing is critically important to the expansion and diversification of the agricultural sector in Sri Lanka. Such activities would reduce seasonality of consumption of a range of processed food, minimize post-harvest losses, and increase profitability and sustainability of production systems besides their impact on increasing farm income, rural employment and foreign exchange earnings and reduction in marketing risks (Roy and Ojha, 2012; Geetanjli, 2017; Ojha, 2018). From time to time, various internal and external shocks have affected negatively on agri-food trade in Sri Lanka. Since, it is timely important to analyze the potentials and constraints regarding the F&V processing sector in Sri Lanka. Further, it is timely important to find the strategies undertaken by the f & v processors in Sri Lanka in order to minimize the adverse effects of crisis situation. Only a limited number of studies have been conducted on the processed F&V industry in Sri Lanka (Hathurusinghe *et al.*, 2011; Edirisinghe, 2016; Vidanapathirana *et al.*, 2020; Rathnayake and De Silva, 2022) and no substantial study has investigated the potentials and constraints regarding the processed F&V industry in Sri Lanka. Further, Perera *et al.*, (2015) also recommended, further research into processed F&V export products and the market situation. Further, processing and value addition is one of the main national research thrust areas which was identified by the National Committee on Postharvest Technology and Human Nutrition (SLCARP, 2017). In this context, there is a timely importance to analyze the present situation, processing potentials, constraints, for locally processed F&V sector.

2. Methodology

Primary and secondary data were collected to perform the qualitative and quantitative analysis. Purposive Sampling was employed in sample selection of processors and traders. A pre-tested structured questionnaire was used to interview the selected F&V processors (30) and traders (30), in the Colombo, Gampaha, and Kandy districts. Further, key informant interviews were conducted with the relevant officials in the key government and private institutions related to processed F&V industry in Sri Lanka. Moreover, twelve case studies were conducted with the top leading F&V processors in Sri Lanka and with the successful small and medium scale processors in this sector. Descriptive analysis, compound growth rate analysis, instability analysis, and constraint-facing index (CFI) were employed in the data analysis.

Compound Growth Rate Analysis

The compound growth function was used to analyze the trend and growth pattern in exports of total processed F&V. The growth rates of export quantities, values processed fruits and vegetables arrived by using the compound growth function of the form (Bhowmick and Ahmed, 1993). The secondary data pertaining to export value (US \$ mn) for selected F&V for the period 2010-2022 were collected from data bases at the Department of Customs Sri Lanka.

$$Y = ab^t e_t \quad (1)$$

Where, Y = Dependent variable for which growth rate is to be estimated (total export earnings)

a = Intercept

b = Regression Coefficient = (1+g), where g is the compound growth rate

t = Time variable (Years which takes values, 1,2...n)

e_t = error term

The equation (1) was estimated after transforming it to logarithmic form as follows:

$$\text{Log } Y = \text{log } a + t \text{ log } b + \text{log } e_t \quad (2)$$

The percent compound growth rate (g) was computed using the following relationship

$$g = (\text{antilog of } (\text{log} b) - 1) \times 100 \quad (3)$$

The standard error of the growth rate was estimated and tested for its significance with 't' statistics.

Instability Index

Co-efficient of variation (CV) and Cuddy Della Valle Index (CDV) (1978) were used to measure the magnitude of instability in export of processed F&V from Sri Lanka to different countries. In general, the coefficient of variation measures the amount of variation of the response variable. The indices are as follows;

$$CV = (\text{Standard deviation}/\text{Mean}) * 100 \quad (4)$$

$$CDV = CV * (\sqrt{1 - \bar{R}^2}) \quad (5)$$

The ranges of CDVI are given as follows; Low instability = 0 to 15, Medium instability = 15 to 30 and High instability = 30 and above (Vilhekar, *et al.*, 2022).

Constraints-Facing Index (CFI)

Constraints faced by processors in the study areas were measured by using structured questionnaire. The respondents were asked to give their opinion on 6 selected constraints which were identified during data collection period. A four-point rating scale were used for computing the constraint score of a respondent. For each constraint score of 3, 2, 1 and 0 was assigned to indicate the extent of constraint as high, medium, low and not at all, respectively. The total constraint scores will be computed for each respondent by adding his scores for all the constraints. The Constraint Facing Index (Mozahid *et al.*, 2017) was computed using the following Eq. (6),

$$CFI = (C_h \times 3) + (C_m \times 2) + (C_l \times 1) + (C_n \times 0) \quad (6)$$

Where, CFI = Constraints Facing Index; C_h = Number of respondents having high constraints; C_m = Number of respondents having medium constraints; C_l = Number of respondents having low constraints; and C_n = Number of respondents having no constraints.

3. Results

3.1 Fruit and Vegetable Processing Industry Performance in Sri Lanka

In 2023, 73 F&V processing companies were registered in the Sri Lanka Food Processors Association while 26 processed F&V exporters were registered in the Export Development Board in the same year. According to the data availability, growth rates for establishments with 25 or more persons engaged were included in Table 1.

Table 1. Growth Rates for Processing Industry Indicators (2015-2019)

Indicator	Compound Annual Growth Rate (Per Annum)
Number of establishments	-7.60 ^{n.s}
Number of Employees	6.61 ^{n.s}
Output (Rs.)	17.94*
Intermediate Consumption (Rs.)	16.65*
Value Added (Rs.)	21.05*

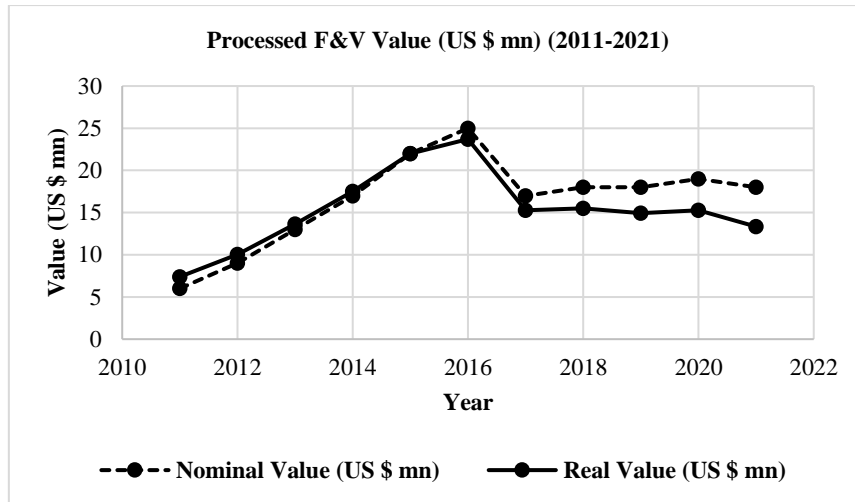
Note: * denotes significant at 10 % level of probability, NS denotes Non-Significant

Source: Authors' Calculation based on Annual Industry Survey, DCS, Various Issues

Of aforementioned performance indicators only number of establishments has shown negative growth rate while other indicators have shown positive growth rates from 2015 to 2019.

3.2 Processed F&V Exports Trend (2011-2021)

Figure 1 shows an increasing trend for Sri Lankan processed F&V in terms of both nominal and real export value, with the exception of the years 2017 and 2021.



Note: for real value GDP Deflator, base year =2015.

Source: Authors' Compilation based on EDB Food & Beverage Industry Capability Report, Multiple Issues

Figure 1: Processed F&V Exports (2011-2021).

Table 2: Growth Rates and Instability of Processed F&V Exports

Indicator	Growth Rate	Instability
Export Value (Nominal)	8.83*	27.08
Export Value (Real)	3.99 ^{n.s}	30.74

Note: * denotes significant at 10 % level of probability, NS denotes Non-Significant

Source: Authors' Calculation based on EDB Food & Beverage Industry Capability Report, Multiple Issues

The results revealed that export values in terms of both real and nominal have shown positive growth rates. Export value in nominal terms shown medium instability while export value in real terms shown high instability.

3.3 Fruit and Vegetable Processing in Sri Lanka

Majority (76.67%) of the sample processed F&V firms has been in operation for less than 11 years. The mean of the years of operation for surveyed firms is 12 years while only one company has been in operation for more than 71 years. The results revealed that most of the organizations are sole proprietorships (46.67%) and private companies (43.33%) whereas partnerships are scarce (10.00%).

Most (76.67%) of the surveyed F&V processing companies have less than 50 employees. A considerable number of processing firms function with a minimum staff while only one firm in sample area employed over 250 employees. According to the results vast majority (83.33%) of the firms have their own premises while the rest is functioning in hired locations.

Quality standards and certifications play significant role in building trust in Sri Lankan processed F&V products in domestic and export market. Majority (63.33%) of the surveyed processing firms have quality certifications such as Good Manufacturing Process (GMP), HACCAP, ISO, SLS, FDA, EU Organic, Kosher, USDA, and BRC. Rest still did not obtain any quality certificate however they are willing to apply for at least GMP certificate in near future.

Most of the processing companies (80.00%) process fruits, vegetables, and other products such as coconut oil, herbs, tea, and spices. According to the results, 17 percent of the companies are involved in fruit processing solely, while very few companies (3.00%) process vegetables and other agricultural products.

Major F&Vs Used as Raw Materials

According to the findings, there are 87 F&V varieties which were used by sample processors in their production process. Among them 19 varieties of F&V were frequently used to produce their major products. Pineapple (46.67%), mango (40.00%), jackfruit (26.67%), papaw (16.67%), breadfruit (13.33%), and woodapple (13.33%) are the major crops that are used in the fruit and vegetable processing industry.

Main Sources of Raw F&V

There were six main sources of raw F&V in the surveyed areas. These included nearby farmers (46.67%), collectors (46.67%), nearby market (33.33%), own farm (23.33%), farmers outside the region (20.00%), and others (20.00%) such as importing countries, companies, out grower model, organic certified farmer groups, and special greenhouse projects. Out of these sources, nearby farmers and collectors remains by far to be the major sources for processors in surveyed areas.

Apart from main sources of fresh F&V, processors were asked to indicate whether they had contracts with suppliers of fruits and vegetables. Majority (73.33%) of the processors do not have any contracts or written agreements with their suppliers of raw fruits and vegetables while only eight processors (26.67%) have contracts with their suppliers. Even though, the majority of the processors do not have any contracts or written agreements with suppliers, the regular supply of quality raw materials by producers (73.33%) is a key strength for their companies. Further, all processors in surveyed areas were concerned about the quality of the fresh produce that they purchased from different sources. They have used different quality parameters; ripen stage, quality, physical appearance, weight, size, and flavour in their selection.

Therefore, two interesting inferences can be derived from the above mentioned findings that is, (i) there is an opportunity for processors to select the quality F&V, and (ii) F&V processing firms have link with suppliers to ensure constant availability of fruits and vegetables, the most vital inputs for processing. This situation might have a positive impact on sustainability of fruit and vegetable processing firms because the fresh raw materials for these firms depend mostly on the supply situation.

Production of Processed F&V

Processors were asked to mention major products which they produced frequently and other products. Majority (53.33%) of them produced dehydrated F&V as their major product category. These dehydrated products include dehydrated vegetable mixes, fruit snacks and mix bites. About 20.00 per cent of processors interested in processing fruit drinks as their major products. Frequently produced fruit drinks are mixed fruit, mango, pineapple, ripe jackfruit, woodapple, and passionfruit. Strawberry, mango, pineapple, woodapple, or mixed fruit jams were produced by 16.67 per cent of the sample processors while 13.33 per cent of the processors produced fruit in syrup such as pineapple, mango, papaya, fruit cocktail, soursop, and rambutan. Moringa, soursop, banana or jackfruit powder were produced by 10.00 percent of the sample processors while similar proportion produced deserts such as jack fruit watalappan, durian watalappan, and durian cupcakes as their major products. Tomato, chilli, tamarind, and mango sauces were produced by 6.67 percent of the sample processors. Only few processors (3.37%) produced fruit pulp such as pineapple, mango, woodapple, passionfruit, and soursop as their major product.

Product Availability in Domestic Market

About 57 percent of the sample F&V processors send their products to both local and export market. About 172 local brand and 110 imported brands are available in the surveyed supermarkets and special outlets.

Table 3: Processed F&V Availability in Domestic Market

Imported Products (No.)	Brands	110
	Product types	Fruits - 26
		Vegetables - 27
	Varieties used	Fruits - 39
Vegetables - 17		
	Importing regions	32
Local Products (No.)	Brands	172
	Product types	Fruits - 27
		Vegetables - 36
	Varieties used	Fruits - 47
Vegetables - 36		

Source: HARTI Survey, 2023

Plan to Expand F&V Processing Capacity

Apart from the major product categories and sources of raw materials, respondents were also asked to indicate actual quantities processed during the harvest and off seasons. However, some of the sample processors reluctant to disclose their production data. Respondents were asked to indicate the ability to reach their optimum capacity during harvest season and off season. About 55.17 per cent of sample processors mentioned that they were unable to reach the maximum capacity during the harvest and off season due to several reasons such as lack of packaging materials, lack of market, inadequate fresh products, lack of working capital, shortage of labour, and high energy cost. Consequently, respondents were also asked to indicate whether they intend to expand production in the future. The majority (93.33%) of sample processing firms would like to expand processing, partly due to availability of fresh produce, profit emanating from F&V processing activities, and increased demand amongst consumers. Rest of the processors mentioned that they are not intended to expand the production in future since some of them recently expand their production and some of them suffering from lack of credit facilities.

Factors Affecting the Performance of F&V Processors in Sri Lanka

Key Strengths of F&V Processors in Sri Lanka

Most (86.67 %) of the sample processors mentioned that they have regular customer basis. The similar number of surveyed processors said that high demand for special products of their firms and regular supply of quality raw materials by producers are the key strengths of their firms. About 57 percent of processors noted that the skilled and effective labour is the key strength for their company while 43.33 percent of the processors said that quality standards and certificates are the key strength for them. About 30 percent of the processors mentioned that their company have brand name. Easy access to information regarding markets and usage of new technology are the other key strengths mentioned by the sample fruit and vegetable processors.

Challenges for F&V Processors in Sri Lanka

The F&V processors were asked to mention the problems they faced in their business. The problems reported by them are discussed below:

Table 4: Major Constraints Faced by F&V Processors

Constraints	High(3)	Medium(2)	Low(1)	Not at all(0)	CFI	Rank
Production	12	14	2	2	66	1
Government Policies	12	10	3	5	59	2
Financial	12	8	1	9	53	3
Marketing	7	11	2	10	45	4
Export Related	9	6	2	13	41	5
Human Resource	3	6	2	19	23	6

Source: Authors' Own Calculation based on HARTI Survey Data, (2023)

According to the CFI results in Table 4, it was revealed that the production process related problems with CFI 66 was ranked 1st. Problems related to Government policies and regulations with CFI 59, financial problems with CFI 53, Problem related to marketing system with CFI 45, export related problems with CFI 41, and human resource problems with CFI 23 were ranked as 2nd, 3rd, 4th, 5th, and 6th respectively.

Problems Related to Production

High cost of inputs/raw materials (71.43%) and high energy cost (67.86%) are the most critical production problem faced by the sample processors. Unavailability of quality raw materials, lack of appropriate processing technology, improper machinery, and underutilization of capacity are other major production issues. High labour cost and other issues such as inconsistency in raw material prices, high cost of testing and lack of cold storage facilities are faced by the similar proportion of the sample. Frequent breakdowns have affected fewer processors.

Financial Problems

Majority (61.90%) of the surveyed processors mentioned high interest rates from financial institutions as their major financial issue while very few processors (4.76%) were mentioned cost overrun. In addition to aforementioned issues these processors have to face: lack of working capital, late payment by buyers, and lack of finance by the financial institutions. It has also been found due to financial constraints these agro based industries are not running smoothly.

Problems Related to Marketing System

The various marketing system related problems were reported by the F&V processors. Marketing problems are related to transportation, price, marketing process, and organized market. The results revealed that the majority of the firms (60.00%) have less market to sell their products in nearby areas. Consequently, there are some entry barriers in the markets. Some of the processors (20.00%) mentioned that it is difficult to find suitable buyers for their products and they are facing with problems in entering to supermarkets due to high profit margins. Poor infrastructure facilities such as transport, lack of sales promotion and advertisement, high transport cost, unavailability of attractive packaging materials, and lack of consumers' awareness are other major issues related to marketing system. Similar proportion of the fewer processors (5.00%) mentioned that the lack of information regarding markets and high competition in the local market are the major marketing related issues faced by them.

Problems Related to Government Policies and Regulations

Majority (64.00%) of the sample processors cited the very high tax rates while similar proportion (44.00%) of the sample processors mentioned difficulties in obtaining license and unnecessary laws formulated by local government as major constraints related to government policies and regulations. About 28.00 percent of processors cited problems related to government institutional procedures such as lack of coordination among institutes, lack of government assistance, and lack of awareness of foreign funded government projects which can provide opportunities for local processors. Very few processors mentioned the failure to protect locally processed products specially dehydrated vegetable sachet packets through importation of imported products from other countries as India and China.

Human Resource Problems

The main asset of any firm is its human resources. If industries get appropriate number and skilled manpower the profitability and productivity enhance manifold. Majority (63.64%) of the sample processors cited limited labour forces as their major human resource problem.

Export Related Problems

Out of sample processors, only 17 processors (56.67%) export their products to different regions in the world. These processors faced with various problems in exporting their products (Table 4). Lack of government assistance (58.82%) is the major issue faced by processors who are engaged in exporting. High cost of exporting, strong international competition, unfavourable foreign exchange rates, entry barriers, trade barriers and tariffs, and limited information about foreign markets are other major export related issues cited by the respondents.

Potential Products and Markets for Locally Processed F&V

Surveyed processors were asked to mentioned the potential products for domestic market and export markets. Majority of surveyed f & v processors mentioned that dehydrated fruit and vegetable products (veggie mix, fruit snacks and mix bites) have the high potential in both domestic (47.62%) and export (75.00%) markets. Fruit drinks, herbal drinks, F&V powders, chutney, jam, organic products, fruit pulp, jack flour, and sauce are the other potential products for domestic market. According to the results, fruit drinks, powder, frozen fruit, fruit pulp, organic products, Jam, chutney, curry, healthy vegan, slow foods, pickles, sauce, pineapple chunks, and food supplements are the other products which have export potential in future.

Potential Export Markets for Sri Lankan Processed F&V Exports

Majority (50.00%) of the surveyed processed F&V exporters indicated that, Middle East has the highest potential for Sri Lankan processed F&V exports, followed by Europe (45.45%), America (45.45%), Oceania (31.82%), and Asia (27.27%). However, nine percent of exporters indicated that South Africa can be considered as potential market for Sri Lankan processed F&V in future.

Effect of Economic Crisis on F&V Processing Industry in Sri Lanka

About 36.67 percent of the processors indicated that their sales have increased while similar proportion of the sample processors mentioned that their sales have decreased over the last two years. However, 26.66 percent of the sample processors stated that sales of their business stayed the same over the last two years. Significant proportion (46.67%) of the sample processors started their business in the year 2020. There were various factors such as demands of buyers, size of the company, access to finance, access to resources, export market trends, taxation, and government support, that influenced the processors' decisions to increase, decrease or maintain the production last two years. Of aforementioned factors demands of the buyers and export market trends are the major factors affecting the processors' decision regarding production quantities during last two years. Majority of the processors adopted strategies to cope with current crisis situation. The coping strategies are as follows: juice

freezing, material storage, reduce staff, cost management, get new orders, reduce package size, provide facilities to workers (transport), online marketing, and collect raw materials from nearby farmers. During the past two years 40.00 percent of the surveyed fruit and vegetable processors approached any government agency to avail of a programme/service to address their business problems or concerns.

4. Conclusion

The vast majority (93.33%) of the sample processors are willing to expand their production capacity in the future. Dehydrated F&V products (veggie mix, fruit snacks and mix bites) have the highest potential in both domestic (47.62%) and export (75.00%) markets. The value-addition process should be strengthened, and processors should be motivated to export processed F&V products since there is an increased demand for value-added F&V products in the world. Majority (50.00%) of the surveyed processed F&V exporters indicated that, Middle East has the highest potential for Sri Lankan processed F&V exports, followed by Europe (45.45%), America (45.45%), Oceania (31.82%), and Asia (27.27%). Sri Lanka can promote its share in above markets by introducing trade representatives, having bilateral trade agreements, observing international quality standards, and expanding exporters' knowledge of marketing and advertising.

According to the CFI results, production process related problems (CFI 66) are the most critical problem faced by the sample processors. Therefore, a close linkage should be established between farmers and processors to guarantee reasonable prices to farmers and a supply of quality products to domestic market or export destinations. Further, the institutional and administrative infrastructures, as well as the legislative framework, must be continuously developed in order to allow processors to access both the domestic and export markets. The awareness about processed F&V is there among the local consumers at a particular level, which is not adequate, and it has to be developed further for the enhancement of the processed F&V industry in Sri Lanka.

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FACTORS AFFECTING SUGARCANE PRODUCTION OF LOW COUNTRY DRY AND INTERMEDIATE ZONES OF SRI LANKA

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Abstract: Sugarcane is an important plantation crop in Sri Lanka due to its foodstuff value and economic reliability. 9.35 % of domestic sugar demand was fulfilled by local sugar production in dry and intermediate zones. According to the production records, sugar cane production per unit area was not reached the optimum level even many of identified facilities including agronomical factors are improved by authorized contingencies in the country especially sugar companies. Therefore, this study had been focused to find out non-agronomical factors affecting sugarcane production in dry and intermediate zones of Sri Lanka. It has been analyzed by using the quantitative method. Primary and secondary data were collected from 368 respondents via a questionnaire and accounting data from Lanka Sugar Company Private Limited. Cobb-Douglas production function was followed to filter the effective factors among selected ten factors (cost of land preparation, seed cane, agrochemical, fertilizer, maintains, education level of the farmers, distance from the factory, age of the farmer, scope of the farmer families and Irrigation). Those independent variables together with the dependent variable of the yield of the sugarcane per unit area were analyzed. There were eight factors (land preparation cost, seed cane cost, agrochemical cost, fertilizer cost, maintains cost, education level of the farmer, distance from the factory, and irrigation) that were significant in the Sri Lankan context to the sugarcane production, and it has been identified via well-fitted regression model with a high level of R^2 value (78.5 %). Based on the finding of this study, irrigation increased cane output in dry and intermediate zones and the education level of the farmer and cost for fertilizer contributed to enhancing sugarcane production and distance from the farm gate to the factory yard is negatively affected on yield.

Keywords: Sugarcane production; Sugar production per unit area; Cobb-Douglas production function; Dry zone; Intermediate zone

1. Introduction

1.1 Research background

Sugarcane is the major crop which used for sugar production in Sri Lanka for sucrose extraction. According to the Central Bank report (2020), the whole sugar industry is produced 52 304 Mt per annum but it embraces only 9.35 % of the annual sugar requirement of the country. The balance requirement is being imported from sugar-producing countries such as Brazil, India, and Thailand and expends about 37,714 million LKR from the annual gross domestic product in 2020.

The total land area allocated for sugarcane production is 12 300 ha (Central bank report, 2020), in Sri Lanka, and the expected total sugar output per annum is 100 000 Mt from this extent. But the average actual production per annum is between 50 000 to 65 000 Mt. However, in the year 1994 domestic sugar production was 72 530 tons displayed its highest level (Department of Census and Statics - Sri Lanka, 2019), and it is a good indication regarding the potential for the production possibility of the lands used.

There is an essential requirement to increase sugar production by improving sugarcane production in the existing areas, to save such a large foreign exchange. This research was conducted to identify the effect of Non-agronomical factors (demographic, economic, and geographic) on the shortage of sugarcane production than potential level in major producing areas where situated in dry and intermediate zones in Sri Lanka. Data was collected from the hotspots of the sugar cane cultivating areas which contributed with major two sugar factories belonging to Lanka Sugar Company (Pvt.) Ltd. known as Pelwatte and Sevanagala sugar factories.

Sugar cane (*Saccharum officinarum*) is one of the primordial crops in Sri Lanka. Almost all production was engaged with small-scale Jaggery production. Establishment of sugar industry and commencement of its commercial sugar production remarked in Sri Lanka by launching the “Sri Lanka Sugar Cooperation” under the state corporations act no. 47 of 1957. In respectively 1960 and 1961, two other sugar factories were established at Higurana in Ampara districts and Kantale in Trincomalee districts which belong to the Eastern province of Sri Lanka (Keerthipala, 2007).

The Sevanagala sugar project started in 1968, with 220 ha of cultivated lands on the riverbanks of the “Walawe Ganga” which is owned by Sri Lanka sugar corporation (Keerthipala, 2007). In 1986 another sugarcane factory with a plantation complex was established at Pelwatte which belongs to Uva province with a 51% share hold by local government and 49% share owned by private companies or individual investors (Keerthipala, 2016). Gal-Oya Plantations (Pvt.) Ltd was formed in the year 2007 as a joint venture between the government of Sri Lanka (GoSL) and a consortium of investors from the private sector comprising of Browns & Company PLC and Lanka ORIX Leasing PLC.

At present sugarcane is the only the species cultivated for sugar manufacturing in Sri Lanka, although there are crops such as Coconut, Kitul, and Palmyra which can be used to manufacture sugar-based commodities such as Jaggery and treacle (Kumarasinghe & Wijayawardhana, 2011).

The annual per capita consumption of sugar is around 30 kg in Sri Lanka in 2020. According to that, the total requirement of sugar is fluctuating around 550,000 to 750,000 Mt per annum (Central Bank of Sri Lanka, 2020). Pelwatte and Sevanagala sugar factories are major manufacturers and it was 41,175 Mt per annum out of total production of 52,304 Mt (Central Bank of Sri Lanka, 2020).

According to the major company processes the sugar industry is driven mainly based on the out-grower system in Sri Lanka. Hence, farmers are the significant stakeholder of the industry. With close supervision and setup of the well-organized hierarchical manner of relevant companies, farmers are engaged with sugarcane cultivation and supply harvest to the factory yard. Farmers and the sugar companies are implementing together with a pre-signed bond to supply and purchase sugar cane.

As the raw material for the sugar industry, sugarcane production under go with quality control system. Since 2014, government involves domestic cane price determines with legal background. With hand of this, the farmer received a fixed price of LKR 5,750.00 per ton plus variable market price (VMP) at present. According to the payment policy of Lanka Sugar Company (Pvt.) Ltd, farmers were paided for their harvest considering the distance from farm gate to the factory yard, row weight of sugarcane, brix value, and top and trash percentages per ton. Under this price determination system, farmers are motivated to increase cane weight but not to enhance cane quality. Therefore, brix value is not much concerned by farmers but it highly impact on sugar production from ton of raw sugar cane. Thus, the potential of sugar production gets affected by the industry and farmers are stagnated at the marginal profit level.

Varieties used for cultivation also not considered by farmers at the expected level under agronomic limitations as well as the other malfunctions and contributions with the cultivation (De Silva & Costa, 2004). Pest and diseases are the other major limitations faced by the farmers restricting optimum sugarcane production (Waidyaratne et al., 2006).

Sugar cane is a C4 plant, belongs to the family Gramminae and is a sucrose-storing perennial crop (Arceneaux et al., 1965), known as the best crop for sugar production and bioenergy in most tropical and subtropical areas of the world (Zhao & Li, 2015), which is suited to intermediate and dry zones of Sri Lanka with minimum average daily water requirement is about 5mm. There are two types of cultivation methods depending on the water availability known as irrigation and rain-fed which practiced in Sri Lanka. Most of the extent is cultivated as rain-fed and standard cropping calendar also depend on the Yale and Maha rainy seasons for sugarcane. Sugarcane Research Institute centered to make recommendations accordingly and SL 7103, SL 8306, SL 8613, SL 8816, SL121, M 438/59 and CO 775 are the recommended and varieties for commercial cultivation of relevant areas (De Silva & Costa, 2004).

Since sugar cane is plantation crop in Sri Lanka, farmers need engage with crushing units as buyers at the stage of harvesting. Sevanagala and Pelwatte sugar factories are the main buyers at present due to the Lanka Sugar Company (Pvt.) Ltd. is the owner of the largest sugar factories and play crucial role as the largest buyer of the country.

According to the industry procedures could identify three types of farmers contributed with sugar cane production known as Settlers, Out growers, and farmers engaged with Integrated Sugarcane Farm Organization (Keerthipala & Dharmawardene, 2000).

Lanka Sugar Company (Pvt.) Ltd. is facilitate farmers by providing fertilizer, agro-chemicals, seed cane, and land development on a loan basis. Farmers should make a bond and agreement to recover their loans at the time of paying for their harvest by the company. This cultivation system engaged about 15 000 farmer families of the area (Kumarasinghe & Wijayawardhana, 2011), and most of them are living in the Monaragala district. All these farmer families are high inter connected with this production chain of the relevant factory to supply a stock of quality products to the factory.

Crushing capacities of the main three factories of the country were recorded as, 3300 TCD in Lanka Sugar Company (Pvt.) Limited -Pelwatte, 2000 TCD in Gal-Oyo Plantation (Pvt) limited, and 1250 TCD in Lanka Sugar Company (Pvt) Limited -Sevanagala. The daily crushing capacity of all Three factories is 6550 tonnes and the annual potential crushing days are 200 (Keerthipala, 2018), and the total annual potential crushing capacity at present is 1,310 000 tonnes. Though in 2017 total cane production of Sri Lanka was full filled 56.99 % of potential crushing capacity. According to the above fact, sugar cane production for the last five years seemed as stagnating without any progress same time average cane yield variation between 55 to 62 Mt per ha is its lowest margin as to the Central Bank Report (2020). And also sugar factories are far beyond the potential of their original crushing capacity, which showing a shortage of supply of cane into the factory yard.

Since relevant authorities facilitate sugar cane farmers depend on industry partnership for land preparation, land development, seed material, and fertilizer, agrochemical, and credit facilities offered by them. Majority of farmers are highly dependent on industrial contribution and almost all sugar industries have a well-established management system to cope with the farmer requirements. Companies withheld extension workforce known as field officers and field assistants are playing a vital role as a linking bridge between industry and the farmers by exchanging the information top and bottom directions. Under this well establish setup of the industry, production at the farmer level is not at the satisfactory level as the country manner.

Faheem et al. (2017), explained sugarcane production is not a single activity it is a multi-dimensional process and has to be identified board perspective because sugarcane production determines by many factors. Growers should have sound knowledge about the relationship of production factors to cane yield. Through that, they can achieve significant changes in their farm to get maximum output. Knowledge of sugarcane production determinants directs strategies by creating plans to improve agricultural efficiency by modelling using which create financial values at the macro level. Production techniques engaged with planting time, soil type, varieties, and irrigation water management have a significant role in sugarcane production. Knowledge of the input costs including inorganic fertilizer, irrigation, compost, cost of seed, and labour used for operational works was measured and displayed to perform a positive role in sugarcane production.

Sugarcane variety plays a more important role in sugarcane yield, therefore, define of sugarcane varietal potential yield is one of the important factors for growers but it is being challenged because it gets time more than twelve months to get outcome but researchers suffering high implementation costs through the study at country level. Most research was shown site-specific and season-specific evidence in their studies (Sanmuganthan & Wyseure, 1993). De-Silva and De-costa (2004), pointed out the sugarcane varieties available in Sri Lanka have adequate genotype variation for higher yield. Improved Sri Lankan variety SL88-116 shows the highest cane and sugar yield in both rain-fed and irrigation regimes. The average yield of varieties of this study shows 140.12 mt / ha in irrigated conditions and 90.61mt/ha in rain-fed conditions. The average sugarcane yield in local plantations is around 56-112 Mt per hectare (Kumarasinghe & Wijayawardhana, 2011).

The following table explains the average sugar cane yield change according to the area expansion. According to that no remarkable average yield obtains from the lands under sugar cane cultivation. There is no significant progress observed in the yield also with the time shed.

Table 1 : Sugar and sugar cane production and per capita sugar consumption

Item	2013	2014	2015	2016	2017	2018	2019
Sugarcane production (Mt)	644 000	657000	750333	798000	748000	720000	729000
Area harvested (Ha)	11801	12608	12305	11784	11156	11228	12300
Yield per ha (Mt/Ha)	67	75	89	58	61	61	61
Sugar Production (Mt)	53 061	52 318	55 972	61 265	55,552	51,265	52,304
Sugar Recovery %	8.2	8	7.5	7.7	7.4	7.1	7.2
Sugar import Value, LKR Mn.	37,187	33,332	34,164	49,919	39,041	40,045	35,714
Per Capita, Kg	29.34	27.66	32.43	33.64	32.12	31.12	27.91

Source: (SRI, 2020), Central Bank of Sri Lanka (2020)

Nazir et al. (2013), pointed out the yield gap between potential and actual determine by many factors such as poor management practices, post-harvest losses, and the use of a traditional system that is sharing dominantly through growers. Srivastava (2014), also argues the yield gap is mainly caused by socioeconomic, credit institutional factors, extension services, and lack of improved technology. There was not enough evidence to explain how demographic, economic and geographic factors are affecting the total sugarcane production in Sri Lanka. Hence, there is a contextual gap to identify what are the limiting factors that affect the sugarcane farmers to have lower production in their farmlands. Therefore, the researcher could identify below research problem related to sugar cane productivity of dry and intermediate zones of Sri Lanka. “Why Sri Lankan sugarcane farmers get low sugarcane yield per hectare”

This research was aimed to find out the other effective factors for the low productivity of sugarcane in dry and intermediate zones other than the agronomical factors. According to the research, the component to investigate the study is oriented to the theory of Cobb Douglas production function. It evaluates the effect of two major production factors labour and capital for the entire output of the manufacturing industry. This function was widely used in economics since it has good evaluation properties and is representative of more production processes as well. This function was used in this research to find out input-output efficiency in sugarcane production.

Although the traditional Cobb-Douglas production function evaluates only labor and capital for output, many researchers who have conducted agriculture industry-based research, used several other social factors along with two economic factors of capital and labor. Owiti et al. (2019), was used land preparation cost, fertilizer application cost, weeding, and weed control cost, and planting material and planting cost with education level to explain sugarcane output. Siriwardana et al. (2014), had identified, farming experience as a factor that effecting to the agriculture output. Moreover, Metiso and Tsvakirai (2019), pointed out farmer age positively affects output, Ambetsa et al. (2020), was justified family size is affected by sugarcane production. Dlamini and Masuku (2012), explained that cost of labor affected sugarcane output. Those factors were identified as having a positive impact on the sugar cane output. Masuku (2011), revealed that farmer distance to the mill was negatively affected for sugarcane output.

Based on those research findings, the research question identified impact of the selected demographic, economic, and geographic factors on the production of sugar cane in farmlands contributed with Pelwatte and Sevanagala sugar factories were executed for the investigation.

Demographic, economic, and geographic factors regarding this research were as follow,

- Factor 01 - Land preparation cost
- Factor 02 - Seed cane price
- Factor 03 - costs for agrochemical
- Factor 04 - Fertilizer cost
- Factor 05 - Labor cost
- Factor 06 - Irrigation
- Factor 07 - Age of farmer
- Factor 08 - Education Level
- Factor 09 - Family size
- Factor 10 - Distance from the mill to farmer plot

Effects of these factors were assessed per hectare of cane production standard.

1.2 Research Objectives

Study the relationship between yield and non-agronomic factors which affected the sugarcane yield in dry and intermediate zones of Sri Lanka.

Specific objectives

- I. To find out the most affective non agronomical factors for sugar cane yield per hectare.
- II. To identify proportional effect of factors for the yield per area by developing production function

2. Methodology

The researcher was selected farmers engaged with both Pelwatte sugar factory which having intermediate zone farmer lands and Sevanagala factory which having farmer lands in the dry zone. With this sample, the researcher was able to select both farmers cultivating sugar cane in the dry zone and intermediate zone.

According to the selected major crushing factories known as Pelwatte and Sevanagala the research study was conducted with farmers belongs to the Monaragala District, in Uva province, Sri Lanka and this is the district that representing both agro-climatic zones suitable for sugar cultivation in the country.

The population includes the entire group of people, events, or things of interest that the researcher wishes to investigate (Sekaran, 2003). The population of the study was the sugarcane farmers who are registered in Lanka Sugar Company (Pvt.) Limited- Pelwatte and Sevangala living in Monaragala district.

With the reference of the whole population of sugarcane farmers scattered in Monaragala district, to collect data, a convenience sampling method was used in this research. The selected population of the study was sugarcane farmers, who are living in Monaragala district associated with Pelwatte and Sevanagala sugar factories. There are 3922 farmers were registered in Sevanagala sugar factory and 4496 farmers in the Pelwatte sugar factory. Accordingly, the total population size of the study was 8418. To determine the sample size of the study researcher was used the formula developed by Krejcie and Morgan (1970).

$$s = \frac{X^2 NP(P-1)}{d^2 (N-1) + X^2 (1-P)} \quad (1)$$

Where,

S = required sample size,

X² = the table value of Chi-square for the degree of freedom at the desired confidence interval,

N = the population size,

P = population proportion and

d = the degree of accuracy expressed as a proportion (0.05).

According to the value of the formula and associated with related table value, a reliable sample size of the study was 368. Both primary and secondary data were collected for the research analysis to identify the factors that affected sugarcane production in Sri Lanka. Primary data was collected in this research directly from the selected farmers in the sample by a questionnaire, and it used to collect demographics data. Secondary data on production and costs factors were collected from records in sugarcane research institute, Udawalawa and farmer records from Lanka Sugar Company (Pvt.) Ltd. Other secondary data regarding the industry was collected from annual reports of the Central Bank of Sri Lanka and annual reports from the Department of Cense and Statics of Sri Lanka.

Reliability to the confidence of the study was analyzed by Cronbach's alpha (or coefficient alpha), developed by Lee Cronbach in 1951, where Cronbach's alpha formula is as follows,

$$\alpha = \frac{N\bar{c}}{u + (N-1)\bar{c}} \quad (2)$$

N - Number of items

\bar{c} - Average inter-item covariance

\bar{u} - Average variance

Statistical techniques and methods of application was driven by brief descriptive coefficients that summarize a given data set.

Regression analysis was done by multi-linear regression used for estimate relationships among variables that have reason and result relation and for the relationship between the dependent variable and independent variables.

3. Result and Discussion

Reliability analysis was done by Cronbach's alpha values to check the reliability of the data set. According to the analysis shows in table 2 Cronbach's alpha value of this data set is 0.817. Explained that the data set is reliable for modelling for the identified factors. That means the data set has a consistent flow of data.

Table 2 :Cronbach's Alpha

Cronbach's Alpha	Number of Items
0.817	10

Correlation Analysis for the hypothesis testing for the correlation analysis resulted correlation within dependent variable (yield per hectare) and independent variables considered in the research were as follows,

Table 3: Pearson Correlation - Coefficient Analysis

Factor	Significant value	Pearson Correlation coefficient	Level of Significant
Land preparation cost per hectare	0	-0.196	< 0.05
Seed cane cost per hectare	0	-0.215	< 0.05
Agro chemical cost per hectare	0.023	-0.062	< 0.05
Fertilizer cost per hectare	0	0.365	< 0.05
Maintenance cost per hectare	0.004	0.15	< 0.05
Age of farmer	0.131	-0.078	> 0.05
Education level of farmer	0.03	0.112	< 0.05
Family size of farmer	0.176	0.07	> 0.05
Distance from the factory	0	-0.299	< 0.05
Irrigation	0	0.499	< 0.05

Tables 3 represent Pearson correlation values for the correlation within the dependent variable and selected independent variables in this research. According to the values of the above analysis, land preparation cost, seed cane cost, agrochemical cost and distance from the factory were showing (followed by -0.196, -0.215, -0.062, -0.299 correlation values under 5% significant level) negative significant relationship with yield obtained per hectare.

In this research land preparation cost has a significant negative relationship with cane output, this finding agrees with the research findings of Owino et al. (2018), and Marie et al. (2019). If farmers invest more in land preparation by using heavy machinery, it's not economically sound due to higher rental cost also seed cane cost per hectare had a significantly negative relationship with cane output. Seed cane cost is negatively correlated with yield in this research. However, Ambesta et al. (2020), Maie (2019), Owino et al. (2018), pointed out a positive relationship between seed cane cost and sugarcane yield. Use of high seed cane rate is not agronomical optimized but farmers use high seed cane rate around 10 to 12 Mt per hectare high rate of seed cane become an extra cost for farmer thus, extra cost for higher seed cane rate is not positively affected to the yield. Hence, high cost negatively impacts yield.

Agrochemical costs also indicate a significantly negative relationship with cane output. However, Zulu et al. (2019) and Dlamini and Masuku (2012), found agrochemical cost positively influences cane yield. In Sri Lanka government intervention to the agrochemical usage by policy development (in 2016 amendment for pesticide act) and banded, globally most using agrochemicals for sugar cane such as Paraquat and Glyphosate (herbicides). Now higher costing agrochemicals are using in Sri Lanka such as Khrismat, Diurone, Glufosinate ammonium to suppress the weeds also labor shortage impact to the higher usage of expensive herbicides. Distance from the factory gate to the farmer's cane plot had a significantly negative relationship with cane output. This was verifying by Masuka et al. (2011), Owino et al. (2018).

Factors of fertilizer cost maintenance cost, education level of farmer and the irrigation were showed (followed by 0.365, 0.150, 0.112 and 0.499 at 5% significant level) positive significant relationship for the yield.

Fertilizer cost per hectare indicates a significantly positive relationship with cane output. Fertilizer cost has a linear relationship with yield because fertilizer application increases yield. This finding was related with Dlamini and Masuku (2012), Yuan (2011), Marie et al. (2019).

Maintenance cost is indicated a significantly positive relationship with cane output and this finding agreed with Ogwang (2009), due to proper maintenance impact positively on the final yield. Farmer education level had a significantly positive relationship with cane output Oduro-Ofori et al. (2014), and Khan et al. (2017), also found education level has a positive influence on cane output because technology adoption is depending on the education level.

The ability to irrigation has indicated a significantly positive relationship with cane output. Cane yield in dry and intermediate zones is highly influenced by the soil moisture level. According to correlation coefficient analysis, there is no linear relationship between age and family size of the farmer to yield of a hectare of sugarcane at 5% level value are 0.131 and 0.176, therefore, both of these variables were not considered for the regression model due to the not satisfying the linear relationship.

According to the above table, there were ten hypotheses were developed for the analysis in research and eight of them were accepted to fit for regression model and two factors were rejected in correlation analysis due to non-linear relationships among dependent and independent variables.

3.1 Demographic data analysis

Table 4: Gender analysis of production workforce

Gender	Frequency	Percentage
Male	125	33.30%
Female	250	66.70%

In this representative sample of the target population as shown in table 4 female involvement was 66.7 % and others were male workers (33.3%). According to the table 5 the production related workforce reflects that 94.1% of the sample was represented by married farmers and 5.9% were unmarried farmers.

Table 5 : Marital Statues of the farmers

Marital status	Frequency	Percentage
Married	353	94.10%
Unmarried	22	5.90%

Table 6: level of experience of a farmers involved

Experience in years	Frequency	Percentage
1-5	10	2.70%
6-10	79	21.10%
11-15	111	29.60%
More than 15	175	46.70%

Table 6 reflect that 46.7% of the total farmers of the sample was gained more than 15 years of experience at the meantime 29.6% of farmers have experienced between 11-15 years, 21.1% of farmers have 6-11 years' experience and 2.7% of farmers have less than six years' experience on sugarcane cultivation.

3.2 Estimation of production function analysis

According to the correlation analysis, eight variables were identified as significant independent variables and used to build up the model to evaluate the extent of those factors affecting the sugarcane yield respectively. The Cobb- Douglas production function used to estimate the inferential analysis of a dependable factor and independent factors.

A goodness of fit for the model computed for this sample comprises the R square, Durbin-Watson, F-statistics, and the variance inflation factors (VIF) statistics.

The Durbin-Watson test $d=1.684$ which is between the two critical values of $1.5 < d < 2.5$ and there is no first-order linear autocorrelation in the data. As a rule of thumb, residuals are uncorrelated if Dur-

bin Watson statistic is approximately 2. A value close to 0 indicates strong positive autocorrelation while a value close to 4 indicates a strong negative autocorrelation.

3.3 Regression Model

The stepwise method was used for the analysis. That means comparing the output of other methods stepwise method was giving the best-fitted model. Therefore, SPSS output of stepwise method as follows.

Table 7: Regression Model

Factor	Regression coefficient
Constant	39.678
Education Level	0.013
Fertilizer cost per hectare	0.001
Distance from the factory	-5.653
Irrigation	25.695

In above table giving the best-fitted model in regression for this study, and stepwise analysis was the result of the best-fitted model among other methods. According to the above regression model fertilizer cost, education level of a farmer, distance from the factory and irrigation were the affected factors for the yield of sugarcane. The developed model with the most fitted factors for sugarcane yield is represented by the following model formulation.

$$\text{Yield} = 39.678 + (25.695 \times \text{Irrigation}) + (0.013 \times \text{Education level}) + (0.001 \times \text{Fertilizer cost}) + (-5.635 \times \text{Distance to the factory})$$

According to the above regression model, irrigation is the most effective factor, education level, and fertilizer cost are the least effective factors that positively related to the sugarcane yield. And the distance to the factory is highly effective and negatively related to the yield.

Model Significance of following hypothesis was analyzed by F- statistics.

H0: The model is not significant

H1: The model is significant

So model F-statistics explain the relationship between the dependent variable and independent variables. The model F value of 48.16 is significant at 5% (p-value =0.000). Therefore, the null hypothesis has to be rejected and conclude that the parameters are jointly statistically significant which implies a statistically significant linear relationship between sugarcane production and the predictor variables at 4 degrees of freedom.

And the variable significant of the hypothesis were analyzed

H0: The variable is not significant

H1: The variable is significant

Table 8: Significant Values of the variables

Factor	Significant value
Constant	0.000
Education Level	0.041
Fertilizer cost per hectare	0.000

Distance from the factory	0.006
Irrigation	0.000

According to the 8th table, all the significant values of independent variables are less than 0.05. Therefore, all the variables of the model are affected by the yield. Farmer educational level had a coefficient of 0.013 at p-value of 0.041 which is greater than 0.05, indicating a farmer education level positively significant with cane output. The alternative hypothesis that farmer educational level affects cane output was accepted. The model shows education level positively affects cane yield. Reimers and Klasen (2013), Oduro-Ofori et al. (2014), Khan et al. (2017), pointed out educational background directly impacts the enhancement of farmer productivity because they have a rapid adjustment to the new technologies. According to Owiti (2019), education levels were not affected by the yield of the sugarcane in Kenya context. And also Pervaiz et al. (2013), in their study of sugarcane farming in Pakistan also found out that cane farmers were not highly educated. The insignificance of educational level implies that farmers learn production by doing which does not necessarily depend on the level of formal education.

But when considering this analysis Education level was the factor which is affected sugarcane production. In the near past of Sri Lanka, there was a huge tend to cultivated industrial crops. Sri Lankan government also gives fullest support and motivation to farmers. Under this situation, most of the farmers were motivated and get the updated knowledge. The involvement of more educated members of the society could enhance the adoption rate of new cane varieties and good crop husbandry leading to improvement in Sugarcane output.

Fertilizer application cost had a coefficient of 0.001 at p-value of 0.000, which is less than 0.05 indicating a fertilizer application cost positively significant with cane output. The null hypothesis that fertilizer application cost does not affect cane output was rejected, and the alternative hypothesis that fertilizer application cost affects cane output was accepted. Farmers should more concern with the effective fertilizer application program to increase cane yield.

According to the fitted model, fertilizer cost was affected to the yield of the sugarcane. Fertilizer application not practiced at the recommended level and under application could be observed. As per the literature, the yield was depending on the correct application of fertilizer which agreed with the findings of Marie et al. (2019), Zulu et al. (2019), and (Dlamini & Masuku, 2012). However, too much investment in fertilizer causes environmental pollution but applying fertilizer at the correct dosage and split application is more effective to reach maximum yield.

Distance from the factory had a coefficient of -5.653 at p-value of 0.000, which is less than 0.05 indicating a significantly positive relationship with cane output. The alternative hypothesis that distance from the factory affects cane output has was accepte.

Regression model found distance from the factory harms sugarcane yield. When distance high between two side attention and monitoring is neglected and low interrelation with the farmer and also farmer has to pay high amount to transport canes to the factory because Most of these farmers were located in very rural areas, therefore, road network facility very poor because of that there were no enough infrastructure facilities to transport the canes. This finding verified by many researchers in various contexts Chetthamrongchai et al. (2001), Distance between farm gate and mill has a significant impact on the total cost of production in sugarcane cultivation, and also McCall et al. (1985), pointed out the distance between farmer homes to farmer field affected to the productivity of the sugar harvest. Marie et al. (2019), pointed out the cost of transport significantly impact sugarcane production

Irrigation had a coefficient of 25.695 at p-value of 0.000, which is less than 0.05 indicating irrigation positively significant with cane output. The null hypothesis that irrigation does not affect cane output was rejected, and the alternative hypothesis that irrigation affects cane output was accepted. Since irrigation was coded as 1= irrigated and 0 = rain-fed and based on the coefficient, it implies that cane output is high with the irrigated field.

The regression model expressed that irrigation was the highly affected factor among the other factors and it was showed a strong relationship to influence the yield of the sugarcane. These results strengthen by the finding of Hussain (2013), shows in Pakistan context one percent increase in the water availability for sugarcane crop increases sugarcane yield by 0.16 percent. In Sri Lanka sugarcane is cultivated in dry and intermediate zones are received a minimum amount of rain comparing wet zones and rain receive in specific monsoon periods. A finding by (Wijayawardhana, & De Silva, 2016), said alternative row furrow saving irrigation water by 35-45% and increasing water productivity of the crop by 46% compared with normal furrow irrigation in the Sri Lankan context in that zones.

According to regression analysis of the stepwise method to develop the model following factors do not significantly affect sugarcane yield. Many researchers find out these factors affect in various contexts but this research Cost of land preparation, Cost of Seed cane, cost of the agrochemical, cost of maintenance, age of the farmer, and family size of the farmer does not affect for the dependent variable.

The result of the regression analysis shows R square and adjusted R square (Coefficient of determination) as 0.785 and 0.616 it says the percentage of the variance of the result that is explained by the model. According to the result, a 61.6 % variation of yield per hectare can be explained by the independent variable in the model. The R (Pearson correlation coefficient) of the model 0.785 says a 78.5 % correlation exists between a dependent variable and independent variables and they showed a strong correlation.

Normality tests are applied to investigate if the data set is well modeled and normally distributed. Random variables are examining to determine each of one measures' goodness of fit to the normal distribution model. Normality computations are very much effective to draw accurate and reliable conclusions about reality. In large data sets which sampled with above 30 entities, distribution is stand to be normal (Kothari, 2004). All the normality assumptions were checked and the above conditions were satisfied.

The independent variables in the model were tested for multicollinearity, and they showed no serious level of multicollinearity based on coefficients output collinearity statistics obtained VIF value of between 1.226 and 1.008 according to the table 9, meaning that the values obtained lie between 1 and 10 this means that there are no multicollinearity symptoms. These values are within the recommended maximum VIF value of 5 (Kennedy, 2008).

Table 9 - Multicollinearity of the independent variables

Factor	VIF Value
Irrigation	1.226
Fertilizer cost per hectare	1.047
Distance from the factory	1.183
Education level	1.008

4. Conclusion

Sugar industries play a very vital role in the dry and intermediate zone of Sri Lanka by generating direct and indirect job opportunities to increase the living standard of the rural community. According to the findings of the researcher, financial support and subsidies in land preparation, weeding and weed control, and seed cane and planting besides fertilizers would lead to improvement in cane production in the dry and intermediate zone of Sri Lanka.

The cost was the most affecting factor to the sugarcane production in Sri Lanka. Subsidizing input materials along with operation cost in short term lead sugar production. But in the long term, proper irrigation schemes along with other subsidiary and cane quality base payment systems will encourage the farmer to increase the cane yield of the hectare. Government and private sector should invest to increase irrigation availability according to geographical variation of the area and improving transportation facilities in remote areas for convenient access for the farmer to increase sugarcane productivity and sustainability.

Labor-intensive sugarcane farming is responsible for the high cost of production and low-profit margin for both farmers and sugar mills. Investment in programs related to research, varietal development, and extension of advanced technologies is most necessary. Further, the guaranteed supply of sufficient and subsidized agricultural commodities like high-yielding varieties sets, modern agromachineries, organic and inorganic fertilizer, and plant protection measures are boons for higher production and revenue. The restructured local, province, and central government should establish dedicated sugarcane subsector organizations for effective, smooth, and fast implementation and operation of the sugarcane-related programs and policies. The existing sugar mills have a significant role in increasing production, but capacity utilization and cost efficiency of the factory is low. To protect both the sugar mills and farmers, some adjustment is essential in existing trade and price policy. An increase in import duty, estimation of the logic price of sugarcane including recovery rate helps to reduce the market distortion. Further, the price policy should be extended to sugar and sugarcane by-products which ultimately enhance the financial status of sugar-mills and enable for dues payment of farmers. Protecting all the actors of sugarcane industries through effective price and trade policy helps to reduce the financial burden and enhance domestic production and consumption. Thus the sound economic balance can exist in the sugarcane industry

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**REVITALIZING EMPLOYEE MOTIVATION VIA THE IMPLEMENTATION OF
GREEN HRM PRACTICES: A COMPELLING CASE STUDY OF CBL EXPORTS
(PVT) LTD**

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Abstract: In the modern world, Green HRM practices go beyond the traditional HRM approaches by incorporating environmental considerations and exhibit green behaviors that contribute to a sustainable future of organizations in food industry. To achieve this sustainability, employee motivation is the key to reach them especially considering the internal success of any organization. This study aimed to find the current integration of environmental considerations into Green HRM policies and practices and how they affected to employee motivation. There was a lack of research in this area in Sri Lanka creating a gap in knowledge, particularly in relation to the potential benefits of Green HRM practices for both the organization and its employees. The data were collected by simple random sampling from 120 employees among 200 populations in the CBL Exports (Pvt) Ltd via a structured physical questionnaire. This study used a quantitative approach of descriptive statistics and inferential statistics by using SPSS software. The results revealed that, green training, carbon foot-print reduction, green recruitment are statistically significant, indicating a strong positive relationship with employee motivation. However, Eco friendly events, sustainable benefits, sustainable workplaces are non-significant. The majority of employees, 60%, are moderately aware of these green training sessions offered by the company and its efforts in reducing carbon footprint. The 92.5% of employees agree that there is a lack of awareness about Green HRM practices and a significant majority of respondents, 90.8% consider training and development on Green HRM practices to be important in overcoming the barriers. These findings will be beneficial to all the employees, policy makers, managers and especially food sector organizations to improve the Green HRM practices of their organizations & motivate & retain the employees.

Keywords: Green HRM; Employee motivation; HRM in food industry; Sustainability in food industry

1. INTRODUCTION

1.1 Introduction

In today's dynamic business environment, organizations are increasingly recognizing the importance of employee motivation and environmental sustainability. However, effectively integrating these two critical aspects remains a challenge for many organizations. Green Human Resource Management (GHRM) has emerged as an important topic of research in recent years due to the increasing recognition of the role that environmental sustainability plays in firm performance (Lepak & Gowan, 2010). Green HRM practices have gained increasing importance in today's business world due to the growing recognition of the need for environmental sustainability. Green HRM practices focus on integrating environmental considerations into HR policies and practices, promoting a culture of environmental responsibility within organizations. In the last few decades, both academics and practitioners are paying more attention to green human resource management concepts due to the increasing global warming in recent years. Recently, there has been renewed interest in green transformation; however, research on green human resource management (GHRM) is still lacking (Siyambalapitiya et al., 2018). While the benefits of Green HRM practices on environmental sustainability have been widely studied, its potential impact on employee motivation has been relatively underexplored in Sri Lanka. While there is a growing body of literature on the integration of Green HRM practices and employee motivation, there is a limited understanding of how to effectively implement these practices in specific organizations like CBL Exports (Pvt) Ltd.

1.2 Background

CBL is a Sri Lankan food manufacturing conglomerate that produces high quality confectionery and convenient nutrition. CBL was started to include the sustainable approach for their activities since 10 years. Therefore, this study aims to fill this gap by examining the implementation of Green HRM practices at CBL Exports (Pvt) Ltd and their impact on the motivation of employees.

1.3 Research Objectives

1.3.1 Broad Objective

- To revitalize employee motivation through the implementation of Green HRM practices in the CBL Exports (Pvt) Ltd.

1.3.2 Specific Objectives

- To identify the awareness of the employees towards the current key Green HRM practices implemented in the CBL Exports (Pvt) Ltd
- To evaluate the level of employee motivation
- To analyze the impact of Green HRM practices on employee motivation
- To identify the barriers and challenges in the implementation of Green HRM practices
- To provide recommendations for the effective implementation of Green HRM practices to enhance employee motivation

2. LITERATURE REVIEW

2.1. Introduction to Green HRM and Employee Motivation

2.1.1. Definition of Green HRM

Green Human Resource Management (GHRM) refers to the integration of environmental concerns into traditional HRM processes (Li et al., 2023). It involves the implementation of HRM practices that aim to shape employee behavior and attitudes towards environmental sustainability (Suharti & Sugiarto, 2020). GHRM practices include recruitment, training, employee motivation, rewards, performance evaluation, and the distribution of pay and benefits (Sheikh & Tjprc, 2019; Li et al., 2023). The goal of GHRM is to improve employee workplace green performance and promote environmentally-friendly behaviors (Wulansari et al., 2018).

2.1.2. Importance of Employee Motivation

Employee motivation is crucial in organizations as it directly impacts their performance and productivity. In the context of implementing Green HRM practices, employee motivation becomes even more important as it can drive employees to engage in sustainable environmental behavior and contribute to the organization's sustainability efforts. Green HRM practices have a positive impact on employees' engagement in proenvironmental behavior (Saeed et al., 2018). Moreover, Gilal et al. (2019) emphasize the importance of integrating environmental sustainability into human resource policies. They argue that the success of organizational initiatives for environmental sustainability relies on employees' sustainable behaviors.

3. METHODOLOGY

3.1. Research Strategy

The research approach was used quantitative analysis.

3.2. Research Sampling Technique

To achieve the objectives of the study, a sample of respondents was randomly selected from the targeted population it was the associate, junior and executive above staff of CBL Exports (Pvt) Ltd. In this study, the population size was 200 and the selected sample size was 120.

3.3. Data Collection

The data collection was done through a structured physical questionnaire.

3.4. Variables of the Study

3.4.1. Demographic Information

The variables are age, gender, department, and years of service.

3.4.2. Independent Variables (Green HRM Practices)

The independent variables included in this study are Eco-friendly Events, Green Training, Sustainable Benefits, Sustainable Workplace, Carbon Footprint Reduction, and Green Recruiting.

3.4.3. Dependent Variable (Employee Motivation)

3.5. Data Analysis

IBM Statistical Package for the Social Sciences software was used.

4. RESULTS AND DISCUSSION

4.1. Demographic Characteristics

4.1.1. Age

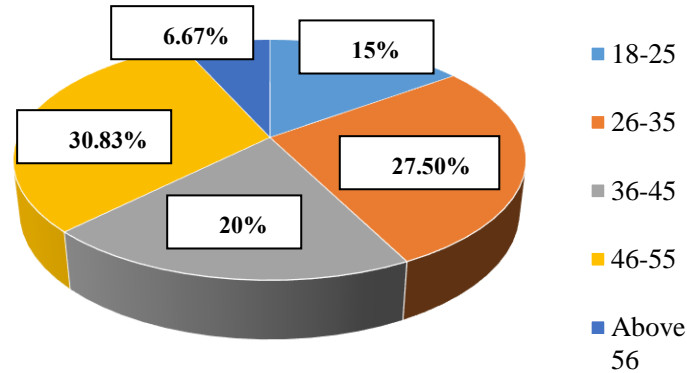


Figure 4.1.1. Age distribution of the associate, junior & executive above staff of CBL Exports(Pvt) Ltd.

Among the 120 respondents, the majority fall into the age categories of 46-55 and 26-35, and representing 30.8% and 27.5% of the total respondents, respectively.

4.1.2. Department Affiliation

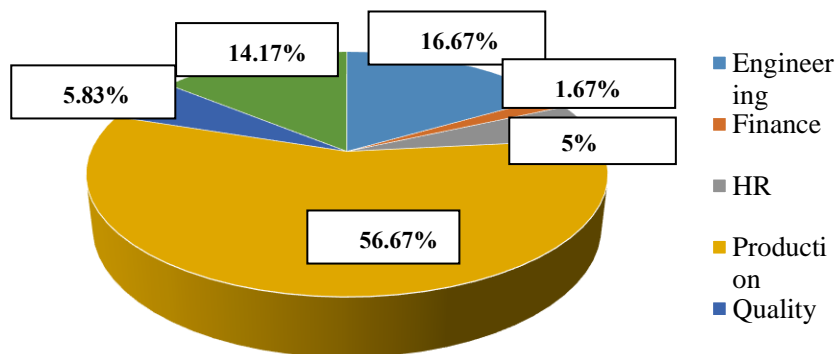


Figure 4.1.2. Distribution of the departments of staff which responded within the organization.

Majority belong to the Production department, accounting for 56.7%.

4.2. The awareness of the employees towards the current key Green HRM practices

4.2.1 Awareness of eco-friendly events organized by the company

The majority of employees, 62.5%, are very aware of the eco-friendly events organized by the company.

Table 4.2.1 Awareness of the eco-friendly events organized by the company

	Frequen- cy	Percent- age
Slightly Aware	10	8.3
Moderately Aware	35	29.2
Very Aware	75	62.5
Total	120	100.0

4.2.2 Awareness of green training sessions offered by the company

The majority of employees, 60.0%, are moderately aware of the green training sessions offered by the company.

Table 4.2.2 Awareness of the green training sessions offered by the company

	Frequency	Percentage
Not Aware	2	1.7
Slightly Aware	13	10.8
Moderately Aware	72	60.0
Very Aware	33	27.5
Total	120	100.0

4.2.3. Awareness of the sustainable benefits provided by the company

The majority of employees, 65.0%, are very aware of the sustainable benefits provided by the company.

Table 4.2.3 Awareness of the sustainable benefits provided by the company.

	Frequency	Percentage
Not Aware	4	3.3
Slightly Aware	9	7.5
Moderately Aware	29	24.2
Very Aware	78	65.0
Total	120	100.0

4.3. The Level of Employee Motivation

Engagement in daily work tasks has a minimum value of 1, a maximum value of 5, an average value of approximately 4.08, and a standard deviation of approximately 0.717. This suggests that, employees reported a high level of engagement in their daily work tasks. Regarding the commitment to the organization's goals and values, the minimum value is 1, the maximum value is 5, the mean is approximately 4.05, and the standard deviation is approximately 0.684. This indicates that, employees express a high level of commitment to the organization goals and values. Work performance over the past year has a minimum value of 1, a maximum value of 5, a mean of approximately 4.05, and a standard deviation of approximately 0.743. It suggests

that, on average, employees perceive their work performance over the past year to be high. Regarding absenteeism from work without a valid reason in the past six months, the minimum value is 1, the maximum value is 5, the mean is approximately 4.38, and the standard deviation is approximately 0.881. This indicates that, on average, employees reported relatively low absenteeism without valid reasons in the past six months. Regarding likely to consider leaving the organization in the next year, the mean is approximately 4.05, and the standard deviation is approximately 0.858. On average, employees seem to be less likely to consider leaving the organization in the next year.

Table 4.3 Descriptive statistics for five different variables related to employee motivation

Variable	Mean	Std. Deviation
Engagement in your daily worktasks	4.08	0.717
Commitment to the organization's goals and values	4.05	0.684
Work performance over thepast year	4.05	0.743
How often have you been absent from work without avalid reason in the past six months	4.38	0.881
Likely to consider leaving the organization in the next year	4.05	0.858

4.4 Multiple Linear Regression Analysis

The correlation coefficient (R) is 0.800. This value represents the correlation between the predicted values (from the regression model) and the actual observed values of the dependent variable. It indicates the strength and direction of the linear relationship between the predictors and the dependent variable. R Square is 0.640, which means that approximately 64% of the variance in the dependent variable is explained by the predictors included in the model. Adjusted R Square is 0.621. It is similar to R Square but considers the number of predictors in the model and adjusts for degrees of freedom. It provides a more conservative estimate of the variance explained by the model. The F-statistic is 33.538, and it is used to test the null hypothesis that all the regression coefficients are equal to zero. The significance level is 0.000 which is very close to zero. This indicates that the regression model is statistically significant at a very high level of confidence ($p < 0.001$). The coefficient for eco-friendly events suggests that for a one-unit increase in this variable, the employee motivation is expected to decrease by approximately 0.070 units. However, the coefficient is not statistically significant (p -value = 0.629), indicating that this variable may not have a significant impact on employee motivation. The coefficient for green training suggests that for a one-unit increase in this variable, the employee motivation is expected to increase by approximately 0.611 units. This variable is statistically significant (p -value = 0.000), indicating a strong positive relationship with employee motivation. The coefficient for sustainable benefits suggests that for a one-unit increase in this variable, the employee motivation is expected to increase by approximately 0.055 units. However, the coefficient is not statistically significant (p -value = 0.648), indicating that this variable may not have a significant impact on employee motivation. The coefficient for sustainable workplace suggests that for a one-unit increase in this variable, the employee motivation is expected to increase by approximately 0.113 units. However, the coefficient is not statistically significant (p -value = 0.151), indicating that this variable may not have a significant impact on employee motivation. The coefficient for carbon footprint reduction suggests that for a one-unit increase in this variable, the employee motivation is expected to increase by approximately 0.206 units. This variable is statistically significant (p -value = 0.040), indicating a positive relationship with employee motivation. The coefficient for green recruiting suggests that for a one-unit increase in this variable, the employee motivation is expected to decrease by approximately 0.316 units. This varia-

ble is statistically significant (p -value = 0.000), indicating a negative relationship with employee motivation. Table

Table 4.4: Coefficients table

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	1.634	0.246		6.640	0.000
Eco Friendly Events	-0.070	0.145	-0.081	-0.484	0.629
Green Training	0.611	0.147	0.718	4.143	0.000
Sustainable Benefits	0.055	0.121	0.069	0.457	0.648
Sustainable Workplace	0.113	0.078	0.147	1.444	0.151
Carbon Footprint Reduction	0.206	0.099	0.208	2.074	0.040
Green Recruiting	-0.316	0.084	-0.335	-3.763	0.000

4.5. The barriers and challenges in the implementation of Green HRM practices

The majority of respondents were (92.5%) agree or strongly agree that there is a lack of awareness about Green HRM practices.

Table 4.5. The barriers and challenges in the implementation of Green HRM practices

	Resistant to change (%)	Lack of awareness about Green HRM practices (%)	Limited resources for implementing Green HRM Initiatives (%)	Organizational culture not aligned with sustainability goals (%)	Inadequate Training and Development for employees on sustainability practices. (%)
Strongly Disagree	0	0	0	13.3	0
Disagree	2.5	0.8	13.3	7.5	0.8
Neutral	10.8	6.7	11.7	68.3	9.2
Agree	63.3	21.7	55.0	3.3	70.0
Strongly Agree	23.3	70.8	20.0	7.5	20.0

4.6 Strategies to overcome barriers and challenges

The majority of respondents (90.9%) consider leadership support to be important (either important or very important) in overcoming barriers and challenges in implementing Green HRM practices. A significant majority of respondents (90.8%) consider training and development on Green HRM practices to be important in overcoming barriers. The majority of respondents (90%) view communication and employee engagement as very important in addressing barriers and challenges.

Table 4.6: Strategies to overcome barriers and challenges

	Leadership Support (%)	Training and Development on Green HRM practices (%)	Communication and Employee Engagement (%)	Resource Allocation for Green HRM initiatives (%)	Employee Involvement and Empowerment in sustainability efforts (%)	Performance Measurement and Incentives for Green HRM practices (%)
Not important at all	0.8	0	0	.8	1.7	1.7
Slightly Important	4.2	2.5	4.2	4.2	1.7	1.7
Neutral	4.2	6.7	5.8	16.7	7.5	7.5
Important	59.2	27.5	13.3	59.2	21.7	21.7
Very Important	31.7	63.3	76.7	19.2	67.5	67.5

4.7. Recommendations for the effective implementation of Green HRM practices to enhance employee motivation

The majorities of respondents (94.2%) either agree or strongly agree that clear communication about the benefits of Green HRM practices is essential for enhancing employee motivation.

Table 4.7: Recommendations for the effective implementation of Green HRM practices to enhance employee motivation

	Integrating Green HRM practices into the organizational culture (%)	Providing clear communication about the benefits of Green HRM practices (%)	Involving employees in decision-making related to sustainability (%)	Enhancing leadership support for Green HRM initiatives (%)
Disagree	1.7	.8	5.0	1.7
Neutral	10.0	5.0	65.0	10.0
Agree	65.0	22.5	19.2	64.2
Strongly Agree	23.3	71.7	10.8	24.2

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has provided valuable knowledge in the implementation of Green Human Resource Management practices and their impact on employee motivation within CBL Exports (Pvt) Ltd. The study revealed that a significant proportion (around 60%) of employee aware of various eco-friendly initiatives within the company. These initiatives include eco- friendly events, green training sessions, sustainable benefits, efforts to create a sustainable workplace, and initiatives to reduce the company's carbon footprint. Among those Green HRM practices, green training, carbon footprint reduction, and green recruiting were identified as statistically significant factors which impacting employee motivation. The study especially identified the major barrier as lack of awareness about green HRM practices. (majority of 92.5%) and as a strategy to overcome the barrier, majority of 76.7% consider communication & employee engagement is very important and recommendation viewed that clear communication about the awareness & benefits of Green HRM practices to be important (majority of 94.2%).

5.2 Recommendations

Integrating Green HRM into the organizational culture, providing clear communication about the benefits of Green HRM practices, involving employees in decision-making related to sustainability, and enhancing leadership support were highlighted as key recommendations. By addressing the identified challenges and implementing the recommended strategies, organizations like CBL Exports (Pvt) Ltd can create a workplace that not only contributes to a greener future but also fosters higher levels of employee motivation and engagement.

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**ASSESSING ENERGY DEMAND AND ENVIRONMENTAL FOOTPRINTS OF
SELECTED CROPS GROWN UNDER PROTECTED HOUSES OF
UPCOUNTRY SRI LANKA
A CASE STUDY IN UPCOUNTRY SRI LANKA**

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Abstract: Protected agriculture, a diverse and resource intensive cultivation method, relies on various sources. Among that, natural resources, particularly water and energy, play a crucial role. As global concerns, resource utilization, and environmental impacts, understanding the energy demand and environmental footprints of crop production becomes significant in sustainable agriculture. This research conducted a Life Cycle Assessment (LCA - Gate to Gate) to evaluate the energy demand and environmental footprints of three selected crops Tomato (*Solanum lycopersicum*), Cucumber (*Cucumis sativus*), and Capsicum (*Capsicum annum*) cultivated under protected houses in Upcountry Sri Lanka. The assessment focused on electricity Consumption (EC), water footprint (WF), carbon footprint (CF), and the overall sustainability of the cultivation practices. For the asses, ISO 14000 series were followed, and functional unit was 1kg of produce. According to the obtained results for tomato, the CF, WF, and EC were recorded as 0.245 kg CO₂eq kg⁻¹, 40.35 L kg⁻¹, and 0.0028 kWh kg⁻¹, respectively. For cucumber CF, WF, and EC values were obtained as 0.196 kg CO₂eq kg⁻¹, 37.41 L kg⁻¹, and 0.0022 kWh kg⁻¹ while capsicum showed values of 0.630 kg CO₂eq kg⁻¹, 121.90 L kg⁻¹, and 0.0054 kWh kg⁻¹ respectively. The highest carbon emission, water consumption, and electricity energy consumption were reported in capsicum when compared to the other two crops of tomato and cucumber due to the low yield of capsicum comparatively. Further study revealed that water footprint is positively correlated in all three crop cycles (R² - 0.985 for tomato, R² - 0.931 for cucumber, and R² - 0.927 for capsicum) with the external environmental conditions of the area under the combination of parameters temperature, rainfall, and relative humidity. This study highlights the potential for cultivating crops with minimal resource utilization and reduced environmental impact in upcountry Sri Lanka under protected houses compared to existing studies.

Keywords: Carbon footprint; Electrical energy consumption; Protected house cultivation; Upcountry; Water footprint

1. Introduction

Greenhouse farming, also known as protected cultivation, is an innovative agricultural production system that offers a controlled environment for cultivating various crops (Castilla, 2013). In a broader perspective, it is defined as a cultivation system in which the micro-climate of the plant is fully or partially controlled during the crop growth according to the requirements of the crop (Kariyawasam *et al.*, 2023; Castilla, 2013). Protected cultivation involves the use of structures such as greenhouses to prolong the harvesting period, alter the conventional cropping cycles, increase yields, improve product quality, stabilize production, and provide products when open-field cultivation is limited (Singh and Sabir, 2022). So, the main goal of protected cultivation is to obtain high-value products using inputs efficiently (Ahuchaogu *et al.*, 2022). Also, quality agricultural produce can be obtained through protected agriculture with lower inputs regardless of climate change (Kariyawasam *et al.*, 2023).

At present, the demand for high-quality agricultural products is constantly on the rise and people have become more intentional about the food they consume (Petrescu and Vermeir, 2019). As a result, there is an increasing desire for fresh, nutritious, and visually appealing produce. So greenhouse production plays a major role in producing fresh, nutritious, and visually appealing produce (Ntinis *et al.*, 2020). When it comes to the worldwide scenario, In order to satisfy the yearly needs of freshly produced vegetables, off-season vegetables are produced either in heated greenhouses or in warm climates (Ntinis *et al.*, 2020). Since 70% of worldwide water extraction is used in agriculture, intensive cultivation of water-demanding crops in water scarce areas of southern Europe or North Africa results in burdened environmental impact (Ntinis *et al.*, 2020). Greenhouse gas emissions associated with heating demands in greenhouse vegetable production are a central issue in northern Europe (Ntinis *et al.*, 2020). Greenhouse gases, mainly carbon dioxide, methane, and nitrous oxide, are produced by energy consumption during horticultural production and contribute to global warming and consequently climate change (Ntinis *et al.*, 2020).

In Sri Lanka, the practice of growing plants in controlled environments are mainly led under mainly polytunnels and these structures are designed to create an optimal growing environment for plants by regulating temperature, humidity, light, and other factors.(Kumara and Weerakkody, 2015). In Sri Lanka, there are varied numbers of stakeholders from the farming community to large scale companies that produce vegetables and fruits for input suppliers and marketing agents who market the final product. Farmers in the districts of Badulla, Nuwara-Eliya, Kandy, and Matale are at the forefront of vegetable production and the rate of adoption of Protected Agriculture techniques has gradually increased (Kumara and Weerakkody 2015; (Nuskiya, 2019).

According to previous studies, consumer rationalism has led to consider sustainability in their purchasing behavior, giving momentum to eco-labeling and the development of environmental impact indicators (Borin, Cerf and Krishnan, 2011). Indicators such as carbon footprint (CF) and water footprint (WF) are widely accepted as communication tools of food products' environmental sustainability (Almeida *et al.*, 2014).

In this particular Life Cycle Assessment (LCA), the carbon footprint (CF) and water footprint (WF), along with the cumulative energy demand, of cultivating Capsicum (*Capsicum annuum*), cucumber (*Cucumis sativus*), and tomato (*Solanum lycopersicum*) in an upcountry greenhouse in Sri Lanka were assessed.

2. Methodology

2.1 Location of the study

The case study was conducted at the Dima Agri Techno Park Lindula which is located in the central province, Nuwara Eliya district in Lindula at N 60 55' 45.776" E 800 41' 43.136" and elevation is 1354 m above sea level. Figure 1 shows the location of the study and the satellite image of the location.

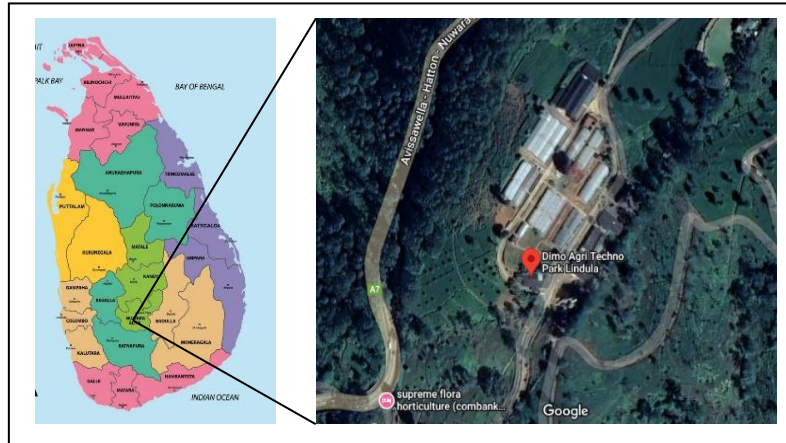


Figure 1. Satellite map of site of study.

The average annual temperature, rainfall, and relative humidity of the area are varied from 14⁰C-18⁰C, 1500mm-2500mm, and 70% - 85% consequently.

2.2 Crop selection

Three main greenhouse vegetables were selected considering the life cycle extent and availability. Consequently, Tomato (*Solanum lycopersicum*) variety - Ceres, Cucumber (*Cucumis sativus*) variety – Bona fide, and Capsicum (*Capsicum annum*) variety – Muriya F1 were chosen grown under protected houses.

2.3 Data collection

For conducting the gate-to-gate LCA of all three crops the following inventory table was followed (Table 01).

Table 1. Inventory table

Farm Data	Weather Data	Secondary Data
Crop – variety / Planting Date/ No. of plants etc.	Temperature – °C	GHG Emission Factors
Fertilizer – Type / Amount etc.	RH (%)	-
Pesticides – Type / Amount etc.	Rainfall (mm)	-
Water consumption (ml)	-	-
Growing media	-	-
Polythene types – grow bags/ mulch etc.	-	-
Structural components – iron / cladding materials	-	-
Electricity – (kwh) - Using energy meters (Model no. CAT 2),	-	-
Total yield – (kg)	-	-

IPCC 2006 standards were employed for the CF calculations (IPCC, 2006; Pereira *et al.*, 2020).

2.4 Data analysis

2.4.1 Procedure of Life Cycle Assessment (LCA)

The following Figure 02 describe the procedure of the LCA

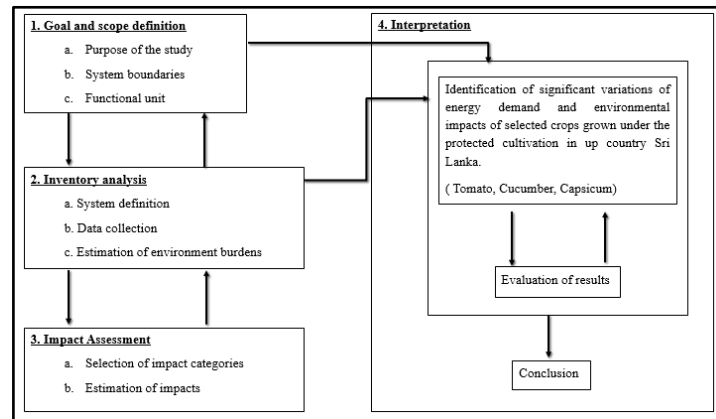


Figure 2. Procedure of Life Cycle Assessment.

2.4.2 Footprints

The foot prints were calculated employing following equations (Pereira *et al.*, 2020; Stanghellini, 2010; Qiu and Wu, 2021)

$$\text{Electricity} = \frac{\text{Total energy usage (kWh)}}{\text{Total crop yeild (kg)}} \quad (1)$$

$$\text{Water Footprint} = \frac{\text{Total Water usage (L)}}{\text{Total crop yeild (kg)}} \quad (2)$$

$$\text{CF (CO}_{2\text{eq kg}^{-1}\text{)}} = \frac{\sum (\text{Activity data} \times \text{Emission Factor})}{\text{Total crop yeild (kg)}} \quad (3)$$

Regression Analysis was performed to identify the relationship between crop stages, different water use, and climate variation.

3. Results and Discussion

3.1 LCA of selected crops

The findings of this LCA highlight the environmental impacts of these selected crops, aiding in understanding their sustainability and informing future agricultural practices for reduced ecological footprint. The initial production process begins with the preparation of grow bags, which is the same for the selected three crops. Inside the polytunnel, various management practices are followed until the end of the crop cycle. These practices include fertilizer management, pest and disease management, pruning, training, and harvesting. The main differences among these crops' LCAs lie in these management practices, such as the amount of fertilizer, water requirements, pest and disease management, and pruning and training methods, which vary among the selected crops. The following figures (Figures 2, 3 and 4) show the pathways of LCA summary for Tomato, Cucumber, and Capsicum, and the productivity of the tomato Cucumber, Capsicum crops were 9.0 kg/m², 11.5 kg/m², 2.1 kg/m² respectively.

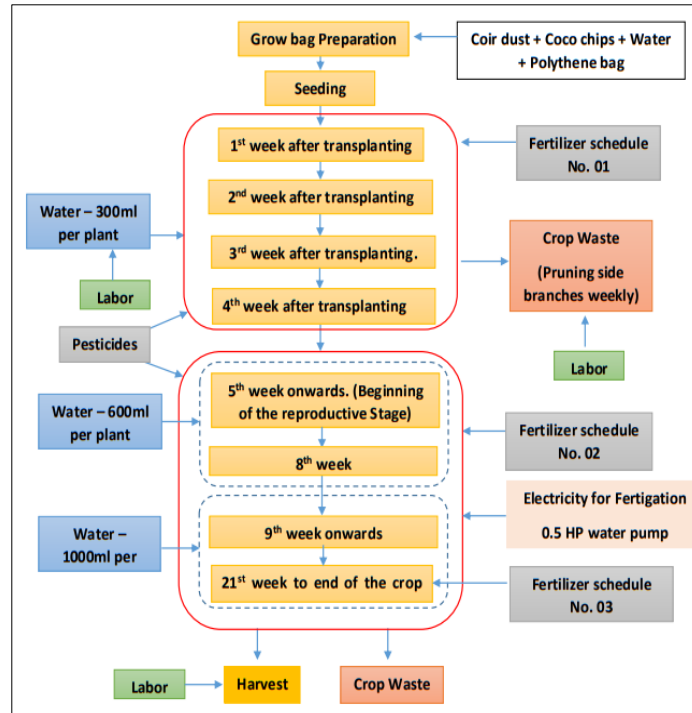


Figure 3. Life cycle of Tomato (*Solanum lycopersicum*).

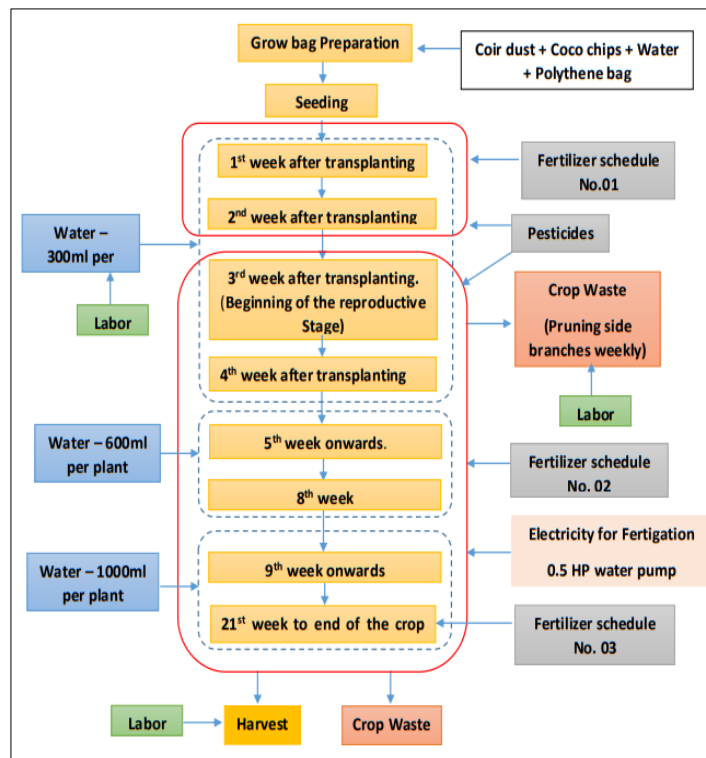


Figure 4. Life cycle of Cucumber (*Cucumis sativus*).

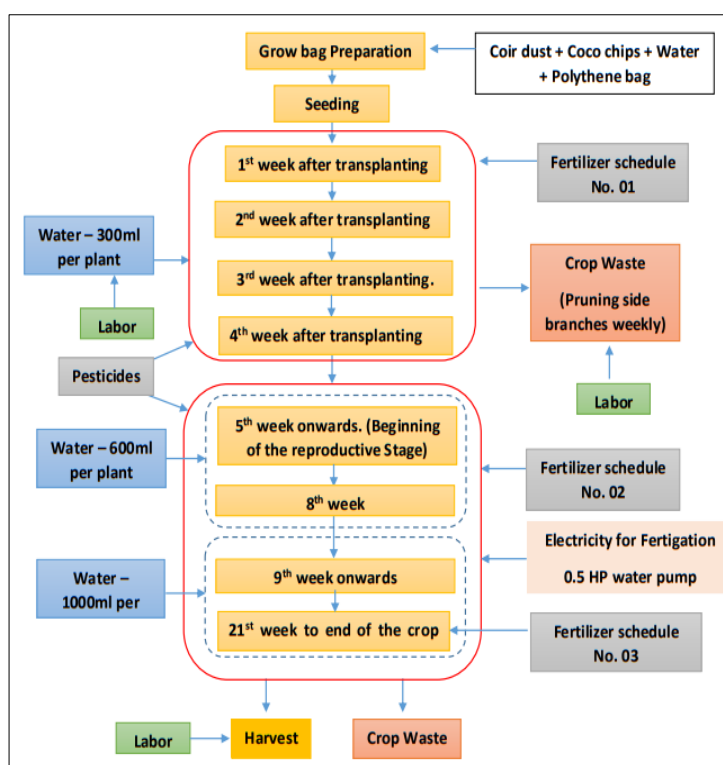


Figure 5. Life Cycle of Capsicum (*Capsicum annum*).

3.2 Assessment of water demand with respect to the climate variations

Table 2 variation of water demand of tomato, cucumber, and capsicum with respect to the outer environmental variations.

	Cas e 1	Case 2	Cas e 3	Cas e 4	Case 5	Case 6	Case 7
Weather parameter	RF, T & RH	T & RH	T & RF	RF & RH	RF	T	RH
Tomato							
R ²	0.985	0.945	0.925	0.972	0.062	0.672	0.152
Adjusted R ²	0.962	0.908	0.875	0.954	(-0.172)	0.590	(-0.060)
Durbin wat-son	2.549	3.293	3.293	3.056	0.716	1.264	0.494
Cucumber							
R ²	0.931	0.473	0.780	0.659	0.523	0.237	0.460
Adjusted R ²	0.826	0.121	0.633	0.431	0.404	0.470	0.325
Durbin wat-son	3.061	1.477	1.866	1.303	0.562	1.021	1.504

Capsicum							
R ²	0.927	0.819	0.833	0.927	0.263	0.818	0.689
Adjusted R ²	0.710	0.637	0.666	0.855	0.017	0.758	0.585
Durbin wat-son	2.866	2.364	2.599	2.847	1.662	2.364	2.340

According to the results, the highest R-squared values are recorded as 0.985 (Case 1), 0.931 (Case 1), and which indicates that 98.05% and 93.1% (Table 02) of the variance in the irrigation can be explained by the Temperature, RH and rainfall in tomato and cucumber. In the case of capsicum, two high R-squared values are observed, namely 0.927 (Case 1) and 0.927 (Case 2). These values indicate that 92.7% of the variance in irrigation can be explained by the variables Temperature, RH, and rainfall in Case 1, and by rainfall and RH in Case 2.

3.3 Comparison of environmental footprints of selected crops

The footprints of the selected crops show variations in their resource consumption and ecological impact (Table 02).

Table 3. Environmental footprints of selected crops

Crop	Water footprint (L/kg)	Electricity footprint (kWh/kg)	Carbon footprint (kg CO ₂ eq kg ⁻¹)
Tomato	40.35	0.0028	0.245
Cucumber	37.41	0.0022	0.196
Capsicum	121.90	0.0054	0.630

According to this study, tomatoes use 40.35 liters of water per kilogram, 0.0028 kWh of electricity per kilogram while producing 0.245 kilograms of carbon per kilogram. Cucumber use 37.41 liters of water per kilogram, 0.0022 kWh of electricity per kilogram while producing .196 kilograms of carbon per kilogram. In the case of capsicum, this higher water usage, higher carbon footprint is due to its low production. The comparison shows (Table 3) that tomato and cucumber cultivations having less environmental impact as less water use, make fewer carbon emissions, and need less electricity.

When comparing available literature, a noticeable difference emerges in this study. In terms of water usage for producing one kilogram of yield, commercial growers in Saudi Arabia have reported approximately 170 liters of water to cultivate 1 kilogram of tomatoes in plastic tunnels equipped with pad and fan cooling systems (Tsafaras *et al.*, 2022). As per Jackson *et al.*, (2015), the average water requirement for producing 1 kilogram of cucumbers stands at 240 liters, while Richard *et al.* (2015) noted a range between 200 and 250 liters per kilogram in Italy. Concerning the capsicum family, Richard *et al.* (2015) highlighted that the water necessity for greenhouse capsicum production varies from 200 to 300 liters per kilogram.

According to the previous studies when tomatoes were grown in open fields, they have typically emitted an average of 80 kg CO₂ per tonne. However, if it was cultivated in a greenhouse, this emission can surge to 700 kg of CO₂ per tonne (Dalgaard, 2021). In Finland, a study conducted in a greenhouse using supplemental lighting and semi-closed structures reported varying carbon footprints for cucumbers: 2.5 kg CO₂ per kg in spring, 1.5 kg CO₂ per kg in summer, and 3.3 kg CO₂ per kg in autumn to mid-winter (Almeida *et al.*, 2014). Similarly, a study in Iran found differing carbon footprints for tomatoes and

cucumbers 0.2 kg CO₂ eq per kg for open-field tomato production, 0.244 kg CO₂ eq per kg for cucumbers, and 0.129 kg CO₂ eq per kg for tomatoes and cucumbers grown in greenhouses (Pereira *et al.*, 2020). Furthermore, according to (Jung *et al.*, 2011) sweet and green peppers in a greenhouse have been carried carbon footprints of 4.34 kg CO₂ eq. per kg and 4.04 kg CO₂ eq. per kg, respectively. So, this variation in carbon footprint across vegetables explains how growing conditions significantly influence emissions.

Greenhouses require electricity for various purposes, including lighting, heating, cooling, ventilation, and automated environmental control systems. These technological interventions are necessary to provide a stable and controlled environment for crops, especially in regions with extreme climates or for year-round production. However, in this study, the fertigation system is the only place where electricity was used because these tunnels were not fully automated. According to this study, all three vegetable production systems have used significantly very low electricity to produce 1 kg of produce. In the process of cultivating vegetables in protected environments, the electricity consumption per kilogram varies among different studies. In the United Arab Emirates, greenhouse cucumber production showed an average electricity usage of 0.112 kWh/kg (Hirich and Choukr-Allah, 2017). Meanwhile, studies in Finland revealed a range from 4.4 to 10.9 kWh/kg for greenhouse cucumber production, contingent upon the lighting systems used (Kaukoranta *et al.*, 2017).

When it comes to tomatoes in arid and semi-arid regions, the electricity consumption for producing 1 kilogram typically falls around 8 kWh (Tsafaras *et al.*, 2022). Contrarily, a study in the Netherlands noted a lower average electricity consumption of 4.2 kWh/kg for greenhouse tomato production (Paris *et al.*, 2022). The electricity required for producing 1 kilogram of capsicum in protected environments varies due to multiple factors. However, it generally falls within a range of 1.5 to 2.5 kWh per kilogram (Samaranayake *et al.*, 2020). The diversity in these findings underlines the variance in electricity usage influenced by different factors and methods across regions and cultivation practices.

4. Conclusion

In this comprehensive case study conducted in upcountry Sri Lanka, the environmental sustainability of tomato, cucumber, and capsicum cultivation was assessed. The findings revealed distinct ecological footprints for each vegetable, with the carbon footprint values of 0.245 kg CO₂ eq kg⁻¹, 0.196 kg CO₂ eq kg⁻¹, and 0.630 kg CO₂ eq kg⁻¹ for Tomato, Cucumber, and Capsicum respectively. Water footprints for Tomato, Cucumber, and Capsicum were 40.35 L/kg, 37.41 L/kg, and 121.90 L/kg, respectively, while electricity usage were 0.0028 kWh/kg, 0.0022 kWh/kg, and 0.0054 kWh/kg Tomato, Cucumber, and Capsicum. Remarkably, the regression analysis demonstrated that the combination of temperature (T), relative humidity (RH), and rainfall (RF) yielded the highest R² values, indicating strong predictability for water use in greenhouses 0.985 for tomato, 0.931 for cucumber, and 0.927 for capsicum. These compelling results reveal that there is a significant potential for cultivating these crops under protected cultivation with minimal resource utilization and a reduced environmental impact in the upcountry of Sri Lanka when compared with the results of previous studies.

Acknowledgement

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ICSD 250

STUDY ON THE APPLICATION OF “ECO-LABEL SRI LANKA” CERTIFICATION FOR AGRI-FOOD EXPORT PRODUCTS in SRI LANKA

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Abstract: Eco-label certification, also known as environmental or sustainability label certification involves the certification and labeling of products to communicate their environmental or sustainable attributes to consumers. The global demand for sustainable and environmentally responsible products has amplified the significance of eco-labeling in international trade. However, it is hard to find research studies related to eco-label certification in agri-food exporting industry in Sri Lanka. This study aimed to investigate the viability and potential of implementing eco-label certification for agri-food exporting products in Sri Lanka. The objectives of the research were to study the awareness of “eco-label Sri Lanka” certification, assess inclination towards its application, and identify the primary barriers that producers encounter in adopting such certifications. Out of the agri-food exporters who are doing both manufacturing and exporting in the country, 186 of exporters’ data were collected through the survey. Data collection was carried out using a survey with the support of a pre-tested questionnaire. Data analyses were conducted using descriptive analysis, factor analysis, and structural equation modeling. According to the results, 69% of exporters are aware of “eco-label Sri Lanka” certification. As per the factor analysis, willingness of application of eco-label certification depends on factors related to profit maximization, higher demand in the international market and enhancement of product uniqueness. Barriers to the application were identified as factors related to complex certification standards and the high cost of certification. Relationships between the various factors and the viability of applying eco-labeling certification were identified through structural equation modeling. These results suggested that conduct awareness programs for the exporters and give them financial concessions to apply for this certification. Also, the findings of this study contribute valuable insights into fostering sustainable practices in the agri-food export sector while promoting economic growth and better global competitiveness for Sri Lanka.

Keywords: Agri-food exporters; eco-labeling; viability; sustainable; Sri Lanka

1. Introduction

Promoting environmentally friendly sustainable items in the marketplace is the idea behind eco-labeling. "Eco-labeling" refers to the application of a mark or symbol to goods or services that are environmentally friendly by a free-from-bias, independent third-party organization. The majority of environmental labels are not legally required, thus a company is free to choose one on its own. A greater percentage of consumers are becoming more conscious of environmental issues, and both domestic and international legislation are driving businesses to continuously develop goods and procedures with lower environmental impact. One of the most successful techniques for informing customers about these initiatives is the eco-label. It is a good practice because it provides buyers with the information needed to make an informed purchasing decision. Eco-label certification is a voluntary method of environmental performance certification and labeling that is practiced around the world. An eco-label identifies products or services proven to have a lesser or reduced effect on the environment compared to similar products and services used for the same purpose (Global Ecolabelling Network, 2023). There are three main types of eco-labels certifications. (Global Ecolabelling Network, 2023):

Type I - Multi-criteria based third party program. This is a voluntary, multiple-criteria based, third party program that awards a license that authorizes the use of environmental labels on products indicating overall environmental prefer ability of a product within a particular product category based on life cycle considerations. Examples include the EU Eco-label and the Nordic Swan.

Type II - Self-declared environmental claims. This refers to environmental claims that are made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim. Sometimes it is referred to as "pseudo-labels".

Type III - Voluntary programs that provide quantified environmental data of a product, under pre-set categories of parameters set by a qualified third party and based on life cycle assessment, and verified by that or another qualified third party. An example is the Environmental Product Declaration (EPD). Eco-label certification provides numerous environmental, economic, and social benefits. Eco-labels help consumers identify products and services that have a reduced environmental impact compared to other similar products (ISO, ISO, 2018). They provide credibility through independent, third-party assessments using scientific evidence or life-cycle considerations (Global Ecolabelling Network, 2023).

This verification is important due to concerns over false or misleading environmental product claims, also known as green washing (Aji & Sutikno, 2015). For producers, eco-labels promote resource efficiency and environmental responsibility while enhancing market access and competitive advantage. They allow companies to gain recognition for sustainability initiatives and demonstrate commitment to corporate social responsibility (Blackman & Rivera, 2010). Eco-labels also enable benchmarking against environmental performance standards and promote continuous improvement (Rex & Baumann, 2007). Overall, eco-labels facilitate more sustainable consumption and production patterns through increased environmental awareness, transparency, and product information to guide greener purchasing decisions (Horne, 2009). Widespread eco-labeling contributes significantly to sustainable development goals and the transition to a global green economy (UNEP, 2017).

Eco-labels and sustainability certifications have proliferated globally as tools to drive responsible production and consumption by providing credibility through third-party verification of environmental and/or social claims (Blackman & Rivera, 2010). As ethical consumer values spread, credibly certified goods can gain market share and price premiums abroad, supporting export competitiveness amid green trade barriers (Nanayakkara & Hossain, 2022).

1.1 Global Experience with Eco-Labels for Agri-Food Exports

Eco-labels have successfully expanded agricultural and food exports for both developed and emerging economies (Herrmann & Grote, 2018). Documented cases span sustainably certified commodities like coffee, cocoa, palm oil, and seafood commanding price premiums under labels like Fair trade, Rainforest Alliance, etc. (Blackman & Rivera, 2010). Such examples demonstrate potential for smallholder inclusion under accredited environmental and ethical standards catering to rising sustainability demands abroad (International Trade Centre, 2011).

1.2 Eco-Label Landscape in Sri Lanka

Sri Lanka introduced its first eco-label for products and services in 2006 through the state-backed National Cleaner Production Center (Abewardene & Udugama, 2022). The “Environmental Friendly” label aims to develop both supply and demand for goods with reduced environmental impacts versus substitutes, verified through life cycle assessment criteria on resources use, manufacturing practices, distribution systems, consumption, and disposal impacts (Jayalath & Aamarasuriya, 2021). Although awareness and adoption remain low domestically, over 100 product certificates have been issued across categories like textiles, paints, bags, teas, and processed foods (Nanayakkara & Hossain, 2022).

1.3 “Eco-Label- Sri Lanka” certification

“Eco-label Sri Lanka” certification was introduced in Sri Lanka in 2006 through the National Cleaner Production Center under the authority of the National Cleaner Production Policy and Program and established a voluntary eco-labeling scheme in 2006 called "Environmental Friendly" to promote the supply and demand of environmentally friendly products in the country (Jayalath & Aamarasuriya, 2021). The Sri Lanka Standard Institute (SLSI) introduced the first eco-label in the country known as the "Environmental Friendly" product certification mark. This voluntary, multiple-criteria based, third party eco-label program aims to incentivize Sri Lankan manufacturers and service providers to offer products and services with reduced environmental impacts. Certified products must meet sustainability considerations related to material extraction, manufacturing processes, distribution, product use, and disposal/recycling (SLSI, 2020). As of 2020, 101 product licenses have been issued across sectors like textiles, paints, bags, skincare, food and beverages (Niroshana, 2020).

“Eco-label-Sri Lanka” of the National Cleaner Production Center Sri Lanka (NCPC-SL) is a Type I label that employs multiple criteria to identify overall environmental prefer ability of products based on life cycle considerations (Gunawardena & Rowe, 2020). Certification involves a third party assessment to verify that products meet standards related to sustainable resource extraction, responsible production processes, product use and disposal, among others (NCPC, National Cleaner Production Centre, Sri Lanka, 2020). The goal of the NCPC-SL eco-label is to incentivize companies to offer more sustainable products and services and to assist consumers in identifying them.

Global demand for eco-labeled products from Sri Lanka is growing steadily, driven by rising sustainability awareness and ethical consumerism (Nanayakkara & Hossain, 2022). However, Sri Lanka’s supply of certified green products has not kept pace, constraining export competitiveness. Key barriers limiting Sri Lankan companies from eco-label certification and export include high compliance costs, low brand awareness, lack of technical skills, and inability to charge significant green premiums abroad (National Frame work on eco-labelling Sri Lanka, 2020). Targeted policy to foster production capacity, stakeholder collaboration, and overseas promotion could significantly boost eco-label penetration and double Sri Lanka’s exports within key (De Silva G.C., 2022) segments like apparel, tea, rubber, and spices.

However, global ethical consumerism and sustainability trends are spurring rising interest in credibly eco-labeled goods from developing countries (De Silva G.C., 2022). Market data confirms demand doubling annually for certified green products in key Sri Lankan export categories like apparel, tea, spices, coconut oil and handicrafts (Herat & Mahalekam, 2018). However, critics argue that tangible trade and welfare gains from eco-labels remain mixed for developing country producers facing

structural challenges around compliance costs, distribution complexities and inconsistent premiums (International Trade Centre, 2011) (Nanayakkara & Hossain, 2022). As such, targeted public and private efforts are essential to build compliant capacity, ensure proper cost-benefit distribution to growers, and orchestrate effective marketing (De Silva G.C., 2022). While NCPCSL's voluntary standards ensure environmental prefer ability for certified goods, increased international adoption requires compliant capacity-building for suppliers, plus consistent branding and effective distribution channels abroad to fulfill consumer expectations (Jayalath & Aamarasuriya, 2021). Strategic support for exporter networking, global partnerships and targeted promotion could significantly boost recognition and demand for Sri Lanka's eco-labeled offerings in priority export markets across Europe and North America.

1.4 Problem Statement & Objectives

When consider the Sri Lankan agri-food exporters, some of them use different types of Eco-label certifications. However, majority of them do not use this valuable certification concept to grab international market. According to above mentioned information, the main objective of this research was to study on feasibility or viability of application of using Eco-Label Sri Lanka Certification for agri- food Export Products in Sri Lanka. It was completed using four specific objectives: measuring awareness about “Eco label Sri Lanka “certification among agri-food exporters”, determining factors that affect willingness to apply this certification, identifying the barriers when applying this certification for agri- food export products and analyzing feasibility for application of “Eco Label Sri Lanka”certification.

2. Research Methodology

The research was focused on the agri-food exporters in Sri Lanka who are doing both manufacturing and exporting. According to the Export Development Board of Sri Lanka (EDBSL) data; exporters categorized as tea, coffee, species, coconut based products and other exporters (Figure 1).

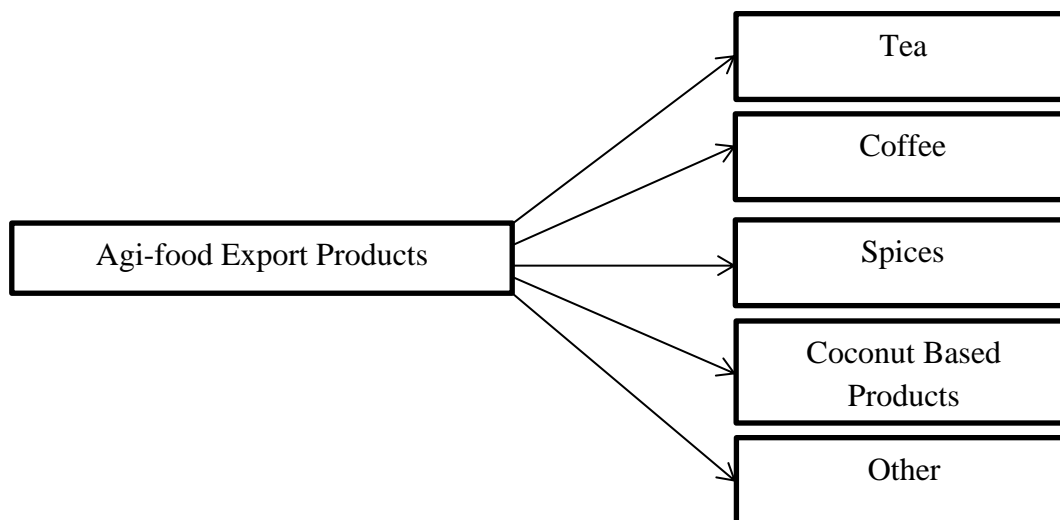


Figure 1: Different types of Agri-food Export products.

2.1 Research Approach

A deductive method was used in this study. There are two general approaches to thinking that can lead to acquiring new knowledge: deductive and inductive. Deductive reasoning is a method of testing hypotheses that begins with a theory or assumptions and attempts to determine whether the hypothesis holds for specific instances.

When using a method known as deductive reasoning, a reasonable theoretical position or theory (or theories) should be developed before the collection of data, and a suitable exploration system should

be designed to test the hypothesis. In this research viability of application will be tested by using hypothesis.

2.2 Research Strategy

Since the deductive approach is used as the methodology, the survey strategy is the strategy associated with the particular methodology. It is famous and generic technique is business and the management research areas and is regularly used to answer who, what, where, how much and the number of types questions. Survey strategy is well known since it permits the assortment of a lot of data from a sizeable populace in an exceptionally economical manner. Usually data has to be collected by utilizing a survey controlled to a sample of the population, further where information is normalized, and permitting simple contrast. Also the strategy of survey is seemed to have authoritative quality by individuals all in all and is both nearly simple to disclose and to comprehend.

2.3 Sample and Sampling Techniques

Agri-Food Products Exporters in Sri Lanka who are doing both manufacturing and exporting considered as the population of the study. There are more than 500 exporters registered in Export Development Board in Sri Lanka. According to the export development data and Sri Lanka custom data; number of tea, coffee, spices and coconut based products export manufactures are higher than the other agri-food exporters. Therefore, sample was divided into five strata or subgroups as tea, coffee, spices, coconut-based products and other product exporters. Calculated sample size is 214 exporters.

Sample size was calculated by considering 95% confidence interval and 5% margin of error with the selected population from following equation.

$$n = \frac{Z^2 P (1-P)}{d^2}$$

Where, n= Sample size

Z= Z Statistic for a level of confidence

P= Expected prevalence or proportion

d= Precision

But due to the limited time and budget data were collected from 186 exporters randomly.

2.4 Theoretical Framework

According to the previous research findings viability or feasibility of application can be identified as unobservable variable. These variables depend on three major dimensions. These are awareness level, willingness to apply and barriers for application (Figure 2).

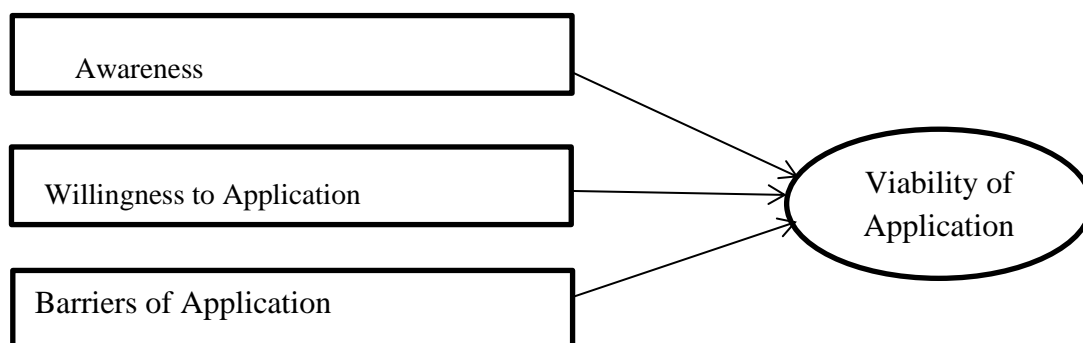


Figure 2: Theoretical Frame work of the study.

2.5 Conceptual Framework

In the structural equation model, the independent variables such as awareness, willingness, and barriers are pivotal factors influencing the dependent variable, Viability (Figure 3).

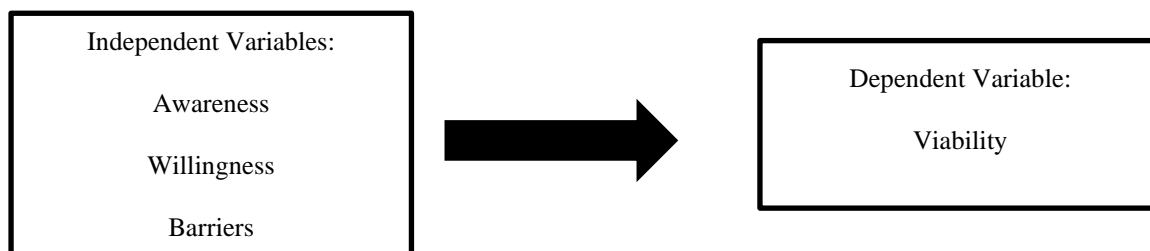


Figure 3: Conceptual Framework of the study.

2.6 Data Collection methods

Primary data were collected from 186 exporters through the questionnaire survey using Google forms (135 respondents), telephone conversations (13 respondents) and face to face interviews (38 respondents) The questionnaire consisted of six sections. Those sections are demographics, awareness about eco-label certification, awareness about consumer demand for certified products, perception of use this certification; identify barriers for application and exporters suggestions and recommendations. Data collection was conducted from October to December 2023, with the support of pre-tested questionnaire. National cleaner production center gave lots of support in data collection. Secondary data were used for buildup research problem and prove some statements. Secondary data were collected through the Export Development Board, Sri Lanka, Sri Lanka Custom, Department of Agriculture, Department of Census and Statistics, National Cleaner Production Center- Sri Lanka, and previous research publications.

2.7 Analysis techniques

Both qualitative and quantitative techniques used for data analysis. Qualitative data were analyzed through the AMOS structural equation modeling and quantitative data were analyzed through the descriptive statistics by using SPSS.

3. Results and Discussion

Results of the study are presented according to the objectives under four sections as Awareness about Eco Label Sri-Lanka certification among agri-food exporters, Factors affecting the level of awareness, Attributes which affect for willingness to apply eco label certification, Barriers for apply eco label certification and Viability (feasibility) of application of Eco-label Sri Lanka.

3.1 Awareness about “Eco Label Sri-Lanka” certification among agri-food exporters in Sri Lanka

Based on the answers for the question of “Have you heard or do you aware about Eco-Label Sri Lanka Certification?” the results of agri-food exporters’ awareness about Eco-Label Sri-Lanka were included in the Table 1. According to the results, while 68.3% of the respondents had awareness about eco-label Sri Lanka certification, 31.7% of them were not aware of it.

Table 1: Awareness of eco-label Sri Lanka Certification by the respondents (n=186)

Awareness	Frequency	Percentage
Yes	127	68.7
No	59	31.3
Total	186	100.0

3.1.1. Factors affecting the level of awareness

The factors or attributes of awareness level were obtained through the likert scale for a better variance of the awareness level and the findings are presented in Table 2. According to table 2 more than 40% exporters have more awareness about only the concept of eco labels Sri-Lanka certification. But more than 60% exporters' awareness level is least about eco-labeling types. 42.5% of exporters have moderate level of awareness about positive impacts on environment. According to these information, most of exporters' general knowledge about eco-label Sri Lanka certification make positive impacts on their business is at low level. This conclusion and the next one are contrasting. You have to adjust this one.

Table 2 Factors affecting the level of awareness

	Attributes for Awareness of Application	Percentage (%)					Mean value
		Least	Less	Moderate	More	Most	
I	About only the concept(AOA 1)	33.3	3.8	15.1	40.9	7.0	2.84
Ii	About eco-labeling types (AOA 2)	65.1	16.7	17.7	5	-	1.54
iii	About its' positive impacts on environment (AOA 3)	32.8	3.8	42.5	18.8	2.2	2.54
Iv	About its' positive impacts on your business (AOA 4)	32.8	15.6	29.9	19.9	2.2	2.43

3.2 Attributes which affect for willingness to apply eco label certification

When consider the attributes on willingness to apply eco label certification most of them highly believe that it can help to expand their market, enhance product demand and also increase profit margins.

Table 3: Attributes on willingness to apply eco label certification

	Attributes for Willingness To Apply	Percentage (%)					Mean value
		Not at all	Slightly	Somewhat	Very important	Extremely Important	
i.	Expand your market (WTA 1)	14.5	1.1	7.0	27.4	50.0	3.97
ii.	Enhance product demand (WTA 2)	-	15.1	19.4	14.5	51.1	4.02
iii.	Enhance product quality (WTA 3)	-	14.5	32.8	40.3	12.4	3.51
iv.	Increase profit margins (WTA 4)	-	1.6	21.0	47.3	30.1	4.06

v.	Increase product recognition/ uniqueness (WTA 5)	-	15.1	39.2	34.9	10.8	3.41
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3.3 Barriers to apply eco label certification

The barriers of application were obtained through a likert scale. According to Table 4, complex certification standards act as barrier for more than 52% exporters to apply this certification. Also high certification cost act as barrier for more than 70% exporters.

Table 4: Barriers for Application of Eco-label certification

	Attributes for Barriers For Application (BFA)	Percentage (%)			Mean value
		Yes	No	Somewhat	
I	Complex certification Standards (BFA 1)	52.2	1.6	32.8	2.08
Ii	Certification requirements may be effect for changes of farming practices, processing or packaging. (BFA 2)	30.6	1.1	54.8	2.51
Iii	Consumer awareness level is differing from region to region. (BFA 3)	30.6	0.5	68.8	2.38
Iv	Difficult to monitoring and verification. (BFA 4)	15.6	2.2	68.8	2.80
V	These global standards may not always align with local farming practices or environmental conditions. (BFA 5)	44.6	5.4	50	2.05
Vi	Supply chain complexity (BFA 6)	28.0	4.3	67.7	2.40
Vii	Eco-labeling regulations and standards can change over time (BFA 7)	8.1	4.3	87.6	2.80
Viii	High cost for certification (BFA 8)	71.5	0.5	28.8	1.56

3.4 Viability (feasibility) of application of Eco-label Sri Lanka certificate

In here three Hypotheses were applied. They are as below.

Hypothesis 1: Awareness level of application has a significantly positive effect on feasibility or viability of application.

Hypothesis 2: Willingness for application has a significantly positive effect on feasibility or viability of application.

Hypothesis 3: Barriers for application has a significantly positive effect on feasibility or viability of application.

Hypotheses were tested through the path analysis.

The structure equation model was run in order to identify the relationships described through the hypothesis (Table 5). The model has CMIN/DF value of 2.335 which was in the range of 1 to 3 as per the model fit requirement. Also, RMSE value 0.092 which was less than model fit requirement 0.1. However model has only achieved absolute fit indices.

Table 5: Model fit indices of the measurement model

Category	Goodness of fit Indices	Threshold	Observed Value
Absolute Fit Indices	CMIN/DF	< 3	2.335
	GFI=The Goodness of Fit Index	>0.9	0.978
	AGFI= Adjusted Goodness of Fit Index	>0.9	0.952
	RMR= Root Mean Square Error of Residual	<0.1	0.099
	RMSEA= Root Mean Square Error of Approximating	<0.1	0.092

Table 6 seems to represent the results of a structural equation model, showing the estimated coefficients (Estimate), standard errors (S.E.), critical ratios (C.R.), probabilities (P), and labels for each path or relationship between variables.

The path from "Awareness Of Application" to "Viability" has an estimated coefficient of 0.075. The critical ratio is 0.180, and the p-value is 0.001, indicating a statistically significant positive relationship between these variables.

The path from "Willingness To Application" to "Viability" has an estimated coefficient of 0.085. The critical ratio of 0.357 and the low p-value of 0.001 suggest a statistically significant relationship.

The path from "Barriers For Application" to "Viability" has an estimated coefficient of 0.072. The critical ratio is 0.063, and the p-value is 0.001, indicating a statistically significant positive relationship.

The path from "Attribute Of Awareness" (specifically AOA_3) to "Attribute Of Awareness" has a very high estimated coefficient of 0.999 with a substantial critical ratio of 58.260, denoted by three asterisks (***) , indicating an extremely strong and statistically significant relationship. The path from "Willingness To Apply" (specifically WTA_1) to "Willingness To Apply" has an estimated coefficient of 2.536. The critical ratio of 4.772, denoted by three asterisks (***) , suggests a strong and statistically significant relationship.

According to the results, all the hypotheses can be accepted.

Table 6: Regression Weights

			Estimate	S.E.	C.R.	P	Label
Viability	<---	Awareness Of Application	.075	.006	.180	.001	par_18
Viability	<---	Willingness To Application	.085	.083	.357	.001	par_19
Viability	<---	Barriers For Application	.072	.005	.063	.001	par_20
AOA_4	<---	Attribute Of Awareness	1.000				
AOA_3	<---	Attribute Of Awareness	.999	.017	58.260	***	par_1
AOA_2	<---	Attribute Of Awareness	.335	.038	8.822	***	par_2
AOA_1	<---	Attribute Of Awareness	.893	.039	22.959	***	par_3
WTA_6	<---	Willingness To Apply	1.000				
WTA_5	<---	Willingness To Apply	1.004	.299	3.361	***	par_4
WTA_4	<---	Willingness To Apply	2.359	.491	4.802	***	par_5
WTA_3	<---	Willingness To Apply	2.217	.323	3.773	***	par_6
WTA_2	<---	Willingness To Apply	2.200	.466	4.740	***	par_7
WTA_1	<---	Willingness To Apply	2.536	.531	4.772	***	par_8
BFA_6	<---	Barriers For Application	1.000				
BFA_5	<---	Barriers For Application	.793	.186	4.271	***	par_9
BFA_4	<---	Barriers For Application	.990	.214	4.634	***	par_10
BFA_3	<---	Barriers For Application	.723	.187	3.874	***	par_11
BFA_2	<---	Barriers For Application	.693	.185	3.736	***	par_12
BFA_1	<---	Barriers For Application	1.831	.283	6.466	***	par_13
BFA_7	<---	Barriers For Application	.685	.172	3.996	***	par_14
BFA_8	<---	Barriers For Application	1.851	.287	6.453	***	par_15

4. Conclusions & Recommendations

In here several conclusions were drawn based on the findings of the research study. Most of the exporters are aware about eco-labeling certification. But their awareness level about different attributes is difference. Market expansion, demand enhancement, and profit maximization are the main factors for willing to apply for this certificate by the exporters. Common barriers of application are high certification cost, and complex certification standards. Application feasibility depend on their awareness, willingness and barriers for apply.

Based on the findings of the study, following recommendations can be suggested. Conducting awareness programs to improve awareness level of the exporters, connecting exporters with agriculture experts to give knowledge about how to apply this concept with ensuring supply chain availability and providing financial supports for them that need to apply this concept, especially small scale exporters.

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**DIGITAL MARKETING STRATEGIES FOR REDUCE POST HARVEST LOSSES
DUE TO CLIMATE CHANGES IN SRI LANKA: A REVIEW**

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Abstract: Climate change has a major influence on Sri Lankan agriculture, increasing post-harvest losses and food shortages. Sri Lanka has witnessed significant climate changes in recent decades, impacting crop production and disrupting farmers' lives and the food supply chain. The annual production barely meets the nation's food needs, making food security an ongoing top priority. Therefore, the objective of this review was, to identify the main causes of post-harvest losses, including the effects of climate change, inefficient storage and transportation, and problems with market accessibility. In order to gain insights relevant to Sri Lanka, a subsequent analysis of effective digital marketing strategies implemented in countries facing the same problems were carried out. This review considers 20 studies published Science direct, from 2012 to 2022. The creation of online and mobile platforms offering real-time weather updates, market trends, and professional guidance on post-harvest procedures is one of the suggested digital marketing strategies. Farmers' understanding of climate-resilient post-harvest practices have been increased through social media marketing, targeted ads, and informative webinars. The effective implementation and sustainability of these strategies have ensured through the pro-motion of collaboration with governmental and non-governmental organizations. The literature study, on the nation's current adaptation initiatives, has highlighted several concerns. These include reduced crop productivity and the well-being of rural farmers, post-harvest losses, disruption in the supply chain, and substantial investments in food exports.

Keywords: Climate change; Digital marketing; Mobile applications; Online platforms; post-harvest losses

1. Introduction

Agriculture is the core of the Sri Lankan economy, employing over 70% of the country's rural population and providing their major source of in-come. The industry now employs more than 31.2% of the workforce and accounts for 7.9% of the nation's GDP. The tropical island of Sri Lanka has two primary wet seasons, or monsoons, and 46 unique agro-ecological zones. Nonetheless, agricultural output is often seasonal and dependent on water availability (Rajapaksha et al., 2021).

Significant shifts in Sri Lanka's climatic patterns over the last few decades have had significant effects on the country's agriculture sector, and by consequently, its food security issue. Climate change has wide-ranging consequences on the agricultural sector, such increasing post-harvest losses, food shortages, and major challenges to the country's ability fulfil nutritional demands (Amarasinghe et al., 2005a). Climate change emerged as the main problem in much research and also resulted in mitigating the consequences of post-harvest losses due to climate change (Esham et al., 2017). There has not been a single study conducted to identify the hidden reasons behind the post-harvest losses, climate change and a lack of transportation and storage facilities. In the study, we will explore the relationship between post-harvest losses, climate change, and a lack of transportation and storage facilities.

Poor and general post-harvest practices and handling, voids in the integration of cold chain practices and elements with the post-harvest process, and a lack of knowledge and awareness on many related aspects at the grass-root farmer level, among other things, appear to contribute to losses that ultimately prevent due economic benefits from reaching the small-scale producers (Amarasinghe et al., 2005b). To improve the efficacy of post-harvest handling of fruits and vegetable products, suitable corrective methods aimed at both small-scale and commercial farmers must be disseminated and implemented (Adhikarinayake et al., 2006). At the small- and medium-producer level, promoting suitable low-cost post-harvest techniques and processes, supporting low-cost cold chain elements, and implementing a user-friendly information flow system on market conditions will undoubtedly assist in preventing some of the stages that contribute to losses (Bandara and Cai, 2014). A monitoring system for the commercial post-harvest handling process that ensures scientific bulk handling, storage, and transportation of fruits and vegetables and properly designed economic centers with well-regulated environment-controlled storages would significantly reduce bulk handling losses (Abeysekera et al., 2015), ensuring better food security on the island (Rajapaksha et al., 2021).

Managing food production and security for a growing population in the face of climate change is a significant problem for civilization. Climate change, particularly rising temperatures, will impact crop suitability and cultivation techniques. To maintain yields, farmers may need to adjust cultivation practices, timing, and crop types. One of the main problems is meeting the Paris Agreement's aim of limiting global warming to far below 2°C. Meanwhile, food security is another high-priority topic in the United Nation Sustainable Development Goals that may suffer as a result of strict climate mitigation measures. Using a multi-model comparison exercise, we demonstrate the possible negative trade-offs between food security and climate change mitigation. We discovered that improperly conceived climate mitigation initiatives might raise the number of people at risk of famine by 110 million by 2050 (Fujimori et al., 2019).

Farmers are frequently at a disadvantage due to limited access to timely market information and unbalanced power dynamics within the supply chain, which increases their susceptibility to price volatility and shifts in the market (Azlarova, 2022). A wide range of digital marketing strategies have emerged as potential answers to solve convoluted difficulties and strengthen Sri Lanka's agricultural sector. With real-time weather up-dates, market trends, and expert

guides on post-harvest best practices, the expansion of internet and mobile platforms has huge potential to offer farmers practical insight (Apostolidis et al., 2021).

Furthermore, the revolutionary potential of interactive webinars, targeted advertising, and social media marketing for disseminating knowledge about climate-resilient agricultural practices cannot be overestimated (Apostolidis et al., 2021). Post-harvest losses are caused by primary, secondary, and tertiary variables that have a direct impact on the harvesting, handling, storage, processing, packing, marketing, and usage of food. The key causes are intrinsic produce features, biological, physiological, environmental, storage infrastructure, and processing issues. Secondary variables include supplementary services that facilitate the transfer of products from farm to market, as well as customers and consumer behavior. Tertiary causes are external variables that have a direct influence on post-harvest technology access and delivery (Brinkman et al., 2010).

2. Methodology

Twenty research articles related to post-harvest loss mitigation in Sri Lanka were reviewed in the Science Direct journal (Figure 01).

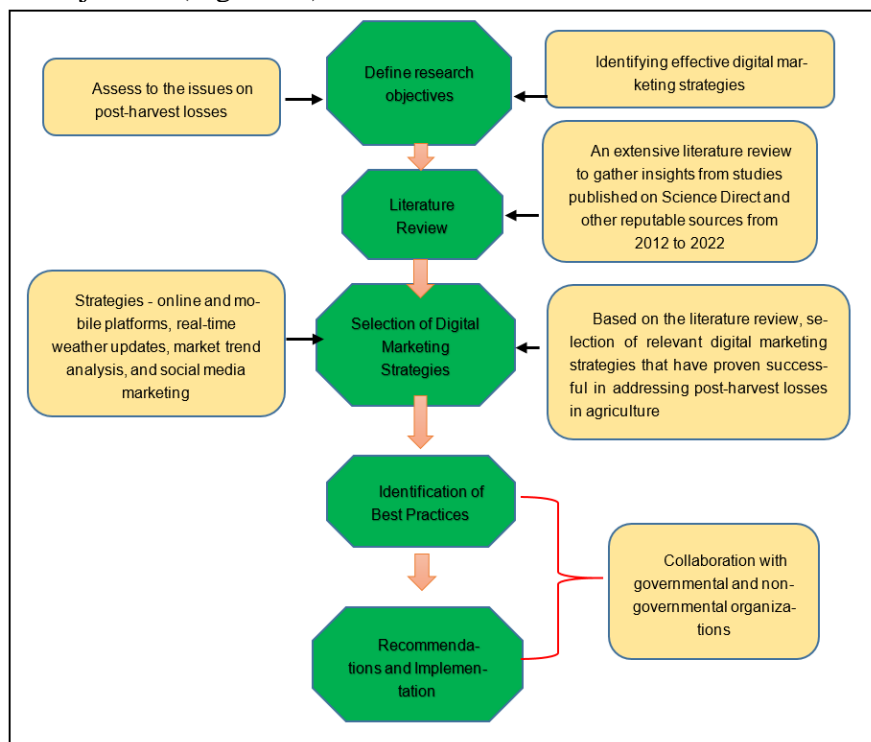


Figure 1: The expected procedure for research from objectives to documentation.

3. Results

Climate change issues, transport problems, a lack of ideal storage facilities, and issues related to market accessibility were major problems related to post-harvest losses (Figure 2). Moreover, digital marketing strategies emerged as a way to control post-harvest losses by improving Sri Lankan farmers' knowledge.

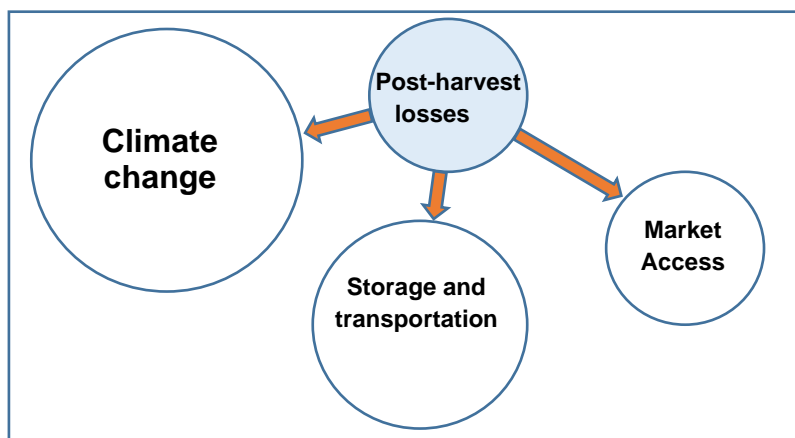


Figure 2: Factors effect on post-harvest losses. Climate change, storage and transportation problems and market access effect on post-harvest losses predominantly, moderately, and diminitively respectively.

Climate change is well recognized as having a detrimental influence on food security. However, the majority of the literature focuses on the complex and many processes that relate to climatic stressors; the links to food production or efficiency rather than availability of food, and future rather than current implications. Storing and transporting vegetables and fruits without suitable packaging contributes significantly to post-harvest loss. Trucks have limited air circulation the availability of minimal facilities in the Colombo market complex for unloading fruits and vegetables from Lorries, as well as receiving less ventilation due to loading a large number of polysack gung bags one after another, striking crushed and scrunched vegetables and fruits with good staff, significantly increase harvest loss (Perera et al., 2011).

To achieve the Sustainable Development Goals of poverty alleviation and access to safe and nutritious meals, the National Postharvest Management Institute expects to minimize postharvest loss of vegetables and fruits by up to 15% by 2022. According to the Institute, the post-harvest loss of the mango crop was reduced from 39.6 percent to 6% by strengthening supply chain operations of mango, guava, papaw, and banana in the zones they monitored. Even though this is a laudable trend, it was discovered that this initiative, which is only monitored in a few regions, should be expanded over the entire island. A comprehensive literature study was done in order to assess the role of digital agricultural technology in allowing food loss and waste prevention/reduction, or lack thereof, on a worldwide scale (Abeysekera et al., 2015)

4. Discussion

To offset the consequences of climate change on food security, governments and organizations must take proactive measures to build food production and access systems that can resist extreme weather events and climatic unpredictability. These initiatives should include investments in agricultural infrastructure, crop, and food source diversification, long-term food storage systems, and training for local farmers in sustainable agriculture approaches (Rajapaksha et al., 2021). By taking action now to address the effects of climate change on food insecurity, we can ensure that food supply is not at risk by changing weather.

Since the roof of the Lorries use in the transportation is not covered the harvest gets wet and congregates water in the raining and dries in the sun-light adding the warm emits from harvest damage the harvest quantitatively and qualitatively. Furthermore, it can be generally seen that the persons who go with the Lorries transport vegetables sit sleep on the packages and it will affect the lift time of crops but not rules or laws will apply thereon. Parking and unloading the goods in economic centers need to be happened in a shaded proofed place (Tito et al., 2017).

Vegetables and fruits are natural products that provide life. Crops continue to respire even after harvest. Storing them without a specified temperature might disrupt this process, resulting in lower-quality fruits and vegetables. If a given standard product reaches the retailer, the loss occurred inside the marketing there will be a minimum process. Veggie and Fruits delivered from farm to market Damage occurs in phases. Which include reaping harvest before becoming matured and departing from certain methods (Rajapaksha et al., 2021b).

Despite being discussed at the District Agricultural Committee meeting on April 26, 2018, it was not possible to provide accurate data on the extent of land to be cultivated for each crop to farmers. Despite 44 training programs on vegetable cultivation in secure shelters in Badulla District in 2017 and 2018, farmers were not provided with the necessary financial and material assistance despite being made aware of value-added produce. Climate change and food security are inextricably linked, as evidenced in the literature. The Intergovernmental Panel on Climate Change asserts with "high confidence" that climate change is already causing global food insecurity. However, there are still inadequate attempts to quantify this link and investigate the extent to which changes in food security may be attributed to climate change. Rather, the majority of the literature addressing climate change impacts focuses on agricultural yields, output, and productivity, as well as future climate change consequences, with far less emphasis paid to the current detrimental impact on food security (Tito et al., 2017).

Fresh goods, especially fruits and vegetables, decay quickly after harvesting owing to the warm, humid air. To improve the storage life of fruits and vegetables, remove heat from the field and chill immediately after harvesting. Temperature and humidity significantly impact post-harvest losses for fruits and vegetables (Rajapaksha et al., 2021). Climate change's detrimental impact on agricultural productivity is expected to worsen when global temperatures rise to 2.6-4°C by the end of the century. Climate change, particularly rising temperatures, will impact crop suitability and cultivation techniques (Gunaratne et al., 2021). To sustain yields, producers may need to adjust cultivation procedures, timing, and crop types. Farmers can relocate crops to more favorable climates, avoiding the need to withstand greater temperatures and potential pests (Tito et al., 2017b). Insufficient storage and transportation facilities cause post-harvest losses in Sri Lanka. Limited access to appropriate storage facilities and poor transportation infrastructure lead to increased rotting and waste of fruits and vegetables (Perera et al., 2011).

5. Conclusion

Post-harvest food loss is defined as a shown drop in the amount or quality of food produced following harvesting. This may be a large proportion, as over one-third of worldwide food output is lost or squandered each year. For many households, these losses jeopardize food, nutrition, and financial stability. Losses in quantity limit food availability, raise food costs, and lower farmers' revenues when product is used for household use rather than sale. Quality losses result in less nutritious or even hazardous food, lower market prices and farmer earnings, and decreased food availability. Transporting a ripe crop requires special attention to avoid disconnected grain from dropping on the road before reaching storage or threshing facilities. Harvest collection and transportation are affected by storage conditions, particularly during threshing. More research is needed to minimize post-harvest losses. The Agricultural Research Policy Council should supervise all public institutions' post-harvest loss research, both agricultural and non-agricultural, to ensure it is not repetitious and that its recommendations are implemented.

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CONSUMER PERCEPTIONS VS SUPPLY OF LOBSTER AND GIANT FRESHWATER PRWANS: OVERCOMING OBSTACLES

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Abstract: Both marine lobster and aquatic Giant Freshwater Prawns (GFP) are one of the most lucrative high value fish species in Sri Lanka which is mainly catering to the export market. This study eyed to conduct market analysis for both lobster and GFP supply chains, to identify consumer perceptions on lobster and GFP, and to develop innovative strategies to overcome market obstacles. The study was carried out in Southern, Western and North-Central provinces where lobster and GFP catch is prominent. Primary data were collected from randomly selected 20 foreign and 30 local consumers, 40 fishermen, 08 exporters and 07 collectors from each subsector by using interviewer administrated questionnaire and in-depth interviews. The results revealed that, scattered small-scale fishermen commence both supply chains which feed international high-end consumers. Whole lobster represented the most popular product with minimum weight of 300g with zero damages and followed by tail, lobster meat and claw are trading to the export markets and low quality (Grade-II) lobsters are buying for half of the price of the original. The quality is determined by damages in claws and in abdomen area and also based on size of the animal (<500g, 300-500g and 200-300g). GFP, the grading system is maintained as 100-150g, 150g-250g, 250 –400g, 400g-500g and <500g. If the head is damaged, animals are selling to local consumers. Value pricing is common for both markets with its premium nutrient value and taste. Moreover, landing site prices are started from 3-10USD where consumers have to spend 22-50USD for 1Kg. There are different value attributes are concerning by both local and foreign consumers such as; physical appearance, size of the animal, colour, odour, nutrient value, date of catch and also the price. Even though these animals are having higher export market demand, poor post-harvest handling, overexploitation of lobsters resist the pathway of earning higher profits.

Keywords: Giant freshwater prawns; Lobster; Sri Lanka; Sustainability

1. Introduction

The seafood and aquaculture products exportation are playing a key role in Sri Lanka's economy which generating foreign income as well as creating job opportunities. Meanwhile, there are mandatory quality requirements in exportation specially on keeping food hygiene and safety, to overcome tough price competition, keep the high-quality standards to satisfy the foreign consumer markets (Lo and Minh,2010). Further, advances in cold-chain facilities and transportation technology have enabled access to seafood and aquaculture products from any region in the world, at any time of year and this availability has fuelled the growing demand for fisheries products on a global scale (Future of Fish,2015).

Lobster fishery is one of the most economically important high value marine coastal fishing activities in Sri Lanka. The lobster market is export oriented and household consumption is negligible (Koralagama *et.al.*,2007). Major exporting countries are Japan, Hong Kong, UK, Singapore, and Korea. Export oriented lobster fishery generated 879 million LKR (US\$) in 2021(EDB, 2020) Giant Freshwater Prawns (GFP) are also considering as main candidate for aquaculture fisheries due to its high market value and market demand. Mainly, the harvests of giant freshwater prawns are going to high-end restaurants and hotels in Sri Lanka or are exported (Ariyaratne and Amaraweera,2015). The main exporting destinations of GFP are Thailand and China.

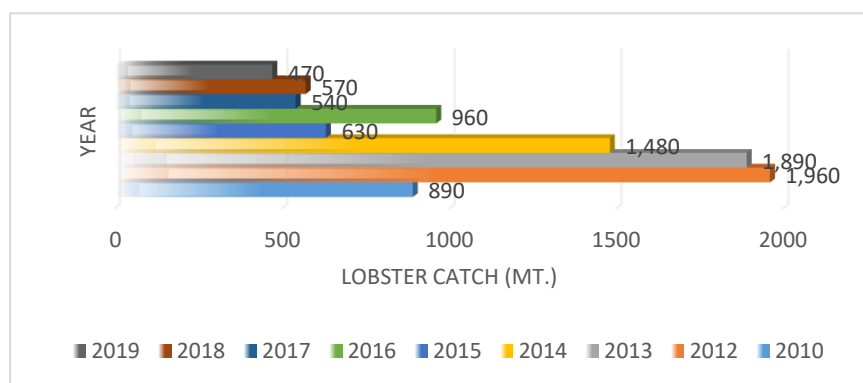


Figure1: Lobster Catch Volume (Mt.)
Source: Ministry of Fisheries (2022)

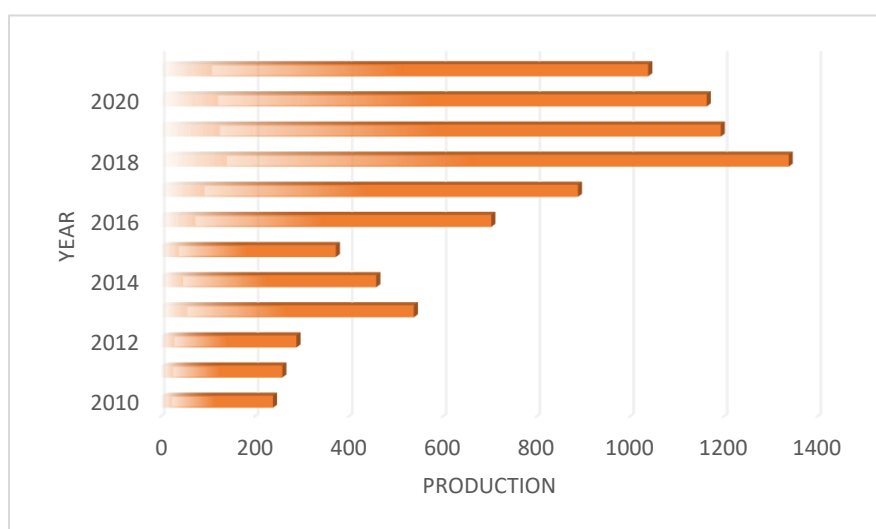


Figure 2: Giant Freshwater Prawns Production (Mt.) 2010-2021.
Source: National Aquaculture Development Authority (NAQDA)

The above figure 1 and 2 illustrate the production trends of lobster and GFP and both industries are showing positive increasing trends. Majority of consumers of exporting destinations are prefer to purchase both lobsters and GFPs as live animals for later cooking, which is believed to be healthier for the consumer and better tasting than fish that are killed earlier or preserved (Zhang *et.al.*,2019). Therefore, exporters have to transport these animals as live animals and tourist hotels are maintaining tanks inside the hotels to keep animals alive after caught from sea or reservoir. If there are any damages occurred during catching and handling of lobsters and GFP could be cause to reduce the price of selling (Liyanage and Long,2019). Moreover, inappropriate handling, air exposure, food deprivation, poor water quality, inappropriate transport densities, sudden changes in water temperature, and rapid water movement could be cause to reduce the vitality and increase mortality (Sampaio and Freire,2016) and due to higher market demand, overexploitation and increasing number of undersized and egg bearing lobsters in the catch is also recorded (Jayakody,1999).

In Sri Lanka, exporters have adopted their own system in logistics still in primitive level with lot of loopholes and not catering to the growing demand. Even though both lobster and GFP are having higher export market demand, usage of primitive methods of handling, storing while transporting from sea or reservoir to plate resist the pathway of earning higher profits. Further, global lobster market recorded continuous demand due to increased health awareness, preference for high protein diet, expansion of restaurant industry and with higher disposable income, consumers are tending to spend more on premium and specialty food products like Lobsters. The present study performs a in depth analysis of the market requirements based on consumer perceptions in both lobster giant freshwater prawns supply chains and to develop innovative strategies to improve the system and overcome existing market obstacles.

2. Methodology

2.1. Study Location

The study was conducted in South and West coast of Sri Lanka, prominent locations of lobster production. Six perennial reservoirs were selected from North-central province as significant contributors for export oriented GFP production. Huruluwewa tank (4208.7ha), Girithale tank(3075ha), Thuruvila tank (4856ha), Minneriya tank (9095.3ha), Nachchaduwa tank (2832.7 ha) and Rajanganaya tank (7211ha) were considered for data collection (Irrigation Department of Sri Lanka,2022). Further, primary data on downstream of the lobster and GFP value chain were collected from western province where both lobster and GFP exporters and consumers are concentrated.

2.2. Data Collection

Research approach was deductive and the study was mainly based on primary data. A combination of participatory, qualitative, and quantitative data collection methods was used for wide and in-depth analysis. The principal data collection tools were interviewer administrated questionnaire, in-depth interviews with key informants including field level managers of local tourist hotels and high-end restaurants (03) and both 20 foreign and 30 local consumers. Further, on-site observations carried out to find out the existing market system and current practices and issues in those systems. The sample size was randomly selected 08 exporters (06-Lobster and 02-GFP), 07 collectors (5-lobster and 3-GFP) and 40 fishermen (20 Fishermen from each) of both supply chains.

2.3Sample Profile

Both lobster and GFP supply chains are masculine, male actors are dominant in supply chain governance while majority of respondents of both supply chains are belongs to 30-50 age category.

Fishing method comprised of 70% were practiced skindiving and 30% were using nets to catch the lobsters while all the GFP fishermen are using their own boats to catch fish and prawns. Of the sample, 100% of GFP and 99% of lobster collectors are men and more than 80% are completed primary education level in both supply chains. The exporters 98% are men while there are women exporters who run the business in higher competitive manner. More than 80% are belongs to 30-50 age category and secondary education level.

Composition of the local consumers were 56% are female and 44% male and 75% were belongs to 200-300USD monthly income category. Of the sample foreign consumer profile comprised of 52% male and 48% were female and 85% are in <500USD as their monthly income.

2.4. Data Analysis

Data analysis mainly done by using descriptive statistics and Microsoft Excel (2019) software package and NVivo software were instrumental to analyse the data and to develop figures.

3. Results and Discussion

3.1 Market Analysis

The supply chain of the lobster fisheries consists with fishermen, collectors, distributors, local hotels and restaurants and exporters. Institutional landscape of the export-oriented fisheries comprised of both private and public sector institutions. Key players are Department of Fisheries and Aquatic Resources, National Aquatic Resources Research and Development Agency (NARA), Village level Fisheries organizations are involving on governing the industry. Handling and grading begin at the collecting centres and grading based on the weight and level of damage. Poor quality (Grade -II) lobsters are buying for half of the price of the original. The quality is determined by damages in claws and in abdomen area and also based on size of the animal (<500g, 300-500g and 200-300g). The product of the lobster is available as whole lobster, lobster tail, lobster meat and lobster claw. However, whole lobster represented the most popular product with minimum weight of 300g with zero damages and followed by tail, lobster meat and claw. If there are any damages occurred during the catch and handling of lobsters could be cause to rapid quality deterioration. Figure 3 explains the income distribution among supply chain actors. The price mainly determined based on the demand, type of species, animal size and quality.

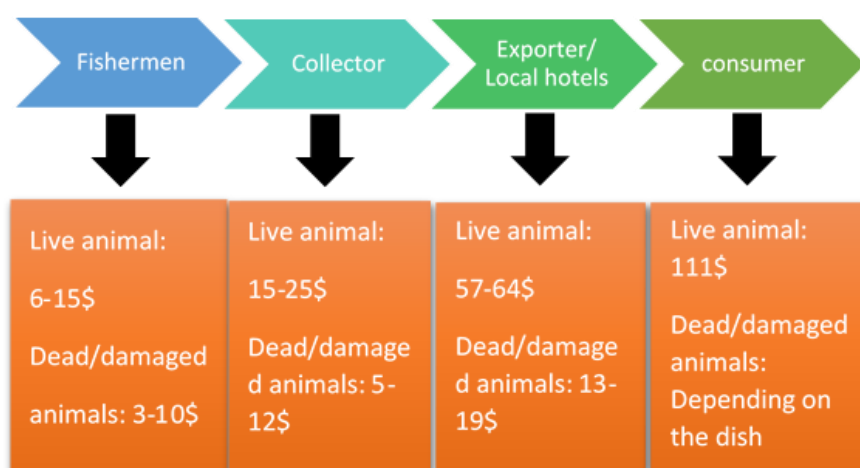


Figure 3: Income distribution among supply chain members: Lobster

Main export markets are Hong-Kong, China, Singapore, Dubai and Maldives and the types of lobsters are mainly tiger (*Panulirus ornatus*), sand (*Panulirus Homarus*), Bamboo (*Panulirus versicolor*) and rock lobsters (*Panulirus longipes*). According to the exporters, the life span and keeping quality is higher in sand lobster type comparing to other lobster species. and they highly preferred to export sand lobsters.

The GFP supply chain consists with mainly inland (aquaculture) fishermen, collectors, Exporters and local tourist hotels and high-end restaurants. Further, same as the lobster supply chain, the institutional landscape of GFP supply chain consists with private companies, fisheries organizations, National Aquaculture Development Authority (NAQDA), Irrigation Department Sri Lanka. Intermediaries are playing big role to reach the final product to end consumers, while there are lot of fishermen are engaging in supply. In the landing site, they are weighing, sorting and grading according the damages, size and weight of the animal. Then they are determining the price accordingly. The grading system is keeping as 100-150g, 150g-250g, 250g – 400g, 400g- 500g and <500g. Same as the lobster supply chain, the downstream node mainly governs by the exporters and high-end restaurants and hotels suppliers. Majority of GFP harvest is exporting as dead animal due to poor techniques and handling. Our main exporting destinations are Thailand and China. As per the exporters, not same like lobsters its difficult send live GFP, and they are using their own specific techniques which they are keeping as a trade-secret. The following figure 4 illustrates the income distribution.

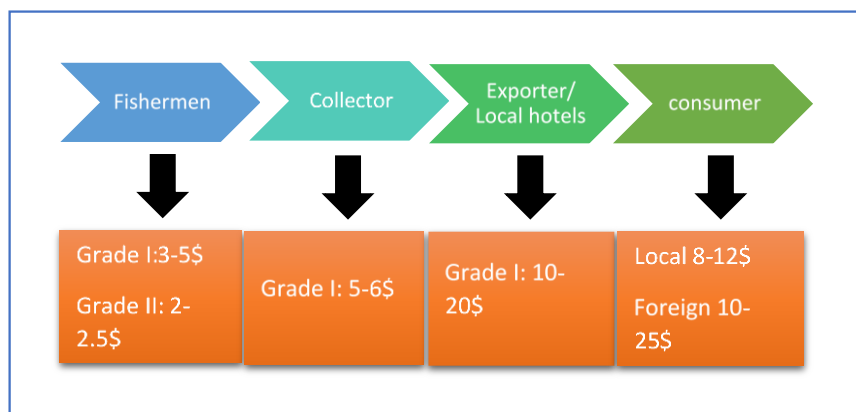


Figure 4: Income distribution among supply chain members: GFP.

3.2 Consumer Perception

The consumer perception model mainly studied based on the consumer motivation. The consumer motivation again categorized as personal motivations, nature of the product, and social acceptability (Charlebois *et.al.*,2024).

3.2.1 Personal Motivations

As personal motivational factors, socio-economic factors, education level, media, image and motivation criteria were considered. 90% of local consumers are consuming lobsters only in special occasions or maintain the social class. However, majority of consumers are consuming GFP as an alternative to lobster which less in price and the availability throughout the year. Consumer perception on high value seafood and farmed GFP connected with personal characteristics of the consumers along with socio-economic status and food culture. In contrast, consumers of GFP behave slightly different way, there is a considerable number of local consumers, especially high-end local consumers, and export market. The locals are preparing lobster as a dish of whole lobster or lobster meat while GFP is preparing as a curry or fried animal without head. Foreign consumers are mainly consuming lobsters and GFP with the purpose of exploring the taste and in special occasions. They are considering both animals are premium food. More

preferred to cook either by boiling, steaming, or grilling the lobster and fried in olive oil or butter as a whole animal with garlic, onion, tomato paste or mixed herbs or fried claws of GFP.

3.2.2 Nature of the product

As shown in the following table 01, the consumers of lobsters are mainly concerning on physical appearance, texture, price and catch date criteria as value attributes. Consumer willingness to consume and purchase behaviour depends on product quality. Export market requirements and local market requirements vary significantly the foreign consumers who are purchasing live whole lobster, specifically checking the animal movements by picking up the animal to check the status of animal (alive and healthy).

Table 01: Value attributes and critical control points of value: Lobster

Value Attribute	Value Characteristics for local tourists	Value Characteristics for foreign tourists	Critical Control Points of Value	Responsible Actor
Physical appearance	Less or zero damage to legs, claws and body parts Fresh appearance Contains high amount of flesh Live or Full dead animal	Less or zero damages specially to antenna, claws, tail and without crack shell Fresh appearance Length from carapace to tail	<ul style="list-style-type: none"> - Storage - Proper transporting - Sorting and grading - Proper handling 	<ul style="list-style-type: none"> - Fishermen - Collector - Transporter End customer (Hotel/exporter)
Species	Not specified preferences always try for a cheaper in price (Mostly sand lobster or rock lobster)	Specified the preferences on species before buying Tiger lobster is high in preference Some of them check the gender of the animal	Catch- based on the demand	Fishermen End customer (Retailer/Hotel/exporter)
Size	More preferred in smaller size because of easiness to prepare (300-500g and 200-300g)	Depending on the dish they will prepare. Most of the time larger animals (<500g)	Catch- proper size animals based on the standards	Fishermen End customer (Retailer/Hotel/exporter)
Texture	Carapace should be thick Soft or hard shell	Hard shell When animal pick it up it should be move its claws, legs, and tail	transportation Storage Post-harvest practices	Fishermen Collector End customer (Retailer/Hotel/exporter)
Nutrient Value	Considering as a good protein source	Believe it has high nutrient value	<ul style="list-style-type: none"> - Handling and Storage Transportation 	Fishermen Collector End customer (Retailer/Hotel/exporter)
Price	USD 20- USD 30 per Kg	USD 20-USD 50 per Kg	Proper post-harvest practices	All the value chain actors

	(Price depends on the size of the animal)		Efficiency of the supply chain	
Catch date	Same day caught or frozen	If live same day catch If dead- frozen not more than 2-3days	Efficiency of the supply chain	Fishermen Customer

The following table 02, shows the nature of the GFP preferred by local and foreign consumers. The local consumers are having access to purchase unprocessed animals directly from fishermen or a retail shop. In there, they are mainly focusing on physical appearance, size of the animal, taste, colour, odour, texture, nutrient value, date of catch and also the price. Majority of consumers are preferred on small size animal (less than 300g) of GFP. All believe larger animals are less in taste and the buying intention for GFP is its taste and high nutritious value. They are mostly like to purchase fresh product rather than frozen.

Table 02: Value attributes and critical control points of value: GFP

Value Attribute	Value Characteristics for local tourists	Value Characteristics for foreign tourists	Critical Control Points of Value	Responsible Actor
Physical appearance	Less or zero damage to legs, claws and body parts Fresh appearance Contains high amount of flesh	Less or zero damage to legs, claws and body parts Fresh appearance Contains high amount of flesh	Proper transporting Storing Sorting and grading Proper handling	Fishermen Transporter End customer (Hotel/exporter)
Color	Not black color head part Without any dark spots or color patches	Normal color/ not any specified color preference	Proper transporting Storing Proper post-harvest practices (maintain proper hygiene and biosecurity measures)	Fishermen Transporter End customer (Hotel/exporter)
Size	Smaller size (100g -300g) Not over matured (>300g) (They believe small animals are more taste and high in nutrient than larger animals)	Depending on the dish they will prepare. Most of the time larger animals (<300g)	- Selection of a good breed variety in hatching Catch- proper size animals	Breeders (Private and Government) Fishermen
Texture	Carapace should be thick Soft mussels/flesh	Soft mussels/flesh	Proper culturing practices proper transporting Storing proper post-harvest practices	Breeders (Private and Government) Fishermen
Nutrient Value	Considering as a good protein source	Believe it has high nutrient value	Proper culturing practices	Breeders (Private and Government) Fishermen
Odour	Not having any bad smell	Not having any bad smell	- Sorting - Storing - Proper handling Transporting	Fishermen Transporter End customer (Hotel/exporter)
Price	USD 5- USD 8 per Kg	USD 10-USD 15 per Kg	- Proper post-harvest practices	All the supply chain actors

	(Price depends on the size of the animal)		- Efficiency of the value chain	
Catch date	Same day caught prawns (not freeze ones)	Same day caught prawns	Efficiency of the value chain	Fishermen Customer

3.2.3 Social Acceptability

As shown on the figure 5, majority of local consumers are concerning on cultural acceptance while foreign consumers are more focusing on ethical fishing. Sustainability of lobster and GFP fishery is vital to manage the regular supplies to the market. Lobster management regulations, especially on fishing ban during the month of September-November and February, provide space for breeding. Consumer responsibility as well as awareness on fishing ban is key to maintain the sustainable fishery.

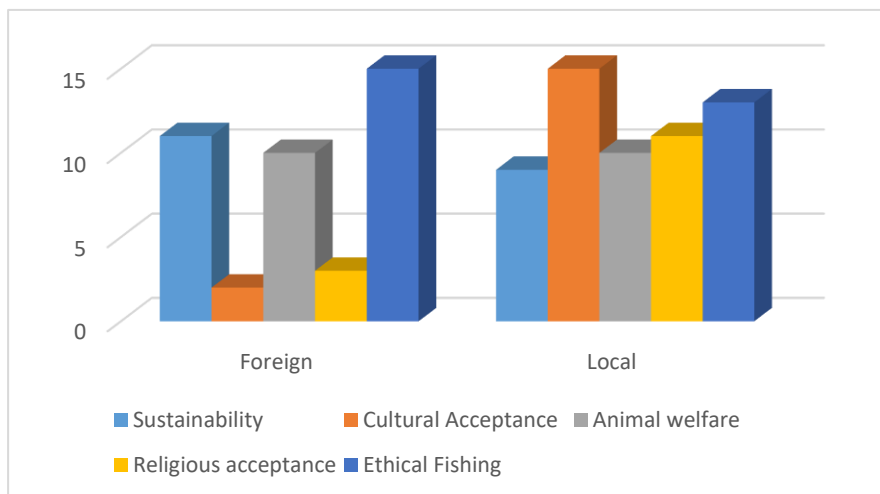


Figure 5: Social Acceptability: Lobster.

As shown on the following figure 6, in GFP purchasing both foreign and local consumers are believed that it will support for rural fishermen and foreign consumers are not focusing on cultural or religious acceptance while majority of local consumers are concerning it as a major factor.

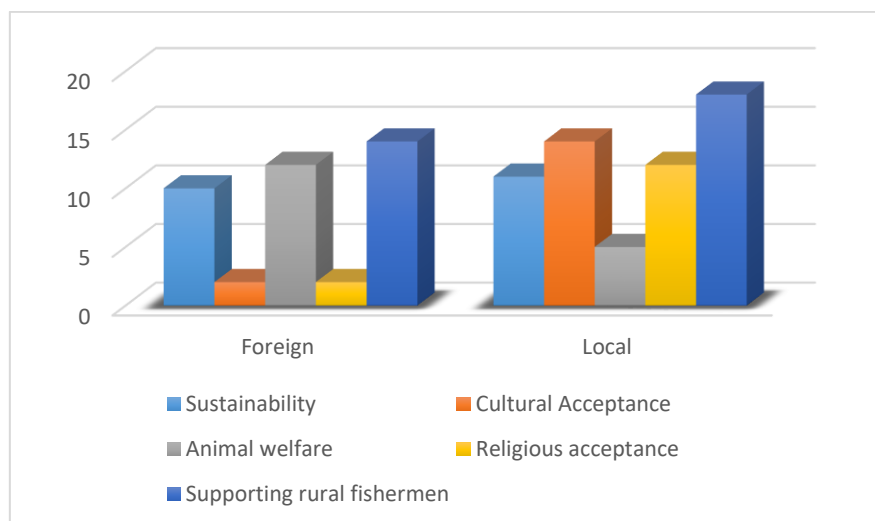


Figure 6: Social Acceptability: GFP.

3.3 Market Obstacles and Developed Strategies

The key market obstacles are recognized as using traditional methods of handling the animals with poor awareness on importance of proper handling method from catching to transport until end consumer, poor fisheries management relate to lack of transparency, limited traceability from individual fishermen to exporter level which creates opportunity for substitution, mislabelling, and lost information, and improper inbound logistics practices. Moreover, mixing of product from different fishing levels throughout the supply chain into a single volume which caused difficulty in accurately determine the origin of catch, method of catch, date of harvest, size composition, or any other data related to the fishing activity. Further, high monopoly power of exporters who are controlling most major steps in the supply chain and directly link with end consumer leads to unaware of market information and market requirements by fishermen.

The strategies and recommendations have analysed by using prioritizing recommendations matrix (Figure7) commonly for both supply chains. As shown there, the recommendations and strategies have organized based on its impact and difficulty level of implementation. The color gradient express the time-bound of each recommendation and strategies.

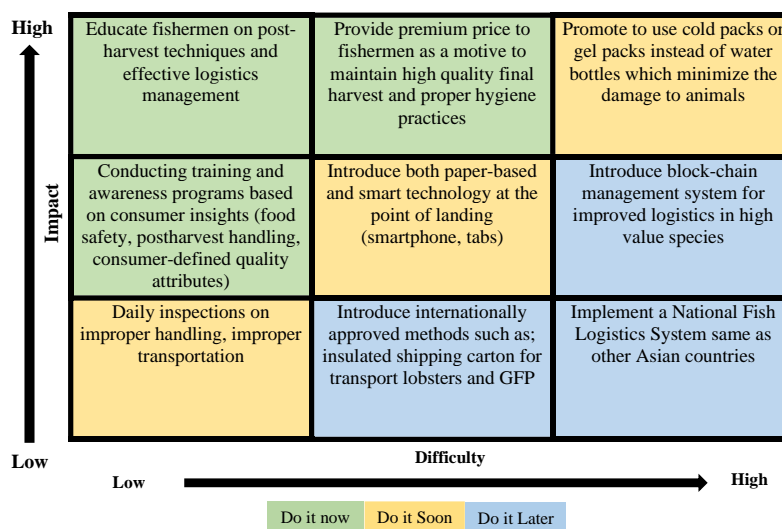


Figure 4: Prioritizing recommendations matrix (Adopted from Dent and Collins,2021).

As the strategies to improve the existing value chain immediately, it's very important to educate and aware the fishermen on effective logistics management and following post-harvest practices correctly are a critical success factor for them as well to gain higher profits and reduce waste generation and also capacity building through training and awareness programs on regarding market requirements, quality and safety, consumer attributes also could be support to uplift the supply chain. Further, providing a premium or higher price for high quality grade animals will be another option to adopt fishermen on concerning the safety and quality measures.

Daily inspections will be a good strategy as secondary level immediate actions to check the loopholes of logistics system and inspecting illegal fishing in off-season period in lobster fisheries. Promote to use cold packs or gel packs instead of water bottles which minimize the damage to animals is also could be immediate action to adopt for the market demand. Further, introduce both paper-based and smart technology (e.g., smartphones, tablets) to the fishermen leader or collector at the point of landing in order to increase data capture which could aid in providing a way to measure and weigh landed lobsters or GFP quickly and accurately with real time data will also be essential to build efficient and effective market system.

Introducing internationally approved methods such as; insulated shipping carton for transport the animals which are having protective foam container that keeps animals protected from temperature changing and providing natural cushioning is also an essential strategy that most of developed countries are adopted and highly concerning in their importation (Yang *et.al.*,2021). Introducing a blockchain system specially in upper stream node to improve the efficiency in shipping, transparency, shipment or goods tracking, customs collaboration and faster processing of invoicing and payment which could reduce unnecessary delays (Jagtap *et.al.*,2020). Further, as per the most of Asian countries are adopted, implement a national fish logistics system which is valid for all the seafood and aquaculture products also a good strategy which could initiate in national level (Azhar *et.al.*,2018).

4. Conclusion

The supply chain of the lobster fisheries and GFP consists with fishermen, collector, distributor, local hotels and exporters. The market of both industries is mainly based on export market while local consumption is negligible. Scattered small scale fishermen commence the supply chain which feeds the international high-end consumers. While high quality animals are going for the export markets, low quality died animals are mainly going to the tourist local hotels. The consumer perception in three folds such as personal motivations, nature of the product, and social acceptability. In personal motivation, majority of local consumers are purchasing lobster and GFP as a protein source as well as to maintain their social class while foreign consumers are purchasing to experience the taste. In the nature of products, both local and foreign consumers are concerning on physical appearance, size of the animal, colour, odour, texture, nutrient value, date of catch and also the price as value attributes of their purchasing while all the stakeholder of the suppliers are responsible to cater the expected value. As social acceptability local consumers are rely on cultural and religion acceptance while foreign consumers are more focusing on ethical and sustainable business practices. The study found that the existing market for both is in very poor level with zero traceability from upstream to downstream while using primitive methods of handling and storing. Downstream actors are concerning on keeping high quality since, the end product is exporting as live animals. Inefficient market chain due to using primitive and traditional methods of post-harvest handling, poor fisheries management, lack of transparency, lack of or zero traceability mislabelling, and loss of information, and improper inbound logistics practices are hiding the avenue of gaining higher profits and to preserve key marketable criteria such as proper physical appearance and vigour highly managed integrated market system with internationally approved safety-quality methods and also with proper traceability, precise planning, implement national fish logistics system, block chain management and efficient monitoring to manage the movement of high value-live fish forms from sea or reservoir to plate with minimum wastage is essential to mitigate the current market obstacles.

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DELIVERING DIGITAL HEALTH: CHALLENGES OF DIGITAL TRANSFORMATION

ICSD 014

NEWBORN SCREENING INFORMATION SYSTEM DATABASE (NSISD) IMPLEMENTATION AND CHALLENGES IN DIGITAL TRANSFORMATION

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Abstract: The social and economic burden caused by congenital hypothyroidism prompted many countries to implement formalized screening programs directed at newborns that has become an integral part of neonatal care. A well-established newborn screening infrastructure provides an opportunity to expand case detection to other serious conditions, thus increasing the potential for saving lives, preventing mental retardation, physical disabilities and improving the health and well-being of society. Sri Lanka's first ever newborn screening program for congenital hypothyroidism was implemented in the Southern province in 2011 and then the national program in 2016 through a circular from the Ministry of Health. The Faculty of Medicine, University of Ruhuna provided the laboratory and implementation assistance and the Family Health Bureau coordinated the activities. Initially all results including screening positive babies were notified to the relevant public health midwife through the Medical-officer-of-Health and found that the delivery of results took a longer time, thereby delaying confirmation of the condition of the baby. Rapid transfer of results to the end user (parents in this program) will ensure confidence and acceptance too. As a result of this a web-based database and digital short message system was developed with the assistance from the mobile communication industry to reduce the transit time as well as printing/posting costs and other additional workload of the team. The dedicated website www.nsisd.ruh.ac.lk is in operation since 2016. Parents and healthcare personnel have access to the screening results which are uploaded continuously. This provides a convenient and rapid mode of delivering results and thereby curtailing the delays seen at times in the diagnosis and management of babies with congenital hypothyroidism. The database provided the cost-benefit and effectiveness calculations of the national program. The website has unrestricted access to obtain necessary health information too.

Keywords: Newborn screening; Congenital hypothyroidism; Database; Digital health

1. Introduction

Most of the Asian countries including Japan, Korea, India, Philippines, Thailand and Bangladesh have already implemented newborn screening programmes (Padilla, 2008). In Sri Lanka, a pilot study was conducted among newborns of Teaching Hospital Mahamodara by Hettiarachchi et al., in 2009. It was extended to the other hospitals in Galle district (Hettiarachchi, 2009), before embarking on a Regional National Programme. Thus, the Nuclear Medicine Unit of the Faculty of Medicine, Galle with the support of the Family Health Bureau of the Ministry of Health and National Research Council of Sri Lanka has executed a newborn screening program for Congenital Hypothyroidism in Southern Sri Lanka by Amarasena & Hettiarachchi in 2018.

Brown and Rose reported in 2006, that Congenital hypothyroidism (CH) is one of the most common preventable causes of Intellectual disability in children. The International Atomic Energy Agency published in 2005 that, in most cases, the disorder is permanent and results from an abnormality in thyroid gland development (dysgenesis or agenesis) or a defect in thyroid hormonogenesis. Less commonly, the altered neonatal thyroid function is transient, attributable to the transplacental passage of maternal medication, maternal blocking antibodies, or iodine deficiency or excess. In rare cases, CH may result from a pituitary or hypothalamic abnormality (central or secondary/tertiary hypothyroidism). Worldwide, the incidence of CH is 1 in every 3000 births (IAEA, 2005). In iodine deficient areas, the incidence has been reported to be as high as 1 in 600 births, particularly in developing countries where iodine deficiency exists. The suffering and heavy social and economic burden caused by congenital hypothyroidism prompted many countries to implement formalized screening programmes directed at newborns, just as a vaccination programme that has become an integral part of child health care (IAEA 2005, Brown and Rose, 2006). The goal of the newborn screening is to detect CH and begin treatment before the infant reaches one month of age. Studies showed that by detecting CH at birth or shortly thereafter, and by beginning thyroid replacement therapy with L-thyroxin (usually as the sodium salt) within the first few weeks of life, hypothyroid infants can be expected to grow and develop normally with only minor problems (IAEA, 2005).

Digital health, or digital healthcare, is a broad, multidisciplinary concept that includes concepts from an intersection between technology and healthcare (Woods et al., 2018). Under its umbrella, digital health includes mobile health apps, electronic health records, electronic medical records, wearable devices, telehealth and telemedicine, as well as personalized medicine. Sri Lanka is also looking into development of electronic health solutions for the preventive and curative healthcare sectors of the country in the new millennium (Rajapaksa et al., 2021). The national eHealth Policy was first articulated with the vision to streamline the adoption and use of ICT in the Healthcare Sector of Sri Lanka in late 90s (Björkman, 1985). Its mission is to facilitate adoption of ICT solutions appropriately in the healthcare sector of Sri Lanka to improve the quality, efficiency, patient safety, and cost effectiveness of health care thus contributing to achieve the goals set out in the National Health Policy. Representatives from the Ministry of Health and ICTA have come together to formulate a National Digital Health Blueprint (Sri Lanka Digital Health Blueprint, 2022). This revision was done in 2021. The blueprint serves as a comprehensive roadmap with standards, policies, guidance, and specifications for implementation that will facilitate a higher quality of healthcare for citizens of Sri Lanka. It is a significant step in the right direction to transform the healthcare sector in Sri Lanka. The outcome of this initiative is to build a resilient and sustainable system for quality healthcare in Sri Lanka (Annual Health Bulletin, 2017). Under this initiative, a Digital Healthcare architecture blueprint, operational interoperability plan, leadership, governance, point of care services including community health information system, electronic medical records, lab systems, pharmacy, logistics management systems, including capacity development and technical assistance will be looked into as a holistic approach (Rajapaksa et al., 2021).

With this development in the health sector, it was suggested to develop direct communication systems both internet service providers and mobile service providers to link in the newborn screening program to the family unit. This would enhance timely follow-up for screen-positive infants and facilitate information sharing. Therefore, this study to develop newborn screening information system data was initiated by the Faculty of Medicine, University of Ruhuna.

2. Methods

Once a sample was received for this program the relevant data (i.e., mother's name, hospital & bedhead ticket number to identify the person; date & time of baby's birth and date & time of the sample collection to interpret results; parent's contact number, midwifery area and the health divisions to arrange follow up in screening positive babies) were documented in an excel sheet in the receiving order once a laboratory number issued. Hence, the initial model we were thinking of was just a data storage server where the data were stored, expecting to deliver it to the end users. With the gradual expansion of service area from the regional hospital (TH Mahamadara) to the Galle district and to the Southern province, maintain an electronic or web-based data retrieval system base was identified. This project became a reality with the funding from National Research Council of Sri Lanka through their two-research grant in 2008 and 2011 to have all necessary equipment for a separate IT unit in the Nuclear Medicine Unit. The ceremonial launch of the initial web-site was done at the annual academic sessions of the University of Ruhuna in March 2013. Later this service was modified as the model we are expecting was not simply a data storage in a server and then directed to the individuals, but more interaction between parents/ doctors and public health staff in order to monitor the neonatal health. While continuing the southern regional screening program we offer it on fee-levying to the rest of the country so that our program became a sustainable project. Further a pdf report of data can be generated which was emailed to relevant focal point in each district i.e., Medical Officer for Maternal and Child Health (MOMCH) and the consultant pediatrician of the hospital. So that it makes sure not only the test results delivered to the mother but also to the relevant midwifery clinic.

3. Results

The newborn screening for congenital hypothyroidism program was officially implemented in the Southern province in latter part of 2010. Then it was expanded gradually in Sri Lanka till 2015 when the national program was executed with a second center in Colombo. Faculty of Medicine is responsible for five provinces in the country namely Southern, Uva, Sabaragamuwa, Central and Eastern province. The number of samples received in each year is shown in Table 1.

All these samples once received a lab number is issued and then all relevant data were entered to the database as shown in figure 1. Once the laboratory analysis of the dried blood spot was completed the data relevant to each laboratory number was entered to the database (Figure 2) through a excel datasheet and the accuracy and validity was checked manually too. Once all the data were available a short message was delivered to the given each individual mobile number through the mobile interphase connected to the database by the service provider, i.e., Sri Lanka Mobitel Pvt Ltd. Further a PDF sheet is generated to each district/ hospital and emailed to the relevant MOMCH and the Pediatrician of the hospital. Additional annual summary report was prepared and submitted to the Ministry of Health.

Table 1 Summary of screening performances 2010-2023

Year	No screened	No Recalled	No Confirmed	Incidence
2010 -Sep	4666	98	03	1 in 1,555
2011	42474	322	24	1 in 1,770
2012	45479	249	31	1 in 1,467
2013	61665	74	36	1 in 1,713
2014	93525	107	53	1 in 1,765
2015	102,063	122	72	1 in 1,417
2016	137,934	229	111	1 in 1,242
2017	151,783	245	82	1 in 1,850
2018	158,846	247	125	1 in 1,271
2019	159,559	192	126	1 in 1,266
2020	158,334	208	111	1 in 1,426
2021	137,879	272	107	1 in 1,289
2022	131,499	353	96	1 in 1,370
2023	104,262	206	72	1 in 1,448
Total	1,489,968	2,924	1,049	1 in 1420

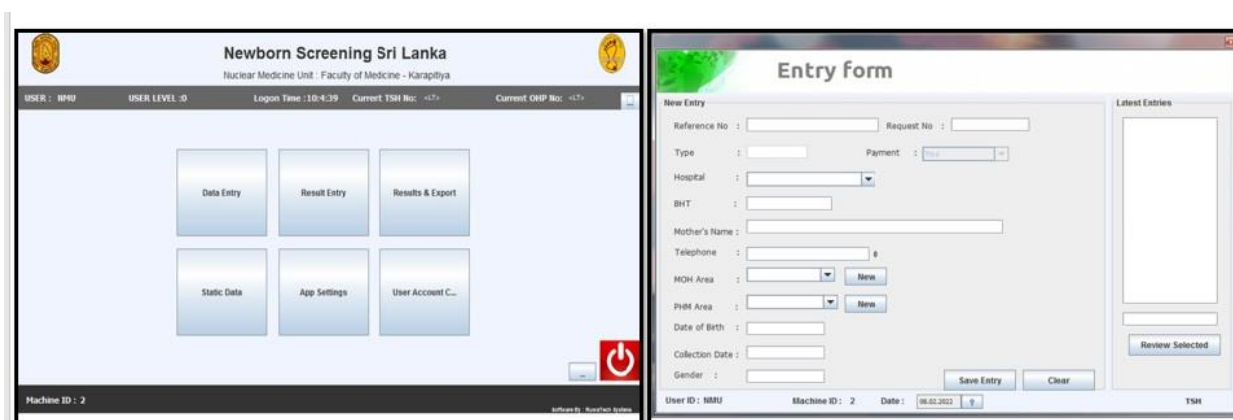


Figure 1: Data base log and the entry form.

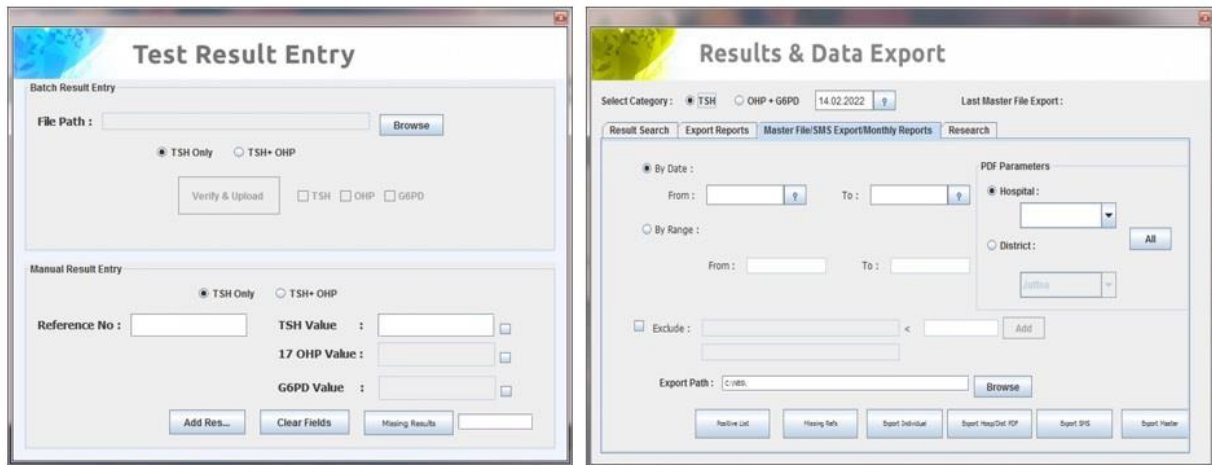


Figure 2: Test results entry and extort to SMS/ delivery platform.

4. Discussion & Conclusions

With the introduction of national newborn screening program, this information system database became the national focal point for the research related to the newborn screening. So, it is an essential part of every project. The software that is used for storing data has to support all the features necessary. For storing and handling massive volumes of data, relational databases are usually the best option (Sri Lanka Digital Health Blueprint, 2022). The use of a computer database is typically involved in efficient data management. A shared, integrated computer structure, a database stores the end-user data i.e. raw data relevant to the end user as well as the metadata, through which end-user data is integrated and managed in the analysis.

Having a database like this is essential to undertake periodic audits of the system; then, we can identify and improve the overall quality of the program with coordinated efforts of the laboratory and clinical services of the country. Maintaining confidentiality and security of data is of utmost importance. Yet we allowed several personal to have restricted access in order to generate some publications (Amarasena & Hettiarachchi, 2018, Liyanage & Hettiarachchi, 2021, Karunarathna & Hettiarachchi, 2021, Karunarathna et la., 2021). Economic evaluations will determine policy decisions on any screening programs as estimates of short-term or long-term clinical and economic outcomes are analyzed through a systematic approach. Therefore, a cost-effectiveness analysis was performed as an important tool to allocate funds and make decisions on feasibility of new interventions with budget constraint in healthcare costs and it was published recently (Karunarathna & Hettiarachchi, 2021).

This Digital Health project continued to progress of healthcare that can strengthen the relationship between patients and doctors too. The data, the timeliness and its availability will enable providers to make better decisions and provide better service to the Sri Lankan health sector stakeholders including decision makers.

Given the expected growth in digital health solutions, as well as the impact this will have on future health care delivery, the development of improved methods for evaluating the contribution of digital health services to patients, care providers and health systems is of utmost importance.

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ICSD 062

**USING DIGITAL HEALTH PLATFORMS FOR INFECTIOUS DISEASE
CONTAINMENT AMID UNANTICIPATED CLIMATE CHANGE SRI LANKA:
A REVIEW**

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Abstract: Unpredictable climate change poses new challenges to infectious disease control in Sri Lanka. The Badulla region of the Uva hills has recently been hit hard by mosquito-borne epidemics such as dengue fever and chikungunya. This review investigates how digital health platforms can help improve disease surveillance and track epidemic response in Sri Lanka. This study's objective was to elaborate on how well digital health platforms work in Sri Lanka, to improve infectious disease containment strategies, especially in light of unforeseen climate change impacts. Existing studies on digital health platforms for infectious disease containment show strengths in improving surveillance and response. An EpiHack event also resulted in the creation of mobile surveillance tools for dengue illness, which addresses critical functions such as surveillance, health communication and civic participation. However, limitations include potential access disparities and challenges in sustained community involvement, warranting continued research for comprehensive solutions. The results of this review used methods for digital health platforms in some areas of Sri Lanka, which has proven to be crucial in containing infectious diseases in the face of unexpected climate change. This review highlights the effectiveness of active technological interference for public health resilience. Implications include Building a strong digital health platform that includes mobile apps, and data analytics, connecting app data to current health surveillance systems for real-time monitoring of illness trends and epidemic sites.

Keywords: Climate change impacts; Community involvement; Digital health platforms; GIS Mapping; Mobile surveillance; Scalability

1. Introduction

Sri Lanka, an island nation in South Asia, is highly susceptible to the impacts of climate change, including extreme weather events, changing rainfall patterns, and rising temperatures. These environmental shifts have profound implications for public health, particularly in the context of infectious diseases. Sri Lanka has already experienced outbreaks of vector-borne diseases such as dengue fever and malaria, which are exacerbated by environmental factors influenced by climate change. Additionally, water-borne diseases like cholera and leptospirosis pose significant threats in the aftermath of floods and heavy rains (Fernando *et al.*, 2008).

This review article discusses using digital health platforms for infectious disease containment amid unanticipated climate change in Sri Lanka. It explains how changes in average climate conditions and climate variability can affect human well-being indirectly, for instance, changes in biological and ecological processes that can influence infectious disease transmission and food production. Additionally, the chapter examines the influence of climatic factors on infectious diseases. The impact of global climate change on infectious diseases is a contemporary concern. Though the seasonal patterns and climatic sensitivities of many diseases are well-known, it is still unclear how changes in disease patterns will occur (Patz *et al.*, 2003).

The changing tempo and pattern of infectious diseases is a consequence of the increasing intensity and scale of human activities. This is due to various factors like changes in human demography, ecology, and environmental impact. These factors are unprecedented and have a significant impact on the spread and occurrence of diseases (McMichael and Woodruff, 2008). Sri Lanka has been greatly impacted by emerging infectious diseases (EIDs) like chikungunya, dengue, and antibiotic-resistant bacterial infections. Even diseases like leptospirosis, which have been present in Sri Lanka for many decades, are now causing significant public health problems and are associated with high mortality rates. The increase in Emerging Infectious Diseases (EIDs) is believed to be caused by several factors, such as changes in the environment, unplanned urbanization, new agricultural methods, changes in population density, antibiotic usage, and increased contact with wild animals. Additionally, overcrowded living and working conditions, as well as increased international travel, contribute to the spread of infections worldwide (Fernando *et al.*, 2008).

Digital health technologies are computing devices that include platforms that facilitate connectivity and sensors used by healthcare providers for issues related to healthcare. Using telemedicine is a promising and emerging way to improve healthcare outcomes. That can help with disease prevention, diagnosis, medication adherence, treatment compliance, and honoring clinic appointments (Tilahun *et al.*, 2021). After analysing the capabilities of the latest information technologies available across the globe, primarily in developed nations, that is evident that there is still significant scope for developing and implementing more digital health products, especially intelligent ones, to manage viral infections and other health emergencies (Kalhori *et al.*, 2021).

This review investigates how digital health platforms can help improve disease surveillance and track epidemic response in Sri Lanka. This study's objective was to elaborate on how well digital health platforms work in Sri Lanka, to improve infectious disease containment strategies, especially in light of unforeseen climate change impacts. Existing studies on digital health platforms for infectious disease containment show strengths in improving surveillance and response.

2. Methodology

A systemic review was performed and reported following the preferred reporting items for systemic reviews. A systemic literature review was conducted by searching electronic databases for peer-reviewed journal articles.

3. Discussion

3.1 Digital health platforms for infectious disease surveillance

Digital health platforms have the potential to improve infectious disease surveillance in Sri Lanka. Mobile applications can allow for real-time reporting of disease outbreaks and encourage community involvement in disease monitoring efforts. As well as, telemedicine services can improve access to healthcare in remote areas, facilitating early detection and treatment of infectious diseases. By integrating these digital platforms with existing surveillance systems, health authorities can receive timely and accurate data to support informed decision-making.

Digital health refers to the use of information technologies in three main areas. Those are digital patients, digital devices, and digital clinics. A digital patient is someone who uses mobile health (mHealth) devices to modify and maintain healthy behaviors. Examples are digital patient technologies include telemedicine, self-measurements, and digital retention. Digital devices are designed to solve clinical problems and include wireless and wearable devices, smartphone-connected rhythm monitoring devices, as well as implantable and ingestible sensors. The digital clinic aspect of digital health focuses on generating mHealth data, analyzing it for clinical relevance, and integrating it into clinical workflows (Kalhori *et al.*, 2021.)

Electronic health record (EHR) data is widely used in infectious disease surveillance. In particular, EHR data has been used to track the incidence of Lyme disease and identify new HIV infections. As well as EHR disease detection algorithms combine laboratory reports, diagnosis codes, and medication orders to identify cases, which has resulted in Lyme disease incidence rates 4–7 times higher than those from traditional surveillance methods. Moreover, EHR data has been used to evaluate temporal trends in sexually transmitted disease testing, positivity, and re-testing in multiple primary care settings. Several studies have also been able to control for additional confounders, such as the number of sexual partners and concurrent infections, using multivariable models. This is possible because EHR systems provide a broad range of data (Willis *et al.*, 2019).

Digital surveillance has become increasingly common to use digital platforms and media, such as mobile and web apps, to source infectious disease-related data. A study conducted in Colombia by Rodriguez, Sanz, Llano, Navarro, Parra-Lara, Krystosik, and Rosso (2020) found that a specially built mobile app called FeverDX was effective in detecting and surveilling diseases. In Nigeria, Subair *et al.*, (2019) identified WhatsApp, Facebook, Instagram, and YouTube as the most commonly used digital platforms by students. That is most important for identifying the influence of disease in a short period.

According to the weekly epidemiological report in Sri Lanka, 2022, in 2009, swine flu emerged as a contagious disease-causing global concern. The Saudi Ministry of Health (MOH) focused on treating Swine Flu during the Haj pilgrimage, where the holy sites in Saudi Arabia welcome pilgrims from around the world. A Geographic Information System (GIS) is a technique that manages, analyzes, maps, and creates all kinds of data. By connecting data to a map, GIS integrates location data with descriptive information of all types. This creates a foundation for mapping and analysis that is used in almost every industry and science. It helps users understand patterns, relationships, and geographic context. As well as it approach is ideal for improving the accuracy and timeliness of detecting and managing infectious disease outbreaks. In most developing countries, including Sri Lanka, the earlier barriers to the application of GIS techniques, such as the non-availability of base maps and GIS devices, are less of a concern. In Sri Lanka, GIS base maps for each Grama Niladari have already been developed by the survey department. The health sector is also moving forward with the development of Public Health Midwife and Public Health Inspector-wise base maps. This will remove a significant bottleneck in implementing GIS techniques in disease and outbreak surveillance. Additionally, the wider public use of smartphones with improved connectivity has lessened the burden of the capital cost of purchasing GIS devices. GIS techniques can be applied to local geography and environmental and climatic conditions that Favour

vector-borne diseases, zoonosis, and emerging outbreaks, which can be effectively analysed using mapping and modelling techniques.

3.2 Early Warning Systems and Response Mechanisms

Digital technologies have the potential to enhance early warning systems for infectious disease outbreaks in Sri Lanka. By analysing climate and environmental data along with disease surveillance information, predictive models can forecast the possibility of disease transmission and help in taking proactive measures. As well as, digital platforms can enable swift response mechanisms, allowing healthcare workers to mobilize resources and implement control measures effectively during outbreaks. The effectiveness of the existing Early Warning System for Tsunami and other coastal hazards has been questioned several times. Several studies have been conducted to identify gaps and recommendations in coastal disaster resilience, particularly in the Early Warning (EW) and Evacuation Procedures (EP) related to coastal hazards. These studies have highlighted gaps in governance, modes of EW and EP dissemination, and the response of authorities and communities. However, only a few attempts have been made to investigate gaps related to the use of social media in EW and EP dissemination, and the impacts of pandemics on response mechanisms for tsunami and other hazards. That is mainly used under the impact of COVID-19 and other pandemics (Jayasekara *et al.*, 2023).

3.4 Utilizing Telemedicine for Remote Healthcare Access

Telehealth describes healthcare at a distance using telecommunication technologies. The climate-related disasters can often disrupt healthcare access, particularly in remote and vulnerable communities. As well as telemedicine platforms can also help bridge this gap by enabling remote consultations and medical support services. Through telemedicine networks, healthcare professionals can provide timely diagnosis and treatment recommendations to individuals in disaster-affected areas, thereby mitigating the impact of climate-induced health emergencies. Sri Lanka's Telemedicine Unit and initiatives like the "Doc990" mobile application are great examples of how telemedicine can be integrated into a country's healthcare system, enhancing accessibility and resilience in the face of climate change challenges (Kulatunga *et al.*, 2020).

3.5 Effectiveness Of Digital Health Platforms in Containing Infectious Diseases Amid Unanticipated Climate Change In Sri Lanka

Sri Lanka is incorporating digital health platforms into its healthcare system. Initiatives like the Sri Lanka Health Information Network (SLHIN) are digitizing health records, improving data management, and facilitating telemedicine services (Fernando, 2020). The prevalence and distribution of the diseases can be influenced by climate change through factors such as altered vector habitats and changing weather patterns (Hapugoda *et al.*, 2018).

3.6 Benefits of Using Digital Health Platforms

The benefits of digital health platforms in disease control can be noted like this:

1. **Early Detection:** Real-time monitoring of disease outbreaks can be facilitated, enabling early detection and rapid response.
2. **Data Analytics:** Advanced analytics tools can process large volumes of data from various sources such as environmental sensors and healthcare facilities. This helps to identify patterns and trends in disease transmission.
3. **Remote Healthcare:** Telemedicine and mobile health apps can improve access to healthcare services, especially in remote or underserved areas.
4. **Community Engagement:** Digital platforms can be used to disseminate information, raise awareness, and engage with communities to promote preventive measures and behavior change.
5. **Coordination and Collaboration:** Digital platforms facilitate communication and coordination among different stakeholders involved in infectious disease control, including government agencies, healthcare providers, and international organizations (Imison *et al.*, 2016).

Digital health platforms comprise a broad range of technologies that include mobile applications, telemedicine, electronic health records (EHRs), as well as data analytics. These platforms can be used to improve disease surveillance, early warning systems, and outbreak response mechanisms. Such as, mobile applications can empower citizens to report symptoms, access health information, and receive real-time alerts about disease outbreaks or climate-related health risks. Telemedicine facilitates remote consultations, enabling healthcare providers to reach underserved communities in remote areas. Additionally, EHRs streamline data management and allow for prompt decision-making by policymakers and public health officials (Msiska *et al.*, 2019).

4. Challenges and Opportunities

Despite the potential benefits, integrating digital health platforms into infectious disease containment strategies faces several challenges. The limited internet connectivity, digital literacy barriers, and resource constraints hinder the widespread adoption of these technologies, particularly in rural and marginalized communities. Furthermore, ensuring data privacy and security is paramount to maintaining public trust and compliance with regulatory frameworks. Addressing these challenges requires collaborative efforts between government agencies, technology developers, healthcare providers, and community stakeholders. Investing in infrastructure development, capacity building, and user education is essential to harnessing the full potential of digital health platforms for infectious disease containment in Sri Lanka.

5. Conclusion

The digital health platforms offer promising opportunities for strengthening infectious disease containment efforts in Sri Lanka amidst unanticipated climate change events. By enhancing disease surveillance, facilitating remote healthcare access, and fostering community engagement, these technologies can bolster resilience and mitigate the impact of climate-related health challenges. However, addressing infrastructure gaps, promoting digital literacy, and safeguarding data privacy are critical considerations for successful implementation. Through collaborative action and strategic investments, Sri Lanka can harness the transformative potential of digital health to safeguard public health in an era of climate uncertainty.

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**DIGITAL DIETETICS: BUILDING AN ARTIFICIAL-INTELLIGENCE-
POWERED DIET PLANNING PLATFORM FOR EVIDENCE-BASED
NUTRITIONAL GUIDANCE**

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Abstract: The advent of personalized nutrition strategies underscores the limitations of traditional dietetic planning paradigms in meeting individual health needs with requisite efficiency and specificity. In response, our study introduces "Diet Planner," an innovative AI-powered platform designed to revolutionize dietary management. This study leverages artificial intelligence, notably through the capabilities of Chat-GPT, integrated via a PHP-based API-connected framework. "Diet Planner" stands out by offering a web-based repository that combines extensive nutritional data with user inputs to generate customized diet plans, ensuring dynamic and evidence-informed dietary advice. This research extends to the revision of the Sri Lankan food exchange system, tailored originally for diabetics in the United States since 1950, to better accommodate the local dietary preferences and nutritional profiles within the Sri Lankan context. Through comprehensive data collection and statistical analysis, we identified significant nutritional variances, highlighting the necessity for an updated dietary planning approach that aligns with regional dietary habits. The efficacy of the "Diet Planner" was rigorously assessed through a pilot study involving ten professional dietitians. The findings reveal the platform's user-friendly interface, high satisfaction rates, and notable enhancements in diet planning efficiency. Such advancements are pivotal for the integration of AI in clinical nutrition, emphasizing the importance of culturally and regionally adapted dietary planning tools. Despite the promising outcomes, it's crucial to acknowledge the system's current limitations, including the need for a broader integration of therapeutic diet options and enhanced user customization capabilities. These areas offer fertile ground for further research and development aimed at refining the tool's functionality and broadening its applicability. In conclusion, the "Diet Planner" signifies a substantial leap forward in embedding AI within healthcare, particularly in nutritional science. As the tool evolves, it is poised to transform dietary planning practices and contribute to the wider acceptance of AI technologies in healthcare settings. This promises a more personalized, efficient, and informed approach to nutrition and health management, thereby revolutionizing the field of clinical nutrition.

Keywords: Artificial intelligence; Clinical nutrition; DIETETICS; Personalized nutrition; Dietetic planning; Healthcare technology; Sri Lankan food exchange system

1. Introduction

Diet plays a pivotal role in contemporary life, with a balanced diet being crucial for maintaining good health by supplying adequate energy, macro, and micronutrients. Recent changes in lifestyle and dietary behaviors have led to an increase in non-communicable diseases such as obesity, metabolic syndrome, diabetes, cardiovascular diseases, and hypertension. These conditions are attributed to unhealthy lifestyles, increased intake of high-energy and high-fat foods, larger portion sizes, and nutrient-dense foods promoted by environmental changes, alongside decreased physical activity and increased sedentary behaviors (Fabiani et al., 2019). In response to these challenges, there is a pressing need for effective, affordable, and personalized meal planning to assist individuals in choosing foods that cater to their unique needs and preferences. This need highlights the critical role of dietitians and nutritionists in addressing diet-related health issues. However, traditional methods of dietary counseling face hurdles such as time constraints, administrative burdens, and the necessity for up-to-date information, which can hinder the efficiency and reach of healthcare professionals in this field (Skouroliakou et al., 2009).

The advent of Artificial Intelligence (AI) in health promotion, research, and practice presents a promising solution to these challenges, with a growing interest in leveraging AI to provide personalized, evidence-based nutritional guidance (Gurinović et al., 2018). Despite the availability of diet planning apps, many lack advanced features such as personalized plans, comprehensive use of AI, and a dynamic food database, making them less adaptable to individual needs (Franco et al., 2016).

Our research introduces "Digital Dietetics," an AI-powered diet planning platform designed to bridge the gap between qualified dietary advice and the general public. This platform, supported by the cutting-edge AI and NLP technology of ChatGPT, offers real-time, evidence-based nutritional recommendations. A distinctive aspect of this platform is its focus on providing dietary plans that are culturally relevant to the Sri Lankan population, thereby enhancing acceptance and adherence (Jadhav et al., 2022).

The historical development of the food exchange system, initially established in 1950 by the American Diabetes Association, the American Nutrition Association, and the U.S. Public Health Service, marked a significant advancement in dietary planning for diabetics, offering a structured approach to include a wider range of foods through standardized quantities and nutritional content analysis (N/A, 2019; Gordon M. Wardlaw, 2003). This system's adaptability to local contexts, such as Sri Lanka, can greatly enhance dietary planning by aligning with the availability, affordability, and nutritional content of local foods, thereby addressing the unique health challenges and dietary needs of the population (Aida Maribel Chisaguano-Tonato, 2023; Mahnaz Nasir Khan, 2017). The increasing prevalence of diet-related health issues, such as obesity, diabetes, and cardiovascular diseases, underscores the critical need for effective and personalized dietary planning. Traditional dietary counseling methods, while valuable, often struggle with scalability and the ability to provide tailored advice to a diverse population with varying nutritional requirements. The advent of digital technologies, particularly Artificial Intelligence (AI), offers a transformative solution to these challenges. By leveraging AI, we can significantly enhance the efficiency, accuracy, and personalization of dietary advice, enabling dietitians and nutritionists to manage a larger clientele more effectively. This approach not only optimizes the allocation of healthcare resources but also ensures that individuals receive dietary plans that are specifically tailored to their unique health conditions, preferences, and cultural backgrounds.

The primary aim of this study is to develop and validate an AI-powered diet planning platform named "EDIETETICS," designed to support clinical nutritionists in offering personalized, evi-

dence-based nutritional guidance. The platform seeks to bridge the gap between advanced dietary counseling and the needs of the general population, with a specific focus on the Sri Lankan context. By integrating the revised Sri Lankan Food Exchange system, the platform will provide dietary recommendations that are not only scientifically sound but also culturally relevant and accessible.

2. Methods

Technical Details of the Program

The diet-planning application, leveraging open-source PHP technology, offers a web-based interface compatible with Android platforms, utilizing JavaScript and jQuery for client-side scripting, MySQL for data storage, and Bootstrap with WordPress for interface design and development. This system facilitates user input of personal and dietary information, processed by Chat-GPT through an API to generate personalized diet plans based on the EDIETETICS database.

2.1. Development of the Software Program

The development followed distinct phases, beginning with an analysis of user requirements through literature reviews, observations, and expert discussions. The design phase focused on creating an intuitive interface and integrating with Chat-GPT using NLP techniques. The system was devised to exclude intolerances, allergies, and dietary restrictions from automatically generated menus, with an option for dietitian modifications.

2.2. Data Integration and Study of the Sri Lankan Food Exchange System

This study, conducted from November to January, aimed to update the Sri Lankan food composition table based on commonly consumed foods, considering local preparation and cooking methods. Foods were selected from current and 2021 food composition tables and popular restaurant items, categorized into eight food groups. (Gordon M. Wardlaw, 2009)(Hardner, 2023)(Yalini Shanmuganathan, 2017)

Selection of Food Items

Food items were chosen based on their prevalence in the current Sri Lankan food composition tables and fast-moving restaurant items, ensuring relevance to local dietary patterns.

Nutrient Composition Analysis

An observational method was employed for bread products, with visits to bread stores for ingredient proportion data. For dairy, a CIC agent provided ingredient details for nutritional analysis. The mixing method was used for pulses, proteins, vegetables, and greens, with manual food preparation and recipe recording. Cooking weight changes were noted, and yield factors were applied to account for raw food retained post-cooking. Nutrient retention factors were assigned at the ingredient level to accurately assess the nutritional content of the final dish. (Verma, 2018)(Greenfield & Southgate, 2003)

2.3. User Interface Design

The EDIETETICS website, developed with WordPress, serves as a central hub for evidence-based nutritional data, accessible by the Chat-GPT platform. Advanced NLP techniques were applied to ensure the system's dietary recommendations align with scientific evidence and user preferences.

2.4. Testing

The application underwent extensive testing to identify and resolve issues. Evaluation involved a structured questionnaire administered to ten dietitians, assessing functionality, accu-

racy, and user satisfaction. Statistical analysis was conducted to compare manual and automated diet planning efficiencies.

Software development places a high value on testing. A few coding errors and other problems were fixed throughout the application's testing. The two testing cycles were conducted throughout the system development cycle. Initially, the developer tested the application features and functionalities of the platform and fixed coding issues. After that the system was tested manually and the prompts were corrected until get the expected output from the system.

2.5. Evaluation

To identify the user satisfaction level with the diet planning application, functionality, accuracy, and limitations of the system, the system evaluation process was conducted using a questionnaire with 10 dietitians. And the responses were collected from participants.

The dietitians calculated the patient's daily requirements manually and developed a daily menu plan. Following the manual development of the daily menu, all data collected by the same dietitian were entered into the developed platform. Then, the program automatically calculated the nutritional requirements and produced a daily menu. To avoid the between-person variability, the user of the software was the same dietitian who performed the manual method. Dietitians were asked to record the time taken to design the daily menu, manually and using the developed system, and the responses were collected and evaluated.

User satisfaction was analyzed through survey data using descriptive statistics, including mean satisfaction scores and response distributions. Statistical analyses were performed to determine if there are significant differences in outcomes between groups. Statistical analysis was done using the Statistical Package for Social Sciences software (SPSS) 16.0 version. Associations were considered statistically significant at the $p < 0.5$ level. Comparisons concerning time spent for each procedure (manual and automated) were performed using the non-parametric Wilcoxon signed rank test, as data is not normally distributed.

3. Results

This study aimed to develop a user-friendly diet planning tool that can be used by clinical nutritionists as a professional tool, to deliver evidence-based nutritional guidance. The results of this study are presented in this section.

The results of this study illustrate the successful development of "Diet Planner," (<https://www.edietetics.com/>) a user-friendly digital tool designed for clinical nutritionists to provide evidence-based nutritional guidance efficiently. The tool incorporates a food exchange system tailored to the nutritional needs and health challenges of the Sri Lankan population, utilizing data integrated into the EDIETETICS platform. This platform, developed on WordPress, centralizes the nutritional values of commonly consumed Sri Lankan foods, thereby facilitating the AI model to generate personalized diet plans.

3.1. Nutritional Data Integration:

The study meticulously cataloged the macronutrient content and energy values of various food categories, including starches, pulses/legumes, proteins, dairy, vegetables, green leaves, and fruits. This comprehensive database serves as the foundation for the AI model to construct diet plans that are both nutritionally balanced and culturally relevant. This EDIETETICS website includes the nutritional values of foods that we got from the part of this research study, the results are presented in below *Tables 1-7*

Table 2: Macronutrients and energy content of Starch category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Bread	2 slices	28.3	1.8	3.8	146.92
Bun	1 medium	39.24	5.17	0.54	227.38
Manioc curry	36g	18.17	1.35	1.02	89.87
Potato curry	30g	10.37	1.15	0.92	55.95
Pumpkin curry	30g	10.05	1.11	0.9	54.18
Rice	½ cup	29.25	0.68	3.12	135.55
String hoppers	30g	21.76	0.14	0.58	99.03

Table 2: Macronutrients and energy content of pulse/Legume category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Chick pea boiled	½ cup	5.17	0.65	2.43	37.46
Chick pea tempered	½ cup	8.16	3.9	3.82	84.97
Dhal curry	3 Tbsp	13.6	0.93	3.47	77.74
Wing bean mal-lum	3 Tbsp	3.05	7.54	2.08	89.64
Wing bean tempered	30g	5.64	27.88	1.94	282.37

Table 3: Macronutrients and energy content of protein category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Balaya fish curry	48g- 60g	1.45	4.6	14.15	104.55
Chicken curry	48g- 60g	0.7	2.97	3.83	44.91
Crab curry	48g- 60g	3.53	9.45	1.93	26.9
Dry fish tempered	48g- 60g	3.53	9.45	1.93	26.9
Prawn tempered	48g- 60g	1.35	4.19	1.87	50.8
Sardine curry	48g- 60g	0.57	1.41	11.53	61.52

Table 4: Macronutrients and energy content of dairy category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Yogurt	1 cup	11.28	2.48	2.88	79.2

Table 5: Macronutrients and energy content of Vegetables Category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Brinjal curry	36g	1.07	3.88	0.41	40.97
Cucumber salad	36g	2.76	0.24	0.56	15.9
Kakiri curry	36g	7.6	1.11	2.93	52.41
Okra curry	48g- 60g	7.26	0.81	1.36	41.66
Okra tempered	36g	5.62	24.24	2.42	252.26
Thalana batu curry	36g	12.48	1.64	2.42	71.62

Table 6: Macronutrients and energy content of green leaves Category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Gotukola sambal	48g- 60g	1.3	2.1	0.41	25.24
Kan kun tempered	48g- 60g	3.17	16.89	0.62	167.42
Onion leaves sambal	48g- 60g	1.18	2.25	0.68	28.18
Passion leaves sambal	36g	1.45	2.29	20.52	30.57

Table 7: Macronutrients and energy content of fruit category food items per serving

Food items	Serving size	Carbohydrate	Fat	Protein	Energy
Kolikuttu	(1)45-50g	12.49	0.18	0.72	55.85
Ambul	(1)45-50g	13.84	0.65	0.66	64.53
Apple	½(70g)	9.26	0.45	0.2	43.77
Mango (vi-lard)	½ (72g)	7.33	0.5	0.66	38.19

3.2. User-Friendly Interface:

"Diet Planner" is designed as a web-based application, ensuring broad compatibility and ease of use. The login interface, depicted in the study, underscores the application's focus on accessibility and user engagement. The developed tool named "Diet Planner" was a user-friendly tool for planning diets. This is a web-based application compatible with any version of Windows. The login interface of this system is shown in Figure 1.

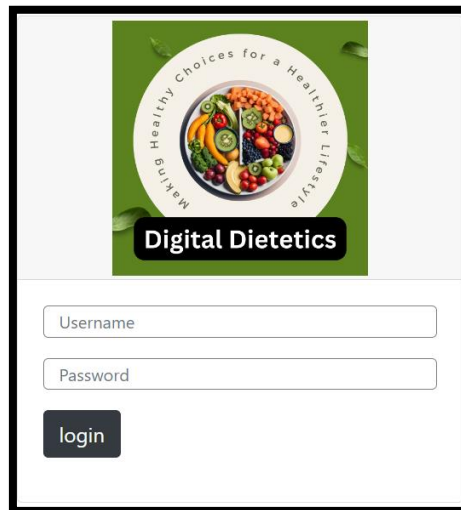


Figure 1: Login interface of the developed model.

3.3. Evaluation and Feedback:

The tool was evaluated by ten dietitians, focusing on aspects like user-friendliness, functionality, adaptability, efficiency, reliability, and overall satisfaction. The feedback was predominantly positive, with high agreement on the tool's user-friendliness and efficiency. Dietitians appreciated the time-saving aspect and the intuitive design of the system, though they also suggested areas for improvement, including the addition of therapeutic diet options and the enhancement of the dietary plan customization features. The evaluation assessment by dietitians(n-10) of the developed software named: “Diet Planner”, for its characteristics such as user-friendliness, functions, efficiency in results providing, reliability of the results, and overall satisfaction for a five-scale rating are presented in below Table 8:

Table 8: Evaluation results of the system characters

Assessment Criteria	Strongly disagree	Disagree	Moderate	Agree	Strongly agree
	n (%)	n (%)	n (%)	n (%)	n (%)
User friendliness	1(10%)	-	-	5(50%)	4(40%)
Functionality	-	-	5(50%)	4(40%)	1(10%)
Adaptation speed	-	-	1(10%)	4(40%)	5(50%)
Efficiency	-	-	2(20%)	5(50%)	3(30%)
Reliability	-	1(10%)	2(20%)	5(50%)	2(20%)
Level of inconsistency	-	-	7(70%)	2(20%)	1(10%)
Overall satisfaction	-	-	3(30%)	6(60%)	1(10%)

Participants' acceptance of the developed tool was collected by the questionnaire form and the percentage of participants who have accept the tool that can be used as a professional tool in their future practice presented as graphical representation in the below Figure 2:

13. Would you recommend this tool to be used by professionals in their future practice.

10 responses

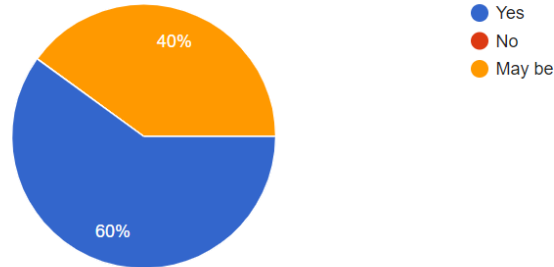


Figure 2: Representation of the acceptance of the developed tool by the professionals.

3.4. Professional Acceptance:

The graphical representation of professional acceptance indicates a positive reception among dietitians, suggesting a high potential for integration into clinical practice. The constructive comments provided by the dietitians highlight the system's potential impact on improving dietary counseling efficiency while also pointing out areas for future development.

Below are some comments that are given by the dietitians who have participated in the evaluation of this system. Most dietitians praised the system for its time-saving and user-friendliness. The system lagging was the main concern that should be corrected, by most of dietitians. The suggestions that are given for the improvements include the incorporation of therapeutic diets, editing or replacing options for the diet plans that are given by this system, and the need for a reliable database.

The comparison of time taken to plan diet with using the current meal planning system and with the developed model was tested using non-parametric related samples Wilcoxon signed rank test, and the results are presented below Table 9.

Table 9: Comparison of time taken to plan diet with using the current meal planning system and with the developed model.

Parameter	Using the current existing system	Using developed model	P-Value
Median time taken	45	8	0.005

Wilcoxon signed rank test (Non-Parametric Related samples)

The SPSS Wilcoxon sign rank test results for the comparison of median values for the time taken to plan the diet with the current practices and with using our developed system. The median time taken for planning the diet using our developed system significantly differed to about 8 minutes compared to the diet planned with the use of current practices.

4. Discussion

The introduction of the "Diet Planner" streamlines the responsibilities of the integration of Artificial Intelligence (AI) in healthcare, particularly in dietary planning, and represents a transformative shift towards more efficient and personalized health services. Despite AI's slower adoption in healthcare compared to other sectors, this study demonstrates the substantial bene-

fits of AI-enhanced dietetic services through the development of the "Diet Planner." This tool epitomizes the potential of AI to streamline dietary planning processes, offering a significant leap in the way health professionals provide nutritional support.

Enhanced Efficiency and Personalization:

The "Diet Planner" tool, as evidenced by the study's results, significantly reduces the time required for dietitians to devise nutritional plans, thereby allocating more time for patient-centered care and professional development. This efficiency is not only a testament to the tool's robust AI capabilities but also highlights its potential to democratize personalized dietary guidance, making it more accessible and affordable.

Comparison with Existing Systems:

When juxtaposed with existing diet planning systems that often lack personalization and are limited by static databases, the "Diet Planner" stands out due to its dynamic integration of AI, particularly Chat-GPT. This integration allows for the creation of customized meal plans that adapt to individual health conditions, dietary restrictions, and preferences, leveraging a comprehensive and evolving dataset.

Limitations and Future Directions:

While the study underscores the tool's innovative approach, it also delineates certain limitations, such as the need for enhanced source reliability, the inclusion of therapeutic diets, and more extensive customization features. Addressing these limitations is crucial for ensuring the ethical and practical application of AI in nutrition.

Moreover, the study suggests an ongoing development trajectory for the "Diet Planner," focusing on improving accuracy, speed, user-friendliness, and the integration of new features such as meal preference selection, economic and geographical adaptability, and comprehensive meal planning options.

Implications for Future Research:

Future research is imperative to assess the long-term impact of the "Diet Planner" on user satisfaction, health outcomes, and its adaptability to diverse dietary needs. A more extensive user study, encompassing a broader demographic and longer evaluation period, would provide invaluable insights into the tool's effectiveness in real-world settings and its potential to enhance the quality of life and health of its users.

5. Conclusion

This investigation has successfully led to the development of "Diet Planner," a state-of-the-art, AI-powered system designed to assist nutrition professionals in meal planning. This platform, powered by the impressive capabilities of Chat-GPT, generates personalized meal plans that incorporate individual-specific data such as demographic factors, levels of physical activity, health goals, and food preferences. The creation and deployment of "Diet Planner" are critical milestones in the evolution of clinical nutrition, demonstrating the expansive potential of AI in reshaping how nutritional information is managed and in aiding the delivery of digital, evidence-informed dietary counsel.

The outcomes of this study shine a light on the system's operational effectiveness and user-friendly nature, as well as its capacity to reduce the workload for dietitians, thereby providing them with more opportunities for patient interaction and professional advancement. The affirmative evaluations and reported time efficiencies by the dietitians who tested the system are a testament to its ability to significantly improve the standard and reach of individualized nutrition consultation. Nonetheless, it is of the utmost importance to address the system's present

shortcomings, which include the necessity for wider integration of specific therapeutic diets and greater customization functionalities for users. These shortcomings present significant opportunities for future research and development endeavors aimed at enhancing the platform's features and extending its range of applications.

"Diet Planner" signifies an important progression towards the assimilation of AI within the healthcare sector, notably in the field of nutritional science. As the platform evolves, it is expected to not only transform the practices of dietary planning but also to encourage the broader adoption and normalization of AI technologies in healthcare environments, fostering a paradigm that prioritizes personalized, efficient, and knowledgeable nutrition and health administration.

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**FOSTERING SUSTAINABLE UNIVERSITY-INDUSTRY
TECHNO-ENTREPRENEURIAL COLLABORATIONS AND
INNOVATIONS IN ASIAN UNIVERSITIES**

ICSD 324
**ASSESSING UNDERGRADUATE PERCEPTIONS ON UNIVERSITY INDUSTRY
COLLABORATION IN SRI LANKA**

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Abstract: Promoting university-industry collaboration is an important societal endeavour in the national innovation system. Despite intended encouragement of such collaborations in many advanced economies, many developing countries are still in the process of completely integrating this crucial link. The main intention of study as a part of the FOUNTAIN (Fostering sustainable University-industry Techno-entrepreneurial Collaborations and innovations in Asian universities) project was to identify the current state of University-Industry Collaborations in Higher Education institutes in Sri Lanka and involve in the assessment of entrepreneurial skills and perceptions of undergraduates to assess their expectations, root causes of lack of entrepreneurship developments, and market mismatch with the graduate profile. A systematic literature review and a comprehensive survey with pretested questionnaire were carried out. Empirical data were collected from a sample of 225 students of categorized under new entrants, from state Universities of Sri Lanka and major trends were identified. The analysis highlighted key trends, such as deficit in entrepreneurial skills and limited interactions with industrial experts. Though the majority of students (85%) expressed keen interest in becoming entrepreneurs, the readiness of undergraduates to take risks stands out (87.5%), reflecting an entrepreneurial mindset. Despite time limitations in undergraduate studies, students prioritize industrial training (65%), valuing focused projects and strategic university-industry collaborations for the practical experiences and insights offered within the available time frame. Results suggest practical implications of contemporary models of university-industry collaboration, the challenges hindering collaboration like unawareness of intellectual property rights the financial aspects. Majority of students 95% lack industry sponsorships for fostering collaborative initiatives. Majority of Students (79 %) are not aware about international university-industry collaborations, as well which could result in them overlooking valuable chances for global exposure and hands-on learning experiences. In (88%) of the survey responses address the absence of a liaison office or business incubator as a significant concern. The presence of entrepreneurial skill gap is noticeable, signaling a requirement for enhancements in university industry collaborative activities. Also, students lack leadership capabilities and teamwork skills as well. In conclusion, these findings shed light on valuable insights with significant implications for advancing future knowledge. Addressing gaps in early exposure to industrial training can equip undergraduate students in Sri Lanka's government universities with the skills and mindset crucial for entrepreneurial success, thus fostering regional economic growth and innovation.

Keywords: Entrepreneurial skills; Industrial training; Undergraduates; University industry collaboration

1. Introduction

There are a number of terminologies that are linked with the University-Industry Collaboration (UIC), including University-Industry Linkages (UIL), University-Industry Partnership (UIP), University-Industry Alliance (UIA), and University-Industry Relationship (UIR) (Mgonja, 2017). Steenkamp and Rigard's (2019) study delved into "The Quadruple Helix (QH) Model of Innovation for Industry," elucidating effective systems that serve to motivate University-Industry Collaborations (UICs). These systems encompass "entrepreneurial universities," "innovation centers," and "exhibitions and technology transfer offices (TTOs)" embedded within academic institutions, all of which constitute integral components of burgeoning innovation ecosystem (Ariyawansa, 2022). In Sri Lanka, the collaboration between universities and industries holds significant promise for driving innovation and economic growth. This study aims to assess undergraduate perceptions regarding this collaboration, exploring its effectiveness, challenges, and opportunities.

1.2 Global Context

The partnership between universities and the industry is increasingly seen as a means to boost innovation through the exchange of knowledge. This is evident in a notable rise in research exploring the subject from various angles. However, this existing body of knowledge is often characterized as fragmented and lacking an efficient, comprehensive perspective Ankraha *et al.*, (2015). The significance of sustainability is increasingly recognized, not just by academics and businesses, but by a broader audience. Achieving sustainable progress is a complex task that cannot be fully accomplished by individual efforts or single organizations. As a result, entrepreneurs aiming for sustainable change may explore partnerships with universities to overcome limitations in resources and technology Jirapong *et al.* (2021). As universities, navigate the increasingly competitive and dynamic global economy, understanding the dynamics, benefits, and challenges of these collaborations from a global perspective.

1.3 Asian Context

"In developed countries, university-industry collaboration usually starts with utilizing already-existing knowledge networks and connections, with an emphasis on using codified knowledge to innovate and create new technical tools and product (Nsanzumuhire and Groot, 2020). On the other hand, in emerging industries, working with academic institutions usually puts the development of new knowledge first. Businesses in these fields frequently look to collaborate with academic institutions in order to gain access to cutting-edge research and scientific know-how, especially to aid in the creation of innovative products (Lee, 2000).

Although there is limited evidence on UIC in Asian countries, there are a few studies done on UIC in South Asian and Asian region. Identified three types of University-Industry collaborations as high (research partnerships and services with shared infrastructure), medium (academic entrepreneurship and trainings) and low (informal, low-level connections). In Sri Lanka, most of the links between universities and companies can best be described as short term, informal interactions with low direct transfer of knowledge and innovation (Larsen *et al.*, 2016).

1.4 Sri Lankan context

UIC offer numerous benefits, particularly acting as strategic partnerships for industrial firms. These often lead to the development of new technologies and product prototypes, enabling firms to target untapped markets. Additionally, academic partners benefit by gaining insight into the complexities of the Entrepreneurship. When considering long-term collaborations, industrial firms may seek ways to measure the success of the collaborations. Main factors could include the commercialization of new products or technologies, increased market share, improved research outcomes, and enhanced reputation or brand recognition resulting from collaborative efforts as per mentioned by (Wickramasinghe and Malik, 2016).

In Sri Lanka, there is a notably general lack of active participation by academic staff in collaborative research work, contractual research endeavors, human resource mobility, and industry-oriented training (Ariyawansa *et.al*, 2022). Academic research seen as significant moderator in the correlation between academic contributions and the exchange of knowledge between universities and industries in Sri Lanka (Weerasinghe and Dedunu, 2021).

Also, predominant reliance on 'harder' metrics, such as patents and publications, as exclusive measures for evaluating the success of UIC.

A favorable financial and regulatory environment is found as essential factors in promoting UIC (Ankrah and AL-Tabbaa, 2015). However, many Asian countries do not have these two essential facilities in first place. The present study focus on bridging the gap between university industry collaboration to a sustainable future in the state university perspective.

1.5 Research gap

Limited understanding of the current state of university-industry collaborations. A comprehensive assessment of existing collaborative frameworks and their effectiveness is lacking, hindering the identification of areas in Sri Lanka for improvement and the formulation of targeted interventions (Ariyawansa, 2022). Inadequate entrepreneurial competencies and perceptions among undergraduates. The root causes of the lack of entrepreneurship developments and market mismatches with graduate profiles remain unclear, preventing the development of effective interventions to foster entrepreneurial mindsets and skills (Ariyawansa, 2022).

1.6 Objectives

The objective of the study was to collect information from the undergraduates of the state universities of Sri Lanka,

- To identify Entrepreneurial potential and entrepreneurial experience of state university students in Sri Lanka.
- To identify Current status of University-Industry Collaborations (UIC) in Sri Lanka in state universities perspective.
- Stakeholder engagement and partnerships with state universities in Sri Lanka.

2. Methodology

A pretested questionnaire was circulated among most all the State Universities in Sri Lanka which focusses on, Biological and Agriculture related fields. The questionnaire was distributed to reach each individuals of the universities representing New Entrants (Fresh Graduates/first years) as an online survey. There were altogether 225 responses came from randomly selected first year students of state universities in Sri Lanka. Questionnaire has been navigated through 11 key categories, including demographic information, educational backgrounds, business engagement, industrial training exposure, entrepreneurial knowledge and aspirations, entrepreneurial education and university activities, startup experiences and funding, industry exposure, knowledge on university industry collaborations (UIC), future plans, and leadership, skills, and risk-taking attitudes. Major Trends were analyzed respectively under major categories.

3. Results and Discussion

3.1. Entrepreneurial Skills

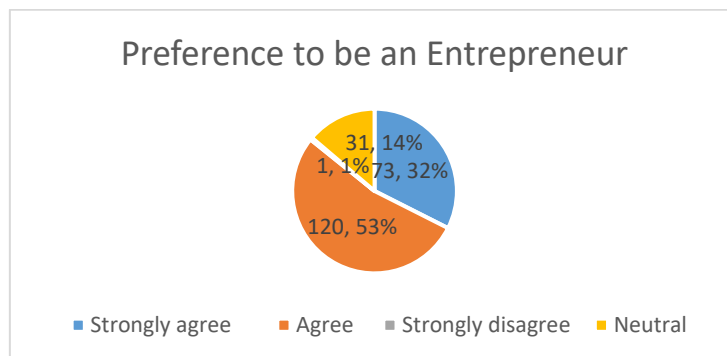


Figure 1: Willingness on becoming an entrepreneur.

The survey findings among government university students in Sri Lanka, indicating a remarkable willingness among first-year students to pursue entrepreneurship, resonate strongly with recent research in the scientific world, reflecting an increasing interest in entrepreneurial attitudes and intentions among students as shown in Figure 1. This positive orientation towards entrepreneurship emphasize a favorable environment within the university community for fostering entrepreneurial initiatives and education(Malik and Wickramasinghe, 2015).

Recent studies, such as those by Kuratko(2017),emphasize the importance of entrepreneurial ecosystems in shaping individuals' entrepreneurial intentions and behaviors. Therefore, the widespread and affirmative mindset observed among Sri Lankan university students regarding entrepreneurial pursuits may be indicative of a conducive entrepreneurial ecosystem within the university community.

Additionally, research by Kautonen, van Gelderen, and Fink (2015) argue that exposure to entrepreneurship education programs can positively impact students' attitudes towards entrepreneurship and increase their likelihood of pursuing entrepreneurial careers. Therefore, the positive inclination towards entrepreneurship among Sri Lankan university students could serve as a foundation for implementing effective entrepreneurship education programs, workshops, and support structures within the university community(Malik and Wickramasinghe, 2015). Moreover, recent studies by Bosma et al. (2018) emphasize the importance of cultural and institutional factors in shaping entrepreneurial intentions. The survey findings among government university students in Sri Lanka provide valuable insights into the prevailing entrepreneurial orientation among students.This positive inclination towards entrepreneurship can facilitate the implementation of tailored programs and support structures within the university community, ultimately fostering socio-economic development and innovation.

3.2 Risk Taking ability



Figure 2: Pie chart on Risk taking ability.

The findings from the survey among government university students in Sri Lanka, indicating a high inclination toward risk-taking among respondents, contrast with the challenge of risk-taking ability identified in other studies (Larsen *et al.*, 2016). This suggests a divided mindset among students regarding risk tolerance, which presents both opportunities and limitations in fostering an entrepreneurial mindset within the university community as shown in figure 2.

One limitation of the survey findings is the potential for social desirability bias, where respondents may overstate their willingness to take risks due to perceived societal expectations or norms associated with entrepreneurship. Additionally, the survey may not capture the nuances of risk-taking behavior, as individuals' actual risk propensity may vary depending on the context and type of risk involved. However, these findings also present opportunities for educational initiatives and mentorship programs to address the divided mindset towards risk-taking among students. Recent research suggests that entrepreneurship education programs can effectively enhance students' risk perception and tolerance by providing experiential learning opportunities and exposure to real-world entrepreneurial challenges (Toutain *et al.*, 2017). Furthermore, mentorship programs that connect students with experienced entrepreneurs can offer valuable insights and guidance on navigating risks in entrepreneurial endeavors (Kuratko, 2017).

Moreover, recent studies highlight the importance of psychological factors such as resilience and self-efficacy in shaping individuals' risk-taking behavior (Shepherd & Patzelt, 2020). Educational interventions that focus on developing these psychological attributes can empower students to embrace challenges and uncertainties associated with entrepreneurship, fostering a more resilient and adaptive entrepreneurial mindset.

3.3 Prioritizing on Industrial Training over final year Research

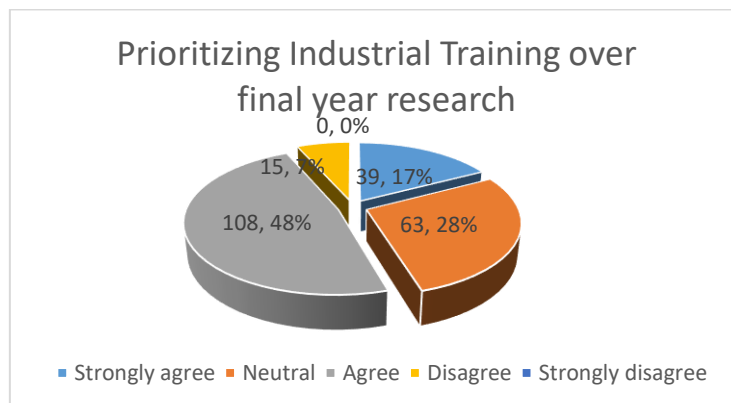


Figure 3: Preference on prioritizing Industrial Training over Final Year Research.

The Importance of Industrial Training for a successful UIC is discussed in. (Weerasinghe and Dedunu,2020).The survey results among government university students in Sri Lanka showcase a predominant positive inclination towards prioritizing industrial training over final year research.A significant portion of respondents strongly supports this perspective, indicating a clear preference for practical, hands-on experience in an industrial exposure as shown in Figure 3.These findings suggest a prevailing sentiment among students favoring real-world, experiential learning through industrial training over the traditional emphasis on final year research projects. The emphasis on industrial training for successful UIC is a topic of growing interest, as evidenced by the study conducted by Weerasinghe and Dedunu (2020).Their research highlights the importance of prioritizing practical, hands-on experience in an industrial setting over traditional final year research projects. Similarly, recent studies have explored the benefits of experiential learning and industry engagement for students. However, it's important to acknowledge potential limitations associated with prioritizing industrial training over final year research projects.

3.4 Have you received any sponsorship in your carrier?

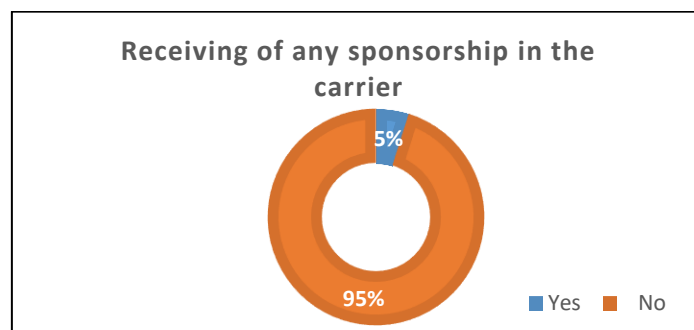


Figure 4: Information on any sponsorship in the carrier.

It has found that Financial handling with universities is difficult and it mainly stands as a barrier in successful UIC in Sri Lanka (Gedara Ariyawansa and Ariyawansa, 2022).The majority have not benefited from such sponsorships as shown in figure 4.

The study conducted by Gedara and Ariyawansa (2022) sheds light on the challenges associated with financial handling in UIC initiatives in Sri Lanka. Their findings indicate that financial constraints stand as a significant barrier to the successful implementation of UICs, with the majority of respondents (95%) reporting that they have not benefited from sponsorships or financial support for collaborative projects. Similar studies in the scientific world have also highlighted the importance of financial resources in facilitating effective collaboration between universities and industries(Dollinger *et al.*, 2018).

Moreover, the complex administrative procedures and bureaucratic hurdles involved in accessing and managing funds can pose significant challenges for both universities and industry partners. Research highlights the administrative burden associated with securing research grants and finances, which can divert time and resources away from core research and collaboration activities(Guan, Yan and Zhang, 2017).

Going forward, although financial management presents a major obstacle to the success of UICs in Sri Lanka, comparable difficulties are present in other settings throughout the world. Through acknowledgement and resolution of these obstacles, interested parties can endeavor to create enduring funding sources and optimize administrative procedures to facilitate efficient cooperation between academic institutions and business sectors, thereby propelling innovation and socio-economic advancement(Senathiraja, Buvanendra and Kapiyangoda, 2022).Addressing this

gap by promoting and facilitating industry sponsorships may enhance students' opportunities for practical engagement, financial support, and industry collaboration, ultimately contributing to the development of an entrepreneurial mindset among the student population in the scientific world.

3.5 Knowledge on International UIC Knowledge

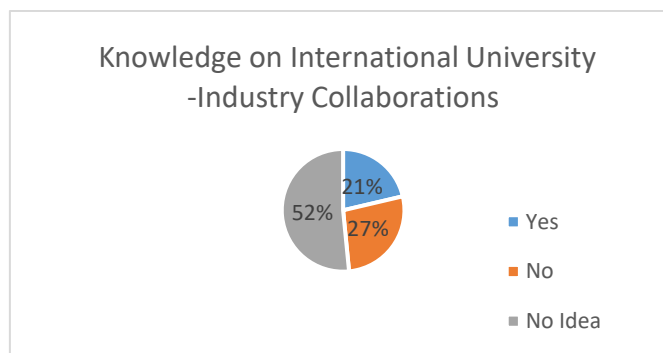


Figure 5: Pie chart on Knowledge on International UIC.

The survey findings among government university students in Sri Lanka highlight varied levels of awareness regarding International (UICs), with a significant majority expressing a lack of awareness about such initiatives as depicted in Figure 5. This lack of awareness can pose challenges to the successful implementation and participation in UICs, as effective collaboration often depends on informed and engaged stakeholders. The EU has funded several projects, including Erasmus+ Capacity Building for Higher Education projects, the EU-Sri Lanka Science and Technology Cooperation Programme, and participation in Horizon 2020, providing funding and opportunities for collaboration with European partners (El Allame *et al.*, 2022). Similar studies in the scientific world have also examined the awareness and understanding of university-industry collaborations among students and other stakeholders. For example, research by Zhao *et al.* (2018) explores the factors influencing students' awareness and perceptions of UICs in the Chinese context. Their findings suggest that factors such as institutional support, communication channels, and exposure to real-world examples of collaboration play a significant role in shaping students' awareness and attitudes towards UICs.

However, there are limitations to consider when interpreting survey findings on awareness of UICs among university students. One limitation is the potential for biases in self-reported awareness levels, as individuals may overstate or understate their familiarity with UICs based on social desirability or lack of understanding of the concept. Additionally, survey responses may be influenced by contextual factors such as the framing of survey questions, respondents' prior knowledge and experiences, and cultural differences in the perception of university-industry collaboration.

Furthermore, while awareness is an important first step towards fostering participation in UICs, it does not necessarily guarantee active engagement or effective collaboration. Research by Barge-Gil *et al.* (2014) highlights the importance of creating conducive environments and incentives for collaboration to encourage meaningful engagement from both academic and industry partners. By addressing limitations in understanding, fostering informed awareness, and creating conducive environments for collaboration, stakeholders can work towards enhancing the effectiveness and impact of UIC.

This highlights a considerable gap in communication and awareness within the student population. The low percentage of students aware of these collaborations suggests an opportunity for educational initiatives and improved communication strategies to disseminate information about the associated benefits and opportunities (Senathiraja, Buvanendra and Kapiyangoda, 2022). The survey emphasizes the need for universities, institutions, and industry bodies to enhance communication and educational efforts, fostering a globally aware and engaged student body in the realm of International UIC.

3.6 Presence of an Incubator /Liaison Office

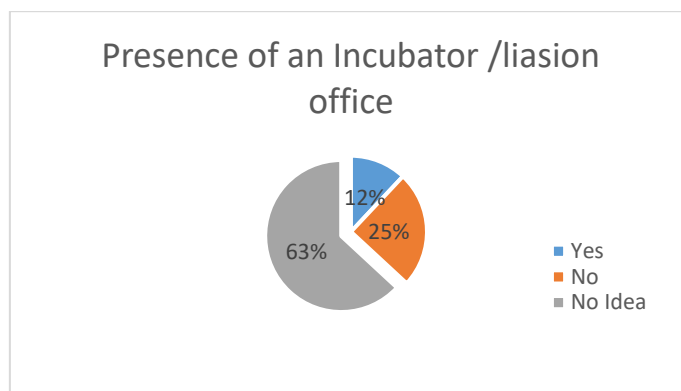


Figure 6: Presence of an Incubator or a liaison office.

The survey findings indicating a significant gap in awareness and access to University-Business Linkage (UBL) offices among students in government universities in Sri Lanka highlight an important area for improvement in facilitating university-business collaborations. This gap suggests that students may not be fully aware of the resources available to them for engaging with industry partners and accessing support for collaborative projects, as depicted in Figure 6.

Similar studies, research explores the factors influencing the effectiveness of UBL offices in fostering innovation and knowledge transfer between universities and businesses (Senathiraja, Buvanendra and Kapiyangoda, 2022). Their findings suggest that factors such as organizational structure, leadership, and resource allocation can significantly impact the effectiveness of UBL offices in facilitating collaboration. However, one limitation is the potential for biases in self-reported awareness levels, as individuals may overstate or understate their familiarity with UBL offices based on social desirability or lack of understanding of their functions. Additionally, survey responses may be influenced by factors such as the framing of survey questions, respondents' prior experiences with UBL offices, and cultural differences in the perception of university-business collaborations.

Furthermore, while UBL offices can play a crucial role in bridging the gap between academia and industry, their effectiveness may be hindered by various challenges, including limited funding, inadequate staffing, and lack of coordination with industry partners in Sri Lanka (Senathiraja, Buvanendra and Kapiyangoda, 2022).

Conclusion

A survey of first-year students at state universities in Sri Lanka reveals their strong propensity for entrepreneurship and suggests that the academic community is supportive of entrepreneurial endeavors. Though there is agreement on the value of hands-on industrial training, opinions on the significance of conventional research projects are not so unanimous. The results also show a notable lack of knowledge and resources for university-industry collaboration, underscoring the need for enhanced support networks and communication within the university ecosystem.

Resolving these issues and encouraging students to have a stronger entrepreneurial mindset could have a big impact on promoting innovation and socioeconomic growth in Sri Lanka. Entrepreneurial potential and entrepreneurial experience of state university students in Sri Lanka were identified. Also the Current status of University-Industry Collaborations (UIC) in Sri Lanka in state universities perspective was disclosed. Stakeholder engagement and partnerships with state universities in Sri Lanka were discovered.

Acknowledgement

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**SOCIAL LIFE CYCLE ASSESSMENT: A NOVEL PERSPECTIVE TO ASSESS THE
INDIRECT SOCIAL IMPACTS OF A DISASTER**

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Abstract: This paper speculates how Social Life Cycle Assessment can be used to compare social impacts for key products for countries pre and post disaster. The method can reveal the indirect social impacts that span far into the future for a products life cycle after a disaster. This moves away from a focus on the direct effects of a disaster, human health, to widen the scope to indirect social impacts that can span through temporal periods. This could highlight where support may be needed and the learning from the past can assist in resilience in the future. To achieve this, there is a need for industry collaboration within SLCA in order to baseline the positive and negative impacts for key products within a country. This will allow Social Life Cycle Assessment to be conducted after disasters to hotspot highlight areas along a products lifecycle that need to be a focus for intervention ensuring resilience and sustainability into the future. Currently industries only offer data which they are willing to be held accountable for, this prevents the baselining of impacts, and the effect disasters can have on social impacts.

Keywords: Social Life Cycle Assessment; SLCA; LCA; Disaster

1. Introduction

This paper will introduce Social Life Cycle Assessment (SLCA) briefly describing its methods and nuances, highlighting the difference between SLCA and Environmental Life Cycle Assessment (ELCA). The paper then introduces how SLCA could be used as a novel lens to assess the impacts of disasters and the possibilities of identifying systemic effects that impact upon key industries within a country. SLCA methodology allows for a repeatable methodological insight into the direct and indirect impacts of a products life cycle and can offer up a novel lens to assess social impact for key industries after a disaster. It then explores the need for industry and government collaboration. Due to the independent nature of business producing products, a look into the impacts for many businesses within a sector can explore whether there are certain systemic impacts for stakeholders or impacts. However, there can be barriers preventing this from happening. A has been literature review is utilised to address the need for industry collaboration to provide the information to model product from an SLCA perspective, as there are barriers preventing this from happening.

2. What is Social Life Cycle Assessment?

Social life cycle assessment, SLCA, is “a technique for collecting, analyzing and communicating information about the social conditions and impacts associated with production and consumption” (Norris et al., 2014, p.6974). Thus, the technique can be used to assess, highlight, and compare social impacts for or between products, much like a Environmental Life Cycle Assessment, ELCA, can for environmental impacts (ISO, 2006a; ISO, 2006b). SLCAs ultimate goal is to promote the improvement of social conditions for the stakeholders involved and affected along the products life cycle (Jørgensen et al., 2012). One major difference between ELCA and SLCA is that the former can account for both positive and negative impacts whereas ELCA can only account for negative impacts (Norris et al., 2014).

Social life cycle assessments are in their infancy. In 2018, Zimeck et al (2019) conducted a topic modelling literature review assessing the top themes throughout the 15302 papers covering LCA, highlighting that the social and economic aspects are still underrepresented. This is not to say that SLCAs are not gaining attention as that studies tackling social issues through a LCA lens are increasing, especially after the implementation of comprehensive guidance (Petti et al., 2018). But the case studies in many publications focus on simple products with a reduced number of stakeholders, life cycle phases and social impacts. There is currently no standardised method for assessing the social aspects of a products life cycle. The first guidance published on the topic was in 2009 by the United Nations Environmental Programme, claiming the guidelines provide a map, a skeleton and a flashlight for stakeholders engaging in the social aspects of a products life cycle (UNEP-SETAC Life Cycle Initiative, 2009). These guidelines compliment the environmental life cycle assessment and life cycle costing allowing for a complete approach for assessing the sustainability through the life cycles of products or systems. To support the guidelines UNEP published “The methodological sheets for subcategories in social life cycle assessment (SLCA)” (Traverso et al., 2021) which are to be used in combination with the guidelines. The sheets are a work in progress representing the most up to date knowledge on methods to assess the subcategories and their stakeholders. UNEP highlighted that the methodological sheets were not definitive and will continue to evolve as knowledge within the field expands. Thus, the sheets and guidance are a public resource that is meant to guide and inspire the application of SLCA. The methodological sheets contained a list of stakeholders that could be impacted, the type of social impacts and example of how to quantify impacts. These stake holders are Workers, Local communities, Value chain actors (e.g.suppliers), Consumers and Society. The interest in SLCA has been gaining academic interest due to these documents, with spikes in interest in the years following their publication (Petti et al., 2018). The interest within the academic setting also diverged to stakeholders within industry, policy makers and businesses. The 2009 guidelines needed prior knowledge of LCA to be understood. This led to a large portion of SLCAs that were focused upon areas with large environmental impacts, negating the areas were SLCA would have the most significant results (Petti et al., 2018). To prevent this, the implementation of guidelines and information that did not need prior knowledge in life cycle assessment were published. Thus, the

implementation of the 2020 “guidelines for social life cycle assessment of products and organisations”. Due to how new these guidelines are it is currently not feasible to state the impact they have had. The updated guidelines provide a technique for assessing the social impacts, or potential impacts, on several stakeholders and their subcategories throughout the life cycle of a product. (Zimek et al., 2019).

As the decision to include stakeholders is made by the practitioner based on the goal of the study, some stakeholders can be underrepresented, even though all relevant stakeholders should be included within the SLCA. The new guidelines state that “consumers, value chain actors, and society are often overlooked as stakeholder categories, while workers and local communities appear to be frequently included” (United Nations Environment Programme, 2020, p.18). This is not a comprehensive list of stakeholders and more can be included if it aligns with the goal but using predefined categories allows for an easier comparison with other studies. These stakeholders are then linked to impact categories, and subcategories, which are linked to inventory indicators and finally to the inventory data. Due to the infancy of SLCA there are currently no commonly accepted indicators to measure social performance, but academics highlight the need for even a small set of standardised indicators to promote comparability (Kühnen & Hahn, 2017). Impact categories are “logical groupings of S-LCA results, related to social issues of interest to stakeholders and decision makers.” (UNEP-SETAC Life Cycle Initiative, 2009, p.67). These impact categories can be modelled either at mid-point level or at end point level, representing different points along the causal-effect chain. Mid-point level separates and contextualises inventory data into the relevant impact categories, which provides no information on the scale of the impact in relation to the final effect it will have. To link the scale of the impact in relation to its final effect, further modelling and characterizations needs to take place, leading to end-point modelling. (Kühnen & Hahn, 2017).

3. Social indicators

As SLCA is a relatively new methodology the social indicators are currently not standardised, nor is there a consensus within the literature on what should be used. As social indicators do not follow physical cause and effect chains there are complexities in trying to find accurate and objective proxies to represent social indicators (Huertas-Valdivia et al., 2020). This leads to a debate on how to measure some impacts and thus influences what impact categories should be chosen. The UNEP SETAC methodological sheet provide a list of 31 subcategories but do not specify the indicators to be used (UNEP-SETAC Life Cycle Initiative, 2009). Meaning that there can be a large variation of selected indicators covering the same aspect of social impacts, leading to results which are difficult to compare. Kühnen and Hahn (2017) conducted a systematic literature review highlighting that although most studies include indicators relating to the UNEP subcategories, there are still many other indicators used that are not linked to the subcategories listed by UNEP. Leading them to conclude that the subcategories presented by UNEP may be incomplete because “Thus, the SLCA subcategories might lack completeness because they do not include performance categories deemed important by a majority of research in this field.” (Kühnen & Hahn, 2017, p.1552) . Others argue that the social indicators are based of social values and ethical and ideological positions which could differ according to political, ethical and cultural values. Providing an example of child labour which in most developed countries, is viewed as unwanted but others argued that child labour can increase general wellbeing in certain circumstances (Dessy & Pallage, 2005). Although SLCA can account for both positive and negative social impacts, this does not mean that all impact categories can provide positive impacts. Ekener et al (2018) highlight that previous studies have attributed a positive impact when a negative impact is absent (Ciroth & Franze, 2011), but in their view and Jørgensen et al. (2007) view, positive impacts are related to issues that add value in themselves. Thus, the absence of a negative impact is not always a positive impact. Take for example the subcategory ‘forced labour’ and ‘local employment’, the absence of forced labour is not a positive impact because this would have already accounted for in the subcategory ‘local employment’. If the absence of forced labour was taken as a positive score, double counting for ‘local employment’ would occur. The guidelines also state that a positive impact must go beyond compliance with laws, regulations, standards etc (Sureau

et al., 2020). Arvidsson et al (2018) conducted a SLCA on air bags to evaluate if the production of an airbag injured more people than the airbag saved when in use. To do this he structured his work like a conventional ELCA using cause effect chains, they focused on the health impacts using disability adjusted life years (DALY). This impact category was chosen because it can directly account for the positive impacts on the consumer and the negative impacts for other stakeholders, allowing the results throughout the life cycle to be added and subtracted, providing the results in one score. Some authors argue that human health is already evaluated by ELCA and therefore shouldn't be include in SLC, how ELCA only consider the damage to human health as a consequence of environmental impact, thus SLCA be used to widen the scope to cover a holistic selection of social impacts (Dreyer et al., 2006).

4. The need for industry collaboration

There are many different theoretical frameworks for selecting impact categories and the reasons for selecting impact categories. Sureau et al. (2018) found that within SLCA literature there were 14 differing frameworks for the selection of assessment criteria (impact categories) and indicators. These 14 frameworks were grouped into 5 differing categories based on their rational behind the definition and selection of Criteria and indicators. These were value-based frameworks, context orientated frameworks, theory structured frameworks, impact-based frameworks and applicability-orientated frameworks (Sureau et al., 2018). The selection of indicators should be related to the goal and scope of the study, but this will not limit the practitioner's choice of indicators, and improper selection can lead to burden shifting. Dreyer el al. (2006) and Kruse et al. (2008) both believe that indicator selection should be based of top down and bottom-up approaches. Top-down approaches are closely related to indicators presented within the SLCA guidelines representing broadly recognised societal values, thus being based on international conventions, agreements, and guidelines. Bottom-up approaches are therefore based on the stakeholders on industry and stakeholder interests and/or data availability, thus allowing indicators to address industry specific interests. Dreyer et al. (2006) did raise concerns over the use of bottom-up approaches as they could be based only on data availability or impacts for which industries are willing to be held accountable for. Conventional ELCA has the use of databases to assess the impact from production facilities, producing a material with the same technology in different areas has the same impact except for energy input (Simapro Help Center, 2023). However, the same technology to produce a product in different areas can have vastly different social impacts related to the businesses involved and thus data must be collected on a site-by-site basis. However, the barriers to conducting SLCA are the need for stakeholder participation, but companies can often provide unreliable information and tend (unintentionally) to green wash, or the access to sensitive data might be denied (Pollok et al., 2021). This highlights the need for industry collaboration, in order to get access to the data to ensure a holistic covered of stakeholders and social impacts are contained.

As the methodology can assess both positive and negative impacts, it is capable of highlighting the positive social impacts regarding a products production as did Mulyasari et al. (2023) regarding palm oil production in Indonesia. Haryati et al (2022) also addressed palm oil production in Malaysia highlight where improvements can be made but also showing the benefits provided. There were also finding related to the similarities between the companies as they are all constrained by the same overarching rules, highlight the importance of the stakeholder governance which can often be omitted from SLCA as the focus is on workers. It also highlighted the links between governance and negative social impacts that are out of control of the production facilities. The findings of systemic negative impacts associated with governance would be a suitable place to start planning interventions due to the large-scale effect it can have. Mulyasari (2023) showed that the market price for palm oil is often linked to the scale of social impacts, thus the importance of the stakeholder governance is key. However, identifying the relevant stakeholder in governance can be difficult (Balasbaneh et al., 2020). The work by Rahmah et al (2023) on coffee produced in rural areas of Indonesia showed the social benefits that farmer groups offer and highlight how the government should prioritize these types of activities. Therefore, to conduct thorough SLCAs there is need for collaboration between universities,

industries and governance. This can help in quantifying the social impact before and after a local or global disaster to effectively hotspot highlight areas to focus and to understand the temporal aspects of these impacts. Previous work has been conducted looking at the effect disasters can have on social communities and industry but not from a life cycle perspective, rather the focus is on certain regions (Khazai et al., 2013). This limits the ability of conclusions drawn from a population of an industry to be applied to the rest of the industry sector or applied past conclusion within an industry to present or future issues. The large amount of work gone into producing the SLCA guidelines and methodological sheets, could be a starting point from monitoring social impacts in key industries pre and post disaster. It should be noted that work should first identify the relevant stakeholders and impacts categories to be used. This can help in direct intervention needed but also present data on the social ramifications of the production of key products after a disaster to help in preparing for future disasters and helping to produce resilience on key industries for a country. Previous work has compared social impacts between agricultural products, but this is little work comparing impacts pre and post disaster (Prasara-A & Gheewala, 2019). The use of SLCA for comparing pre and post disaster could widen the scope of impacts caused by the disaster. Rather than focusing on the impact on human health directly caused by the disaster it could include social impacts that are drawn out for long periods after disasters, especially for key industries within an area. Much like how ELCA only focuses on human health impacts as a consequence of environmental impacts but disregards other important social impacts that can be evaluated with SLCA. Thus, the use of SLCA could be a novel lens to assess the long-term social impacts from a disaster in order to concentrate efforts but also to provide resilience for future disasters. The use of SLCA could allow an understanding of the expected changes to key products within a country and where interventions may best be focused, the life cycle perspective will allow an understanding of the interlinked nature between stakeholders and impacts.

5. Conclusions

SLCA could be a suitable novel approach for assess the social impacts pre and post disaster for key industries within a country. This would allow intervention strategies to be proposed targeting the most vulnerable stakeholders. The learnings provided by a small sample of a sector could be used to address the whole sector and learning from the past can be used to plan for resilience in the future. Due to the infancy of this method, there is little work conducted from this novel perspective and work to baseline impact should be taken. The first steps would be to gain industry and governance collaboration allowing the relevant stakeholders and impact categories to be identified and impacts for certain product baselined. This would allow the baseline study to be reconducted after disasters to direct intervention and plan for resilience for future disasters.

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**ARE UNIVERSITIES ADEQUATELY SHOWCASING THEIR UNIVERSITY-
INDUSTRY COLLABORATIONS TO HELP STUDENTS MAKE THEIR CHOICE OF
HIGHER EDUCATION?**

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Abstract: University-industry collaboration (UIC) is a mutually rewarding interaction between higher education systems and industries that mainly fosters technological and knowledge advancements. Graduates produced by universities play a key role in shaping the futures of universities and industries building a triangular relationship. Prospects of employment are important in a student's selection of a university. University-industry collaborations help students achieve their goals including securing a decent job. Assuming that showcasing UICs on university websites helps prospective students recognize the links the universities have with industries, the websites of the top ten universities of Webometrics Regional Ranking were examined for the display of UICs or advertised job opportunities. Three layers of visibility were set, the top layer (information on the home page), the second layer (information one click away from the home page), and the third layer (information two or more clicks away from the home page). The top ten universities of Sri Lanka and Thailand were given special attention as these countries partner in the EU co-funded FOUNTAIN project. A noteworthy relationship between university rankings and the display of UICs was not observed in the study. Engineering and Technology-based universities in India have shown their industry links on websites. The world's top ten universities did not have any UICs posted on their websites. Although job opportunities were displayed on many websites, most were vacancies advertised by the universities. A wide range of terms was used to indicate UICs by universities worldwide. This superficial examination did not clearly show the attempts of universities to showcase their UICs on their websites. However, UICs may be posted on faculty, campus, or college websites because UICs could have a tie to the discipline or degree programs. Displaying UICs on university websites could give universities many additional advantages such as industry endorsement. Therefore, showcasing UICs on websites is worthy for universities.

Keywords: University Ranking; Job opportunities; UICs; Visibility; Employment

1. Introduction

Universities and Industry Collaboration (UIC) is a multifaceted and interdisciplinary interaction between higher education systems and industries that mainly fosters technological and knowledge advancements (Nsanzumuhire and Groot, 2020). These collaborative initiatives have been successfully implemented in various countries, including European countries, the United States of America, Australia, Japan, and Singapore. Notably, there has been a significant increase in such partnerships in developing countries across Asia (Ankrah and AL-Tabbaa, 2015).

The benefits derived from UIC are extensive and play a crucial role in skills development, knowledge acquisition and adoption, promotion of entrepreneurship, and fostering start-ups (Belov, 2004). The prime product of universities, *i.e.*, the graduates, are the primary beneficiaries of the UICs because their future is in the hands of the industries either as employees, intrapreneurs, or entrepreneurs. The selection of a matching university is a key decision students must make. If a student rationally selects a university for his or her education, he or she should primarily focus on the subject area of preference and the prospects for future employment. Numerous factors could influence students' choices of higher education. According to Briggs (2006), the major factors are the location relative to their hometown, proximity to social life, interest in the field of study, academic reputation, quality of the university, university entry requirements, research standing, graduate employment rates, and the information provided by the university on its website.

In the authors' opinion, universities should help students make this key decision by showcasing UICs on their websites. The rationale behind this can be explained as follows. The internet is a source of information for almost every decision we make today, and the selection of a university is not different from the rest of our decisions. Therefore, vital information should be displayed on the university websites for the information seekers. Prospects of future employment depend on how universities cater to the industry's needs through industry-oriented curricula and the rapport the university has with industries (Ishengoma and Vaaland, 2016). UICs are the basis for that and, displaying them on the websites indirectly tells the students how it is committed to orient it in the industries. Therefore, this study aims to examine how top universities in different regions of the world showcase their industry relationships on their websites.

2. Materials and Methods

The study examines the extent to which, the top 10 Webometric-ranked universities, colleges, or institutes in selected educational regions, *i.e.*, North America, Europe, Asia, Oceania, and Africa are showcasing their University-Industry Collaborations and Job opportunities on their official websites. Advertising industry-related job opportunities on university websites was considered an attempt made by universities to showcase their industry ties. The regions used in the study are analogous to those shown on the Webometrics website. This study specifically considered the top 10 universities in Sri Lanka and Thailand as the Asian partners in the EU co-funded FOUNTAIN project.

A total of nearly 100 institutes were selected, and their websites were examined for the presence of content related to UICs or Job opportunities. Three levels of visibility were identified. If the information was available clearly on the university homepage it was considered as the top-layer information. If the information was one click away it was considered as the second-layer information. If the information was available three clicks or more, such information was considered as third-layer information.

3. Results and Discussion

All information presented and discussed below is up to the first week of February 2024. Figure 1 illustrates the count of universities that displayed any information regarding UICs or Job opportunities on their websites at any layer. Except for North America, one or more universities in all other regions display both UICs and Job opportunities on their websites.

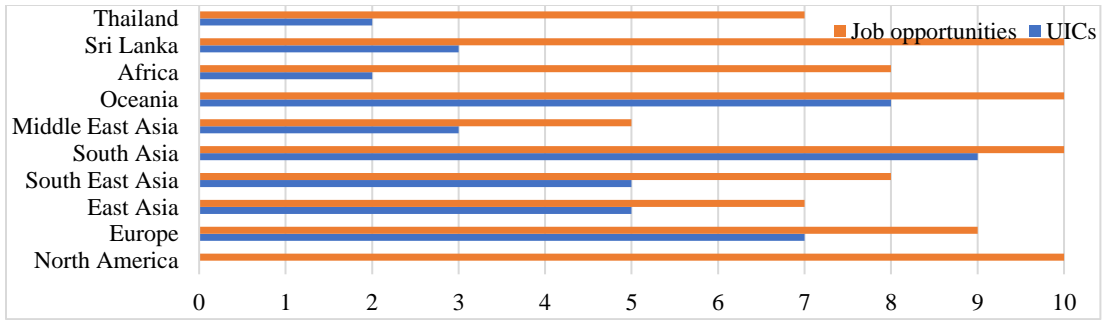


Figure 1: Region-wise comparison of display of UICs and Job opportunities on university websites.

Figure 02 shows the visibility of UIC and Job opportunities in terms of layers. The majority of the UIC and job opportunities are displayed either as top-layer or second-layer information. Job opportunities are mostly published as top-layer information. Most of the job opportunities advertised are vacancies within the university and only a few had advertised outside job opportunities. This implies that the advertising of job opportunities on the university website is not primarily to attract prospective students.

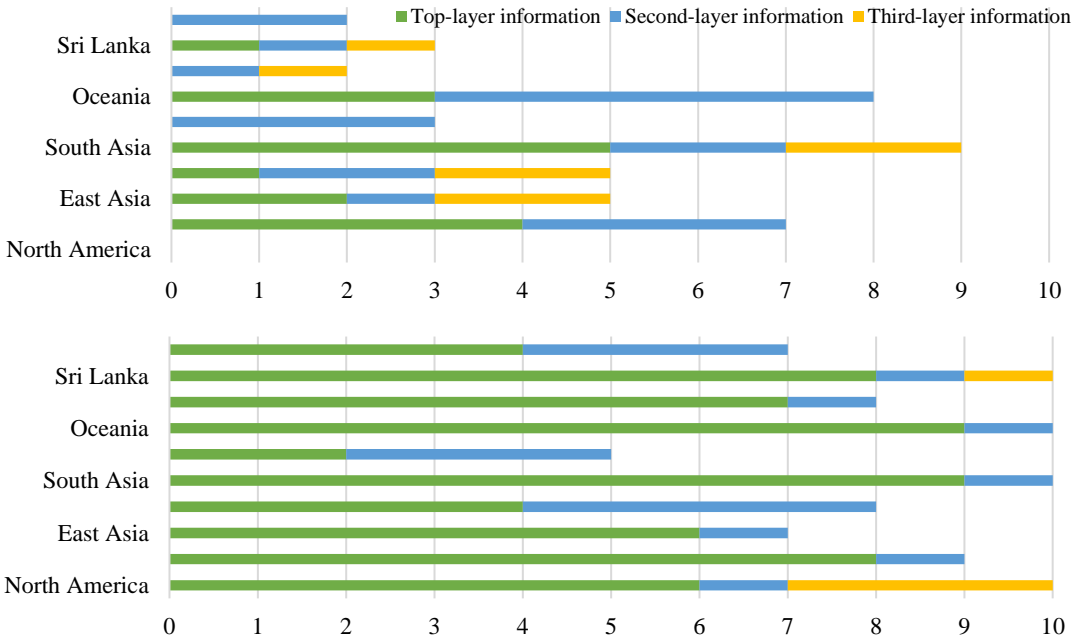


Figure 2: The visibility of UIC (a) and job opportunities (b) on the university websites in terms of layers.

When considering North America, it is evident that the top 10 universities are in the United States of America (USA), and notably, they represent the top 11 ranked universities in the world. According to observations, all top-ranked universities in the USA display job opportunities on their websites, among them six universities show them as top-layer information, one as second-layer information, and three as third-layer information but none of them showcase University-Industry Collaborations (UICs) in a way a regular student visitor notices them. Being among the top-ranked institutions it is highly unlikely that they do not have prolific UICs.

In Europe, the top 10 universities are ranked within the top 100 worldwide and most of them are in the United Kingdom. Among them, seven universities display UICs, four as top-layer information, and three

as second-layer information. Nine universities feature job opportunities, eight as top-layer information and one as second-layer information. In Europe, UICs are referred to by universities using various terms, Industrial Strategy, Business and enterprise, Industry and business partnerships, Industry and Knowledge Transfer, Industry partnerships and commercialization, and Business engagement services.

The top 10 universities in East Asia are also ranked within the top 100 worldwide and most of them are Chinese Universities. Among them, five universities display UICs, two top-layer information, one second-layer information, and two third-layer information. In contrast, seven universities show job opportunities, six top-layer information, and one second-layer information. The university-industry connections are presented under various names such as Collaborations, International University Alliances, Cooperation with industries, Partnerships, and Internships.

In Southeast Asia, the top 10 universities are in Singapore, Malaysia, Thailand, and Indonesia. Two of these universities are ranked among the top 100 globally, while the remaining eight are ranked between 101-1000 worldwide. Among these universities, five showcase University-Industry Collaborations (UICs), with one providing top-layer information, two providing second-layer information, and two providing third-layer information. These industrial collaborations are presented under various names such as Career Guidance and Industry Collaborations, Center for Internship Training, Industrial Linkages, and Community & Industry. Additionally, eight universities feature job opportunities, four as top-layer information and four as second-layer information.

In South Asia, nine out of the top 10 universities are in India with world ranks ranging from 101 to 1000. These top universities in India primarily cater to the fields of Engineering and Technology. Consequently, they actively engage in industrial interactions and all of them prominently display University-Industry Collaborations (UICs) on their homepages, five top-layer information, two second-layer information, and two third-layer information. These collaborations are showcased under various names such as Industrial Consultancy, Corporate Relations, Industry-Academia Collaboration, and Central Placement Center which serves as an interface between the industry and the students. All South Asian universities showcase job opportunities on their homepages, with nine providing top-layer information and one providing second-layer information.

In the Middle East, the top 10 universities are in Israel, Saudi Arabia, and Iran, and are ranked between 101-1000 worldwide. Among these universities, three showcase University-Industry Collaborations (UICs) as second-layer information. These industrial collaborations are presented under various names such as Industry Collaborations, Industry Cooperation, and Our Partners. Moreover, five universities feature job opportunities, with two as top-layer information and three as second-layer information.

In Oceania, nine out of the top 10 universities are in Australia, and the remainder is in New Zealand. Six of these universities are ranked in the top 100 globally, while the remaining four are ranked between 101-1000 worldwide. Among these universities, eight showcase UICs, with three as top-layer information and five as second-layer information. These industrial collaborations are offered under several names as Partnerships, Industry Partnerships, Partner Industry and Business, Internships, Industry Engagement Programs, and Partners with us. Moreover, all top 10 universities feature job opportunities, with nine presenting top-layer information and one as second-layer information.

In Africa, seven out of the top 10 universities are in South Africa, with the remaining three in Egypt with global rankings between 101-1000. Among them, two universities showcase UICs, with one as second-layer information and one as third-layer information. These industrial collaborations are expressed as Innovation, Technology Transfer & Commercialization (Training), and University & Industry. Moreover,

eight universities feature job opportunities, with seven presenting top-layer information and one presenting second-layer information.

The study considered Sri Lanka and Thailand as a special category because they are partners in the FOUNTAIN project. In Sri Lanka, all the top 10 universities are ranked above 1000, and three of them showcase UICs on their home pages. They are presented as top layer, second layer, and third layer information each and identified as Academic-University Business Linkage, Business Incubation, and Industrial Collaborations. All top 10 universities in Sri Lanka feature job opportunities, with eight as top-layer information, one as second-layer information, and one as third-layer information. In Thailand, out of the top ten universities, six are ranked within the top 1000 and the rest above 1000 globally. There are two universities showcasing UICs as second-layer information, identifying as Academic services of industries and Industrial Liaison & Technology Transfer. Seven out of the top ten showcase job opportunities, four as top-layer information and three as second-layer information.

The study could not find a relationship between the university rankings and the display of university-industry collaborations on their websites. The reputation may help the universities attract both students and industries to them and the job prospects also could be high for the graduates of those universities. However, for the universities that are yet to build a good reputation, the industries may be attracted to those showing university-industry linkages. On the other hand, university-industry links can be manifested as research publications, patents, or any other outputs (Morgan, 2017). That was not focused on the present study because such information may not be clearly visible to most students who seek universities for their future undergraduate education. University-industry collaborations are identified in using wide variety of terms across the studied regions. Despite some are giving straight meaning, some may not be clear to public.

Examining only the university level information is one of the limitations of this study. UIC or Job opportunities may be available at faculty, campus, college, or other levels because the links are specific or limited to those entities. As in the case of India, the technology-related universities and faculties may have more conspicuous linkages with the industries in contrast to the other disciplines. Such subject-wise assessment was not done in this study.

In Sri Lanka, although the students select the university of their choice, the final decision is with the University Grants Commission. However, the student demand for the degree programs offered by the university and the cutoff level (z-score) depends on the number of students who are applying for the program. Therefore, the attempts of the universities to showcase their industry ties to prospective students may influence student choice.

4. Conclusion

University-industry collaboration (UIC) offers a range of benefits for both academia and industry. The future of both universities and the industry depends heavily on graduate performance and the healthiness of this triangular relationship is a key determinant of socioeconomic development. Therefore, attracting focused and dedicated students is a complement to the universities and the industries. The authors' idea of "displaying university-industry collaborations on university websites would help guide prospective students to select university" was perceived by the top universities as a good practice could not be fully verified through the study. Although some universities displayed such information, a relationship between their rankings could not be observed. Engineering and Technology-based universities in India had the most showcased linkages as a group indicating a relationship to the nature of the discipline. Displaying university-industry links on the website can be advantageous in many ways if they are presented in a way understandable and accessible to any visitor.

Disclaimer

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INNOVATION CULTURE OF THE AGRICULTURAL SECTORS

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UNMANNED AERIAL VEHICLE USAGE FOR MONITORING HIGHER PLANTATION CROPS IN SRI LANKA

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Abstract: The agriculture sector in Sri Lanka plays a pivotal role in the country's economy, with higher plantation crops such as rubber, coconut which are serving as vital contributors to agricultural output. As technology continues to advance, there is a growing need for efficient and innovative methods to monitor and manage plantation crops effectively. Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as a transformative tool in agriculture, offering a cost-effective and scalable solution for crop monitoring. As a result, this systematic review was carried out in order to assess the effectiveness of UAVs in providing real-time and high-resolution imagery for the monitoring and management of plantation crops, identify the utilization of UAVs for monitoring higher plantation crops in Sri Lanka and explores the benefits and challenges associated with this technology. Peer-reviewed articles from the years 2017 through 2023 can be found in “Scopus” and “Web of Science” databases. “Precision agriculture”, “unmanned aerial vehicle”, “future sustainability”, “plantation”, “drones”, and “innovative technology” were used as inclusive keywords during the article screening process. UAVs equipped with advanced imaging technologies, such as multispectral and thermal sensors, enable precise data collection that aids in crop health analysis, disease detection, and yield prediction. By processing the data from UAV images accurately, powerful tools and algorithms such as Deep Learning approaches can be used for deriving traditional agriculture system to modern agriculture system. This paper aims to serve as a guide to contribute to the advancement of precision agriculture for higher plantation crops in Sri Lanka, promoting sustainable practices and enhancing overall crop productivity. By harnessing the potential of UAVs for plantation crop monitoring, this study focuses to provide actionable information to farmers, policymakers, and agricultural stakeholders, ultimately supporting the modernization and sustainability of the agriculture sector in Sri Lanka.

Keywords: Higher Plantation crops; Real-time data; Precision agriculture; Unmanned aerial vehicle

1. Introduction

By utilizing cutting-edge technologies to maximize yields and enhance crop management, precision agriculture has completely changed agricultural practices (Priyankara et al., 2022). Growing in importance as a means of improving agricultural productivity and product quality is precision agriculture. Drones, also referred to as unmanned aerial vehicles, or UAVs, have become important instruments for gathering high-resolution aerial data in agriculture. Unmanned aerial vehicles (UAVs) offer an effective and non-destructive way to evaluate the health of plants and their nutritional state, including the amount of nitrogen present. In order to implement sustainable agriculture techniques, it is essential to monitor the health conditions of higher plantation crops. This is because such monitoring enables the early diagnosis of illnesses, nutritional deficiencies, and stress factors, all of which can cause decreased productivity or even tree mortality. Higher plantation crops have historically been evaluated mostly by manual visual inspection, which can be labour-intensive, subjective, and prone to human mistake. But new developments in remote sensing technologies, especially with regard to Unmanned Aerial Vehicles (UAVs), offer a viable way to monitor large-scale plantations accurately and effectively. Plant health can be monitored by tracking changes in specific biophysical characteristics, such as plant height, diameter at breast height (DBH), crown diameter, frond form and size, Leaf Area Index (LAI), and Crown Projection Area with NDVI. The basis for assessing the vegetation indicators' performance was their ability to accurately estimate the percentage of green cover and the leaf area index (LAI).

New methods of developing agricultural monitoring and management systems are always being developed with the use of cutting-edge technologies such as big data analytics, machine learning, and artificial intelligence. The goal of these methods is to give farmers ever-more precise and in-depth data about the growth, health, and yield of their crops so they may make data-driven decisions to boost productivity. Using satellite-based remote sensing is an innovative method. Farmers can keep an eye on their crops globally by using satellite data, which can continuously cover large areas. The information can be utilized to accurately forecast yields and spot early indicators of stress. Real-time remote sensing photos and data from connected sensors can create information that can increase crop productivity by mapping changes in spatial information in the field (Khuzaimah et al., 2022).

Using intelligent farming systems is another innovative strategy. These systems collect data on crop growth and health by integrating a variety of technologies, such as sensors, drones, and autonomous vehicles. Farmers can obtain up-to-date information on crop production through machine learning techniques after the data has been analysed. Employing a smart farming system to track stress conditions and increase yields on Malaysian oil palm plantations (Shamshiri et al., 2018).

According to Gupta et al. (2015), traditional remote sensing platforms are currently unable to acquire data at temporal and spatial scales that are made possible by UAVs, or unmanned aerial vehicles. These airplanes are cleverly made to function without a human pilot in the cockpit, either remotely or autonomously. The range of unmanned aerial vehicles (UAVs) is broad, including small recreational drones and very complex versions used for a variety of commercial, military, and professional uses. UAVs are composite machines that combine a variety of essential parts, such as strong frames, motor-driven propulsion systems, a wide range of sensors, such as GPS, cameras, and LiDAR technology, reliable communication systems, and the crucial onboard computer or flight controller that controls their movements (Madushanka et al., 2019). UAV-captured images in various spectrums have proven to be able to provide crucial information regarding crop conditions for efficient fertilizer management (Yuhao et al., 2020). When compared to satellite-based remote sensing for agricultural growth monitoring, the expensive UAV remote sensing technology has generated a lot of interest. Because of its sim-

plicity and adaptability in terms of operation and image processing, UAV remote sensing has shown great potential for practical applications in small areas and LAI estimation (Lu et al., 2019). Numerous factors, such as canopy structure, lighting, and development stages, may have an impact on the data obtained from the UAV remote sensing platform (Du et al., 2020).

2. Methodology

Within this industry, the systematic literature review approach is gaining traction over the more traditional, conventional review procedure. The application of systematic reviews and their combination with qualitative and quantitative analysis have become more common in the academic setting. Consequently, a systematic approach was employed to gradually integrate the sources of peer-reviewed literature. Because of the significance and relevance of this topic setting, we employed specific criteria to cut down on the study's material. Two academic search engines were used to locate research publications about the use of UAVs in higher plantation crop monitoring: Scopus and Google Scholar. The selection of these platforms by search engines is justified because they provide a wealth of information in a variety of domains, including interdisciplinary studies related to precision agriculture.

3. Result and Discussion

The agricultural research community has been paying more attention to smart agriculture as a way to improve present processes by incorporating data engineering techniques. Unmanned aerial vehicles, or drones, have been used in farming for a few years now, and the sector is experiencing a boom in this use of technology. Despite the fact that this technology is still in its infancy, with all of its promising future applications, it has the potential to revolutionize the global agricultural sector and advance farming methods. In comparison to the new technology being used in precision farming, drones are still seen as a relatively fresh and less developed instrument.

In the 1980s, the first unmanned aerial vehicles (UAVs) were used in agriculture for crop dusting. Drones are now used for precise airborne application of pesticides and fertilizers over agricultural areas, as well as aerial imaging to support crop field mapping and growth monitoring, thanks to technological advancements in the agricultural sector over the years.

In agricultural production and administration, monitoring is crucial. Rubber tree monitoring has historically required a lot of labour and time (Mahakalanda et al., 2022). Drone technology covers a sizable portion of an obstructed area in terms of geographical and temporal information. It has been essential in helping to map rubber trees at the local and regional levels and has made it easier to comprehend how rubber plantations' spatial patterns have changed over time (Azizan et al., 2021).

In oil palm cultivation, UAVs are also used for disease diagnosis, and image-based analysis is used to count the number of oil palm trees in a plantation. The two primary methods used in current research to identify Ganoderma disease infections in oil palms are laboratory-based analysis and on-the-ground sampling of individual oil palms. Analyzing an overhead image of the oil palm plantation area is a practical method for spotting Ganoderma infections. It is quick because a UAV sortie equipped with a camera may quickly cover a huge region (Izzuddin et al., 2020).

Utilizing vegetation indices from drone photos is essential for determining the health of plants and the presence of diseases. Drones can be used to use image-based analysis to identify the injured palm trees in coconut plantations (Nainanayake et al., 2016). Additionally, it can be used in coconut plantations for pollination purposes (Rehna et al., 2022).

One of the primary issues is the application of drone technology in the plantation industry (Jayed et al., 2017). The likelihood of using drones effectively is increased by factors such as the cost of purchasing drones, sensors, and related components, flight duration, payload limitations, and frequently changing laws by the appropriate authorities. Drone technology presented a number of issues for monitoring higher plantation crops in Sri Lanka. One of the difficulties is found in rubber plantations. Less vigour in rubber trees results in less vegetation being detected in UAV images, which reduces efficiency. The price of drones is another. While in flight, the so-called "inflorescence drone" will assist in determining the health of the plants. But, there is no way to use it in Sri Lanka due to the country's economic circumstances and technological barriers.

When paired with the appropriate sensors, drones may help farmers navigate and observe their fields and provide statistical data about the condition and health of their crops. Drone measurements and observations must be inside the drone operator's visual line of sight (VLOS) in accordance with Department of Civil Aviation (DCA) regulations. Due to their increased VLOS distances, most larger farms provide a challenge for drone applications. It is not feasible to stitch together several photos into a larger map by performing many procedures simultaneously, as this would need a great deal of time and technological know-how. Furthermore, the use of UAVs in agriculture is increasingly reliant on commerce, and it is important to abide by all applicable national and legal regulations (Khuzaimah et al., 2022).

4. Conclusion

For those involved in the agricultural plantation industry, this article provides a comprehensive reference by offering insights into the deliberate application of unmanned aerial vehicle (UAV) technology in monitoring higher plantation crops. Stakeholders may enhance farming practices by making the most of technological breakthroughs and carefully navigating cutting-edge technologies. Long-term economic viability, efficient resource usage, and environmentally friendly agricultural output are all guaranteed by this approach. A vital first step toward building a solid and sustainable future for Sri Lanka's plantation industry, precision agriculture employing unmanned aerial vehicles (UAVs) is not only a revolutionary force in modern farming.

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CHARACTERIZATION OF PHYSICOCHEMICAL PROPERTIES AND POST-PRANDIAL GLYCEMIC RESPONSE OF GARLIC AND BEE HONEY COMBINED PRODUCT

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Abstract: Although bee honey and garlic have been employed as valuable remedies since ancient times in Ayurvedic medicine to promote weight loss and induce a hypoglycemic effect, there is limited scientific research available to substantiate these claims. The objective of this study was to assess the physicochemical properties and post-prandial glycaemic response of the garlic-bee honey combination. The parameters measured included proximate composition, viscosity, pH, acidity, and sugar content. Glycemic index (GI) and glycaemic load (GL) analyses were conducted with 10 healthy subjects aged between 22-25 years, following the ISO 26642:2010 (E) method. Participants were administered 50 g of glucose as the reference food and the bee honey and garlic-bee honey product, which contains 50 g of available carbohydrates, as the test foods. The results of the proximate analysis indicated that the carbohydrate content of bee honey and the garlic-bee honey product was 79.9% and 73%, respectively. Furthermore, the garlic-bee honey product contained 1.6% protein, 0.4% ash, and 25% moisture. GI testing revealed that bee honey had a mean GI of 53 ± 5.80 (low GI), while the garlic-bee honey product exhibited a mean GI of 62 ± 7.25 (medium GI) with a significant difference ($P < 0.05$). The calculated GL for pure bee honey and the garlic-bee honey product was 8 ± 0.87 and 10 ± 1.22 , respectively, categorizing both as low GL foods without a significant difference ($P > 0.05$). In conclusion, this research suggests that both bee honey and garlic-bee honey products, with their low post-prandial glycaemic potential, could be recommended for diabetic patients, particularly when compared to table sugar (reported $GI \approx 80$), and due to their reported high antioxidant capacity. Future research should investigate the long-term effects of the garlic-bee honey product on human health.

Keywords: Bee honey; Garlic; Glycemic index; Glycemic load; Post-prandial

1. Introduction

Type 2 diabetes mellitus is a burgeoning global health concern. According to World Health Organization (WHO) statistics, approximately 422 million people were afflicted with diabetes in 2014 (Lovic *et al.*, 2020; WHO, 2023). Individuals with obesity often face an elevated risk of diabetes due to insulin deficiency and insulin resistance (Meng *et al.*, 2017). Therefore, dietary management is crucial for individuals with diabetes to avert organ dysfunction (Pathirana *et al.*, 2022). For diabetic patients, it is advisable to incorporate low-glycaemic index (GI) foods into their diets, as these foods release glucose into the bloodstream gradually (Burger *et al.*, 2012). GI gauges a food's capacity to raise blood glucose levels in comparison to a reference food, but for a more comprehensive assessment of the influence of carbohydrates on blood glucose levels, glycaemic load (GL) is a superior indicator (Raja Nurfatin *et al.*, 2021). GL is derived by multiplying the quality of carbohydrates (GI) in a specific food by the quantity of carbohydrates in a serving of that food (Venn & Green, 2007). Another general recommendation for type 2 diabetes patients is to restrict the consumption of simple carbohydrates like granulated or powdered sugar (Lovic *et al.*, 2020). However, refraining from sugar or sugar-containing foods can be challenging, and diabetic patients often seek alternatives that are less detrimental than sugar.

Bee honey is a natural sweetener with a historical legacy, primarily composed of high fructose and glucose, along with small quantities of sucrose (WHO, 2023). Due to its sugar profile, honey elicits a low post-prandial glycemic response (Meng *et al.*, 2017). Additionally, the combination of bee honey and garlic has been employed as an Ayurvedic remedy to enhance weight loss and induce a hypoglycemic effect (Suvarna & Rajagopalan, 2016). Both substances boast rich antioxidant properties, resulting in a synergistic effect that benefits these health claims (Waheeb & Ali, 2020). In bee honey, polyphenols are the predominant compounds with antioxidant attributes (Cianciosi *et al.*, 2018). In garlic, allicin is the primary compound endowed with antioxidant properties (Koca & Tasci, 2016). Despite the observed hypoglycemic effects of bee honey, garlic, and the bee honey-garlic combination, human studies on these topics remain limited, warranting further investigation. Thus, this study aims to explore the impact of consuming bee honey and garlic-bee honey combined products on post-prandial plasma glucose responses and to assess the GI and GL of bee honey products.

2. Materials and Methods

2.1 Development of Garlic and Bee Honey Product

The garlic-bee honey product was prepared by Bio Extracts (Pvt) Ltd., Sri Lanka, using pure bee honey sourced from a local supplier in the Polonnaruwa area. Garlic was procured from the local market. No preservatives or food additives were incorporated into the garlic and bee honey product. During the production process, garlic cloves were peeled and cleaned, then sliced into three segments per clove. These slices were spread on trays, covered with tissue papers, and left overnight to evaporate moisture. Subsequently, the sliced cloves were gently heated under low flame at 60°C with 5% honey until the garlic pieces became tender. This temperature does not influence the degradation of allicin in garlic because allicin rapidly degrades at 70°C – 85°C. The adequacy of garlic cooking was assessed, and the honey used for cooking was strained off. The cooked garlic was then packed into bottles after letting them to cool, with each containing 70 g of garlic and 180 g of honey. Finally, the product was sealed and capped. Figure 1 illustrates the process flow chart of the garlic-bee honey production process.

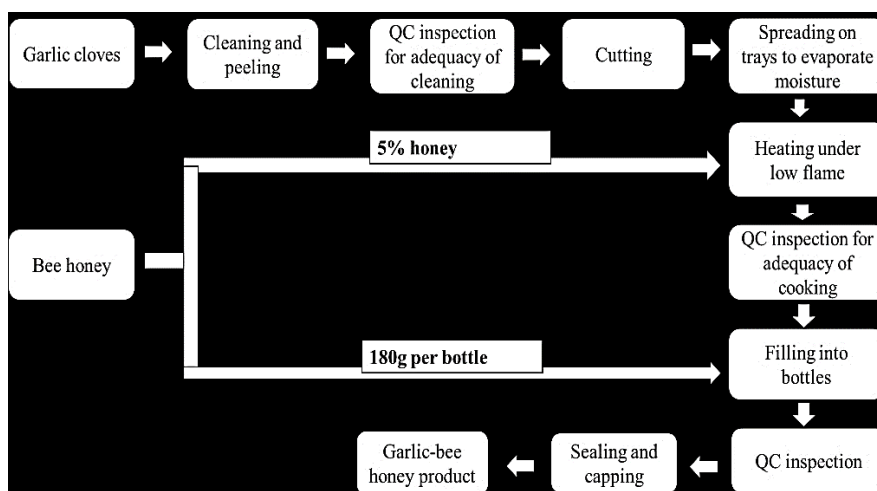


Figure 1: The process flow chart of the garlic-bee honey product. QC: Quality Control.

2.2 Chemical Composition Analysis

A proximate analysis was conducted to determine the composition of the garlic-bee honey product and pure bee honey. The moisture content was assessed using the Association of Analytical Communities (AOAC) method 990.20. Protein content was determined using the Kjeldahl method (AOAC method 955.04). Protein content was calculated using the general factor 6.25. Dry ash content was determined using AOAC method 900.02A, while fiber content was determined by the Weende method (AOAC method 978.10). Additionally, the total carbohydrate and available carbohydrate content of the garlic-bee honey product and pure bee honey were calculated. The levels of reducing and non-reducing sugars, as well as the fructose-to-glucose ratio (F/G ratio) in bee honey and the garlic-bee honey product, were determined following the methods specified in the Sri Lanka Standard Institute (SLS 464) specification for bee honey.

2.3 Physicochemical Characterization

2.3.1 Total Soluble Solids

Total soluble solids were determined by measuring the refractive index using an Erma hand refractometer (Erma, MXP-32385, Delhi, India).

2.3.2 pH

The pH was measured using a benchtop pH meter (Sper scientific, SP-860031, Scarborough, Canada) in a solution prepared by dissolving 10 g of honey in 40 mL of distilled water.

2.3.3 Viscosity

Product viscosity was determined using a viscometer (BL TOKIMEC viscometer, Tokyo, Japan) at 12 rpm using spindle no.2.

2.3.4 Water Activity

The water activity of the garlic-bee honey product was determined using a water activity meter (Infitek, WA-A5, China). For the garlic-bee honey product, water activity was determined separately for the honey phase and garlic phase.

2.3.5 Acidity

Acidity was determined according to the SLS 464 specification for bee honey. In brief, 10 g of honey was measured into a 250 mL conical flask and dissolved in 75 mL of distilled water. The burette was filled with 0.1 g/L NaOH, and a phenolphthalein indicator was added to the conical flask solution. The

solution was titrated against the 0.1 g/L NaOH until the colorless solution turned pink, and acidity was calculated.

2.4 Determination of Postprandial Glycaemic Response

Ethical clearance (ECC/2022/E/035) was obtained from the Ethical Clearance Committee of the Faculty of Agriculture, University of Peradeniya, Sri Lanka, and permission was granted to conduct clinical trials at the Department of Food Science and Technology, University of Peradeniya. A total of 10 volunteers provided written consent to participate in the clinical trials. The panel consisted of both male and female subjects (5 males and 5 females) aged between 20 and 23 years. Subjects were selected based on questionnaires and anthropometric measurements, including weight, height, waist circumference, and hip circumference. Subjects with a body mass index (BMI) ranging from 18.5 kg/m² to 22.9 kg/m², free from diabetes and chronic diseases such as cardiovascular diseases, cancer, and mental disorders, were chosen. Additionally, participants had no known food allergies or intolerances, were not on medications affecting glucose tolerance, had not participated in clinical trials in the past three months, and did not use steroids, protease inhibitors, or antipsychotics.

The protocol for determining the GI values of pure bee honey and the garlic-bee honey product followed the International Organization for Standardization (ISO) ISO 26642:2010 (E). Subjects were instructed to fast for 10 hours before the experiment. Glucose (SPC, 100% pure pharmaceutical-grade glucose) served as the reference food. Participants were given 50 g of available carbohydrates from glucose (dissolved in 250 mL of water), pure bee honey (63 g), and the garlic-bee honey product (69 g, consisting of 20 g of garlic and 49 g of bee honey) on separate days. They were instructed to consume the three types of food within 15 minutes and to minimize physical activity during the test.

Before consuming the test food, blood samples were collected through finger pricking from participants who had completed a 12-hour fasting period. Glucose concentrations in the blood samples were analyzed using a standardized glucometer (CLEVER CHEK TD-4279 Blood Glucose Monitoring System, MedNet EC-REP GmbH, Germany). Following the consumption of the test food, blood samples were collected at intervals over 2 hours (15, 30, 45, 60, 90, and 120 minutes). The blood samples were collected by trained registered nurses at the Department of Food Science and Technology, University of Peradeniya. The postprandial glycaemic response curve for each food item was generated using Microsoft Excel, utilizing mean blood glucose concentrations for each time point for each subject.

2.5 Determination of GI and GL

The collected blood glucose data were analyzed using Glycemic Spy software, and the GI values for pure bee honey and the garlic-bee honey product were calculated. The Incremental Area Under the Curve (IAUC) was determined for the blood glucose response of each individual for the test foods and glucose. GI was calculated as the ratio between the IAUC of the test food and the reference food. GL was estimated by multiplying the GI by the amount of carbohydrates in the recommended serving of bee honey and the garlic-bee honey product, respectively. GL calculations were performed using Microsoft Excel.

2.6 Statistical Analysis

The final GI value represents the average GI value of valid participants. Valid results are defined as those falling within ± 2 standard deviations (SD) of the mean GI value. GI data are presented as mean \pm standard error (SE) of the mean, while GL data are expressed as mean \pm SD. The results obtained from proximate composition and physicochemical analysis conducted in triplicate are expressed as mean \pm SD. Statistical analysis was performed using Student's t-test in Microsoft Excel and Minitab (version 20), at a 95% confidence interval.

3. Results and Discussion

3.1 Chemical Composition of Test Foods

The proximate composition of pure bee honey and the garlic-bee honey product is presented in Table 1. The carbohydrate content of bee honey was 79.9%, constituting three-fourths of the total composition. However, in the garlic-bee honey product, the carbohydrate content decreased to 73%. The addition of garlic resulted in increased fiber, protein, and moisture content, contributing to the reduction in carbohydrate content in the garlic-bee honey product. The moisture content of the garlic-bee honey product is 25%, whereas the moisture content of pure bee honey is 19.8%. The higher moisture content in the garlic-bee honey product is attributed to the exosmosis caused by the garlic pieces due to the supersaturated nature of bee honey. The moisture content in bee honey is a critical factor in determining its quality and shelf life. Given the elevated moisture content in the garlic-bee honey product, there is a higher risk of fermentation by yeasts, which warrants further investigation. Ash percentages indicate that the garlic-bee honey product contains more minerals than pure bee honey.

Table 1: Chemical composition of pure bee honey and garlic-bee honey product

Component	Bee honey (%)	Garlic - bee honey product (%)
Total Carbohydrate	79.9 ± 0.3 ^a	73 ± 0.6 ^b
Protein	0.2 ± 0.1 ^b	1.6 ± 0.7 ^a
Ash	0.1 ± 0.0 ^b	0.4 ± 0.2 ^a
Moisture	19.8 ± 0.3 ^b	25 ± 4.6 ^a
Fiber	0.00 ± 0.0 ^b	1.0 ± 0.5 ^a

All values are presented as the mean ± SD of three replications in dry basis. Means within the same row that share a common superscript are not significantly different according to the 't' test (P > 0.05).

Table 2 displays the sugar profile of pure bee honey and the garlic-bee honey product. Glucose and fructose are the primary sugars found as carbohydrates in bee honey (Amariei *et al.*, 2020; Krishnan *et al.*, 2021). As per the SLS specifications for bee honey, the reducing sugar content of pure bee honey should exceed 65%, but in the product, this value has decreased to 52.40%. Consequently, the reducing sugar content of the product has also decreased compared to pure bee honey. The decreased reducing sugar content could be the result of Maillard reaction taking place during the heating process of honey and garlic. Although only 5% of honey was used, depending on whether the honey coated garlic pieces were cooled down prior to filling might impact. The F/G ratio of the product is 0.996, whereas the F/G ratio for pure bee honey should be greater than 0.95. However, this value of 0.996 for the product is not solely due to the quality of bee honey used, as the F/G ratio of the bee honey before adding garlic is 0.87.

Table 2: Sugar profile of pure bee honey and garlic-bee honey product

Component	Bee honey	Garlic - bee honey product
Reducing sugar content (%)	66.98 ± 0.01 ^a	52.4 ± 1.60 ^b
Non-reducing sugar content (%)	67.20 ± 0.04 ^a	53.2 ± 0.25 ^b
F/G ratio	0.87 ± 0.01 ^b	1.00 ± 0.00 ^a

All values are represented as the mean ± SD of three replications. Means within the same row sharing a common superscript are not significantly different according to the 't' test (P > 0.05).

3.2 Physicochemical Characterization

The physicochemical properties of the garlic-bee honey product are presented in Table 3. Viscosity is an essential parameter that affects the composition of bee honey. Typically, the viscosity of bee honey varies between 1.76 and 252.6 Pa s, depending on the type of honey and temperature (Santos *et al.*, 2014). However, in the garlic-bee honey product, this viscosity has decreased significantly to 0.1625 Pa s. This reduction is attributed to the fact that bee honey is a supersaturated sugar solution, and it absorbs water from garlic, thus lowering its viscosity. Bee honey typically has an acidic pH, ranging from 3.2 to 5, which contributes to its antimicrobial properties (Ilija *et al.*, 2021). In contrast, garlic has a pH value that varies between 5-6 (Wang *et al.*, 2015). The pH value of the product measures at 4.40, much closer to the pH of bee honey. This is because bee honey constitutes a significant portion of the product, with a ratio of 2.5:1 between bee honey and garlic. The acidity of the product is 0.016%, while the acidity of pure bee honey should be less than 0.1%.

Table 3: Physicochemical properties of the pure bee honey and garlic-bee honey product

Parameter	Bee honey	Garlic - bee honey product	Test conditions
Viscosity (Pa s)	4.92 ± 0.03 ^a	0.16 ± 0.00 ^b	Spindle number 2 Rpm 12 25 °C
pH	4.2 ± 0.1 ^a	4.4 ± 0.2 ^a	27 °C
Acidity (%)	0.016 ± 0.0 ^a	0.016 ± 0.0 ^a	SLS 464 specification

All values are mean ± SD of three replications. Means in a row having common superscript are not significantly different by 't' test (P > 0.05).

3.3 Screening Results of Human Subjects Used for Glycaemic Response Analysis

The screening results of the selected subjects are presented in Table 4. The age and anthropometric measurements, including weight, height, BMI, waist circumference, hip circumference, and waist-to-hip ratio, were recorded. All the chosen subjects were aged between 22-25 years and had a BMI ranging from 18.5 kg/m² to 23.4 kg/m². The healthy BMI range for the Asia-Pacific region is between 18.5-22.9 kg/m² (Lim *et al.*, 2017). The mean height of the selected subjects is 1.62 ± 0.05 m. Among the selected subjects, none were alcohol users or had diabetes.

Table 4: Mean values of age and anthropometric measurements of the subjects

Characteristic	Mean ± SD	Range
Age (years)	23.45 ± 0.82	22 – 25
Body weight (kg)	54.32 ± 6.17	47.7 – 68
Height (m)	1.62 ± 0.05	1.5 – 1.7
BMI (kg/m ²)	20.80 ± 1.89	18.5 – 23.4
Waist circumference (m)	0.72 ± 0.04	0.6 – 0.8
Hip circumference (m)	0.89 ± 0.04	0.8 – 0.9
Waist: hip ratio	0.80 ± 0.05	0.72 – 0.88

Values are mean ± SD of (n=10) study participants.

3.4 Blood Glucose Response Curves after the Consumption of Glucose and Test Foods

The plasma glucose responses following the consumption of glucose and the test foods (pure bee honey and bee honey-garlic product) are depicted in Figure 2. Both pure bee honey and bee honey-garlic product exhibit peak blood glucose concentrations after 30 minutes of ingestion.

Although bee honey and the garlic-bee honey product initially elevate blood glucose levels within 30 minutes, they rapidly reduce postprandial blood glucose levels at 60 and 90 minutes compared to the glucose solution. This is due to the action of insulin because it can quickly reduce the blood glucose level increased by the two products compared to glucose. The two products do not release a high amount of glucose to blood at once as glucose itself does. The mean area under the curve (AUC) for glucose was significantly different from all samples ($P < 0.05$), and no significant difference was found among the test samples (Table 5).

The hypoglycemic effect in bee honey-containing products is attributed to the presence of fructose. Fructose has the ability to reduce the rate of intestinal absorption, prolong gastric emptying time, and decrease food intake. Fructose also stimulates glucokinase in hepatocytes, which plays a major role in the uptake and storage of glucose as glycogen in the liver (Hengist *et al.*, 2019). While this study reflects the acute changes in blood glucose response after the consumption of bee honey and the garlic-bee honey product, the long-term effects of the garlic-bee honey combination on human health remain uncertain. Therefore, further research should be conducted on a long-term basis to observe its hypoglycemic impact.

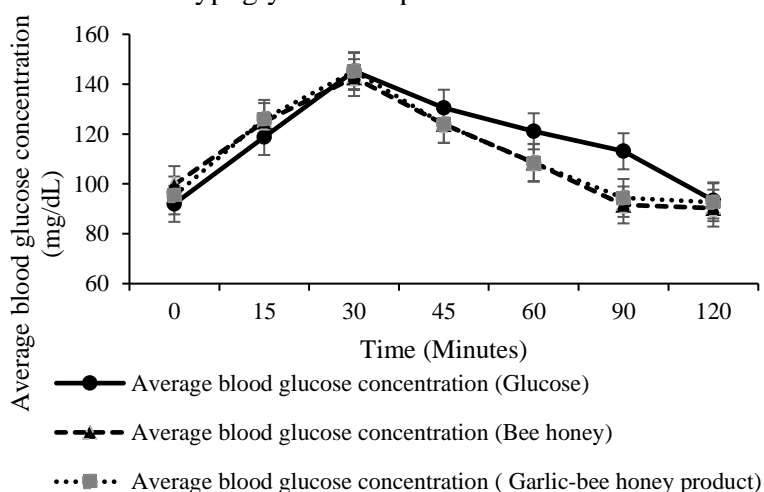


Figure 2: The changes in blood glucose concentration (mg/dL) following the consumption of the reference food and test foods. The reference food is glucose, and the test foods are pure bee honey and the garlic-bee honey product. The error bars indicate the SD of the mean blood glucose concentration at different time points.

3.5 GI and GL of Pure Bee Honey and Garlic-Bee Honey Product

The calculated GI values for pure bee honey and the garlic-bee honey product are $53 \pm 5.80\%$ and $62 \pm 7.25\%$, respectively. According to Student's t-test, there was a significant difference ($P < 0.05$) between the GI values of the garlic-bee honey product and pure bee honey. It's worth noting that garlic contains abundant bioactive sulfur compounds that have the potential to offer benefits in managing diabetes (Saikat *et al.*, 2022). Moreover, garlic can potentially help lower the rise in blood sugar levels after a meal, which is beneficial for managing diabetes and promoting better blood sugar control (Sanie-Jahromi *et al.*, 2023). The GI value obtained in this study was not consistent with those found in previous studies for bee honey, which varies from 32 to 85 (Ilia *et al.*, 2021) This variation could be attributed to differences in sugar composition, processing techniques, variability due to geographical location, climate, and bee foraging patterns.

According to the ISO recommended GI categories, products with a GI value below 55 are considered low GI, those between 55 and 70 fall into the medium GI category, and values above 70

are considered high GI. Therefore, tested products in this study fall into the low GI and medium GI category. Notably, the GI value of common table sugar is 80, classifying it as a high-GI food. In comparison, pure bee honey and the garlic-bee honey product have a low and medium GI value respectively. Both bee honey and garlic are rich in phytochemicals with antioxidant activity (Cianciosi *et al.*, 2018; Koca & Tasci, 2016; Sampath Kumar & Bhowmik, 2010), therefore, with the addition of garlic the increased phytochemical activity may contribute to the lower GI of garlic-bee honey products compared to common table sugar. Therefore, this garlic-bee honey product can be recommended for diabetic patients than table sugar, as oxidative stress is implicated in diabetic development and can be managed by both the hypoglycaemic and antioxidant effects of this product (Burgos-Morón *et al.*, 2019).

While GI measures the blood glucose response to a specific food, it doesn't provide information on the magnitude and duration of glycaemia when consuming a particular amount of carbohydrate-rich food. This is where the GL comes into play, offering a more accurate assessment of a food's real-life impact on postprandial glycaemia. The GL values for an approximate portion size of 12 g per day for pure bee honey and the garlic-bee honey product are 8 ± 0.87 and 10 ± 1.22 , respectively. According to the Student's t-test, there was no significant difference ($P > 0.05$) between the GL values of the garlic-bee honey product and pure bee honey. GL is categorized as high (≥ 20), medium (11 - 19), and low (≤ 10) (Eleazu, 2016). Therefore, the serving portions of both products belong to the low GL category.

Table 5: GI, and GL of pure bee honey and garlic-bee honey product

Parameter	<i>Bee honey</i>	<i>Garlic - bee honey product</i>
GI \pm SE (%)	53 ± 5.80^b	62 ± 7.25^a
GI Category	Low (≤ 55)	Medium (56-69)
GL \pm SE	8 ± 0.87^a	10 ± 1.22^a
GL Category	Low (≤ 10)	Low (≤ 10)

GI: glycaemic index, GL: glycaemic load

GI and GL values are mean \pm SE of 10 subjects. Means in a row having common superscript are not significantly different by 't' test ($P > 0.05$).

4. Conclusions

In conclusion, this research suggests that both bee honey and garlic-bee honey products, with their low postprandial glycaemic potential, could be recommended for diabetic patients, particularly when compared to table sugar (reported GI \approx 80), and due to their reported high antioxidant capacity.

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ENSILING GUINEA GRASS FORAGE WITH *Lactobacillus* INOCULANTS

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Abstract: Lactic acid bacteria (LAB) inoculants are employed to minimize nutrient loss during ensiling and ensure silage quality. Such silage inoculants are not produced locally and are restricted from importation in Sri Lanka. This study evaluates the impact of locally produced, freeze-dried LAB inoculants containing *Lactobacillus plantarum*, *Lactobacillus rhamnosus*, and *Lactobacillus oris*, isolated from maize, sorghum, and guinea grass silage, respectively, on the ensiling of guinea grass forage. Two experiments were conducted, each designed as a completely randomized design with three replicates. In both experiments, guinea grass, harvested at the 10% flowering stage (19.29% dry matter), was chopped into 10 mm pieces and inoculated with LAB inoculant (10^6 CFU/g fresh fodder). The forage was ensiled in laboratory silos (1L Weck glass jar), with guinea grass without inoculant serving as the control. In the first and second experiments, the forage was ensiled for 2 weeks and 52 weeks, respectively, and assessed for pH and lactic acid content. Additionally, forage ensiled for 52 weeks underwent analysis for organic matter digestibility (OMD) and metabolizable energy content (ME). In comparison to the control, guinea grass ensiled with investigated *Lactobacillus* species exhibited significantly ($P < 0.05$) higher lactic acid content and lower pH values as early as 2 weeks. Guinea grass inoculated with *L. plantarum* recorded exceptionally low ($P < 0.05$) lactic acid content while those inoculated with *L. rhamnosus* recorded exceptionally high ($P < 0.05$) lactic acid content at 52 weeks. Furthermore, guinea grass forage ensiled with, both *L. rhamnosus* and *L. oris* recorded significantly lower ($P < 0.05$) pH values at 52 weeks. Guinea grass inoculated with *Lactobacillus* significantly increased the OMD and ME contents of their silage. In conclusion, this study suggests that locally produced, freeze-dried inoculants with *L. rhamnosus*, and *L. oris* can be effectively utilized to enhance the quality of guinea grass silage.

Keywords: *Lactobacillus plantarum*; *Lactobacillus rhamnosus*; *Lactobacillus oris*; Digestibility, Metabolizable energy, pH, Lactic acid

1. Introduction

Guinea grass (*Megathyrsus maximus* Type A) is naturalized, and most abundant forage for feeding dairy cattle in Sri Lanka (Weerasinghe, 2019). The species is considered as medium-quality forage (DM 20.21%, CP 9.14%, in-vitro OMD 40.45 g/kg DM, (de Moura Zanine et al., 2018). Additionally, the growth and yield of the grass depend on the bimodal monsoon rainfall pattern of the country. Therefore, conservation of guinea grass during excess seasons would be one of the potential strategies to overcome the nutrient deficiency of dairy cows. Forage ensiling is primarily driven by lactic acid bacteria (LAB), which anaerobically ferment water-soluble carbohydrates in forage resulting in organic acids. Strong lactic acid reduces the pH value of forage thereby preserve the quality of forage. Forage ensiling largely influenced by LAB, and therefore, changes in microbial community play a crucial role in silage fermentation (Driehuis et al., 2018). Epiphytic LAB naturally present on forage crops are responsible for silage fermentation and also influences silage quality (Cai et al., 1998). Production of high-quality silages in tropical environment is challenging due to the low density of naturally occurring epiphytic LAB and low level of water-soluble carbohydrate (WSC) in forages (Khota et al., 2016). In addition, inadequate fermentation and contamination have the potential to introduce pathogenic or undesirable microbes to silage (Queiroz et al., 2018). Lactic acid bacteria inoculants are commonly employed to enhance silage quality by optimizing the fermentation process and enhancing the aerobic stability of the silage. Guinea grass forage inoculated with epiphytic LAB isolated from guinea grass at 105 CFU/g reduced the pH value within 14 days post-ensiling (Pasebani et al., 2011). Importation of forage ensiling microbial inoculants to Sri Lanka is strictly restricted by the biodiversity concerns of the government. The present experiment investigated the influence of inoculation of freeze-dried LAB produced from *Lactobacillus plantarum*, *L. rhamnosus* and *L. oris* isolated locally from maize, sorghum and guinea grass silage, respectively on silage quality of guinea grass.

2. Materials and Methods

The experiment was conducted at the laboratories of the Department of Animal Science, University of Peradeniya and Veterinary Research Institute (VRI), Peradeniya. Guinea grass forage re-grown 6 weeks after harvesting to approximate 60-70 cm height was harvested. The fresh forage was chopped into pieces of about 15 - 20 mm in length using a commercial forage chopper. The fresh chopped forage had 19.29% dry matter (DM). Freeze-dried *L. plantarum*, *L. rhamnosus* and *L. oris* inoculants produced by isolating the species from maize, sorghum and guinea grass silage, respectively in our previous experiment (Dissanayake et al., 2022) were used in the treatments. Viability of the freeze-dried *L. plantarum*, *L. rhamnosus* and *L. oris* inoculants were 3×10^9 CFU/mL, 1.6×10^9 CFU/mL and 3.4×10^9 CFU/mL, respectively. The experiment was conducted as a complete randomized design (CRD) with 3 replicates ($n=3$). Each freeze-dried inoculant was dissolved in 15 mL deionized water and sprayed on 1 kg fresh, chopped forage at 106 CFU/g of fresh fodder concentration. The control was sprayed with deionized water (15 mL/ kg fresh forage) without any inoculant. The inoculated forage was pressed into airtight 1L Weck glass jars (Laboratory silo) and ensiled at room temperature (25 - 30° C). The silos were opened at 2 weeks and 52 weeks post-ensiling stages and the pH value (AFIA, 2011) and DM, lactic acid (Barnett, 1951) and soluble carbohydrate (AFIA, 2003) contents were determined. The organic matter digestibility (OMD) and metabolizable (ME) content were also determined in forage ensiled for 52 weeks. The data were subjected to analysis of variance (ANOVA) procedures ($P<0.05$). Means were separated by Duncan's multiple range test ($P<0.05$).

3. Results and Discussion

Guinea grass provides invaluable roughage source for feeding dairy cattle in Sri Lanka. High forage yield, perennial growth, low aerobic deterioration of silage, and potential to improve the silage quality by ensiling with additives are some of the favourable characteristics of the forage (Zanine et al., 2010; Santos et al., 2011). Ensiling of forage containing DM content exceeding 30% ensures favourable fermentation and avoids undesirable fermentation by *Clostridia* (Ashbell and Weinberg, 2003). The low DM, water-soluble carbohydrate, and energy content and high buffering capacity are the major inferior qualities of the guinea grass for silage production

(Santos et al., 2013). Pre-ensile guinea grass forage used in the present study had relatively low DM content (19.29%). Microbial inoculants used to influence the quality parameters of silage including lactic acid content and pH value. They often accelerate forage ensiling by enhancing acidification, thereby lowering the pH value in silage (Weinberg and muck,1996). The effect of inoculation of guinea grass forage at 10⁶ CFU/g fresh matter concentration on lactic acid content and pH value at 2 weeks and 52 weeks ensiling has been presented in Table 1.

Table 1: Effects of *Lactobacillus* inoculation (10⁶ CFU/g fresh forage) on lactic acid content and Ph value of Guinea grass silage

Inoculated <i>Lactobacillus</i> species	2 weeks ¹						52 weeks ¹					
	Lactic acid content (%)			pH value			Lactic acid content (%)			pH value		
<i>Lactobacillus plantarum</i>	14.705	±	0.145a	4.900	±	0.030b	0.595	±	0.075c	5.670	±	0.001a
<i>Lactobacillus rhamnosus</i>	15.044	±	0.603a	4.845	±	0.275b	17.015	±	0.465a	4.960	±	0.001c
<i>Lactobacillus oris</i>	14.443	±	0.289a	5.225	±	0.115b	3.220	±	0.150b	4.570	±	0.001d
Without inoculum (Control)	0.9020	±	0.187b	5.600	±	0.230a	2.675	±	0.485b	5.520	±	0.001b

¹, Mean ± SE.
Means within a column followed by different lower-case letters are significantly different (P<0.05).

Guinea grass inoculated with *Lactobacillus* species recorded significantly (P<0.05) higher lactic acid content compared to the forage ensiled without inoculation (i.e. control). Greater lactic acid formation has resulted in significantly (P<0.05) low pH value in the inoculated silage at 2 weeks ensiling. However, at 52 weeks ensiling, extremely low (P<0.05) lactic acid content and the highest (P<0.05) pH value was reported in the silage inoculated with *L. plantarum*. They were not effective in improving the quality of ensiling guinea grass. Lin et al. (1992) also reported that inoculants are not always successful in improving silage quality. Further, at 52 weeks ensiling, the observation of low lactic acid content associated with low pH value in silage inoculated with *L. oris* provides evidence for the formation of organic acid other than lactic acid by the species. An experiment conducted in our laboratory reported the presence of *L. oris* in guinea grass silage for the first time (Dissanayake et al., 2022). *Lactobacillus oris* isolated from the experiment was used to produce the inoculant for the present experiment. The fermentation pathways of tropical forage silage were different from those of temperate silage and the factors responsible for preservation are not fully understood (Miller et al., 1966). However, Panditharathna (1984) suggested that acetic acid rather than lactic acid may be the main preservative in tropical forage ensiling process. Unfortunately, organic acids other than lactic acid were not analysed in the present experiment. The pH values recorded in the present experiment are comparable with those reported for guinea grass silage (i.e. 5.04) which inoculated with *L. plantarum* (Santos et al., 2014)). The pH value reflects the ultimate acidity of the ensiled product and thus serves as a key indicator of both ensiling efficiency and quality of silage. Low pH value in silage often associated with poor silage intake and stability in rumen digestion. Contrary, higher pH value in silage frequently associated with elevated ammonia nitrogen content, resulting in low silage intake and compromise preservation ability (Whiter and Kung, 2001). During the forage ensiling process, rapid acidification is always a favourable characteristic of microbial inoculants as it preserves silage by inactivating plant proteases and reducing the growth of pathogenic and spoilage microorganisms (Dunière et al. 2013).

Guinea grass inoculated with *Lactobacillus* significantly (P<0.05) increased the OMD and ME contents of silage at 52 weeks (Table 2). In commercial silage production, *Lactobacillus* inoculants are used to

increase the ratio of lactic acid to acetic acid, to reduce proteolysis, and to increase dry matter recovery. Rapid lowering of pH value by lactic acid reduces proteolytic enzyme activity and thereby prevents break down of forage proteins during ensiling. Nevertheless, in-vitro responses of microbial inoculants on OMD greatly depends on the species or strain of microorganism, and the substrate (Aydin and Denek, 2023). The key determinant of successful microbial inoculants is the compatibility of ensiling forage and microorganisms (Muck, 1988). Compared to the present experiment, greater in-vitro OMD (60.1 %) reported for guinea grass silage (Panditharathna,1984) may be due to the differences in the stage of maturity of the ensiling forage which greatly influence both fermentation characteristics and the nutritive value of the post ensiled material.

Table 2: Effect of *Lactobacillus* inoculation (10⁶ CFU/g fresh forage) on organic matter digestibility (OMD) and metabolizable energy content (ME) of Guinea grass silage at 52 weeks ensiling

Inoculated <i>Lactobacillus</i> species	OMD (%)			ME content (MJ/kg DM)		
<i>Lactobacillus plantarum</i>	33.540	±	0.643a	4.833	±	0.097a
<i>Lactobacillus rhamnosus</i>	32.406	±	0.255a	4.653	±	0.037a
<i>Lactobacillus oris</i>	32.793	±	0.860a	4.703	±	0.132a
Without inoculum (Control)	29.926	±	0.673b	4.246	±	0.130b

¹, Mean ± SE.
Means within a column followed by different lower-case letters are significantly different (P<0.05).
Dry matter and crude protein percentage of silage ranged between 12.32% to 18.10% and 6.89% to 8.88%, respectively.

Lactobacillus plantarum, *L. rhamnosus* and *L. oris* inoculants produced in the present study had been isolated from maize, sorghum and guinea grass silage (Dissanayake et al., 2022). Microbial inoculants produced from the strains selected from environments different to the environment harvested the ensiling forage as well from different forage cultures can perform well in ensiling forages (Puntillo et al. 2020). Therefore, *L. plantarum*, *L. rhamnosus* and *L. oris* inoculants which produced silage with significantly (P<0.05) low pH as early as 2 weeks and showed significant increase *in-vitro* OMD and ME would be better options for ensiling guinea grass.

4. Conclusions

The present study concludes that inoculation of guinea grass forage with freeze-dried *L. rhamnosus* and *L. oris* at 10⁶ CFU/g fresh fodder concentration can ensure rapid drop of pH value during ensiling and potential to improve the quality of guinea grass silage.

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**ANTIFUNGAL ACTIVITY OF *Padina antillarum* AND *Sargassum ilicifolium*
COLLECTED FROM AHANGAMA, SOUTHERN COAST IN SRI LANKA,
AGAINST RUBBER PATHOGENIC FUNGI**

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Abstract: The frequent use of fungicides is unsafe and toxic for living organisms. Antifungal properties of seaweed can be utilized as an alternative remedy to cure fungal pathogenic infections. This research is aimed to study, the antifungal activity of brown seaweeds, *Padina antillarum* and *Sargassum ilicifolium* extracts against rubber pathogenic fungi (*Neopestalotiopsis sp.*, *Corynespora cassiicola*, *Colletotrichum siamense* and *Phellinus noxius*). *P. antillarum* & *S. ilicifolium* were collected from Ahangama, Southern coast in Sri Lanka. Extraction was carried out through maceration technique with 95% ethanol. Antifungal activity was assessed separately by using disc diffusion method including 5 mg/mL, 25 mg/mL, 50 mg/mL, and 100 mg/mL concentration series. After 6 days, *P. antillarum* and *S. ilicifolium* extracts were effective on the inhibition of mycelial growth (MGI) of *Neopestalotiopsis sp.*, *Corynespora cassiicola* and *Colletotrichum siamense* while *Phellinus noxius* was only sensitive to 0.005 mg/mL carbendazim (positive control) and not to either of the used seaweed extract. The strongest inhibition was observed at 100 mg/mL among four species. The highest MGI% (78.34%) was displayed by *Corynespora cassiicola* with *S. ilicifolium* while *Colletotrichum siamense* showed 63.19% with *P. antillarum*. The fungistatic effects of seaweed extract revealed that *Neopestalotiopsis sp.* initiated the growth after 5 days, followed by *Colletotrichum siamense* on 6 days and *Corynespora cassiicola* on 8 days of incubation. Ethanolic extract of both species contained specific phytochemicals such as Glycosides, Saponins, Diterpenes, Tannin, Phenol, and Flavonoids while Alkaloids was available only in *S. ilicifolium* which were analyzed by using preliminary phytochemical tests and Fourier transform infrared – attenuated total reflectance spectroscopy. This study suggested that the *S. ilicifolium* is more effective than *P. antillarum* which provides the highest antifungal activity against rubber pathogenic fungi.

Keywords: Seaweed; Antifungal activity; Phytochemicals; Rubber pathogenic fungi; MGI%

1. Introduction

Seaweeds are benthic organisms ubiquitously distributed along coasts from tropical to polar regions. They belong to Plantae kingdom, which are considered as one of main primary producers. They are structuring species in coastal zones, that alter the environment by modifying light, sedimentation rates and hydrodynamics. Seaweeds are part of food webs and provide ecosystem services such as habitats, food, and refuge to a diversity of associated organisms which are of conservation and economic importance from different trophic levels of apex predators, fish, and invertebrates. In addition, marine seaweeds contribute to the coastal defense by reducing the hydrodynamic energy of waves and maintaining a high bed-level at tidal flats, thus helping to protect those coastal areas from erosion. (Garc *et al.*, 2020).

Numerous metabolites of seaweeds produce bioactive compounds and have been widely acknowledged because of their therapeutic properties for health and disease management. (Rengasamy *et al.*, 2014). Previously, marine macro algae were used only as gelling and thickening agents in pharmaceutical and industries but recently those are being used as products of anticancer, anti-inflammatory, anticoagulant, anti-obesity, antihypertensive, antidiabetic, antioxidant, immunomodulatory, thyroid stimulating, anti-estrogenic, antiviral, antibacterial, antifungal, antiestrogenic, neuroprotective and tissue healing (Stirk *et al.*, 2014). Seaweed is rich in dietary fibers, minerals, proteins, vitamins, peptides, polyunsaturated fatty acids, and antioxidants. Besides sulphated polysaccharide (fucoidan in brown algae), phlorotannin, carotenoids, sulfolipids, auxin, cytokinin, alkaloids, terpenoids, sterols, quinones, flavonoids, oligosaccharides, phenolic compounds, and pigments are found in marine seaweeds (Wang *et al.*, 2013). Natural variability of the composition of bioactive compounds can be linked to evolutionary linkages, ecological and chemical diversification, but these should not be regarded as commercialization barriers. Light, nutrients, pollutants, salinity, CO₂ availability, pH, temperature, and biotic interactions will influence the concentration of bioactive compounds in natural seaweed populations (Maiti *et al.*, 2018).

Seaweed extracts have antifungal properties against different kinds of plant pathogenic fungi. The crude extracts of brown seaweeds of *Sargassum muticum*, *Dictyota bartyreusiana*, *Padina gymospora*, *Chnoospora implexa* and *S. wightii* have shown positive effects for controlling sheath blight disease on rice, caused by *Rhizoctonia solani* in India (Raj *et al.*, 2016). Jayaraj *et al.*, (2008) found that the foliar application of seaweed extracts on carrot leaf blights caused by *Alternaria sp.* and *Botrytis sp.*, having similar effects as fungicide chlorothalonil. Also, commercial extract of *Ascophyllum nodosum* has reduced fungal diseases in greenhouse cucumber (Jayaraman *et al.*, 2011). Ethanolic extract of *S. myricocystum* effectively inhibited the mycelial growth of *Colletotrichum falcatum*, the causative agent of red root disease on sugarcane in India (Ambika and Sujatha, 2015). Generally, brown seaweeds have higher antifungal activity than red and green algae. As it contains many lipophilic compounds such as terpenoids, glycolipids and unsaturated fatty acids more than other algal types. Phenolic compounds of brown algae were responsible for their antifungal action and more soluble in ethanol (De Corato *et al.*, 2017).

Sri Lanka is a tropical island located in the Indian ocean, with an area of 65610 km². Over the past 4 decades, seaweed aquaculture has shown a significant contribution to the Sri Lankan economy, poverty reduction, and food security. Sri Lanka possesses nearly 400 seaweeds species along the coastline, which is estimated to be 1573km. In the 1950s, the most prevalent brown seaweed found in Sri Lanka was an alginates rich *Sargassum* species. Also, *Padina sp.* are highly abundant in Southern coast in Sri Lanka (Nagarajah, 2022).

The brown seaweed *Padina antillarum* and *Sargassum ilicifolium* are commonly found algal flora highly inhabiting in the Southern coast of Sri Lanka mainly Ahangama reef area. To the best of knowledge and availability of literature, no studies were found regarding the antifungal activity against the rubber pathogenic fungi of these seaweeds located in Southern coastal waters of Sri Lanka.

Rubber (*Hevea brasiliensis*) tree is an angiosperm plant native to the Amazon rainforest that belongs to the Euphorbiaceae family. Among many plant species, *Hevea brasiliensis* is commercially significant because of its ability to generate milky latex with exceptional yield and outstanding physical qualities and suited for using in a wide range of applications (Thaochan *et al.*, 2022). Sri Lanka is the 13th largest rubber producer in the world playing a major role in Sri Lankan economy. Mainly rubber plantations are concentrated in wet zone with a total land area of 12,7500 ha including Kegalle, Gampaha, Rathnapura, Kaluthara, Colombo, Galle districts etc. Sri Lankan rubber industry produces and exports raw rubber as well as a variety of value-added products. Although Sri Lankan rubber renowned for its premium quality. Rubber productivity has declined due to the spreading of different kinds of diseases.

Fungal pathogens are the major disease causative agents in rubber cultivations which can be divided into four categories as leaf, stem, panel, and root diseases (Jayasinghe *et al.*, 2001). There are 5 leaf diseases that cause sever damages to the rubber plant including, *Corynespora* leaf fall (CLF) disease, *Colletotrichum* leaf disease, *Oidium* leaf disease, *Phytophthora* leaf fall (Jayasinghe *et al.*, 2001) and Circular spot leaf disease (CLSD) (Alchemi and Jamin, 2022). Root decaying pathogens caused root diseases and the most economically significant diseases after leaf diseases. There are 2 types of root diseases commonly found in Sri Lanka as white root disease and brown root disease. The most popular method of controlling fungal diseases in rubber plantations is the use of fungicides. Commonly used fungicides are mancozeb, benzomyl, captan, propineb, Cu based chemicals, Sulphur dust, thiram, carbendazim, thiophanate methyl, tebuconazole, hexaconazole etc., (Jayasinghe *et al.*, 2001). However, concerns about the adverse effect of commercial fungicides have sparked interest in alternative approaches as intensive use of fungicides raises the possibility of fungicide residues after being ingested by animals lived in relevant areas. It will cause negative effects on biodiversity, by decreasing the soil microbial biomass and activity and being toxic and unsafe for living organisms. Hence, there is a critical need to introduce eco-friendly fungicides as a substitute for synthetic fungicides at present (Wu, Chang and Shen, 2023).

Therefore, the present study was designed with the aim to evaluate the presence of antifungal activity in brown seaweeds, *Padina antillarum* & *Sargassum ilicifolium* extracts against commonly found rubber pathogenic fungi (*Neopestalotiopsis* sp., *Corynespora cassicola*, *Colletotrichum siamense* and *Phellinus noxius*) representing the first investigation of its kind.

2. Materials and methods

2.1 Collection of seaweed

Specimens of brown seaweeds *Padina antillarum* & *Sargassum ilicifolium* were collected on August 10th 2024 from the littoral zone of rocky shorelines in Ahangama, (5° 58' 40" N, 80° 22' 28" E), Southern coast of Sri Lanka. In the field thalli were washed well to remove any epiphytes and sand particles, kept in sterile clean plastic box, and transported chilled in the ice box to Post-harvest laboratory of Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna. Collected seaweed were washed well again in the lab using tap water to be completely free from any debris, salt and sand particles, and air dried at room temperature for 2 weeks. Then the dried seaweed powder was made by grinding to 0.5 mm particle size. The product was stored in the freezer at -20°C.

2.2 Preparation of seaweed extract

The maceration method was used for the preparation of both *P. antillarum* & *S. ilicifolium* extracts according to Amara *et al.*, 2012. The pulverized seaweed of *P. antillarum* & *S. ilicifolium* crude were extracted by using 95% ethanol as its solvent. 50.0 g of dry powdered seaweed was mixed with 200 mL of 95% ethanol (1:4 W/V) in a glass beaker and mouth of the beaker was covered to avoid evaporation. It was shaken at 27°C for 3 days by using magnetic stir 200 rpm to ensure the better extraction of compounds to solvent. The extract was filtered through a grade 2 Whatman filter paper. The extracted

was concentrated by using rotary evaporator under reduced pressure at 60°C. Then crude was stored in a sterilized sealed glass container in darkness and kept in refrigerator until further use.

2.3 Determination of extraction yield

The percentage of yield of extracted material obtained from two seaweed species was calculated by using the following formula (Elnabris *et al.*, 2022).

$$\% \text{ Yield} = [(\text{weight of dried crude extract}) / (\text{weight of dried seaweed sample})] \times 100$$

2.4 Preliminary phytochemical screening

Phytochemical screening of both extracts was done for Alkaloids, Tannins / Phenol, Flavonoids, Quinones, Diterpenes, Glycosides and Saponins according to the method described by Variou, (2014) with slight modifications.

2.5 FTIR-ATR characterization analysis of seaweed extracts

Seaweed crude samples were analyzed using Fourier transform infrared – attenuated total reflectance spectroscopy (FTIR-ATR) to identify functional groups of bio active compounds found in two seaweed samples. For this analysis, 1.0 mg of samples were obtained. The attenuated total reflectance infrared absorption spectra of the samples were 525 -4000 cm^{-1} and 32 scans were recorded at a resolution of 4 cm^{-1} .

2.6 Preparation of treatments

One gram of dried seaweed crude extract was dissolved in 10 mL of distilled water to prepare 100 mg/mL stock solution. By diluting this stock solution, other concentrations that were used for the experiments were prepared.

Table 1: List of treatment used for the study.

Treatment	Description
PT1	5 mg/mL of <i>P. antillarum</i> crude extract
PT2	25 mg/mL of <i>P. antillarum</i> crude extract
PT3	50 mg/mL of <i>P. antillarum</i> crude extract
PT4	100 mg/mL of <i>P. antillarum</i> crude extract
ST1	5 mg/mL of <i>S. ilicifolium</i> crude extract
ST2	25 mg/mL of <i>S. ilicifolium</i> crude extract
ST3	50 mg/mL of <i>S. ilicifolium</i> crude extract
ST4	100 mg/mL of <i>S. ilicifolium</i> crude extract
PCT (Positive control)	0.005 mg/mL Carbendazim
NCT (Negative control)	Distilled water

2.7 Obtaining test organisms

The test organisms (fungal species) used in this study *Neopestalotiopsis sp.*, *Corynespora cassiicola*, *Colletotrichum siamense* and *Phellinus noxius* were obtained by the Rubber Research Institute, Agalawatta in Sri Lanka. These fungal strains were cultured in the prepared potato-dextrose agar (PDA) media.

2.8 Antifungal assay

Screening of the antifungal activity of *P. antillarum* and *S. ilicifolium* crude extracts were performed by using the agar disc diffusion assay with slight modifications of Mohamed and Saber, 2019. Firstly,

the sterilized filter paper discs (6mm) were soaked in relevant treatment. Then it was placed on PDA media near relevant mark. Then 6mm holes were aseptically punched from the relevant fungal species by using a sterile cork borer and it was placed on the opposite side of the filter paper disc. All the plates were sealed with parafilm. This assay was carried out for triplicates for each treatment. Then, distance of fungal growth was measured by using vernier caliper after six days. The inhibitory effect of the extract on the mycelial growth of the fungi was calculated for each concentration by using the following formula.

$$\text{MGI (\%)} = \left(\frac{dc - dt}{dc} \right) \times 100$$

where MGI: the mycelial growth inhibition, dc: the mean linear distance (mm) of the fungal mycelial growth in the control treatment, and dt: the mean linear distance (mm) of the fungal mycelial growth, extract-containing treatment (Pourakbar *et al.*, 2021).

2.9 Fungistatic effect of extract

At the end of the trials, another experiment was conducted on the eight treatments in which highly inhibited treatments to determine whether extracts had killed the fungi or had inhibited their growth temporarily. In this experiment, a fresh PDA culture medium was prepared and plugs which were taken from inhibited zones were transferred into fresh PDA plates. The petri dishes were placed under room temperature at 27°C and re-checked after 8 days.

2.10 Statistical analysis

The obtained results were analyzed by using ANOVA with IBM SPSS 25 software. The mean values were compared with Tukey's honestly significant (Tukey's HSD) test as post hoc test at 5% probability level. Results were expressed in the average of three replications \pm standard deviation. Additionally, graphs were drawn in MS-Excel.

3. Results

3.1 Determination of extraction yield

50 g of dried seaweed extracted with ethanol (95%) yielded both seaweed extracts residues ranging from 1.2 to 1.9 g. The highest percentage of the yield was obtained from *P. antillarum* (3.611 \pm 0.03) followed by *S. ilicifolium* having the yield (2.519 \pm 0.03).

3.2 Phytochemical screening of seaweed extracts

The results for phytochemical screening of seaweed extracts revealed that the presence of glycosides, saponins, diterpenes, tannin/phenol, flavonoids in both extracts whereas quinones were not found in the extracts. In addition to that ethanolic extract of *S. ilicifolium* was found with less availability of alkaloids. Diterpenes and saponin showed the maximum presence in ethanolic extracts of both *P. antillarum* and *S. ilicifolium*.

3.3 FTIR-ATR characterization analysis of seaweed extracts

Fourier transform infrared-ATR analysis was performed to obtain more information on the functional groups of bioactive compounds in both seaweed extracts. Figure 1 shows the IR spectra of *P. antillarum* and *S. ilicifolium* used for comparison between them. Twelve important bands were detected from 620 to 3400 cm^{-1} the comparison was carried out between transmittance and wavenumber. The anomeric region of carbohydrate was between 947-811 cm^{-1} (Sellimi *et al.*, 2015). The alginic FTIR spectra showed typical alginic acid peaks, which indicate the mannuronic and guluronic acid (878.52 cm^{-1} and 878.37 cm^{-1}). Another peak was detected at near 1045 cm^{-1} (1043.46 and 1044.86 cm^{-1}), representative of C-O-C skeletal vibrations and at 1080 cm^{-1} (only *S. ilicifolium*) a vibration of C-O-C structure of polysaccharides (Díaz-Vázquez *et al.*, 2015). Likewise, a shoulder at 1162.22 and 1165.41 cm^{-1} were detected, corresponding to vibrations of C-O saturated alcoholic constituents. A medium intensity peak

was displayed at 1378.25 and 1377.99 cm^{-1} in both extracts representative symmetric deformations in CH_2 in proteins and $\text{N}(\text{CH}_3)$ methyl bending in lipids (Zapata *et al.*, 2021). 1455.22 cm^{-1} wavenumber visualized by only *S. ilicifolium* which detected C-H bending vibrations and a scissoring vibration of CH_2 or an asymmetric bending vibration of CH_3 of fucose (Rashedy *et al.*, 2021). Similarly, peaks at 1645.03 cm^{-1} and 1633.09 cm^{-1} representing the stretching vibrations of C=O of protein amide (Zapata *et al.*, 2021). At 1721.47 cm^{-1} corresponds to C=O vibrations was attributed to aldehyde groups showing the possibility that the terpenoids in *S. ilicifolium*. The bands at 2800-3000 cm^{-1} were related to triple bonds in alkynes and those vibrations might be derived from water soluble compounds such as flavonoids and terpenoids in both extracts. A prominent peak visualized at 3000-34000 cm^{-1} was attributed to O-H stretching vibrations of hydroxyl functional groups in carboxylic, phenolic, and alcoholic constituents (Díaz-Vázquez *et al.*, 2015).

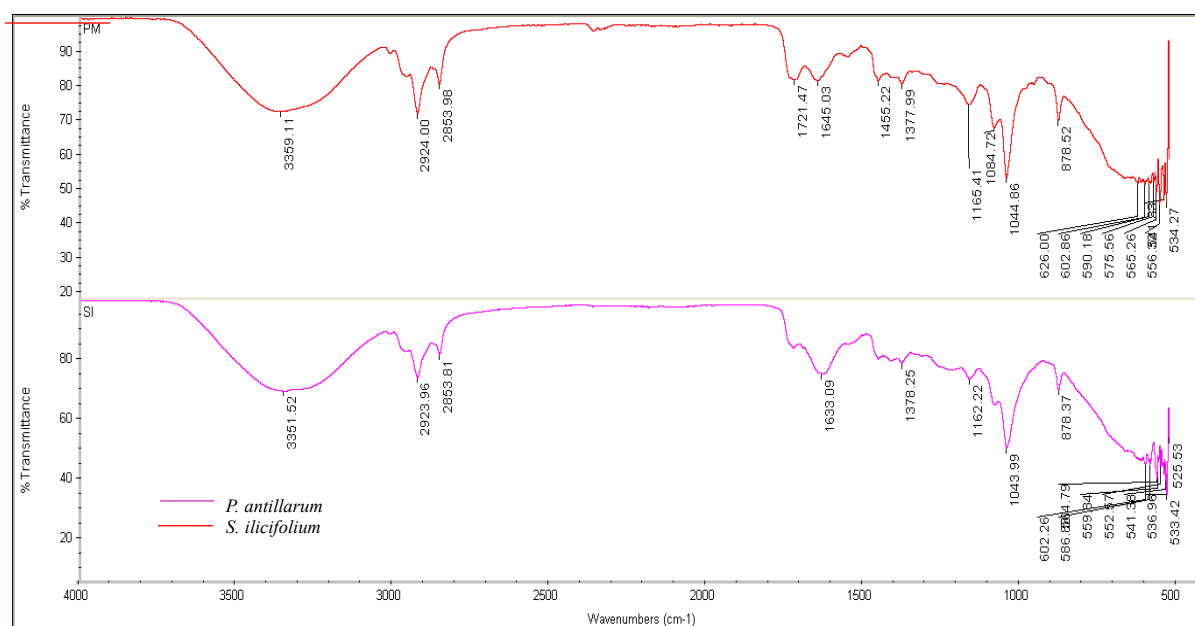


Figure 1: ATR-FTIR spectra, plotting wavenumber (cm^{-1}) by %transmittance, for *P. antillarum* and *S. ilicifolium* crude extracts.

3.4 Evaluation of antifungal activity of the crude ethanol extract of *Padina antillarum* against rubber pathogenic fungi.

3.4.1 Inhibitory effectiveness of different fungal species

After 6 days, there were significant differences in the MGI%, which indicates the differences in the antifungal capacities of different treatments for *Neopestalotiopsis sp.* The maximum activity was observed from PT4 (100 mg/mL). It showed 61.28% inhibition which was significantly different from the other four treatments. The minimum value was observed from PT1 (5mg/mL), that showed 18.45% and -8.47% inhibition with respect to negative and positive controls (Figure 2A).

Corynespora cassiicola has similarly effective in reducing mycelial growth as *Neopestalotiopsis sp.* It showed the highest inhibition percentage (52.27 %) in PT4, and lowest inhibition percentage (0.88%) was found in PT1, which was lower than the MGI% of positive control (Figure 2B). Consequently, all the MGI% were significantly different in five treatments. However, mycelial growth inhibition percentage values of *Corynespora cassiicola* were lower than MGI% values of *Neopestalotiopsis sp.* comparatively.

P. antillarum crude seaweed extract showed best results in PT4 having 63.19% (Figure 2C) inhibiting on *Colletotrichum siamense* and it exerts fungicide (0.005 mg/mL carbendazim) affect with 53.13%. PT4 was significantly different from all other treatments, despite there was no significant difference between PT1 and PCT. Minimum inhibition percentage was observed in PT1, which represented 21.74% and 0.66% of MGI% negative and positive controls respectively.

Phellinus noxius didn't display any inhibition with the crude extract of *P. antillarum* but still significant inhibition (25.32%) was found on PCT (Figure 2D).

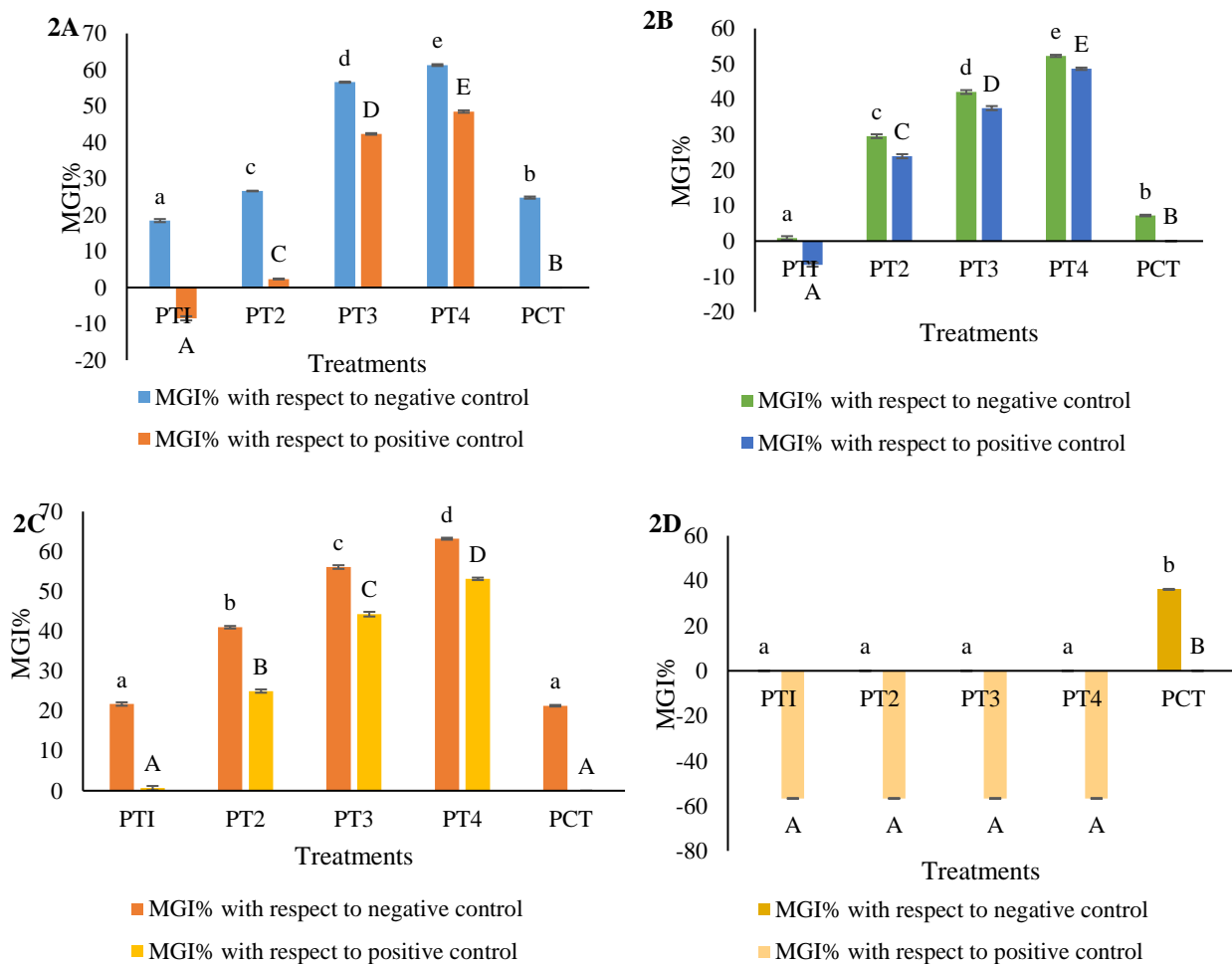


Figure 2: Inhibitory effectiveness of *P. antillarum* with different fungal species.

2A; MGI% of *Neopestalotiopsis sp.*, 2B; MGI% of *Corynespora cassiicola*, 2C; MGI% of *Colletotrichum siamense*, 2D; MGI% of *Phellinus noxius* (Mean of three replicates \pm SD with different super-script letters (a,b,c,d,e,f,A,B,C,D,E,F) were significantly different from each other at the $p < 0.05$ level based on Tukey test).

3.4.2 Inhibitory effectiveness of different concentrations

Extract of 5 mg/mL *P. antillarum* has induced inhibition of mycelia growth 18.45%, 0.88%, 21.74%, 0% with respect to negative control and -8.47%, -6.67%, 0.66%, -56.69% (Figure 3A) with respect to 0.005 mg/mL Carbendazim on cultures of *Neopestalotiopsis sp.*, *Corynespora cassiicola*, *Colletotrichum siamense* and *Phellinus noxius* respectively. However, with the comparison of the MGI% all

values are significantly different from each other. Contrarily to this, lowest inhibition was instead seen on for all fungi with 5 mg/mL dose of extract.

The highest reduction of mycelial growth being (41%) (Figure 3B) was observed in 25 mg/mL of *P. antillarum* crude extract against *Colletotrichum siamense*, while the lowest value being 0% in *Phellinus noxius*. The MGI% of 4 species of fungi at 25 mg/mL (PT2) were significantly different from each other.

According to the MGI% with respect to negative control displayed similar effectiveness between isolates of *Neopestalotiopsis sp.* and *Colletotrichum siamense*. Hence there was no significant difference observed between them statistically. The highest inhibition (56.67%) was reported on *Neopestalotiopsis sp* while the lowest 0% was displayed *Phellinus noxius* respectively. However, considering the MGI% represented with respect to positive control, all values were significantly difference from each other (Figure 3C).

Neopestalotiopsis sp., *Corynespora cassicola*, and *Colletotrichum siamense* were displayed best results at 100 mg/mL (PT4) dose. The strongest inhibitory effect was displayed in *Colletotrichum siamense* (63.19%) having the lowest value (0.00%) was displayed *Phellinus noxius* (Figure 3D). In addition to that antifungal activity of 100 mg/mL *P. antillarum* extract against *Corynespora cassicola*, and *Neopestalotiopsis sp.* was found more than 50% and 48% on mycelial growth inhibition with respect negative control and positive control. MGI% with respect to negative control displayed similar effectiveness between isolates of *Neopestalotiopsis sp.* and *Colletotrichum siamense* and MGI% with respect to positive control displayed similar effectiveness between isolates of *Neopestalotiopsis sp.* and *Corynespora cassicola*. Hence there wasn't significant difference between them statistically.

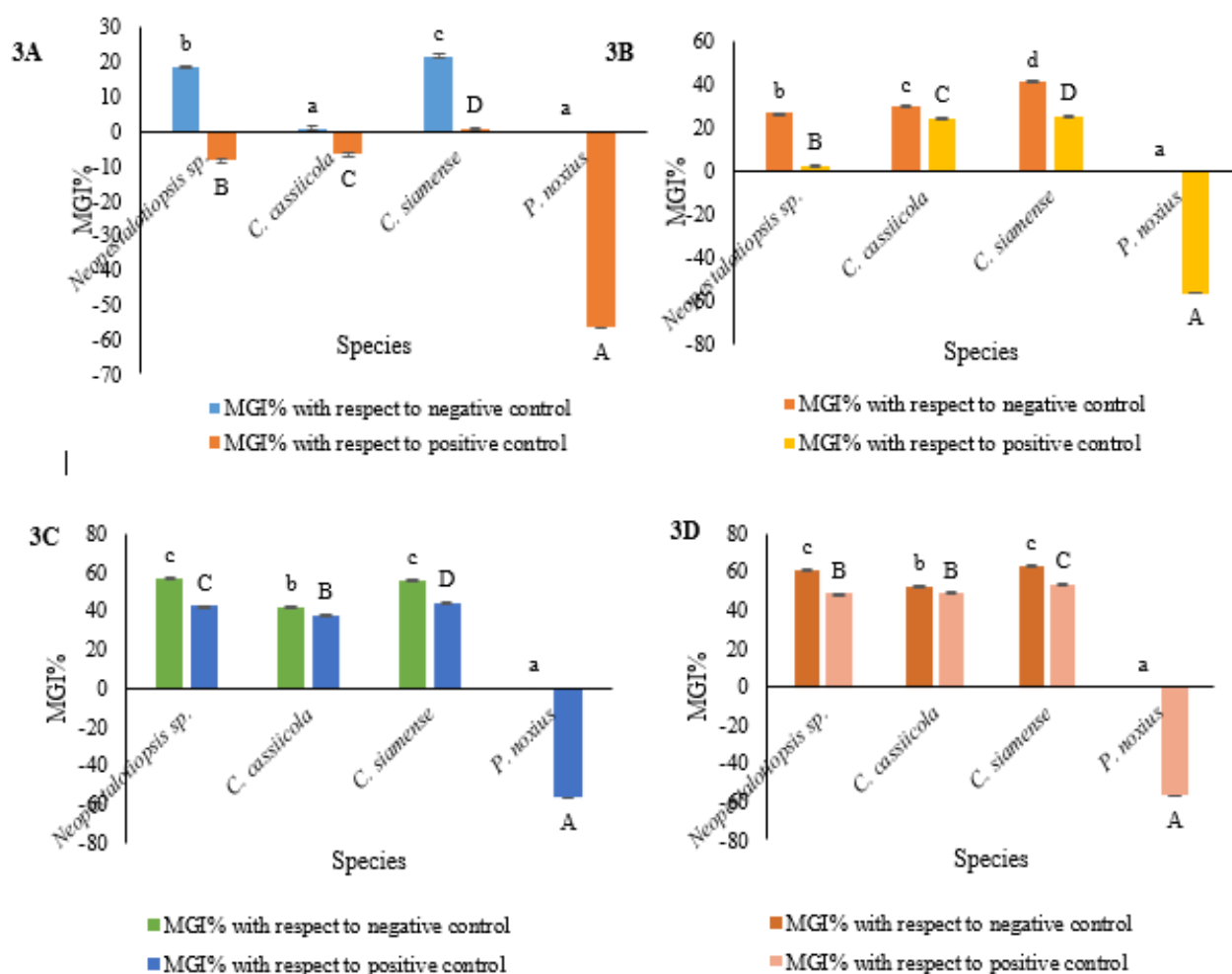


Figure 3: Inhibitory effectiveness of different treatments of *P. antillarum*.

3A; MGI% of 5 mg/mL (PT1) with 4 fungal species, 3B; MGI% of 25 mg/mL (PT2) with 4 fungal species, 3C; MGI% of 50 mg/mL (PT3) with 4 fungal species, 3D; MGI% of 100 mg/mL (PT4) with 4 fungal species. (Mean of three replicates \pm SD with different superscript letters (a,b,c,d,e,f,A,B,C,D) were significantly different from each other at the $p < 0.05$ level based on Tukey test).

3.5 Evaluation of antifungal activity of the crude ethanol extract of *Sargassum ilicifolium* against rubber pathogenic fungi.

3.5.1 Inhibitory effectiveness of different fungal species

As shown in Figure 4A, the maximum activity was observed from ST4 (100 mg/mL). It showed 73% and 64.05% inhibition with respect to negative and positive controls which were significantly different from other four treatments. The minimum MGI% was observed from ST1 (5mg/mL), that shows 25.03% and 0.49% inhibition with respect to negative and positive controls, while there is no significant difference with PCT and significantly differ from other 3 treatments.

After 6 days, the highest inhibition percentage was indicated (78.34 %) in ST4 and lowest inhibition percentage (21.48%) in ST1 was found with respect to negative control (Figure 4B). Consequently, all the MGI% with respect to positive & negative controls are significantly different between five

treatments. *Corynespora cassiicola* was the highest sensitive pathogen to the antifungal effect of *S. ilicifolium* seaweed extract.

S. ilicifolium crude seaweed extract showed best results in ST4 having 63.19% inhibiting on *Colletotrichum siamense* and it exerts fungicide (0.005 mg/mL carbendazim) affect with 53.13% (Figure 4C), which was significantly different from all other treatments. Minimum inhibition percentage was observed in ST1, which represented 21.03% and -1.26% of MGI% with respect to the negative and positive controls and that was statistically significant difference with other four treatments.

According to all treatments conducted to study, the inhibitory effect of seaweed extract fraction tested at different concentrations on mycelial growth, reduced antifungal activity was observed against *Phellinus noxius* with 100 mg/mL treated with *S. ilicifolium* crude seaweed extract with 0.00% (Figure 4D) with respect to negative control. Finally, no antifungal activity was observed after being treated with both ethanol fraction of *S. ilicifolium* and *P. antillarum* in the same conditions.

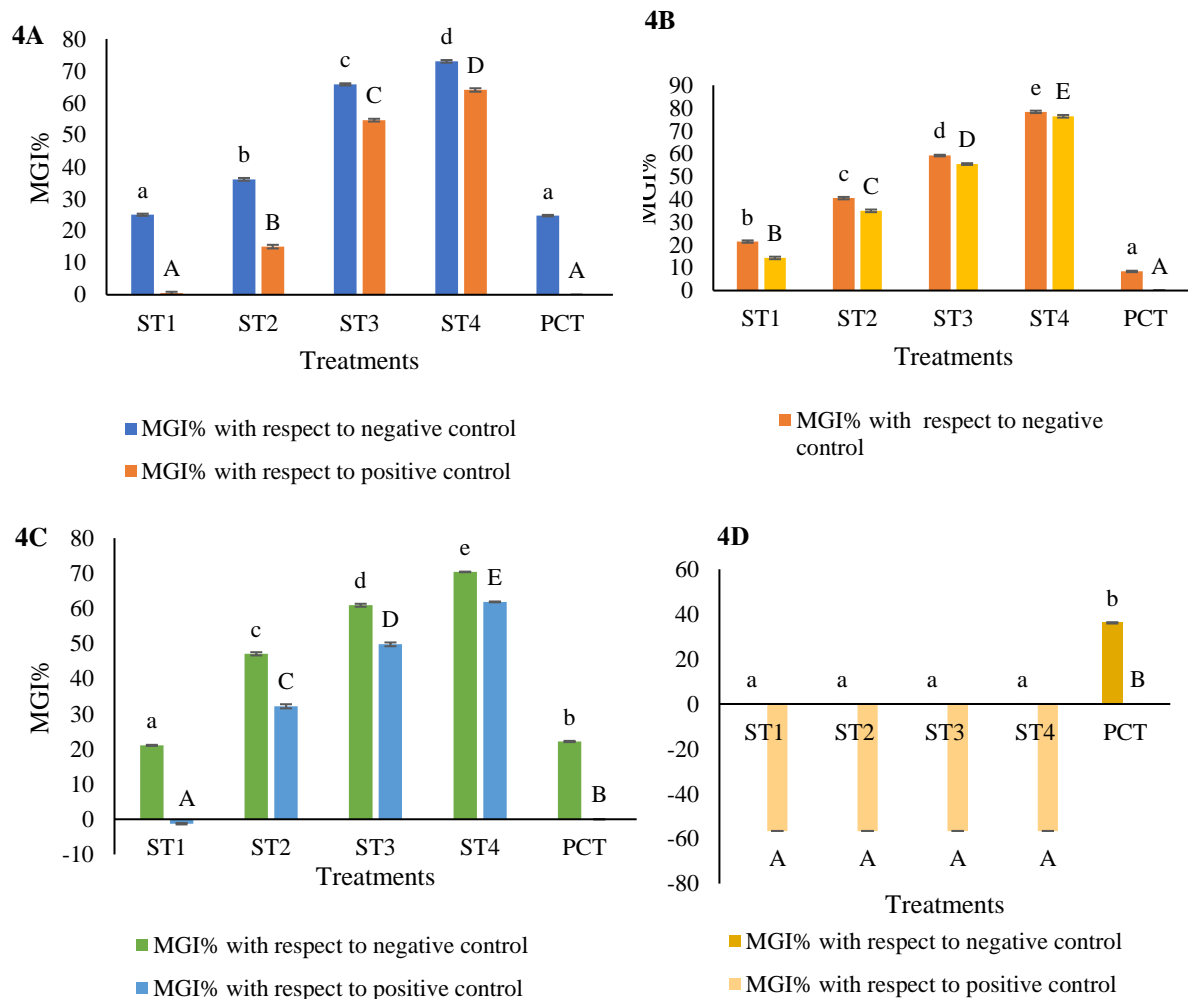


Figure 4 : Inhibitory effectiveness of *S. ilicifolium* with different fungal species.

4A; MGI% of *Neopestalotiopsis sp.*, 4B; MGI% of *Corynespora cassiicola*, 4C; MGI% of *Colletotrichum siamense*, 4D; MGI% of *Phellinus noxius* (Mean of three replicates \pm SD with different superscript letters (a,b,c,d,e,f,A,B,C,D) were significantly different from each other at the $p < 0.05$ level based on Tukey test).

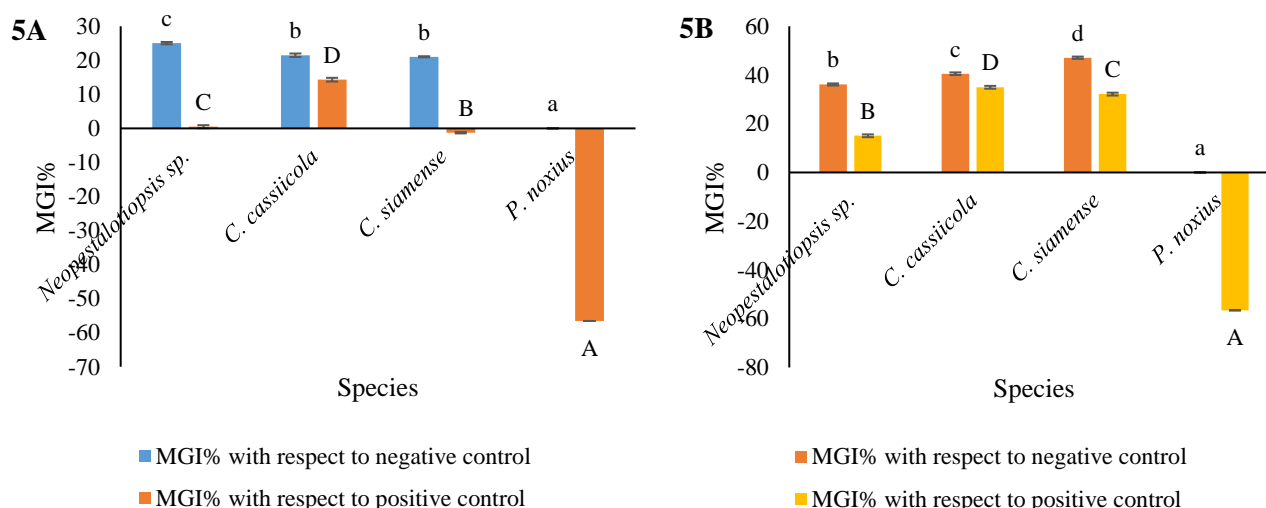
3.5.2 Inhibitory effectiveness of different concentrations

Extract of 5 mg/mL *S. ilicifolium* has induced the inhibition of mycelia growth 25.03%, 21.48%, 21.03%, 0% with respect to negative control and 0.50%, 14.30%, -1.26%, -56.55% with (Figure 5A) respect to 0.005 mg/mL Carbendazim (positive control) on cultures of *Neopestalotiopsis sp.*, *Corynespora cassiicola*, *Colletotrichum siamense* and *Phellinus noxius*. The isolates of *Corynespora cassiicola* and *Colletotrichum siamense* exhibited similar sensitivity and statistically there is no significant difference in MGI% with respect to negative control. MGI% with respect to positive control of four species were significantly different from each other. The highest sensitivity (25.03%) was displayed *Neopestalotiopsis sp.* with ST1. But considering the antifungal activity with respect to positive control *Corynespora cassiicola* displayed higher percentage than *Neopestalotiopsis sp.* Contrarily to this, lowest inhibition was instead seen on for all fungi with 5 mg/mL dose of extract.

The highest reduction of mycelial growth was identified as 47.08% (Figure 5B) in 25 mg/mL of *S. ilicifolium* crude extract against *Colletotrichum siamense*, while the lowest value being (0%) in *Phellinus noxius* respectively. MGI% with respect to positive and negative controls of 4 species at 25 mg/mL (ST2) were significantly different from each other.

According to the MGI% with respect to positive control (Figure 5C) similar effectiveness was observed among the isolates of *Neopestalotiopsis sp.* and *Corynespora cassiicola*. Hence there was no significant difference found between them statistically. Also, there were significant differences between all the MGI% values with respect to negative control and inhibition distances. The highest inhibition was reported on *Neopestalotiopsis sp.* (65.80%) lowest (0%) displayed for *Phellinus noxius* respectively. Contrarily to this, considerable inhibition (more than 50%) was instead seen on *Neopestalotiopsis sp.*, *Corynespora cassiicola*, and *Colletotrichum siamense* with 50 mg/mL dose of extract.

Neopestalotiopsis sp., *Corynespora cassiicola*, and *Colletotrichum siamense* were displayed the best results (more than 70%) at 100 mg/mL (ST4) dose. The strongest inhibitory effect was displayed in *Corynespora cassiicola* (78.34%), while the lowest value was displayed for *Phellinus noxius*. Besides, all MGI% values (Figure 5D) were significantly different from each other.



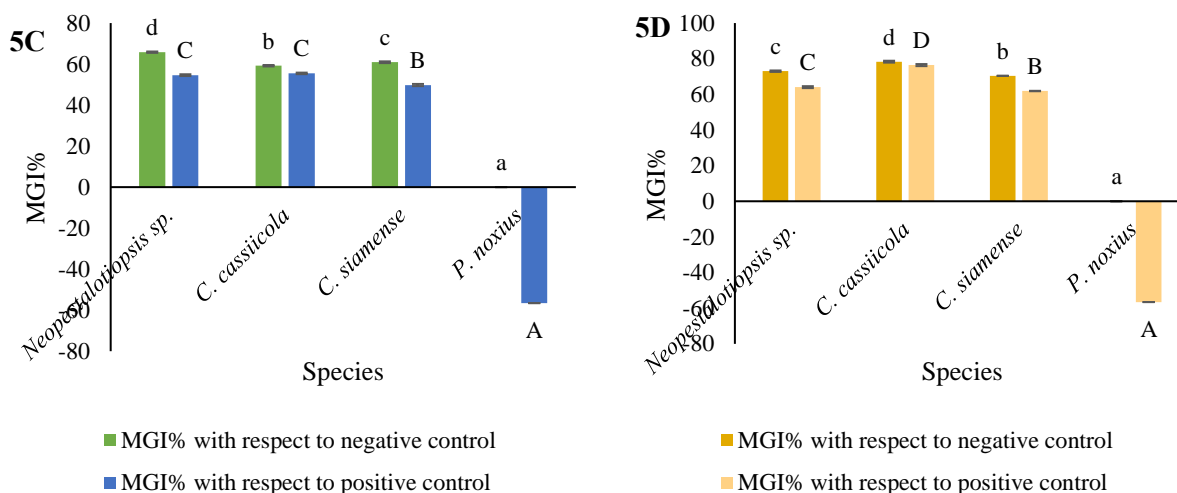


Figure 5: Inhibitory effectiveness of different treatments of *S. ilicifolium*.

5A; MGI% of 5 mg/mL (ST1) with 4 fungal species, 5B; MGI% of 25 mg/mL (ST2) with 4 fungal species, 5C; MGI% of 50 mg/mL (ST3) with 4 fungal species, 5D; MGI% of 100 mg/mL (ST4) with 4 fungal species. (Mean of three replicates \pm SD with different superscript letters (a,b,c,d,e,f,A,B,C,D) were significantly different from each other at the $p < 0.05$ level based on Tukey test).

3.6 Fungistatic effect of the extracts

In the study of fungistatic effects of seaweed extracts at concentrations that more than 70% inhibited mycelium growth, the re-cultures resulting from the transfer of the plugs taken from the end of the inhibition zones to the fresh PDA culture medium showed that the *Neopestalotiopsis sp.*, *Corynespora cassiicola*, and *Colletotrichum siamense* were re-appeared and grew after 5-8 days. The results revealed that *Neopestalotiopsis sp.* was started to grow after 5 days, *Colletotrichum siamense* was started to grow after 6 days and *Corynespora cassiicola* was started to grow after 8 days respectively. During the study period (8 days), mycelium growth in the re-cultures of the fungi were taken from negative controls completely evident from the second day and showed much higher growth at the end of 8 days (*Neopestalotiopsis sp.* - 100%, *Colletotrichum siamense* - 100%, & *Corynespora cassiicola* - 70%).

4. Discussion

Seaweed consists of biologically active compounds which showed inhibitory activity on many pathogenic microorganisms including fungi (Mohamed and Saber, 2019). The variation of antifungal activity may be due to the season and location at which samples were collected, method of extraction and solvent used in extraction (Kandhasamy and Arunachalam, 2008). Most environmental factors like water temperature, salinity, light, and nutrients varied according to the season, which stimulate or inhibit the biosynthesis of several properties include in seaweeds (Lobban *et al.*, 1985). According to the result obtained from Marinho-Soriano *et al.*, (2006), confirmed that contents of seaweeds were higher during the rainfall period. Present study was conducted during the monsoon season in Southern coast and more investigations are needed to identify the variation of bioactive compounds during the monsoon season with the other seasons.

The main objective of any extraction process is to maximize the yield of target compound from the sample while reducing the coextraction of other impurities (Garcia-Vaquero *et al.*, 2018; Tiwari, 2015). Widely used extraction protocols are conventional methods like percolation, Soxhlet extraction, maceration, and steam distillation. These methods were involved extraction of compounds from a solid

medium by using solvents (solid-liquid extraction technique) (Tiwari, 2015; Wang and Weller, 2006). Extraction process of present study was carried out by using maceration technique because it was achieved the extraction of high-value compounds while selecting the polarity of the solvent and applying heat and/or agitation to increase the solubility of relevant compounds. Simultaneously, maceration protocol is easy to operate and low cost than other conventional extraction techniques (Luque de Castro and Priego-Capote, 2010).

Seaweeds produce wide range of bioactive compounds such as polysaccharides, glycoproteins, polyunsaturated fatty acids, saponins, glycosides, tannins, alkaloids sulfolipids, phenolics, terpenoids, peptides and pigments (Wang *et al.*, 2013). In this study 2 tests (FTIR analysis and phytochemical screening test) were carried out to identify bioactive compounds in *P. antillarum* and *S. ilicifolium*. Preliminary phytochemical screening test indicated the presence of saponin, diterpenes, tannin, phenol and flavonoids and absence of quinone in both extracts. In addition to that, the extract of *S. ilicifolium* showed less availability of alkaloids. FTIR spectra of *P. antillarum* and *S. ilicifolium* with various functional groups such as vinyl group, aromatic groups, alkyne, polysaccharides, alcohols, amine, carboxylic acids, sulfonyl group, nitro compounds, amino acids, alkenes, dienes, amine, alkyl group, and secondary amines is revealed in alkaloids, flavonoids, tannins and phenols as reported earlier (Geetha *et al.*, 2019).

The treatment of rubber pathogenic fungi is currently challenging owing to the limited number of available fungicides, increased resistance to those fungicides, high cost and toxicity. Consequently, novel alternative compounds are more effective than conventional antifungal agents. So that it is urgently needed to prevent emergence of fungal resistance by using eco-friendly treatments. Only few studies have assessed the antifungal activity of brown algae found in Sri Lanka.

The antifungal activity of *P. antillarum* and *S. ilicifolium* was examined under disc diffusion method with homemade PDA media. Before commencing the investigation, several trials were conducted to determine the most successful strategy, which may be well diffusion or disc diffusion. According to the trial, the most effective method was identified as disc diffusion. In addition, a few trials were conducted with commercial and homemade PDA, to assess the most successful growth medium for fungal growth. These trails demonstrated that the growth rate of four fungal species was greater in commercial PDA than in homemade PDA. However, as the commercial PDA is very expensive, homemade PDA media was employed as the fungal growth medium in this study.

Previous antifungal experiments were conducted with three replicates on the same plate (Mohamed and Saber, 2019) but we couldn't see the inhibitory zones clearly during the trial time. As a result, three replicates were performed on three plates. The distance of inhibition zones was measured after 6 days in this study because we discovered that *Neopestalotiopsis sp* and *Colletotrichum siamense* were overgrown on the 7th day during the trial period. According to the previous studies (De Corato *et al.*, 2017) 10 mg/mL - 30 mg/mL were selected as the concentration range. However, we were unable to detect significant changes between inhibition zones during the current study's trial time. As a result, it was adjusted to the concentration range to 5 mg/mL - 100 mg/mL. Chemical controlling of fungal pathogens associated rubber plantations has been widely accepted in Sri Lanka and these artificial fungicides effectively destroyed the fungal pathogens (Jayasinghe *et al.*, 2001). Hence, the most popular fungicide, carbendazim was used as the positive control of current study. Also, according to the findings of Rubber Research Institute, 0.005 mg/mL of carbendazim was used as the concentration of positive control.

General coloration of spores of *Colletotrichum siamense* was creamy to pink in color (Oo *et al.*, 2018). However, after 6 days ST4 and ST5 treated plates showed black colored mycelium and same coloration was displayed in repeated treatments also. Therefore 3 plugs were taken from the ST4 and ST5 treated plates and it was cultured in fresh PDA plates. After 6 days it showed creamy ash and pinkish colored spores. Hence spore suspension was done and checked the characteristics of spores by using microscope to confirm the species. As a result, it showed short cylindrical, ovoid, non-septate, falcate, or crescent

shaped conidiophores. According to the literature review (Oo *et al.*, 2018) it was confirmed as *Colletotrichum siamense*. Vegetative appressoria of *Colletotrichum siamense* may cause this coloration (Li *et al.*, 2022).

The antifungal activity of *P. antillarum* and *S. ilicifolium* against four rubber pathogenic fungi differed from each other. The results have revealed that MGI% was increased with the concentration respectively. The highest inhibition was observed at 100 mg/mL among four species. The strongest inhibition was displayed by *Colletotrichum siamense* while 0% inhibition was displayed by *Phellinus noxius* with *P. antillarum*. Also, the highest MGI% was displayed by *Corynespora cassiicola* while 0% inhibition was displayed by *Phellinus noxius* with *S. ilicifolium*. At 5 mg/mL, the MGI% of *Neopestalotiopsis sp.* and *Corynespora cassiicola* was lower than the positive control with *P. antillarum* while MGI% of *Colletotrichum siamense* was lower than the positive control with *S. ilicifolium*. A similar publication of Khompatara *et al.*, 2019 was evaluated *Sargassum polycystum* extract against leaf fall disease caused by *Phytophthora palmivora* in rubber tree seedlings in comparison to the commercial fungicide (1% metalaxyl). The results suggested the seaweed extract and 1% metalaxyl could reduce disease severity by about 50% compared to the positive control. Other studies showed, most of seaweeds stimulate plant defense mechanisms against pathogenic invasions, such as glucuronan and ulvans from the green algae (*Ulva lactuca*) resistance to *Fusarium oxysporum* on tomato seedlings. (Aitouguinane *et al.*, 2020).

The negative control (distilled water) didn't display mycelial growth inhibition which indicates that there was no influence on antifungal activity of crude extract. On the other hand, *Phellinus noxius* was only sensitive to positive control and not to either seaweed extract. The reasons might be that crude concentration of *P. antillarum* and *S. ilicifolium* will be insufficient to prevent mycelial growth, or important chemicals will be lacking in both extracts. The researchers regarding seaweed extract effects on rubber pathogenic fungi limited to few trails and need to investigate further.

5. Conclusion

Biological control of plant fungal disease plays a significant role in plant health and is an inspiring source of new antifungal compounds. It can be concluded that *P. antillarum* and *S. ilicifolium* have a high potential to be used in the fungicide industry to improve plant health owing to its different compounds with antifungal activity.

The inhibitory activity of different treatments of *P. antillarum* and *S. ilicifolium* extract were effective on the inhibition of mycelial growth of *Neopestalotiopsis sp.*, *Corynespora cassiicola* and *Colletotrichum siamense*. While *Phellinus noxius* was only sensitive to positive control and not to either seaweed extract. Fungal mycelial growth was strongly inhibited in 100 mg/mL of seaweed extracts. Furthermore, *S. ilicifolium* seaweed extract was more effective (more than 70% inhibition) than *P. antillarum* and according to the results obtained from FTIR which have higher content of bio active compounds. This may conclude that the *S. ilicifolium* in the southern coastal waters is rich with unique antifungal compounds than *P. antillarum*.

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INCLUSION OF HYBRID NAPIER IN THE PRODUCTION OF FODDER MAIZE SILAGE

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Abstract: Hybrid fodder maize is recognized as a high-yielding and superior-quality forage for silage production in tropical regions. However, its limitations, such as a single harvest, seasonality, and high production costs, have led to the exploration of alternative options. Hybrid Napier, a perennial grass, offers a substantial fodder yield of moderate quality at a lower cost. This research investigates the feasibility of inclusion of hybrid Napier with hybrid fodder maize to produce mixed silage with desirable quality. The study involved harvesting fodder maize at the milk to early dough stage and 60 days regrown Napier. Three silage treatments were arranged (maize alone, maize with 27% Napier, and maize with 50% Napier) as a randomized complete block design. The fodder mixtures were compacted into bales and ensiled for 35 and 45 days, after which the silage quality was analysed. The inclusion of 27% Napier did not significantly ($P>0.05$) reduce the crude protein content of silage, despite a significant ($P<0.05$) reduction in its dry matter percentage. The addition of Napier to maize silage and extended ensiling period, led to an increased ($P<0.05$) lactic acid content in the silage. However, both pure maize and 27% Napier-included silage exhibited less ($P<0.05$) lactic acid content and lower ($P<0.05$) pH values suggesting enhanced production of organic acids other than lactic acid during the ensiling of fodder maize. An increase ($P<0.05$) in ammonia nitrogen and a decreasing trend in crude protein with the higher inclusion of Napier implied enhanced protein fermentation in the Napier included silage, possibly due to fermentation by *Clostridium*. The most ($P<0.05$) digested silage with the highest ($P<0.05$) metabolizable energy was observed in maize silage with 27% Napier, ensiled for 45 days. In conclusion, the study suggests that inclusion of 27% Napier in fodder maize silage is feasible, ensuring an enhanced quality of silage.

Keywords: Crude protein; Dry matter; Ensiling period; Lactic acid, Metabolizable energy; Organic matter digestibility, pH

1. Introduction

The deficiency of the crude protein (CP) and total digestible nutrient (TDN) for animal feeding in Sri Lanka is estimated to be 38.1% and 24.02% of the requirement. As forage can be conserved as silage throughout the year the provision of silage is a potential strategy to overcome the nutrient deficiency of particularly the improved dairy cows.

Maize (*Zea mays* L.) silage is a highly palatable and high-energy forage for all classes of ruminants. Typically, excellent quality maize silage is made from the maize forage harvested when contain 30-35% dry matter (DM). Further, 37.0% DM, 6.8% CP, 11.0 MJ/kg DM metabolizable energy (ME) and 71.9% organic matter digestibility (OMD) has been reported for excellent quality maize silage (Feedipedia, 2024). However, high cost for the importation of hybrid fodder maize seeds, fertilizer, agrochemicals, etc., potential only a single-harvest and seasonality are the limitations for the production of maize silage. On the other hand, hybrid Napier (*Pennisetum purpureum* x *P. Americanum* va. CO3) is a perennial grass which is the second most abundant fodder grass for dairy cattle feeding in the island (Weerasighe, 2019). The cultivar is characterized by profuse tillering ability, high yield potential, quick regrowth capacity, high palatability, free from adverse factors and resistance to pest and disease attacks (Premaratne and Premalal, 2006). Jothirathna et al. (2022) reported that fodder Napier cultivar CO3 is rich in CP (13.7%), while moderate in OMD (50%) and ME (7.3 MJ/kg DM) when harvested at 8 week intervals. In addition, the low level of water-soluble carbohydrate (106-149 g/kg DM) among the Napier hybrids (Manyawn et al., 2003) limits their potential for silage production.

This research was designed to investigate the feasibility of inclusion of hybrid Napier with hybrid fodder maize to produce mixed silage with desirable quality for ruminant feeding.

2. Materials and Methods

The Ethical Clearance Committee of the Faculty of Agriculture approved the conduct of the experiment (ECC/2022/E/048). Forage for silage production was sourced from the DEMO Agro Tech Park, DIMO Agribusiness, Lanka Industrial Estate Ltd. (LINDEL), Lenadora, Dambulla. Fodder maize at the milk to early dough stage and 60 days regrown Napier grass were harvested and chopped into 2-3 cm pieces using a commercial forage chopper. Four forage mixtures (treatments) were prepared as (i) maize alone, (ii) maize with 27% Napier, (iii) maize with 50% Napier, and (iv) maize with 75% Napier. Representative samples of the treatments were analysed for dry matter (DM), ash and crude protein (CP) contents (AFIA, 2003). The fodder mixtures were compacted into 25 kg bales with a density of 485-587 kg/m³. The bales were ensiled for 35 and 45 days at room temperature. The experiment was conducted as a randomized complete block (RCBD) with 4 replicate for each treatment combination.

The silage bales were opened after ensiling the respective ensiling period. It was clearly observed that the replicates of the treatment included 75% Napier were rotten and therefore excluded from the experiment. The other silage bales were sampled (250 g) and stored at -20°C until analysed for the nutritive value. The pH and DM, ash, CP, lactic acid, total soluble carbohydrate, and ammonia nitrogen contents were determined using the appropriate protocols (AFIA, 2011; BARNETT, 1951). The forage ensiled for 45 days were determined for in-vitro organic matter digestibility (OMD) and metabolizable energy (ME) contents (Menke and Steingass, 1988). Data were statistically analysed following Analysis of Variance Procedures (ANOVA) and Duncan's Multiple Range test (DMRT) using version 9.1 of SAS software (SAS Institute, 2002–2003).

3. Results and Discussion

The DM, CP, and ash content of pre-ensiled fodder maize were 23.54%, 9.73%, and 8.53%, respectively, while those of Napier were 17.06%, 8.04%, and 14.89%. Literature reported different nutrient contents for maize and Napier. Sarmini and Premaratne (2017) has reported DM, CP and ash contents of 32.73%, 7.35% and 10.70%, respectively for fodder maize and 17.00%, 10.92% and 16.06%, respectively for Napier. Wangchuk et al. (2015) has reported 10.8% CP content for Napier. The cultivar and

stage of harvesting contribute largely to the composition of forages. The low CP content recorded for Napier in the present study might be due to the differences in cultivar and harvesting stage. The appropriate content of DM (30%) of pre-ensiled forage ensures favourable fermentation and avoid undesirable fermentation by Clostridia (Ashbell and Weinberg, 2003). As expected, inclusion of Napier into fodder maize has resulted in changing the nutrient composition of the pre-ensiled silage treatments accordingly.

The CP content of 27% Napier included silage was not different ($P>0.05$) to that of pure fodder maize silage, despite the significant ($P<0.05$) reduction in their DM content (Table 1). Compared to present study, Puntillo et al. (2020) reported fodder maize silage with greater DM content (37.10%), but lower CP content (5.46%). Silage produced exclusively from Napier grass was of extremely poor quality and, therefore, excluded from the study. However, Rahman et al. (2021) reported 20.2 - 22.8% DM and 10.4 - 11.0% CP in silage exclusively produced from Napier grass.

The effect of inclusion of hybrid Napier and ensiling period on the pH value and lactic acid content of fodder maize silage has been presented in Table 2. The inclusion of Napier grass in maize silage and extended ensiling period, resulted in a significant ($P<0.05$) increase in lactic acid content in the silage. Ofori and Nartey (2018) also reported a similar decreasing trend in pH values with prolonged ensiling period. Achieving a low pH is crucial for ensuring the quality of fermentation in the final stages. Typically, pH serves as a reliable indicator of fermentation quality, providing insight into whether the silage is suitable for prolonged storage. However, in the present study both pure fodder maize and 27% Napier grass included maize silage recorded low pH values along with significantly ($P<0.05$) less lactic acid content. These results suggest an enhanced production of organic acids other than lactic acid during the ensiling of fodder maize.

As shown in the Table 3, a significant ($P<0.05$) increase in ammonia nitrogen content and the decreasing trend in CP content observed in silage with increased inclusion of Napier grass suggest an enhanced protein fermentation, possibly by Clostridium, in Napier-included silage. The ammonia nitrogen concentration in silage reflects the degree of protein degradation. Further, extensive proteolysis adversely affects the utilization of nitrogen in silage by ruminants (Driehuis, Oude Elferink and Van Wikselaar, 2001). The ammonia nitrogen content in silage should not be more than 10% (Umaña et al., 1991). While Rahman et al. (2021) reported 1.79% ammonia nitrogen in pure Napier grass silage ensiled for 30 days, Bureenok et al. (2012) reported 6.8% ammonia nitrogen in Napier grass silage treated 5.00% molasses ensiled for 45 days. The ammonia nitrogen content observed across the silage treatments of the present study was at much lower level (0.04% - 0.10%).

Ensiling consistently increased the in-vitro OMD and ME during the 45 days experiment in both pure maize and 27% Napier included maize silage (Table 4). The highest ($P<0.05$) OMD and ME were recorded for maize silage included 27% Napier grass ensiled for 45 days. The mean in-vitro OMD recorded for pure maize silage was found to be within the range of 34.90% to 78.90% (Ayaşan et al., 2020). Dinkale, Zewdu and Girma (2021) reported 49.93% and 9.21 MJ/kg DM in-vitro OMD and ME, respectively for Napier grass harvested at 3 months after planting. Thus inclusion of Napier in maize silage has led to tremendous improvement in the overall quality of the silage mixture.

The increasing lactic acid content ($P<0.05$, Table 2) while decreasing the soluble carbohydrate content ($P<0.05$, Table 3) until 45 days provide evidence for the continuation of ensiling throughout the 45 days experiment. While, Pahlow et al. (2015) reported that the fermentation phase of the ensiling may last for 7 to 45 days, Kung et al. (2018) reported that the fermentation continuous for much longer period in whole plant corn silage. Therefore, prolong ensiling had resulted in greater OMD and ME in pure Maize and 27% Napier included maize silage.

4. Conclusions

The present study suggests that the inclusion of 27% Napier in the production of fodder maize silage is feasible, ensuring an enhanced silage quality.

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Appendix

Table 1: Inclusion of hybrid Napier and ensiling period on the dry matter, ash and crude protein content of fodder maize silage

Forage inclusion rate (%)		Dry matter content (%)						Ash (%)				CP (%)							
Napier	Maize	35 days			45 days			35 days		45 days		35 days		45 days					
0	100	25.37	±	2.13aA	24.31	±	1.34aA	7.60	±	0.29cA	7.77	±	0.34bA	7.40	±	0.22aA	6.94	±	0.68aA
27	73	19.63	±	0.34bA	20.17	±	0.27bA	8.55	±	0.28bA	8.26	±	0.26bA	7.33	±	0.17aA	6.69	±	0.16aB
50	50	19.16	±	0.31bA	17.60	±	0.11bB	10.33	±	0.22aA	10.43	±	0.18aA	7.03	±	0.18aA	5.02	±	0.11bB
Significance of effects:																			
- Napier inclusion rate		P<0.0001						P<0.0001				P=0.0053							
- Ensiling period		P=0.4807						P=0.9668				P=0.0006							
- Inclusion x Ensiling period		P=0.6207						P=0.6772				P=0.0343							

¹, Mean ± SE.
Means within a column followed by different lower-case letters are significantly different (P<0.001).
Within a row, mean of each parameter followed by different upper-case letters are significantly different (P<0.001).

Table 2: Inclusion of hybrid Napier and ensiling period on the pH value and lactic acid content of fodder maize silage

Forage inclusion rate (%)		Lactic acid content (%)						pH value					
Napier	Maize	35 days			45 days			35 days			45 days		
0	9.69	9.69	±	0.36aB	15.39	±	0.96cA	3.72	±	0.01bA	3.45	±	0.02bB
27	9.54	9.54	±	0.36aB	18.11	±	0.42bA	3.73	±	0.01bA	3.45	±	0.01bB
50	10.01	10.01	±	0.36aB	20.91	±	0.54aA	3.83	±	0.03aA	3.55	±	0.00aB
Significance of effects:													
- Napier inclusion rate		P=0.0042						P<0.0001					
- Ensiling period		P<0.0001						P<0.0001					
- Inclusion x Ensiling period		P=0.0009						P<0.9409					

¹, Mean ± SE.
Means within a column followed by different lower-case letters are significantly different (P<0.001).
Within a row, mean of each parameter followed by different upper-case letters are significantly different (P<0.001).

Table 3: Inclusion of hybrid Napier and ensiling period on the soluble carbohydrate and ammonia nitrogen content of fodder maize silage

Forage inclusion rate (%)		Soluble carbohydrate (%)						Ammonia nitrogen (%)					
Napier	Maize	35 days			45 days			35 days			45 days		
0	100	2.16	±	0.20aA	2.36	±	0.14aA	0.04	±	0.002cA	0.04	±	0.003cA
27	73	2.21	±	0.13aA	2.04	±	0.09aA	0.07	±	0.002bA	0.05	±	0.004bB
50	50	1.09	±	0.18bA	1.49	±	0.16bA	0.10	±	0.006aA	0.07	±	0.003aB
Significance of effects:													
- Napier inclusion rate		P<0.0001						P<0.0001					
- Ensiling period		P=0.3008						P=0.0003					
- Inclusion x Ensiling period		P=0.2096						P=0.1157					

¹, Mean ± SE.
Means within a column followed by different lower-case letters are significantly different (P<0.001).
Within a row, mean of each parameter followed by different upper-case letters are significantly different (P<0.001).

Table 4: Effect of Napier inclusion and ensiling period on the organic matter digestibility (OMD) and metabolizable energy (ME) of fodder maize silage

Forage inclusion rate		Organic matter digestibility (%)						Metabolizable energy (MJ/kg DM)					
Napier (%)	Maize (%)	35 days			45 days			35 days			45 days		
0	100	57.20	±	1.36bB	65.75	±	1.20aA	8.51	±	0.21bB	9.82	±	0.17aA
27	73	61.02	±	0.50aB	68.39	±	1.31aA	9.10	±	0.08aB	10.22	±	0.20aA
50	50	59.98	±	1.00abA	58.51	±	0.74bA	8.94	±	0.15abA	8.71	±	0.11bA
Significance of effects:													
- Napier inclusion rate		P<0.0001						P<0.0001					
- Ensiling period		P<0.0001						P<0.0001					
- Inclusion x Ensiling period		P<0.0001						P<0.0001					
¹ , Mean ± SE. Means within a column followed by different lower-case letters are significantly different (P<0.001). Within a row, mean of each parameter followed by different upper-case letters are significantly different (P<0.001).													

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STUDENT EMPLOYABILITY

ICSD 052

**EXPLORING AREAS TO NOURISH THE SEEDS OF SUCCESS:
DETERMINANTS OF ENTREPRENEURIAL INTENTION OF FIRST YEAR
AGRICULTURAL UNDERGRADUATE STUDENTS IN SRI LANKA**

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Abstract: In the wake of Sri Lanka's escalating economic crisis, unemployment has surged across various sectors, including agriculture. Proposing a solution to this challenge, fostering entrepreneurial behavior emerges as a pivotal strategy, particularly within the agricultural domain. Addressing this issue at its roots, the encouragement and development of entrepreneurial traits during the university period are paramount. Early cultivation of entrepreneurial intentions is essential for nurturing a pipeline of talented future entrepreneurs in agriculture. By identifying and understanding the determinants of entrepreneurial intention at this crucial stage, proactive measures can be implemented, strategically positioning the agricultural sector to combat unemployment and cultivate a resilient, innovative, and empowered workforce for sustainable economic growth. Current study delved into the entrepreneurial intentions of first-year agricultural undergraduates, casting a spotlight on the Theory of Planned Behavior. Conducted at the Faculty of Agriculture, University of Peradeniya, the research engaged 192 students through the census sampling approach. The data collection employed a self-administered questionnaire survey, incorporating validated scales which used 7 points Likert scale for measuring the Theory of Planned Behavior constructs—attitudes, subjective norms, entrepreneurial self-efficacy, and entrepreneurial intention. Data were analyzed using descriptive statistics and path analysis technique. Majority of the participants lacked exposure to entrepreneurship education or familial business engagement. Despite this, attitudes, subjective norms, entrepreneurial self-efficacy, and entrepreneurial intention exhibited mildly positive strengths. Path analysis underscored the significance of attitudes, subjective norms, and entrepreneurial self-efficacy as key determinants of entrepreneurial intention ($P < 0.05$). Notably, a significant, positive and moderate correlation ($P < 0.01$) found among all Theory of Planned Behavior constructs, emphasizing their interconnected influence on the entrepreneurial mindset. This study illuminates determinants of entrepreneurial intention among starting agricultural undergraduates in Sri Lanka, emphasizing the areas need for strategic interventions to cultivate an entrepreneurial workforce, fostering sustainable economic growth amid challenges and rising unemployment.

Keywords: Agricultural undergraduates; Entrepreneurial intention; Theory of Planned Behavior; Sri Lanka

1. Introduction

Currently, Sri Lanka is facing the most severe economic crisis in its history since gaining independence in 1948. While the causes and symptoms of this crisis vary according to different perspectives, both the government and the citizens of the country are now experiencing numerous harsh short-term and long-term consequences (George, George and Baskar, 2022). Among these consequences, the increase in unemployment could be considered a complex social problem encompassing several economic and social nuances. This potential unemployment would not be limited to a particular sector of the economy but would be visible across all agricultural, industrial, and service sectors in the country (Nimal and Namboodiripad, 2022). When particularly considering the agricultural sector of the country contributes to 8.75% of the GDP with 25% of the labour force participation (Central Bank of Sri Lanka, 2022). These statistics emphasize the importance of the sector to the Sri Lankan economy.

While unemployment is an unavoidable macroeconomic phenomenon in any society, unemployment among educated youth, especially graduates, can seriously challenge achieving productivity and development goals in any nation (Gunarathna and Jayasinghe, 2021). Unfortunately, graduate unemployment and underemployment in Sri Lanka are high compared to many other countries (Gunarathna and Jayasinghe, 2021; Singam, 2017; Wijayawardhana, 2019). According to a tracer study conducted by the University Grants Commission in Sri Lanka (2018), the unemployment rate among agricultural graduates is reported to be 15.5%, based on data collected from 6 state universities that offer agriculture degrees. Although this unemployment rate comparatively low compared to other academic streams, the majority of the graduates (45.6%) received jobs around 6 months after their graduation and engaged in government sector employments (63.1%) followed by private sector (24.6%). Although almost all agriculture-related degree programmes provide necessary education to engage in self-employment (University Grant Commission, 2022), tracer study results do not reflect anybody engaging in such employment (University Grants Commission, 2018). One of the key prominent reasons for graduate unemployment in Sri Lanka is the heavy dependency of graduates on the government and private sector, with many expecting them to create jobs without exploring ways to become self-reliant (Wijayawardhana, 2019).

On the other hand, when considering the factors that determine the employability of graduate students, the development of hard and soft skills such as leadership, adaptability, problem-solving abilities, creativity, resilience, and effective communication is also crucial for thriving in diverse professional environments (Chandrakumara, 2014; Gill, 2018; Sahoo et al., 2022). However, it's worth noting that almost all of the aforementioned hard and soft skills can be identified as facets of entrepreneurship (Samydevan, Amin and Piaralal, 2020). Furthermore, fostering entrepreneurship among students during their undergraduate years and promoting entrepreneurial behaviour beyond graduation have emerged as viable strategies to address graduate unemployment (Anwar and Abdullah, 2021). Encouraging students to cultivate entrepreneurial skills not only enhances their employability, but also empowers them to create their own job opportunities in the job market (Kim and Park, 2018). By instilling an entrepreneurial mindset early on, educational institutions can play a crucial role in equipping graduates with the tools needed for success in a competitive economy (Anwar and Abdullah, 2021).

Agricultural entrepreneurship offers a promising avenue for agricultural graduates, presenting opportunities beyond traditional employment. By leveraging their knowledge and skills, graduates can embark on ventures ranging from farm management to agribusiness startups. This proactive approach not only fosters innovation but also contributes to the overall growth and sustainability of the agricultural sector (Madhushyanthi and Wijerathna, 2020). Moreover, agricultural entrepreneurship serves as a catalyst for job creation, enabling graduates to become employers rather than job seekers (Ayat, 2019). By establishing their own enterprises, graduates not only fulfil their professional aspirations but also play a vital role in minimizing unemployment within the sector (Lance, Seuneke and Klerkx, 2014; Sandarekha and Jayathilake, 2017).

The Theory of Planned Behavior (TPB; Ajzen, 1991) proposes that human behaviour is influenced by intentions, attitudes, subjective norms, and perceived behavioural control. Widely applied in psychology and sociology, it effectively predicts various behaviours (Zhang, 2018), including entrepreneurial behaviour of people (See Anal and Singh, 2013; Lihua, 2022; Linan and Chen, 2009; Mfazi and Elliott, 2022; Roy, Akhtar and Das, 2017; Rueda, Moriano and Linan, 2015; Sabah, 2016; Usman and Yennita, 2019). Attitudes toward entrepreneurship encompass individuals' perceptions of business ownership, influenced by cultural, societal, and personal factors. Subjective norms reflect the perceived social pressures and expectations surrounding entrepreneurial endeavours. Entrepreneurial self-efficacy pertains to individuals' belief in their capability to successfully undertake entrepreneurial activities. These elements collectively shape entrepreneurial intentions, driving individuals to pursue or refrain from venturing into business ventures (Anal and Singh, 2013; Lihua, 2022). Entrepreneurial self-efficacy is more reliable than perceived behavioural control because it directly assesses individuals' confidence in their ability to perform entrepreneurial tasks, whereas perceived behavioural control may not accurately reflect individuals' actual capabilities or constraints (Putra and Antonio, 2021)

The objective of the current study is to identify the determinants of the entrepreneurial intention of first-year agricultural undergraduate students in Sri Lanka using the TPB as a theoretical framework. Although the entrepreneurial intention of final-year agricultural undergraduates has been previously investigated within Sri Lanka (Madhushyanthi and Wijerathna, 2020), to the best of our knowledge, the entrepreneurial intention of first-year fresh agricultural undergraduate students, along with its determinants, have not been previously studied within the context Sri Lanka. Understanding these determinants early in university life can inform targeted educational interventions, nurturing a future generation of innovative agricultural leaders who can confidently face future unemployment challenges. Such insights not only enhance the competitiveness and sustainability of the agricultural sector even under the economic crisis but also contribute to the overall socioeconomic development of the country.

2. Methodology

The quantitative research approach was followed using the questionnaire survey design. The research was conducted at Mahailuppallama Sub Campus, affiliated with the Faculty of Agriculture, University of Peradeniya, Sri Lanka. The University of Peradeniya's Faculty of Agriculture is renowned for producing the highest number of agricultural graduates annually in Sri Lanka. Additionally, it is the faculty that admits applicants with the highest scores in their Advanced Level examinations selected to the Agricultural Science stream in the country (University Grant Commission, 2022). The study population comprised first-year agricultural undergraduate students, and a total of 192 students were contacted using a census sampling approach. The characteristics of the sample is given in the Table 1. Most of the sample represented female students who belong to the Sinhala ethnicity group and live in semi-urban areas where they are getting lower middle-level family income. The mean age of the sample were 22.4 years (SD: 2.83). Further, the noticeable characteristic of the sample is that majority is lack of entrepreneurial education and familial engagement in businesses. Additionally, the majority of students preferred to be employed in jobs offered by others in the future, while only a small proportion preferred to engage in businesses in the future.

Table 1: Characteristics of the Sample

Variable	Categories	Frequency (n)	Percentage (%)	
Gender	Male	51	26.6	
	Female	141	73.4	
Ethnicity	Sinhala	173	90.1	
	Tamil	15	7.8	
	Muslim	4	2.1	
Monthly family income	<30,000 LKR	38	19.8	
	30,001- 60,000 LKR	99	51.6	
	60,001-90,000 LKR	27	14.0	
	90001- 120,000 LKR	14	7.3	
	>120,001 LKR	14	7.3	
Area of residence	Urban	49	25.5	
	Semi urban	106	55.2	
	Rural	37	19.3	
Followed an entrepreneurship course previously	Yes	23	12.0	
	No	169	88.0	
Involvement of family members in business activities	Grand parents	Yes	33	17.2
		No	159	82.8
	Parents	Yes	43	22.5
		No	149	77.5
	Siblings	Yes	30	15.6
		No	162	84.4
Sector of preferred future job	Government sector	63	32.8	
	Semi government sector	20	10.4	
	Private sector	84	43.8	
	Business (Full time)	29	15.1	
	Business (Part time)	67	34.9	

Primary data were collected using a self-administered questionnaire. The questionnaire consisted of two major sections: section A, which contained socio-demographic information, and section B, which included questions for assessing TPB constructs. Pre-validated scales (Linan and Chen, 2009) were used to assess TPB constructs, utilizing a 7-point Likert scale. Descriptive statistics and path analysis technique (a mode of structural equation modelling) were used to analyze the data. Data analysis was performed using SPSS version 26 and SPSS AMOS version 26.

3. Results and Discussion

Descriptive statistics of TPB constructs are given in the Table 2. Internal consistency of all scales used for assessing TPB constructs displayed acceptable reliability. Therefore, the results obtained from the

further analysis were interpretable. Despite the lack of entrepreneurship education or familial business engagement of the majority of the sample, the attitudes, subjective norms, entrepreneurial self-efficacy, and entrepreneurial intention exhibited mildly positive strengths. Similar observations were found in previous literature as well (See Lihua, 2022; Mfazi and Elliott, 2022; Roy, Akhtar and Das, 2017; Sandarekha and Jayathilake, 2017; Usman and Yennita, 2019; Madhushyanthi and Wijerathna, 2020). This finding also challenges the previous observations of lower levels of entrepreneurial intention among science stream undergraduates (See Bell, 2018).

Table 2: Descriptive statistics of TPB constructs

TPB Construct	Mean (SD)	Cronbach's α
Attitudes	4.85 (1.523)	0.876
Subjective norms	4.92 (1.615)	0.834
Self efficacy	5.01 (1.412)	0.925
Entrepreneurial Intention	4.58 (1.702)	0.934

Table 3 displays Pearson's correlation matrix of TPB constructs. Notably, a significant, positive and moderate correlation ($P < 0.01$) was found among all TPB constructs, emphasizing their interconnected influence on the entrepreneurial mindset. This finding is also supported by existing literature (See Lihua, 2022; Mfazi and Elliott, 2022; Roy, Akhtar and Das, 2017; Sandarekha and Jayathilake, 2017; Usman and Yennita, 2019; Madhushyanthi and Wijerathna, 2020). Additionally, it underscores the robustness of the TPB framework in understanding entrepreneurial behaviour.

Table 3: Pearson's correlation matrix for TPB constructs

Construct	1	2	3	4
1. Attitudes	1.000			
2. Subjective norms	0.387**	1.000		
3. Self-efficacy	0.432**	0.484**	1.000	
4. Entrepreneurial intention	0.462**	0.402**	0.397**	1.000

Note:** $p < 0.01$ (Two tail)

Table 4 and Figure 1 show the estimated coefficients in path analysis and the path model diagram, respectively. The path model had a good model fit ($\chi^2(4, N=192) = 2.55, p = 0.241$; GFI = 0.990; NFI = .986; CFI = .998; RMSEA = .040; Adjusted $R^2 = 0.66$). Therefore, coefficients were interpretable. Further, path analysis underscored the significance of attitudes, subjective norms, and entrepreneurial self-efficacy as key determinants of entrepreneurial intention ($P < 0.05$).

Table 4: Estimated coefficients of the path model

Path	Unstandardized coefficient (b)	Standard Error (SE)	Standardized coefficient (β)	p
Entrepreneurial intention ← Attitudes	0.49	0.023	0.51	<0.05
Entrepreneurial intention ← Subjective norms	0.36	0.327	0.39	<0.05

Entrepreneurial intention ← Self-efficacy	0.28	0.099	0.32	<0.05
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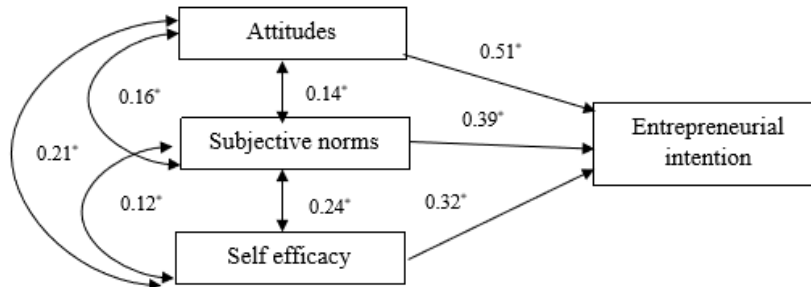


Figure 1: Path model diagram for TPB constructs.
(Note: Standardized estimates are given; * $p < 0.05$)

Moreover, the coefficient relevant to attitudes showed the highest value, emphasizing the comparative strongness of attitudes determining the entrepreneurial intention. When considering the determinants of entrepreneurial intention, many previous research also highlighted the comparatively stronger influence of attitudes (See Lihua, 2022; Mfazi and Elliott, 2022; Roy, Akhtar and Das, 2017; Sandarekha and Jayathilake, 2017; Usman and Yennita, 2019; Madhushyanthi and Wijerathna, 2020) whereas very few studies found more strong influence of self-efficacy (See Linan and Chen, 2009; Rueda, Moriano and Linan, 2015). Additionally, although the majority of undergraduates lack familial engagement in business activities, subjective norms still play a significant impact in determining entrepreneurial intention.

4. Conclusions

The current study investigated the determinants of the entrepreneurial intention of first-year agricultural undergraduate students in Sri Lanka using the Theory of Planned Behavior (TPB) as a theoretical framework. The findings revealed that despite the lack of entrepreneurial education and familial engagement in business activities, students have a mildly positive entrepreneurial intention, where attitudes, subjective norms, and self-efficacy are three key determinants. Furthermore, results confirmed the robustness of TPB as a theory for investigating entrepreneurial intention. Within this context, it can be suggested that proper entrepreneurial education during university can foster greater entrepreneurial intention among agricultural undergraduate students. Entrepreneurial education equips students with essential knowledge, skills, and attitudes needed for entrepreneurship, instilling confidence and self-efficacy and fostering a proactive mindset towards venturing into business endeavours. Thus, it nurtures and enhances entrepreneurial intention towards starting self-employment without relying on jobs offered by others. Additionally, inspiring role models can be used to foster the entrepreneurial intention of undergraduate students, as such role models may impact the development of favourable subjective norms towards fostering entrepreneurial intention. Therefore, it is recommended that the impact of entrepreneurial education and inspiring role models on fostering entrepreneurial intention among agricultural undergraduates could be investigated in future research.

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AUTOMATED SOLUTION FOR RESUME ANALYSIS USING MACHINE LEARNING

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Abstract: Today, the IT industry is very competitive, and it is becoming more and harder to find a good job position in a good company even for candidates with the right skills. When a vacancy is available for even a handful of positions, hundreds of candidates are lining up for the positions. So, the experts in the company have to spend their valuable time going through all those CVs to read, score, and choose. This research aims to build a solution that automates CV analysis and grades and identifies potential candidates with the help of Natural Language Processing, Machine Learning, Data Mining, and TF-IDF Algorithm. With this solution, the IT industry can batch-process resumes and select potential candidates without wasting time on non-potential candidates.

Keywords: Data mining; Machine learning; Natural language processing; TF-IDF algorithm

1. Introduction

The next stage that comes in a person's life after finishing education is a job. There is still, a lot of people who start working before they finish their formal education. There is a curiosity when learning their first work as a new graduate. The reasoning is that most of them have no understanding of their careers. They don't know which work is most appropriate for their subjects, their talents, their extra-curricular interests, etc. However, it is not an easy option to choose a new career, which can depend on several variables, such as wage, job description, and geographical position. The most important item to represent the candidate when applying for work is the Curriculum Vitae (CV) or Resume. Around the same time, career hunting has gotten smarter and faster in this age of technology. However, there are more than enough candidates for a single position, and it is very difficult for an employer to pick a candidate.

Traditional recruitment methods have been used by employees across the world. There are numerous conventional recruiting strategies, such as paper ads, internal recruiting, referrals, and word-of-mouth, but these hiring, and recruitment strategies are simply not enough to get the skilled applicant. The procurement process has become more intelligent and simpler at the same time in this age of technology. However, for a single position, there are more than enough candidates, and it is very complicated and time-consuming for an employer to go through each resume and pick one candidate. There are automated recruiting systems to address this issue, where applicants have to submit their CVs / Resumes to a respected company and then the system classifies the resume according to company requirements (Jagruti, et al., 2019), (Gopalakrishna &, 2019).

In recent years, hiring in the information technology industry has seen massive growth. Companies attract thousands of young talents, and it is difficult to recognize the college every year by campus fairs. A strong fit between the candidate's credentials and the ability a corporation needs by reviewing each HR department resume of either organization. Many firms have moved to using e-recruiting tools to meet this problem. The cost, time, and commitment required to manually process, and screen candidate resumes are minimized by these channels. In order to overcome the difficulties involved with sampling, matching, and classifying applicant resumes, these programs use multiple methods. While these methods create high precision ratios in identifying applicants to fill a vacancy, they pay less attention to the run time complexities of the resulting procedure, i.e., any work offer would be given less attention (Maryam & Mark, 2009), (Maria, et al., 2009).

If there is a vacancy in a company, they will notify the company by means of paper ads or allocate this task to the work-recruiting premises, and the jobseekers will forward those ads, and apply for a job, and submit the CV. CVs / Resumes submitted by work seekers used to be analyzed and evaluated manually by the employers. In the majority of companies, this approach is already followed. However, big companies often need to deal with many CVs / Resumes each and every day, Handling such a large amount of CVs / Resumes one by one has become very problematic and time-consuming to select candidates (Jagruti , et al., 2019), (Maryam & Mark , 2009), (Maria , et al., 2009).

According to this problem, a solution was proposed that automates CV analysis, grade, and identify potential candidates with the help of Natural Language Processing, Sentiment analysis, Machine learning, Data mining, and TF-IDF algorithm. With this solution, the IT industry can batch process CVs / Resumes and select potential candidates without wasting time on non-potential candidates. The significance of this project is to save the time and money of the companies.

2. Literature Survey

This literature survey mainly focuses on the previous research on resume classification, ranking, findings, and features of their systems. A proposed system was developed in 2019 where a semantic analysis technique is used. Two modules are used to develop this namely Natural Language Processing Pipeline and Module of Classification. Tokenization, Stop Word Deletion, POS Marking, and Object Identification are 4 steps in the first level. Tokens for classification will be created after the completion of these measures. It is possible to classify resumes according to requirements in the second stage by applying the classification algorithm method. This method classifies resumes in various structures according to the preferences of candidates. It is also easy for HR or concerned authorities to delegate projects according to their interests to candidates (Gopalakrishna &, 2019), (Pawar & Gawande, 2012).

A system was developed by Vishnunarayanan et al in 2017 where the resume screening process was conducted to qualify and disqualify the applicants according to business criteria. During the recruiting process, separate rounds are conducted to filter the eligible candidates in each round. To do the same, different filtering algorithms are used in resume screening. This primarily aims at minimizing the number of resumes in the corresponding/subsequent recruiting rounds, the meaning of making the procedure as cost-effective as possible was discussed. (Vishnunarayanan, et al., 2017), (Bayraktar & Ozbek, 2011).

A framework that automates applicants' eligibility search and aptitude testing in a recruiting process was presented by Rout et al. in 2019. An online framework was created for the study of the aptitude or personality test and the CV of the applicant to satisfy this requirement. Based on the uploaded CVs, the device is analyzed for technical eligibility. A method of machine learning using the TF-IDF algorithm was used for this framework. A decision was provided for candidate recommendation and the performance of this method. (Bagade, et al., 2019), (Ahmed, et al., 2015), (Palve, et al., 2017).

According to a study that was conducted by Bajpai in 2020, the proposed model extracts required data from a CV / Resume and separates it based on its values. However, the rating and positive weight of a CV / Resume can vary depending on the preference of various companies or employers. The whole process was segmented, and each segmented process was configured to execute its mission independently. In reality, the section that deals with Natural Language Processing operated only with the role of Natural Language Processing and equally with Computer Learning segments dealing exclusively with Machine Learning techniques. A particular approach is recommended to evaluate and analyze the data in a CV / Resume, and it was to translate data to HTML code to recognize different values. Finally, this model provides CVs / Resumes ranking based on the required details and takes prior requirements into consideration regarding employers (Zubeda, et al., 2016), (Bajpai, et al., 2020), (Sanyal, et al., 2017).

An approach for judging the resume of a career seeker was done by Chandola et al. in 2015. Sentiment Analysis was used for this approach and this model proposes to effectively shortlist by applicants based on their resumes according to the company's specifications. While the trustworthiness of a resume to shortlist, an applicant may be disputed, this is not the final procedure of the recruiting process of any organization (Chandola, et al., 2015), (Marjit, et al., 2012).

In 2023, The Classifier resume aims to make the resumes more robust for every job/university interview by using data extraction techniques focused on data from previously chosen and declined applicants which has been proposed by Metin et al. Data were collected from the resume by the device. Natural language processing (NLP) technologies were then used for data

input parsing, tokenizing, stemming, and filtering. By using TF-IDF, based on the recruiter data, can be measured the score of the individual resume and suggest users' missing skills and recommend the top resume to the recruiter (Aydın & Turan, 2023).

The Company Recommender framework was developed in 2020 to assist recruiters with text mining and machine learning tools to identify the best job title candidate by Kelkar et al. Additional information was used according to their pattern, such as the projects in which the applicant was involved, as well as the summary of the project. This data will be collected as input from the applicant and by analyzing the text used by him or her; the applicant has been classified into different levels of expertise. A knowledge base of various keywords that will form the basis for categorization will be designed (Kelkar, et al., 2020).

In 2020, An automated Machine Learning model was developed for the resume short-listing process by Roy, Chowdhary, and Bhatia. The problem for developing this system was separating the proper applicants. Practically, CVs are not normal, and every resume has a different structure and format. The next one maps the CV to the job description to understand whether the applicant can do the job for which is employed. This model takes as input the characteristics extracted from the candidate's resume and finds their categories, further relies on the classified resume mapped on the required job description, and recommends the most fitting candidate profile to HR (Roya, et al., 2020), (Otaibi & Ykhlef, 2012).

3. Materials and Methodology

A resume analysis system has been developed here to easily find the correct candidate from a lot of resumes. In this research, a keyword-based methodology was used to analyze the resumes. Input is the resumes as PDF and the next step is keyword extracting and summarizing. The next clarifier the resumes using machine learning and finally the output is the analyzed resumes. This process is highly accurate because this method extracts the keywords gets the necessary contents matches the inputs and gives the correct solutions. Our proposed solution's main targets can be seen in the below diagram.



Figure 1: Implementation steps.

The detailed design of our system can be seen in the below diagram.

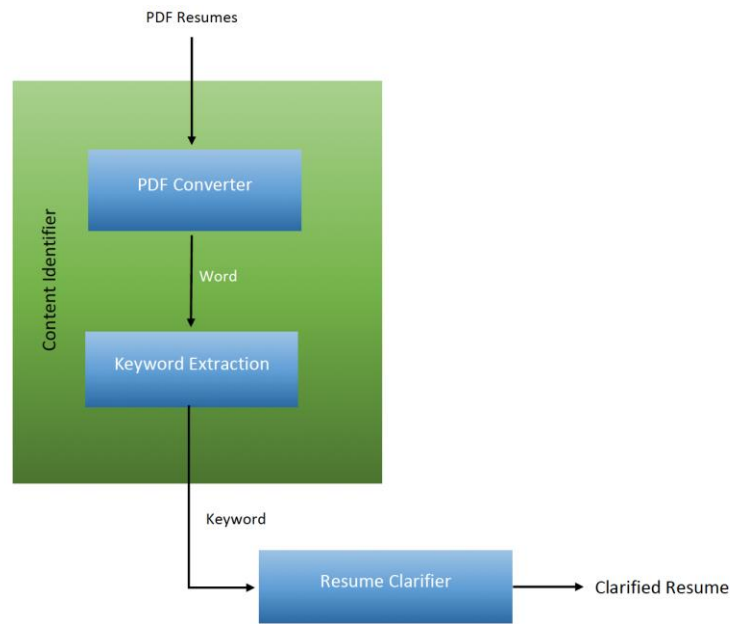


Figure 2: Architectural diagram of the system.

3.1 Content Identifier

There are two subtopics in the content identifier. They are PDF Converter and Keyword Extracting.

3.1.1 PDF Converter

First, the pdf converter was used to convert a pdf format CV to a Word file. Because it is very helpful to identify the content of the whole pdf file. The image processing part was used the get data from the pdf file. However, it was not very effective because a lot of resumes are created in different formats. So that reason it is very hard to find the content of the resumes. Finally, the method was chosen to convert the pdf file to a text file. The content of the resume can be identified easily after converting the pdf resume to a text file and it was very helpful to our next stage of keyword extracting.

3.1.2 Keyword Extracting

Firstly, the word document was read the keyword extracting. The stop words and full stop and comma, etc. were removed. After the keywords were mapped to the resume clarification. For the Keyword extraction, the already identified keywords and topics were used to extract. In the keyword extracting there are three sub-topics

```

import PDFConverter as pd

def get_Document_Data_Set():
    text_D = pd.main()

    return text_D

def main():
    text_D=get_Document_Data_Set()
    return text_D
  
```

Figure 3: PDFDocument.python file.

```

from nltk.stem import PorterStemmer
from nltk.corpus import stopwords
import string
from nltk.tokenize import sent_tokenize, word_tokenize

def create_punctuation_list():
    punctuation_list = []

    for c in string.punctuation:
        punctuation_list.append(c)
    punctuation_list.append('')
    punctuation_list.append('')
    return punctuation_list

def create_stop_word_list():
    stop_word_list = []

    text_stopword_Name = []
    file_stopword_Name = open("StopWord.txt", mode='r')
    text_stopword_Name = file_stopword_Name.read()
    textWord_Tok_stopword_Name = word_tokenize(text_stopword_Name)
    for word in textWord_Tok_stopword_Name:
        stop_word_list.append(word)
    return stop_word_list

```

Figure 4: Stopword.python file.

```

import PDFDocumentWordList as Dw
import PreProcessor as Prp

textSent_Tok_Queue = Dw.main()

key_words = Prp.ignoring_unwanted_words(textSent_Tok_Queue)

def printTheKeyword():
    for key in key_words:
        print(key)

printTheKeyword()

```

Figure 5: ContentIdentifier.python file.

First is Reading the converted Word document. Because before the preprocessing the Word document should be read. In this part, there are PDFDocument.python and PDFDocument-WordList.python files. PDFDocument.python can be seen in Figure 3. The next part is the Preprocessing part of the text document. There are two files in the preprocessing part. They are Stopword.python and PreProcessor.python. The stopword. python file is depicted in Figure 4. The final step of the Keyword extraction is the Content identifier. In this part, the keywords of the input Word document were printed. The ContentIdentifier.python file is depicted in Figure 5.

3.2 TF-IDF Algorithm

The TF-IDF algorithm was used for the keyword extraction. TF-IDF means "Term Frequency—Inverse Document Frequency." This is a technique for quantifying a word in documents. The weight of each word was usually calculated, which means the value of the word in the document and the corpus. This method is a commonly used technique for information retrieval and text mining. The computer can only recognize any data in the form of a numerical value. So, for this purpose, all the text was vectorized so that the computer could understand the text better.

$$\text{TF-IDF} = \text{Term Frequency (TF)} * \text{Inverse Document (IDF) Frequency} \quad (1)$$

3.2.1 Term Frequency

Term Frequency means the frequency of a word in a text. This mostly depends on the length of the document and the generality of the term, for example, a very common word such as "a" may appear several times in the document. But if take two texts, one with 100 words and the other with 10,000 words. There is a high possibility that a common word such as "a" will be more present in the 10,000-word text. But we cannot assume that the longer document is more valuable than the shorter one. For this very purpose perform a normalization of the frequency value and divide the frequency with the total number of words in the text. To vectorize the documents, first check the count of each term. In the worst case, if the phrase does not appear in the document, the particular TF value will be 0 and in the other extreme case, if all the terms in the document are the same, it will be 1. The final value of the normalized TF value will be in the range of [0 to 1]. 0, 1 inclusive of this.

t - term(word)

d – document(set of words)

N – count of corpus

corpus – the total document set

TF (t,d) = count of t in d / number of words in d

3.2.2 Document Frequency

This measures the value of the text in the whole set of corpus, This is similar to TF. The only difference is that the TF is the frequency counter for the term t in document d where the DF is the number of occurrences of the term t in document N. DF is the number of documents in which the word appears.

df(t) = occurrence of t in documents

3.2.3 Inverse Document Frequency

The inverse of the frequency of the document which measures the informativeness of the term t. When the measure IDF, it will be very low for the most common terms like stop words (because stop words like "is" are present in almost all documents, and N/df will offer a very low value to that word).

idf(t) = N/df

When a word that is not in the vocabulary occurs, this time the df will be 0. So that time adding 1 to the denominator.

idf(t) = log(N/(df + 1))

Finally, the TF and IDF values were taken and those Values were multiplied and the TF-IDF score was calculated.

tf-idf(t, d) = tf(t, d) * log(N/(df + 1))

3.3 Resume Clarifier

For the resume clarifier, a model was created for training our dataset. Data preprocessing is one of the main steps in every problem in data analysis, as it ensures that the model is correct because it depends largely on data quality. Data collection, selection, and integration, as well as data cleaning (filling in missing data, minimizing noise in the data, and removing conflicting data), data transformation (normalizing data, discretizing / aggregating data, and creating new attributes), and data reduction (reducing the number of variables, reducing the number of cases, and balancing skewed data) entailed by it. The preprocessed data (well-formed data) can then be fed into a machine-learning algorithm after these steps are completed correctly. Two machine learning algorithms were used for the training of our dataset. They are the Support

Vector Machine algorithm and the Decision Tree algorithm. Train our dataset from the above algorithms has been given high accuracy from the SVM algorithm.

3.3.1 Support Vector Machine (SVM) Algorithm

Support Vector Machine is a supervised machine learning algorithm that can be used for both classification and regression challenges. Every data item was plotted in the SVM algorithm as a point of n-dimensional space with the value of a specific coordinate for every feature. Then, were classified ourselves by finding the hyperplane which makes a very good distinction between the two classes.

a) Scenario 1: (Identify the correct hyper-plane.) The three hyper-planes (A, B, and C) can be seen. A hyper-plane can be selected that better separates the two classes. In this scenario, the hyperplane “B” has done this job well.

b) Scenario 2:(Identify the correct hyper-plane.) In there the three hyper-planes (A, B, and C) can be seen. Maximizing distances between the nearest data point (either class) and the hyper-plane will help to determine the right hyper-plane. This distance is called the Margin. The margin for hyperplane C is high compared to both A and B. This is why name the right hyper-plane as C. Another reason for lightning when selecting a hyperplane with a higher margin is robustness. If select a hyper-plane with a low margin, there is a high chance of misclassification.

c) Scenario 3:(Identify the correct hyper-plane.) The hyper-plans A and B can be seen. Someone may have chosen hyperplane B because it has a higher margin compared to A. But here is the catch, SVM selects a hyper-plane that classifies the classes precisely before maximizing the margin. Hyperplane B has a classification error and A has all been classified correctly. So that the right hyper-plane is A.

d) Scenario 4:(Identify the correct hyper-plane.) Here, someone is unable to separate the two classes using a straight line, as one of the stars lies in the territory of the other (circle) class as an outsider. The one star at the other end is like a star-class outlier. The SVM algorithm has a feature that ignores outliers and finds a hyperplane that has the maximum margin. Therefore, the SVM classification is robust to outsiders.

e) Scenario 5:(Identify the correct hyper-plane.) A linear hyperplane between the two classes can't be seen. Until now, the linear hyper-plane only was looked. This problem can be solved by SVM. This problem is solved by introducing additional features. Here, a new $z=x^2+y^2$ feature was added. The data points on the x and z axis were plotted.: For that, all values for z would always be positive because z is the squared sum of both x and y and in the original plot, red circles appear close to the origin of the x and y axes, resulting in a lower value of z and a star that is relatively different from the origin resulting in a higher value of z.

It is convenient to have a linear hyper-plane between these two groups in the SVM classifier. The SVM algorithm has a kernel trick technique. The SVM kernel is a function that takes low dimensional input space and converts it to higher dimensional space. A non-separable problem is converted into a separable problem. It is mostly useful for non-linear separation problems. Simply put, it does some extremely complex data transformations, and then discovers the process of separating the data based on the labels or outputs defined. The hyper plane in the original input space can be seen. It can be seen as a circle.

3.4 Data and Data Description

For the data collection, data were collected from LinkedIn profiles, and scraping tools were used for that process. That data was downloaded and it was arranged into our dataset. As well as the dataset from Kaggle was downloaded. The all data were not arranged. They were separated by columns and the dataset was prepared. The Description, Job Title, Skills, and Experience Years were included in that dataset, and the level was added to their profiles. Next stage, the dataset was preprocessed. This was the main step in the data analysis. Because that was most important to train our dataset. From that, good accuracy can be obtained from this data. The data preprocessing parts consisted of data integration (collecting data, selecting data, integrating data), data cleaning (filling in missing data, eliminating inconsistent data), data transformation (normalizing data, discretizing / aggregating data), data reduction (reducing the number of variables, reducing the number of cases and balancing skewed data). After those preprocessing steps, our machine learning algorithms were added to the train.

3.4.1 Decision Tree

Decision Tree is a supervised learning method that can be used for both classification and regression problems, but most of the time it is preferred to solve classification problems. It is a tree-structured classifier, where the internal nodes represent the features of the dataset, the branches represent the decision rules, and each leaf node represents the result. There are two nodes in the decision tree, the Decision Node and the Leaf Node. Decision nodes are used to make any decisions and have several branches, while Leaf nodes are the product of such decisions and do not have any additional branches.

4. Results and Discussion

The dataset was trained using two machine-learning algorithms for the experimental results. They are the Support Vector Machine algorithm and Decision Tree algorithm. The model was trained by changing the dataset and as well as changing the algorithm. From those algorithms, each algorithm was tested using 1000 datasets and 10000 datasets. From those datasets, various accuracies have been given for each algorithm. Testing with the SVM algorithm, the accuracy of 37% and 72% from 1000 and 10000 datasets have been given. As well as the Decision tree algorithm the accuracy of 21% and 64% from 1000 and 10000 datasets have been given. The Expected results of accuracy from our training dataset can be seen in Table I. The results of accuracy when training the model changing the algorithm and dataset volume can be seen below in Figure 6.

Table 1: Accuracy of dataset

Algorithm Used	Volume of Dataset	
	1000	10000
Support Vector Machine	37%	72%
Decision Tree	21%	64%

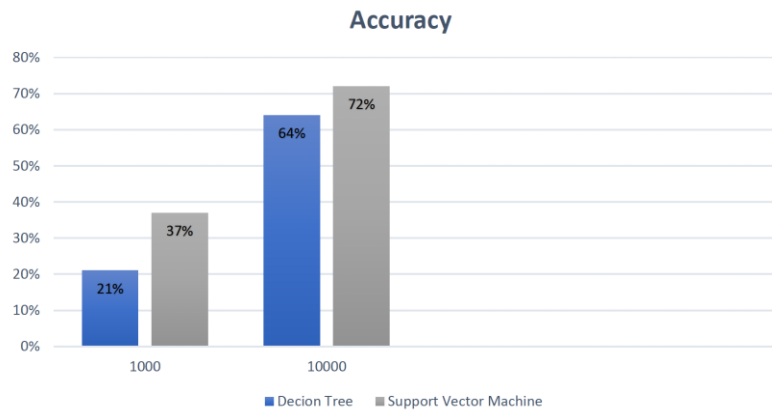


Figure 6: Accuracy of the dataset.

From that, there is a high volume of the dataset in which more accuracy was given, and in the low data set the low accuracy was given. In the above table, the Support Vector Machine algorithm has worked well when training our dataset and more accuracy has been given than the Decision Tree algorithm. So, the Support Vector Machine was used for our work. In this CV analyzing system, some algorithms and machine learning algorithms to implement the system have been used. For the training, in our machine learning model, the 10000 of a dataset was used and 72% accuracy was given. But when the dataset capacity becomes high, and accuracy of this system is increased. As well as the different functionalities can be used to increase accuracy and testing for our model training in the Support Vector Machine algorithm. To do that the keyword extraction process of our system can be more developed using the TF-IDF algorithm functionalities and Natural Language Processing. So that different methods can be used to develop more accuracy in the keyword extraction process. After clarifying resumes, the output was given as the level of the resume. The Low Value, Medium Value, and High Value were given as output. Low value means he has low technical knowledge and low experience. Medium value means Moderate technical skills and moderate working experience. High value means he has a high knowledge of technical skills and more years of experience. That is the main output of our resume clarifier.

5. Conclusion

This Resume analyzing system is developed by keyword extracting and machine learning algorithms. In this research, the main parts are content identifier and resume clarifier. In the content, the Identifier has two sub-parts. They are PDF Extraction and Keyword Extraction. The PDF resume is converted to a Word document by the PDF Extraction algorithm. Next is the Keyword Extraction part. In this part, the converted Word document is gotten and the output of keywords is gotten. In this step, the Natural Language Processing and TF-IDF are used for keyword Extraction. The output of our Keyword Extraction is the keyword of the resume. In this research, the next main part is the Resume clarifier. In this step, the dataset is trained using the Support Vector Machine and Decision Tree algorithms. It has been given more accuracy in the Support Vector Machine algorithm. So, SVM is used for the Model Training. The next step is analyzing the resumes. For that, the output of content identifier keywords is input to our model and the resumes are analyzed for the given inputs. This research has been completed successfully to build a solution that automates CV analysis, and grades and identifies potential candidates with the help of Natural Language Processing, machine learning, data mining, and TF-IDF algorithm. The significance of this project is to save the time and money of the companies.

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ICSD 127

**UNDERGRADUATES' EXPECTATIONS FOR INTERNSHIP PROGRAM: A
CASE STUDY FOR BSC HONOURS IN AGRIBUSINESS MANAGEMENT DEGREE
IN THE FACULTY OF AGRICULTURE, UNIVERSITY OF RUHUNA**

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Abstract: Sri Lankan universities play a crucial role in the intellectual and professional growth of students. The Department of Agricultural Economics and Agribusiness, Faculty of Agriculture, University of Ruhuna was the first in Sri Lanka to introduce the BSc in Agribusiness Management degree program in 2012. However, it was observed in the tracer study conducted by the University of Ruhuna, that significant numbers of graduates who graduated in the past couple of years are still unemployed or underemployed. This situation could be a result of various reasons and it is unknown whether the undergraduates meet their expectations through their internship /industrial training program is one of the reasons. Therefore, this study aimed to find undergraduates' expectations for internship program. The study was carried with the students who are following BSc in agribusiness degree program as the population. Data were collected through a pre-tested questionnaire and analysed using descriptive statistics and one-way ANOVA Duncan test as post-hoc. Results indicated that the majority of the undergraduates have less awareness about internship programs, the Industrial Placement Office (IPO), and the University-Industry Partnership Platform (UIPP). The majority of them expect to conduct their internships in the private sector, followed by the public sector and NGOs. Ethnicity, religion, area of residence, educational performance (GPA), English proficiency, and computer literacy show a positive influence on the selection of internship. Most undergraduates anticipate acquiring communication skills, real-life work experience, and time management skills from internship respectively. Considering the benefits, most of the undergraduate's priority is gaining practical skills through the application of theoretical knowledge, followed by getting industry exposure and understanding, and personality development. Importantly, 53% of undergraduates show a willingness to start their own business after getting exposure to internship training. Therefore, conducting awareness sessions about internship, and considering incorporating elements related to entrepreneurship into the internship would enhance undergraduates' insights about this.

Keywords: Agribusiness; Awareness; Entrepreneurship; Industrial training; Skills; University-Industry partnership

1. Introduction

The Department of Agricultural Economics, and Agribusiness of the Faculty of Agriculture, University of Ruhuna, pioneered offering undergraduates a Bachelor of the Science Honours in Agribusiness Management degree program in 2012. The prime goal of this degree program is to equip undergraduates with the required theoretical knowledge, skills, attitudes, entrepreneurship, business communication skills, and essential management techniques to become competent entrepreneurs and/or researchers in the agribusiness sector. After conducting the program for ten years with six batches completed, it was identified that the degree program needs to be strongly blended and interlinked with the industries. It is apparent that job availability for graduates is scarce due to the huge competition with other competitive degrees in the country and the prevailing financial crisis in the country. A tracer study in 2022 revealed that 33% of the graduates were unemployed (University of Ruhuna, 2022). It is widely accepted that the mismatch between skills possessed by graduates and skills demanded by the labour market leads to unemployment (Dayaratna-Banda, 2022). Therefore, the private sector's labour requirements are not being met by graduates; they prefer to hire non-graduates. Hence, the private sector depends on non-graduates with certain experience or technical qualifications, especially in the areas of agribusiness, marketing, and related services at relatively low wages. When graduates possess the appropriate knowledge and skills demanded by the labour market, graduates become more employable and productive. In this context, internship/ industrial training (IS) provides a better platform for students to apply their theoretical knowledge to practical aspects and reduce the gap between the demanded skill and the supply. According to Renganathan, Karim, and Li (2012), internships provide the opportunity for students to integrate theoretical knowledge with practical work experience. This is done by allowing students to work in a professional setting under the supervision of the planned activities. There are several benefits that internship offers to students, which include the opportunity to learn skills and knowledge related to the job and work environment (Maertz *et. al.*, 2014), develop positive work habits and personal characteristics (Gerken *et. al.*, 2012), and increase students' marketability in the job market after graduation (Renganathan, Karim, and Li, 2012).

The Agribusiness Management (ABM) degree program has produced approximately 50 graduates annually since 2017. Students are compelled to complete a minimum six-week internship training in their final year to complete their degree program. The faculty has established the Industrial Placement Office (IPO) nearly two decades ago and the University-Industry Partnership Platform (UIPP) recently to facilitate the internship training. Through the IPO, the students can select the desired private or public sector institute for industrial training depending on the availability. They are required to complete a daily activity book (logbook) under the supervision of the assigned supervisor in the company. At the end of the training, students are evaluated through a presentation on their industry experience.

It was observed that employment opportunities for the graduates so far have not been significantly improved, and more than 50% of the graduates who graduated last year are still unemployed or underemployed (Madhushika *et. al.*, 2023). Among the possible underlying reasons for above situation, the issues related to the internship could be significant and could be minimized if managed well. In this regard, undergraduates' expectations from internship remains poorly explored. It is important to identify their perceptions in order to develop feasible strategies. Therefore, this study aimed to achieve the following objectives:

1. To identify the undergraduate's awareness and expectations of the internship/ industrial training program.
2. To provide appropriate suggestions to improve the internship program.

2. Methodology

This study was conducted in the faculty of agriculture at the University of Ruhuna using the undergraduate pursuing the BSc in agribusiness management degree program, who are yet to complete the internship. Primary data were collected from the first year to the final year randomly through an electronically distributed pretested questionnaire. Table 01 summarizes the population size.

Table 01: Population characteristics

Batch	Population
First year (45)	76
Second year (44)	67
Third year (43)	57
Fourth year (42)	44
Total	244

The data collected through the questionnaire were assessed using scales from 1 - 5. Undergraduate awareness measured using the scale: 1 = not aware, 2 = slightly aware, 3 = moderately aware, 4 = well aware, and 5 = fully aware; The frequency of usage was measured on a scale: 1 = never used, 2 = rarely use, 3 = occasional use, 4 = frequent use, and 5 = always use. Undergraduate readiness for internship was measured on a scale: 1 = strongly disagree, 2=disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Students' academic performance, English language and basic computer literacy, and demographic factors were also considered for the study. Data were analyzed using descriptive analysis, non-parametric and parametric test viz. one-way ANOVA with the Duncan test as post-hoc.

3. Results and discussion

The response rates of undergraduate categories are shown in table 02 and the rate of responses ranged from 70 to 86%.

Table 02: Responses rate

Batch	Sample	Response rate
First year (45)	55	72%
Second year (44)	58	86%
Third year (43)	42	73%
Fourth year (42)	31	70%
Total	186	76%

3.1 Demographic features of the sample

In general, the number of male students is smaller compared to the females in a batch. The majority of them are from rural areas (54.3%), while 44.1% are from urban areas. Where the ethnicity of the students is concerned, 87.1% of the students were Sinhala and 7% and 5.9% of them were Tamil and Muslim (Table 03).

Table 03: Demographic information

Category		Frequency	Percentage (%)
Gender	Male	46	24.7
	Female	140	75.3
	Rural	101	54.3

Dwelling Set-	Urban	82	44.1
	Estate	3	1.6
Ethnicity	Sinhala	162	87.1
	Tamil	13	7
	Muslim	11	5.9

When the academic performance of the students is considered, it follows the pattern of the normal distribution. However, some students are yet to receive their examination results at the time of writing this paper (Figure 1).

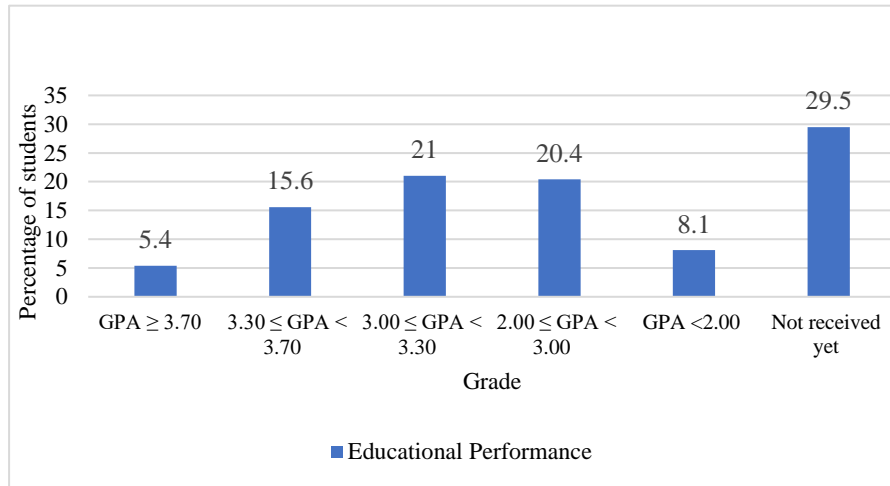


Figure 01: Educational performance of the students.

3.2 Awareness and readiness for the internship

Undergraduates exhibit moderate awareness (2.9) about the internship program, while they have slight awareness (2.4) about the IPO/UIPP website and the IPO. Analysis across academic years from first year to final year provides an increase in awareness regarding internship programs, indicating an improvement. However, awareness about UIPP websites and IPOs shows fluctuations, with second-year students having the highest awareness and final-year students having the lowest (Table 04). This raises concern over the logical selection of internships by the final-year students who are about to start their training in a few months' time. Moreover, students rarely use the UIPP website (2.5) and the services of IPO (2.2). As per the batch-wise distribution, first-year and second-year students are using it more compared to third and final-year students (Table 03). These students, who are in their third and final years, had to complete their orientation program and first-year studies online due to the COVID-19 pandemic situation in 2020, 2021, and 2022 in the country.

This information highlights the need for increasing awareness among students to prepare them for internship. This result also stresses on the requirement of planned orientation program at the beginning of the undergraduate education this regard. These findings are in line with the findings of Martin and Wilkerson (2006). They have done a study on 132 accounting students and the research shows that the students' agreement on prior awareness about their internship.

Table 04: Student awareness and interactions with the internship program, IPO, and UIPP

	Student category			
	First year	Second Year	Third Year	Fourth Year
Awareness				
Internship training program	78.2%	89.7%	97.6%	100%
IPO/UIPP on the university website	70.9%	82.8%	66.7%	58.1%
Industrial Placement Office	69.1%	77.6%	71.4%	64.5%
Frequency of usage				
IPO/UIPP on the university website	78.2%	79.3%	50%	41.9%
Industrial Placement Office	63.6%	70.7%	45.2%	45.5%

When considering the sources of information about the internship program, majority of the students have obtained the information from seniors and friends (60.2%), followed by faculty announcements and social media (44.1%) (Figure 2). Although it is natural for students to seek the help of their friends and seniors to decide on the internship opportunity, misinterpretation and personal biases could affect rational selection. Therefore, the weaknesses of official channels should be investigated and restructured to deliver the information in a simple and friendlier manner.

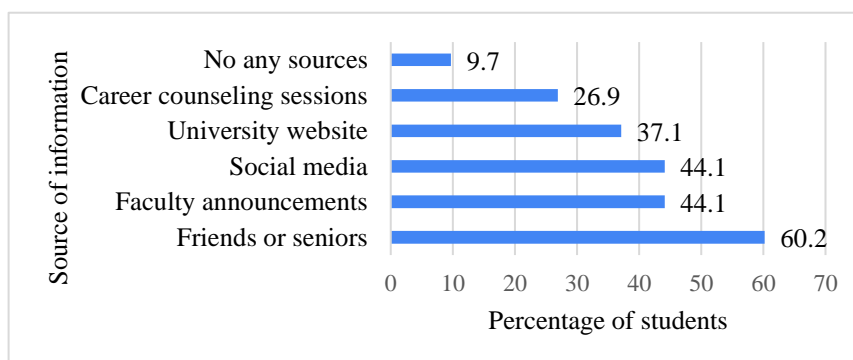


Figure 2: The sources of information used by students for the awareness on internship.

In terms of undergraduate readiness for the internship, whether they are engaging in activities to secure a suitable internship placement, working on improving networking for potential internship opportunities, or seeking advice or guidance on how to prepare for the internship training program, they are not adequately engaging in the process (Table 5).

Table 05: Undergraduate’s readiness for internship

Readiness for the Internship	Mean Rank
I am well-informed about the period during which the internship program takes place.	3.3

I am currently engaged in activities to secure a suitable internship placement.	2.8
I am actively working on improving my networking for potential internship opportunities.	3.0
I actively seek advice or guidance on how to prepare for the internship program.	3.3

Scale: 1 = Strongly disagree and 5 = Strongly agree

3.3 Underlying factors of internship selection

Student preference for the internship and the organization has a significant effect on the performance of the students. Students entering internship with clear expectations and understanding are likely to engage in internship training activities more actively. Moreover, this impacts the educational and professional benefits of the internship program.

3.3.1 Students' preference for public, private, and other sectors for internships

Most of the students (65.6%) have ranked the private sector as their priority for internship. The public sector (31.2%) was considered the second priority, while NGOs (3.2%) were considered the third priority. The past two-year internship selection of the students was studied based on the information available at the IPO. The majority of students completed their internship in the private sector (65%), followed by the public sector (33.3%) and NGOs (4.7%). Student responses coincide with the actual selection of the internship.

Ethnicity, religion, area of residence, educational performance (GPA), English proficiency, and computer literacy show a positive influence on the selection of internships. Most Buddhist students have preferred the private sector whereas Muslim students have preferred public sector institutes. The Tamil students have indicated no special preference for both private and public institutes. Most of the undergraduates who prefer to complete their internship training in the public sector (65.5%) and NGOs (66.7%) are from rural areas, while those who prefer the private sector predominantly consist of urban dwellers (50%). There was a significant relationship between self-assessed English language and computer proficiency with the students' preferred sector. The respondents who have good English proficiency inclined to pursue internship training in the private sector. The students with relatively poor English proficiency have indicated that they prefer their internship in public sector or NGOs. Students with good computer proficiency expect to engage in private sector internship, while those who have low computer proficiency have indicated their willingness to engage in public sector and NGOs. A study conducted in Malaysia with mathematical science students explains that the private sector is usually looking for students who have good English command as they use English as a medium of instruction (Muda *et. al.*, 2012). Undergraduates may be aware of this, and this can be the reason students with good English proficiency shows the confidence to conduct their internship training in the private sector. In a scale of 1 to 6 students ranked their preference to different industries. In the order of their preference, private agribusiness companies, agricultural research institutions, banking sector institutes, agribusiness-related government companies, agri-tech startups, and the service sector were identified.

3.3.2 Specific skills undergraduates expect to acquire during their internship training

Findings of various studies related to the internship shows that the students are expecting four career preparation skill categories such as communication skills, academic skills, interpersonal skills, and job acquisition skills. Therefore, Moghaddam (2011) pointed out that an effective internship program should be able to enhance such skills and prepare students to face real life challenges after their graduation. Present study shows that most undergraduates expect acquiring communication skills (79.6%), followed by real-life work experience (74.7%) and time management (73.7%) from their internship training and it is an indication that students have recognized the importance of these key attributes the students should possess (Figure 3). In a study conducted in Malasia for marketing students, they

perceived that oral communication skills improved during internship training (Prachanant, 2012). Emphasis on acquiring real-life work experience implies the interest of undergraduates in filling the gap between theoretical knowledge and practical application. They have identified the importance of getting hands-on experience to meet their future career aspirations. Time management is a skill that students should possess throughout their life. Ideally, they should have developed this skill by the time they reach their internship. Therefore, it is worth further investigating this situation and help students develop the skill through career development activities.

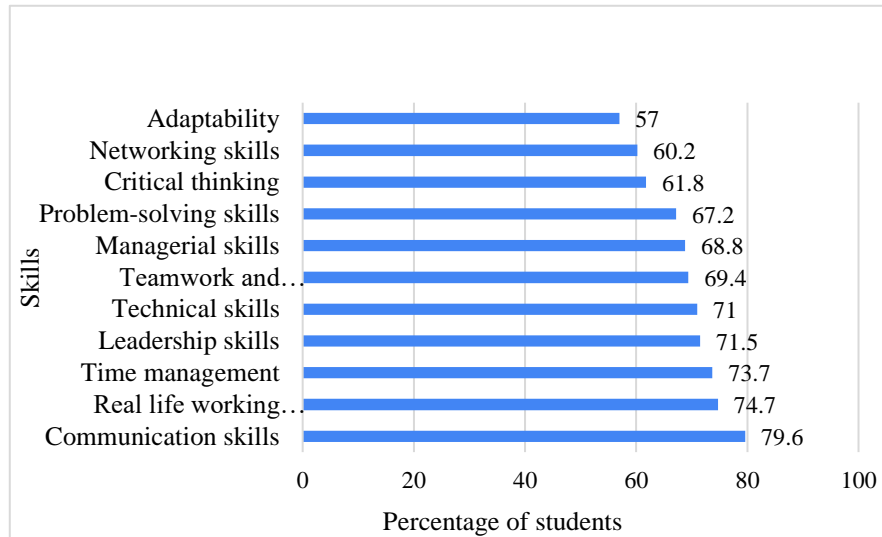


Figure 3: Specific skills undergraduates expect to acquire during their internship.

Further, most of the students (80.6%) prefer to participate in extracurricular activities or additional programs offered alongside their internship training.

3.3.3 Expected benefits from future internship training experience

Internship training is planned to expose undergraduates to the real work environment and, at the same time, gain knowledge through hands-on observation and job execution. It provides students with the opportunity to develop skills and confidence required to perform a job. This aligns with the findings of Rok (2013), who states that internship training places provide real-world work experience for students. According to Tanius (2015), internship training provides a platform for students to check their theoretical knowledge with practical application. In Martin and Wilkerson (2006)' study, accounting students have agreed that their internship provided them with a solidified understanding of prior academic work, was beneficial for subsequent academic work, provided them with new insights into courses and improved understanding of concepts. The IPO office of the faculty of agriculture outlined the internship training objectives. It includes extending the skills in the application of theory to practical work situations, exposing students to real work environment experience, improving good communication, and providing students with the opportunity to test their interest in a particular career before permanent commitments are made. Students also have similar expectations for the future internship training program. The main benefit that students expect to acquire during their internship experience has been ranked from 1 to 7. Accordingly, the first priority is gaining practical skills through the application of academic knowledge, followed by getting industry exposure and understanding, personality development and skill enhancement, networking and public relations opportunities, potential job placement, obtaining valuable insights for launching your own business, and making a contribution to your community.

As agribusiness undergraduates, determining their expectations of starting their own business after getting exposure to internship training is crucial for improving future activities. Accordingly, most of them

(54.3%) had an expectation of starting this, and it includes a variety of business ideas such as animal feed production, tea production business, vegetable and fruit export company, floriculture-related business, and nursery plants. In addition to this, they had some non-agricultural business ideas, including clothing, garments, and pharmaceutical businesses.

3.4 Suggestions

Students seek guidance in improving communication skills, time management, communicating with English, and their lack of IT knowledge as major challenges that they face in the future. It is important to conduct awareness sessions and seminars to improve undergraduates' insights about this. Moreover, recognize the entrepreneurial aspirations of students and consider incorporating elements related to entrepreneurship into the internship training program. Offer workshops on business development and support students in translating their business ideas into practical plans.

4 Conclusion

This study focused on the undergraduates' awareness and expectations of internship training, and it revealed that the majority of the undergraduates have less awareness of internship training programs, the Industrial Placement Office (IPO), and the University Industry Partnership Platform (UIPP) and rarely use them. The majority were made aware by senior, friend, and faculty announcements, respectively. This highlights the need to increase awareness among them. Many undergraduates' express preference toward the private sector in conducting internships, followed by the public sector and NGOs. It can be concluded that there was a significant relation in English and computer proficiency with preferred sectors: students who have good English and computer proficiency prefer the private sector, while those with low proficiency were interested in non-governmental organizations.

Overall, communication skills, real-life work experience, and time management skills are mainly expected skills to be gained from internship training, while expected benefits include gaining practical skills through the application of academic knowledge, followed by industry exposure and understanding, and personality development. The findings appeared to suggest that conducting awareness sessions and seminars about internship training and considering incorporating elements related to entrepreneurship into the internship training program would enhance undergraduates' expectations and benefits from the internship training. Therefore, the study results are helpful in preparing internship training programs and better preparing students for training in universities.

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IMPACT OF STUDENT EMPLOYABILITY ON POVERTY REDUCTION IN A COUNTRY; WITH A SPECIAL REFERENCE TO SANASA CAMPUS

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Abstract: This research aims to explore the critical link between student employability and poverty reduction within a national context. This research has been conducted with the participation of undergraduate students of Sanasa University in Kegalle district of Sri Lanka. The primary objective is to analyse how enhancing the employability of students, particularly in higher education, contributes to alleviating poverty levels in a country. The study hypothesizes that increased employability among students directly correlates with a decrease in poverty, owing to higher income levels and improved economic stability. Employing a mixed-methods approach, the research will combine quantitative data analysis of employment rates, income levels, and poverty indices with qualitative assessments through interviews, questioners and case studies in selected regions. This methodology is chosen to provide a comprehensive understanding of the multifaceted relationship between student employability and poverty reduction. The research will focus on various factors that influence student employability, including the quality of education, access to skill development programs, and the alignment of educational curricula with market demands. Additionally, it will examine the role of government policies and private sector initiatives in enhancing student employability. Expected findings are anticipated to demonstrate a significant connection between improved student employability and poverty reduction. The study aims to provide evidence that investment in education and skill development not only benefits individuals but also contributes to broader economic and social gains by reducing poverty levels. The implications of this research are far-reaching. By identifying effective strategies to enhance student employability, the study will offer valuable insights for policymakers, educational institutions, and private sector stakeholders. It seeks to inform policy decisions and educational reforms that could play a pivotal role in poverty alleviation strategies, ultimately contributing to sustainable economic growth and social development.

Keywords: Student employability; Poverty reduction; Economic development; Workforce skills; Sri Lanka

1. Introduction

1.1 Background of the Research:

In recent decades, the global landscape has witnessed an increasing acknowledgment of the pivotal role education plays in socio-economic development. Specifically, the link between student employability and poverty reduction has garnered considerable attention. As nations strive for sustainable growth, understanding the mechanisms through which enhanced student employability contributes to poverty alleviation becomes imperative. This research delves into this critical nexus, focusing on the context of Sanasa Campus in the Kegalle district of Sri Lanka.

1.1.1 Objectives of the Paper:

The primary objective of this research is to systematically examine the correlation between student employability and poverty reduction, with a particular emphasis on the undergraduate cohort at Sanasa University. By scrutinizing the factors influencing student employability and their subsequent impact on poverty levels, the study aims to contribute nuanced insights to the existing body of knowledge. This research seeks to unravel the dynamics through which investing in education and skill development can act as catalysts for broader economic and social gains.

1.1.2 Importance of the Research:

In the pursuit of national development goals, understanding the multifaceted relationship between education, employability, and poverty is crucial. This research holds significance in shedding light on how policies, both in education and employment sectors, can be strategically designed to address poverty at its roots. The outcomes of this study are anticipated to provide empirical evidence, guiding policymakers, educational institutions, and private sector stakeholders in formulating strategies that not only benefit individuals but also contribute to sustainable economic growth.

1.1.3 Structure of the Paper:

The remainder of this paper is structured to systematically address key aspects of the research. Section 2 presents a comprehensive literature review, setting the stage for the current study by synthesizing existing knowledge on student employability and poverty reduction. Section 3 outlines the specific objectives guiding the research process. In Section 4, the methodology employed, a mixed-methods approach, is detailed, justifying the choice and providing a blueprint for data collection and analysis. Subsequent sections delve into the factors influencing student employability and the role of government policies and private sector initiatives. The anticipated findings and their implications are discussed in Sections 7 and 8, respectively. The paper concludes by summarizing key findings and emphasizing their broader implications for educational reforms and poverty alleviation strategies.

1.2. Research Objectives

- To Examine the Correlation between Student Employability and Poverty Reduction
- To Investigate Factors Influencing Student Employability
- To Identify Effective Strategies for Enhancing Student Employability

1.3 Problem Statement

In the Kegalle district of Sri Lanka, as in many regions globally, the nexus between education, student employability, and poverty reduction presents a critical challenge. Despite the recognized importance of education in fostering socio-economic progress, there exists a gap in understanding the specific mechanisms through which enhanced student employability contributes to poverty reduction. The lack of a comprehensive examination of factors influencing student employability within the context of Sanasa Campus impedes the development of targeted interventions and policies.

Furthermore, existing literature tends to emphasize the outcomes of higher education without delving into the underlying factors that shape employability. The challenge lies not only in increasing the number of graduates but also in equipping them with the necessary skills and attributes to secure gainful employment, ultimately alleviating poverty. The unique socio-economic landscape of the Kegalle district calls for context-specific insights, particularly regarding the role of government policies and private sector initiatives in enhancing student employability and their subsequent impact on poverty levels.

This research seeks to address the gap in knowledge by examining the critical relationship between student employability and poverty reduction within the specific context of Sanasa Campus. The overarching problem is to identify effective strategies that can bridge the gap between education, employability, and poverty reduction, offering insights for policymakers, educational institutions, and private sector stakeholders to contribute meaningfully to sustainable economic growth and social development. Through a systematic exploration of this problem, this research aims to provide actionable recommendations for fostering student employability as a means of poverty alleviation in the Kegalle district of Sri Lanka.

2. Materials and Methods

Mixed method approach is used for this research

2.1 Overview of the Mixed-Methods Approach:

This research employs a mixed-methods approach to provide a comprehensive understanding of the complex relationship between student employability and poverty reduction. By combining both quantitative and qualitative methods, this approach seeks to leverage the strengths of each method, thereby enhancing the overall validity and reliability of the study.

2.2 Quantitative Data Analysis:

Employment Rates:

Quantitative data will be collected to analyse the employment rates of Sanasa University graduates. This involves assessing the percentage of graduates who secure employment within a specific timeframe after completing their education. Employment rates will be analysed across different disciplines to identify patterns and variations.

2.2.1 Income Levels:

The research will examine the income levels of employed graduates, focusing on the relationship between enhanced employability and income. This involves collecting data on salary structures, job positions, and income growth over time to understand the economic impact of improved employability.

2.2.2 Poverty Indices:

Quantitative measures of poverty indices in the Kegalle district will be analysed in correlation with the employment and income data. This includes assessing poverty rates, income distribution, and socio-economic indicators to identify trends and patterns associated with student employability.

2.3 Qualitative Assessments:

2.3.1 Interviews:

In-depth interviews will be conducted with Sanasa University graduates, employers, and key stakeholders in the region. This qualitative approach aims to capture the nuanced experiences, perspectives, and challenges faced by graduates in the employment market. Interviews will be

semi-structured, allowing for exploration of individual narratives and contextual factors influencing employability.

2.3.2 Questionnaires:

Structured questionnaires will be distributed to a representative sample of Sanasa University students and recent graduates. The questionnaires will collect data on perceived employability skills, the effectiveness of educational programs, and the alignment of curriculum with industry needs. The responses will be analysed to identify patterns and correlations.

3. Results and Discussions

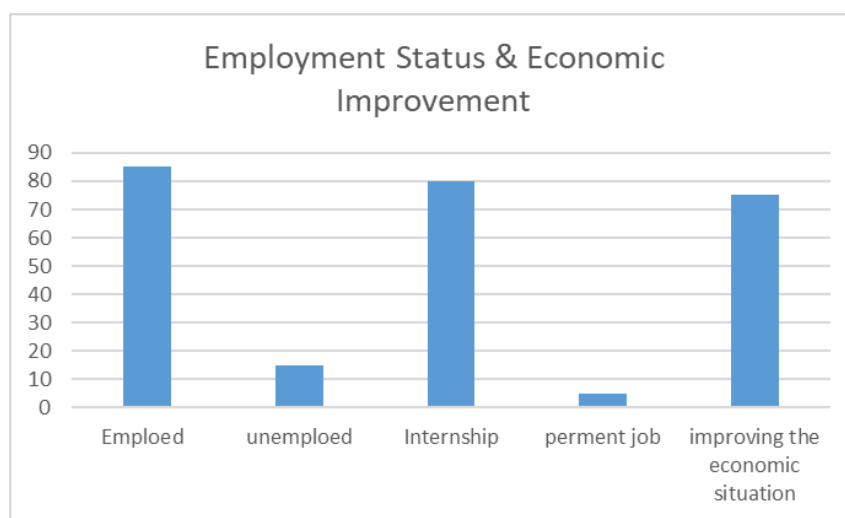


Figure 1: employment Status and Economic Improvement.

A significant majority of respondents (85%) reported being currently employed, indicating a strong correlation between completing higher education and obtaining employment. Among the employed respondents, 75% strongly agreed or agreed that their job significantly improves their economic status, suggesting that employment post-graduation plays a crucial role in poverty reduction.

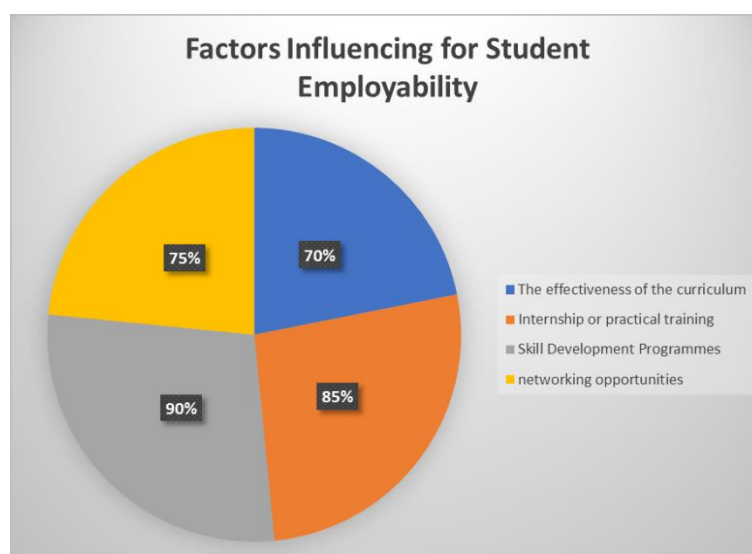


Figure 2: Factors Influencing for Student Employability.

Approximately 70% of the respondents felt that their education prepared them well or very well for their current job, highlighting the effectiveness of the curriculum in meeting job market demands. Internships or practical training were part of the program for 85% of the respondents, with a majority indicating that these experiences were crucial in securing employment.

Skills development programs and networking opportunities were also rated as very important by 90% and 75% of respondents, respectively, underlining the significance of comprehensive education that includes beyond-the-classroom learning experiences.

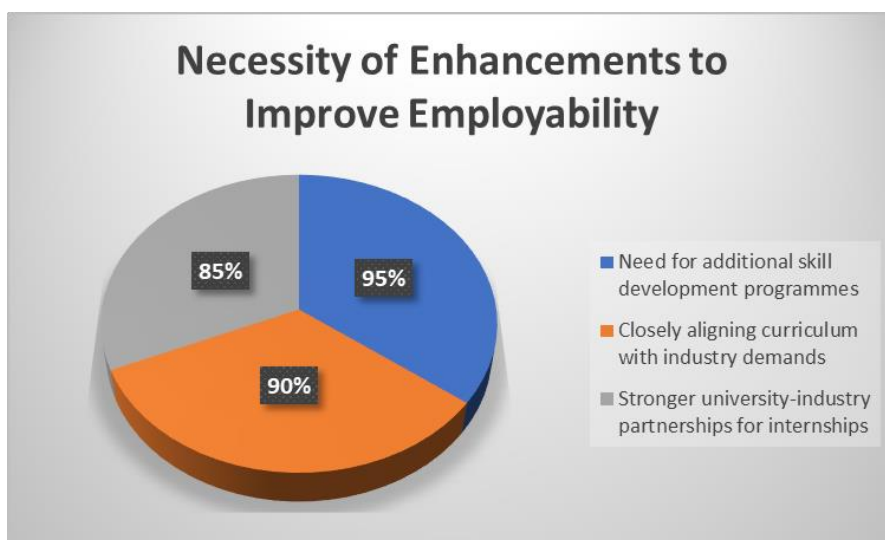


Figure 2: Necessity of Enhancements to Improve Employability.

Additional skill development programs were deemed very necessary by 95% of respondents, reflecting a clear call for integrating more practical skills training into the curriculum. Closer alignment of the curriculum with industry demands and more robust university-industry partnerships for internships were seen as very necessary by 90% and 85% of respondents, respectively.

Table 1: Correlation Table of the Study

No	Statement	Spearman's Correlation Coefficient Value	Significant
1	Correlation between Student Employability and Poverty Reduction	.497	.000

The correlation coefficient value between student employability and poverty reduction is 0.497. There is a weak positive correlation between student employability and poverty alleviation. The above significant null hypothesis is rejected ($0.000 \leq 0.05$). Therefore, it can be concluded that there is a significant relationship between student employability and poverty reduction at 95% confidence level.

4. Conclusion

In conclusion, this study underscores the strong positive correlation between education and employment, emphasizing the significance of a relevant curriculum and practical training in

enhancing student employability. The identified challenges in career services highlight the need for improvements in supporting students' transition to the job market. The practical implications suggest a pressing demand for more robust university-industry partnerships, enhanced career guidance, and continuous curriculum updates. These recommendations aim to empower graduates, contributing not only to individual success but also to broader societal goals of poverty reduction and sustainable economic development. This research provides actionable insights for policymakers, educators, and industry leaders to address the evolving needs of the workforce.

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ANALYSIS OF SOFT SKILLS REQUIRED FROM FRESHLY GRADUATED SRI LANKAN CONSTRUCTION PROFESSIONALS: IN REFERENCE TO CONSTRUCTION INDUSTRY IN SRI LANKA, UNITED ARAB EMIRATES AND SAUDI ARABIA

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Abstract: Sustainable Development Goal 4, titled “Quality Education”, includes specific goals to be achieved by 2030 and those emphasise delivering quality technical, vocational, and tertiary education. The focus is on equipping learners with knowledge and skills encompassing elements such as acquiring global citizenship, respecting cultural diversity, promoting non-violence and adopting sustainable lifestyles. This study aims to analyse the soft skills required from freshly graduated Sri Lankan construction professionals in meeting the demands of the construction industry in Sri Lanka, the United Arab Emirates, and the Kingdom of Saudi Arabia. There are five major soft skills identified in this study, namely, time management, communication, problem-solving and analytical skills, stress management and leadership which are deemed as the most prominent soft skills required in the contemporary construction industry. Data collected through desk research together with data collected through semi-structured interviews, questionnaire surveys, and participation observation methods has been analysed qualitatively. Some data that is of a numerical nature has been analysed quantitatively. Thus, mixed-method approach has been followed. It was found that there is a gap between the soft skills of freshly graduated Sri Lankan construction professionals and the soft skill requirement in the construction industry in the aforesaid countries. The gap adversely affects the projects and has also a negative impact on the personal and professional growth of the individuals. Enhancing soft skills of construction professionals during the stay in university, positively impacts on employability as well as retention of professionals in the industry. Bridging the gap between the soft skill requirement in the industry, through the knowledge and practice acquired by university degree would be one of the major solutions addressing the particular challenge. For that, it is essential to have a good collaboration between stakeholders in the construction industry in the said countries and authorities, officials and academics in university education.

Keywords: Sustainable Development Goals; Soft skills; Construction industry; Freshly graduated construction professionals; Graduate employability

1. Introduction

1.1 Background of the Study

The 2030 Agenda for Sustainable Development adopted by all United Nations Member States in 2015, serves as a collective roadmap for fostering peace and prosperity for both humanity and the planet, presently and in the future. Sustainable Development Goals (SDG) are an urgent call for collective action from every nation, both developed and developing in a global alliance. Comprising 17 distinct objectives, SDGs are integrated - they recognize that action in one field will affect consequences in others, and that development must balance, the four pillars of sustainability namely, human, social, economic and environmental sustainability (United Nations Development Programme, 2024).

Some of the targets under Goal 4, "Quality Education," include ensuring that by 2030, all learners attain the competencies necessary to promote sustainable development. This encompasses education on sustainable lifestyles, human rights, gender equality, peace promotion, non-violence, global citizenship, and cultural diversity appreciation (United Nations, n.d.). In addition to that, by 2030, there is a goal to significantly enhance the number of youth and adults possessing relevant skills, particularly technical and vocational skills, to facilitate employment, decent work, and entrepreneurship opportunities. The construction industry and construction projects are also integrated with most of the SDGs. The construction industry plays a vital role in achieving several SDGs including SDG 6 - clean water and sanitation, SDG 7 - affordable and clean energy, SDG 9 -industry, innovation, and infrastructure, SDG 11 -sustainable cities and communities, SDG 12 -responsible consumption and production, and SDG 13 - climate action.

In the literature on construction, there are generally three levels of defining the construction process, as outlined by (2015 cited in Pheng and Hou, 2019).At one extreme, construction is defined as an economic activity that focuses only on the final phase of the construction process, emphasizing the on-site physical work. In this context, all services such as project management, planning and design as well as the offsite manufacture and supply of building materials are not included. On the other hand, construction is viewed as a comprehensive economic activity that involves the entire construction process from producing and manufacturing raw materials and providing professional services such as design and project management, to executing the on-site physical tasks. This perspective acknowledges construction as an economic activity that crosses over all three economic sectors (Gruneberg, 1997, cited in Pheng and Hou, 2019). According to this perspective, the construction process commences well before the physical work on site that transforms materials and design into complete buildings, structures, and facilities. In this study, we have adopted the latter perspective of construction, which acknowledges the interdependence of various activities and sectors involved in the construction process.

1.2 Research objectives and questions

There are 3 objectives of the study which have been outlined as follows.

1. To understand the need for soft skills required from Sri Lankan freshly graduated professionals to perform duties in the construction industry in Sri Lanka, the United Arab Emirates (UAE), and the Kingdom of Saudi Arabia (KSA).
2. To ascertain the effects of soft skills on the successful completion of construction projects and functions of the construction industry in Sri Lanka, the UAE, and the KSA.
3. To recommend reforms to meet the need for soft skills required from freshly graduated Sri Lankan professionals who are working in the construction industry in Sri Lanka, the UAE, and KSA.

To achieve the aforesaid objectives, the following research questions have been formulated.

1. What is the current need for soft skills expected from freshly graduated professionals who are working in the construction industry in Sri Lanka, the UAE, and the KSA?

2. What are the most required soft skills expected from Sri Lankan freshly graduated professionals to perform their duties effectively in the construction industry in Sri Lanka, the UAE, and the KSA?
3. Among the identified soft skills, what soft skills are lacking in freshly graduated Sri Lankan professionals working in the construction industry in Sri Lanka, the UAE, and the KSA?
4. What are the possible causes of the lack of required soft skills among freshly graduated Sri Lankan professionals who follow construction-related degrees in Sri Lanka?
5. What are the reforms that can be made to develop the soft skills of Sri Lankan graduates who are going to step into the construction industry in Sri Lanka, the UAE, and the KSA?

1.3 Scope of the study

This study only focuses on the graduates who have graduated from Sri Lankan universities and have followed construction-related degrees. The focus of our study is fresh graduates, and the term freshly graduated professionals has been used in this study to indicate construction professionals who graduated recently from their first degree in university (for the purpose of this study, professionals who graduated within the last 5 years have been considered). For the purpose of the study, civil engineers, quantity surveyors, facilities managers, structural engineers, and project managers are termed as construction professionals. Study areas are Sri Lanka, the UAE, and the KSA.

1.4 Significance of the study

Our findings would deepen the understanding of the importance of soft skills required in the contemporary construction industry in Sri Lanka, the UAE, and the KSA. Further, this study makes some significant contributions to soft skill development among Sri Lankan freshly graduated construction professionals and helps new graduates to move forward with contemporary industry demands.

2. Literature Review

Many research studies have demonstrated that the construction industry is one of the most booming industries in the world and responsible for about one-third of the world's gross domestic product. It accounts for seven percent of employment and about forty percent of energy consumption. This industry is a critical metric of 'economic activity and wealth creation' (Wilma and Marc, 2003 cited in Fadumo and Makinde, 2021).

Balcar (2014 cited in Heerden et al., 2023, p. 2) states that soft skills are crucial for both employability as well as for retention of employees. It is very hard to define the term 'Soft skill' and it has to be identified with the context and the industry. Soft skills are non-cognitive skills which are associated with individual personality, those are applied and vital for employability and also referred to as 21st century skills. According to Boyatzis, 'soft skills' are an emotional intelligence which includes the capability of determining how to manage oneself, his life as well as his work (Sarros and Santora, 2011 cited in Mufaricha et al, 2021,p.2). According to Zuo et al, (Zuo et al, 2018 cited in Mufaricha et al,2021,p.2) there are five aspects of soft skills such as motivation skill, communication skill, conflict management skill, teamwork, and cognitive skill. It is evident that communication is one of the soft skills which is deemed mandatory for the effective implementation of any construction project.

According to Mufaricha et al,(2021), a study done in Indonesia, communication is a significant factor among other factors in a successful project. In many countries in the world, communication is deemed as the first project success factor, as it is a key to involvement in the community and making decisions. Effective communication is important for construction projects in many aspects. Project vision can be properly shared with the community through effective communication and it is useful in large-scale construction projects since it can prevent controversies among the community in the project areas. As all stakeholders need to be equipped with information about the project, communication is one of the key competencies required to achieve project success. According to Goldsmith and Newton (2011, Cited in Akinshipe et al., 2022, p.325), the engagement of human beings can 'make or break' a construction project whenever there is poor communication. Moreover, miscommunication may lead

to frequent disputes. According to Nathan et al., (cited in Fadumo and Makinde, 2021, p.13) roads, bridges, houses, and commercial buildings become a reality through effective communication between professionals and teams in that construction project. Effective communication among employees, contractors, subcontractors, clients, and other professionals is important for successful project implementation. As Jiwat (2019, cited in Fadumo and Makinde, 2021, p.13) identifies, language serves as a potential tool that enables collaboration and co-evolving, it has consistently acted as a guiding force in bringing precise views, and actions and catalyzed individuals and societies to move forward in various spheres of life. Effective communication through the use of precise language helps to resensitize ideas in the client's mind from a concept to a clear practice or a final physical structure (cited in Fadumo and Makinde, 2021, p.13). However, the successful completion of construction projects is a major challenge, due to the lack of communication competency. One current study carried out in Pakistan, explores the effects of communication, clarity in the scope of the construction project and organizational culture on project success (Muneer et al., 2022). One Dutch study (Goedknegt, 2015) has revealed a few business-enabling capabilities, and among those capabilities, communication plays a vital role.

Another important soft skill is leadership (Mufaricha et al, 2021). Olawale (2015) identified a few soft skills required in construction projects. A study done in Anambra State, in south-eastern Nigeria, focused on a system that energizes construction managers with the requisite leadership skills. This study highlights the benefits of enhancing leadership capacity. It states that enhancing leadership skills leads to achieving project targets on time, sustaining performances in projects, helping to administer technical expectations, managing stakeholders efficiently, reducing disputes, enabling indigenous contractors' success on a global scale and also serving as a path for personal development. Thus, the objective of the research was to develop a structured framework for enhancing leadership skills among construction managers in Anambra State (Oluwatayomi, 2023).

Sunindijo (2013), has conducted an Australian based- study and revealed that human soft skills help to build better performance at the workplace, and empirical evidence has also been found demonstrating that project managers can use human soft skills, including transformational leadership, in order to improve safety in construction projects. Managers with transformational leadership skills empower employees working under them to accomplish their targets through holistic vision and inspiration. Transformational leaders serve as role models for their subordinates or colleagues, influencing them through their acts and becoming admirable and trustworthy. They have extraordinary abilities and strong determination. Those leaders communicate messages precisely and are committed to achieving their goals and shared vision. They inspire their followers to be creative and innovative. Transformational leaders give proper attention to individuals who work with them, which helps them achieve goals, and sometimes they also play the role of a mentor (Bass and Riggio, 2006 cited in Akinshipe et al., 2022).

A project manager should also engage in negotiations using his problem-solving skills in order to enter into an amicable settlement in case a dispute arises. Conflict resolution is a pivotal role of a project manager. A study conducted in Gauteng Province, South Africa (Akinshipe et al., 2022) has discussed how problem-solving skill operates as a vital trait (among other traits) of a project manager that enables him to accomplish the goals of the project in an assigned time frame. According to Kawesittisankhun and Pongpeng (2020), problem-solving is the most significant skill of an engineer in a construction project.

Stress management is another important skill that operates as a prerequisite in the construction industry. Research conducted by Wu et al., (2019) using data from 191 stakeholders in the construction industry, including owners, supervisors, contractors and subcontractors, has investigated the connection between role stress, burnout of employment and career performance in construction project managers.

According to Shehu (2021) time management is crucial for successful project delivery. Timely completion and quality work within the budget are major deliverables in a successful construction project. This Nigerian-based research has demonstrated that completing construction projects on time has become a principal issue in achieving a holistic solution in the construction industry in Nigeria (Shehu, 2021). A study conducted in Iraq states that it is a major challenge and one of the greatest concerns are to complete large construction projects within a stipulated time frame and within the pre-estimated budget (Dagbui and Smith, 2014).

There is little literature found in Sri Lanka with regard to this field of study. The study report on Skills Gaps Analysis of the Construction Industry Sector in Sri Lanka, done by Survey Research Lanka, is one such research. That study has been planned to evaluate the skills gaps in the construction industry in order to improve the quality, accessibility, and recognition of skills training provisions required in Sri Lanka. Moreover, it has been sought to make revisions to the 'Present Training Plan' in Sri Lanka with a view to bridging the skills gap in the construction industry. That study has also identified the strengths and composition, including gender composition, quality, and other special features of the current workforce in the industry. Gaps in curricula and training were also discovered in the said study (Survey Research Lanka, 2021). According to Silva et al., (2018), the construction industry in Sri Lanka faces many challenges, including a shortage of skilled and professional workers. This study has evaluated skill and labour shortages in Sri Lanka and skill gaps and mismatches.

Rajapakshe (2019) has conducted a research with the aim of identifying the skills and competencies required by the construction professionals (Sri Lankan) in order to manage disputes in the construction industry. In the said study, the researcher has found that 10 competencies including time management skill, competency in cost estimation, management and reporting, procurement tendering are important for dispute avoidance. This study has discussed both hard and soft skills which are required by the construction professionals and that has been done more particularly focusing only on the dispute avoidance and resolution. Some of these studies have highlighted soft skills required in the contemporary construction industry in Sri Lanka to a limited degree. It is apparent that in the UAE and KSA, there is a significant demand for construction professionals who graduated from Sri Lankan universities. Construction industries in those countries also highly value the soft skills expected from freshly graduated Sri Lankan professionals when recruiting them for their projects. This study makes a reasonable attempt to fill this gap identified through a literature review.

3. Methodology

The methodology adopted can be explained using Saunders' research onion (Saunders et al., 2019) as follows. As the focus of this study is soft skills required in the construction industry, the research philosophy employed in this study is pragmatism since the researchers dealt with the practical aspects and relevancy of soft skills required in the construction industry. The research approach followed is neither inductive nor deductive. Instead, an abductive approach has been followed. As opposed to inductive and deductive reasoning approaches, the researchers followed 'abductive' reasoning since it enables them to improve and alter the theoretical framework prior to and after the research process. As it facilitates researchers to move back and forth, it is best suited for this study. Strategies used in this research are an online survey, interviews, participation observation and a systematic literature review. As far as the methodological choices made are concerned, both qualitative and quantitative data collection methods have been deployed. Thus, a mixed method has been followed. The soft skills required in the construction industry at present have been explored, and it is a study of a current-specific phenomenon. Therefore, it is cross-sectional in terms of time horizon.

Secondary data has been gathered through a literature review, whereas primary data has been gathered through semi-structured interviews, observations and an online survey. Five interviewees, in Sri Lanka, UAE, and KSA, have been interviewed using semi-structured interview methods, and all of

these interviewees are experts in the field of construction and have more than 15 years of experience in the said field.

The sampling method used to conduct the online survey is convenience sampling, which is utilized in non-probability-based sampling methods. In addition, data has been gathered through observation, as one of the researchers himself is the CEO of a construction company operating in Sri Lanka and the UAE. The study comprises of both qualitative and quantitative data. The research data has been predominantly analyzed qualitatively. However, some data has also been analyzed quantitatively.

3.1 Limitations and delimitations

As mentioned above, the sampling technique used is convenience sampling due to time constraints, accessibility and availability of the respondents. Further, this study has been done for a period of 3 months, and the researchers have only focused on Sri Lanka, UAE, and KSA. Those can be deemed methodological and other limitations of the study.

As far as delimitations are concerned, only five soft skills, namely, communication, time management, problem-solving, analytical skills, stress management and leadership have been selected and evaluated. Further, the study only focuses on civil engineers, quantity surveyors, facilities managers, structural engineers, and project managers, excluding other construction professionals and workers. This can be considered a delimitation of the research.

4. Data Analysis and Discussion

Five experts, including CEOs of construction companies, have been interviewed, and an online survey has been carried out with 41 respondents. One of the researchers has also done a participation observation. The Respondents are comprised of professionals who are engaged in the field of construction, including civil engineers, quantity surveyors, contract managers and development professionals.

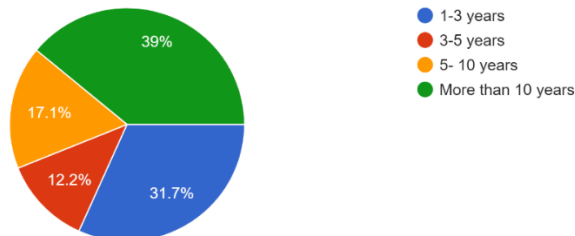


Chart 1: Experiences in the relevant field.

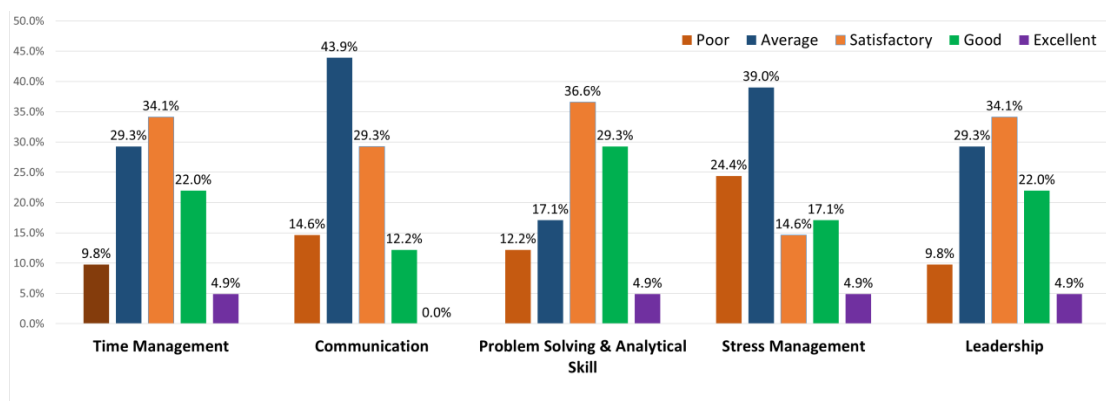


Chart 2: Opinions gathered in response to the question regarding soft skills of freshly graduated Sri Lankan construction professionals.

Responses related to each soft skill are rated as depicted in Chart 3.

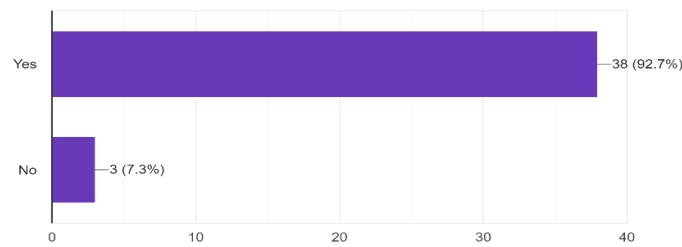


Chart 3: views expressed regarding changing university curricula to improve soft skills.

As per the responses obtained from the survey, 92.7% of the respondents admitted the fact that the curriculum of university degrees needs to be amended in order to meet the soft skills requirement of graduates whereas 7.3% state that there is no such need. All interviewees admitted that there is a gap between the soft skills required from freshly graduated Sri Lankan construction professionals and the demands existing in the construction industry. Results regarding effects of soft skills on the construction projects and the construction industry in general can be capsulated as follows:

Table 1: Soft skills and their effects on the construction projects and the construction industry in general

Soft skill	Effects
Communication	Lack of communication skills causes disputes among stakeholders (clients, contractors, sub-contractors) in a construction project, creates ambiguities in the implementation of the design or plan of the project, disrupts positive collaboration between workers and managers, disrupts good rapport with peers, subordinates and superiors and ultimately adversely affects achieving a shared vision, productivity and project timelines. Proper communication leads to resolve conflicts, promote a positive working environment, smooth functioning of the project team, effective decision-making and avoiding project delays, cordial relationships with clients/ suppliers/ workers and secure a favourable working environment and create a conducive and safe working environment.
Time management	Accomplishment of project goals within the time frame, saving cost, finishing the project within the budget and enable the project team to operate under less pressure as it avoids last-minute deadline pressure
Problem-solving and analytical skills	Evaluate matters and issues efficiently, choosing the best solution when unexpected eventualities happen, avoid project delays and create faith in the minds of clients.
Stress management	Preventing demotivation among peers and subordinates, evaluating an unexpected issue with a clear mind to provide the best solutions, creating a conducive working environment, reducing mistakes happened due to hasty decision-

	making, creating work and life balance and making the most accurate decisions.
Leadership	Ability to perform duties equally even in the absence of superiors, act as a factor to motivate others, avoid disputes and avoid escalating conflicts, being more attractive to clients and workers and indirectly help to build the reputation of the organization.

Sri Lankan universities offer top-notch education for construction industry professionals and it is notable that freshly graduated Sri Lankan construction professionals are in high demand in construction industries in the UAE and KSA. While academic credentials are praised, soft skills remain a challenge for graduate employability. Efforts by universities and professional bodies include integrating soft skills modules, Toastmasters programs, and continuous professional development (CPD) courses. For instance Department of Building Economics, University of Moratuwa, has included some modules such as professional communication skills and human resources management as course modules in BSc in Quantity Surveying and BSc in Facilities Management (University of Moratuwa, 2024). The Toastmasters Club of the Institute of Quantity Surveyors Sri Lanka (IQSL) carries out Toastmaster programmes to improve the leadership skills and public speaking skills of quantity surveyors (Institute of Quantity Surveyors Sri Lanka, 2024). The Institute of Engineers Sri Lanka (IESL) conducts CPD programmes that have been designed to cover specific areas such as communication and management skills, and it was planned to offer courses to meet the demands of industrial trends. IESL has started a programme titled ‘Path to Success by Developing Soft Skills for Engineers’ as an online webinar (Institution of Engineers, Sri Lanka, 2024). However, it was revealed by an interview that uptake among graduates is low, highlighting the need for greater awareness of the importance of these skills.

5. Conclusion and Recommendations

It is evident that there is a gap between the soft skills required from construction industry professionals who have recently completed their degrees in the field of construction and the demand in the industry. Communication, time management, problem-solving and analytical skills, stress management, and leadership are the most required soft skills identified in the study. As discussed, a lack of one or any of these soft skills directly and indirectly affects projects and the advancement of the construction industry in general. It affects the freshly graduated construction professionals individually and hinders their personal and professional growth as well. As discussed in the outset of the paper, the SGD 4, "Quality Education," promotes to enhance relevant skills among professionals while becoming a global citizen and appreciating cultural diversity. Developing the particular soft skills indubitably help to achieve the aforementioned goal.

There are recommendations suggested by industry professionals who have been interviewed, and almost the same reforms were suggested by the respondents who participated in the survey. Establishing collaboration with the construction industry, universities, professional bodies and higher education institutes is one of them. For that, it was suggested to have webinars, seminars, and workshops with industry professionals in order to identify current soft skill requirements in the construction industry. Raising awareness among fresh graduates related to the soft skills programs and providing additional incentives or recognition if they follow these programs would be beneficial. As far as the UAE and KSA construction industry is concerned, to get an understanding of the requirements, it is more fruitful to have collaborations and network with companies and industry professionals operating in the UAE and KSA to explore the soft skill requirements there. It is also suggested to build partnerships with universities and the construction industry. Enhancing the period of industrial training and getting feedback from construction companies regarding the soft skills of graduates and accordingly developing and inculcating those soft skills in individuals is another solution. Conducting continuous profes-

sional development programs in order to meet the demands of the dynamic construction market is presented as another solution. Updating the curriculum of universities is important in this regard. The curriculum should be updated in order to give due recognition to soft skill developments. The inclusion of compulsory module or modules for soft skill development in which students get theoretical knowledge on soft skills and practical application of it is also of vital importance. Ultimately, it is suggested to get input from industry professionals in developing a new curriculum for undergraduates who follow construction-related subjects.

5.2 Future research

There are a few shortcomings in this research. Only 41 respondents participated in the survey, and data has been gathered through five interviews. The sample size is very small, though the subject matter is very extensive. Thus, it may have caused effects on the findings. In addition, this study has been done for a very limited time period of 3 months. Increasing the size of the sample and extending the time duration would lead to more discoveries. Due to the burgeoning demand in the construction industry in the UAE and the KSA, a separate study can be done emphasizing the distinctions between the UAE and KSA markets and that of Sri Lanka. It is observed that the UAE and the KSA construction industries are different from the Sri Lankan construction industry in many aspects. The UAE industry is one of the construction industries in the world that has an incredibly diverse culture. Thus, some soft skills such as communication skills, are more significant in order to work as a construction industry professional in the midst of diversity and multiculturalism than in Sri Lanka. Hence, a separate study can be done in order to identify those soft skills and from which aspects and to what level they should be improved. Moreover, it is worthwhile to conduct an in-depth study of how to develop each soft skill according to priorities. A separate study can also be done regarding soft skills requirement for different category of construction professionals such as quantity surveyors, civil engineers and facilities managers, identifying their specific and different job responsibilities. Further, how the curriculum should be developed specifically to meet the needs of the said soft skills can be researched separately and extensively.

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**THE STUDY OF EMPLOYER-CENTRIC GRADUATE EMPLOYABILITY IN SRI
LANKA: A COMPREHENSIVE LITERATURE REVIEW**

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Abstract: The global economic crisis has negatively impacted several sectors, according to International Monetary Fund (IMF) and Central Bank of Sri Lanka (CBSL) statistics. The International Labor Organization (ILO) connects the high domestic and overseas unemployment rate to that crisis. The global need is to integrate higher education with industry needs and specialized skills to improve graduates' employability, a social group that directly impacts the economy. The discrepancy between graduates' skills and employers' expectations has been highlighted in previous studies on employability skills. Efforts were made to narrow the skills gap in major industries in selected global regions and the current industry. Google Scholar, IEEE, Springer, and other reputable databases have been deployed to evaluate research papers from 2000 to 2023 in a comprehensive literature review. This review outlines the job skills Sri Lankan and international companies expect in each industry. Industry-specific skills vary by country, culture, and industry category, hence higher education curricula must be innovated to meet industry and employer needs. It is evident that narrowing the gap between academic performance and employers' expectations requires initiatives to prepare graduates for different workforce challenges. Future study should address employment market forcefulness. Investigating rapidly changing marketplace requirements is essential. Thus, academics, policymakers, and industry stakeholders must collaborate to establish curriculum and address evolving skills needs in order to maintain up with the evolving employment market.

Keywords: Employability skills; Employers' expectations; Graduate performance; Graduate unemployment; Higher education curricula; Skills gap

1. Introduction

1.1 Economic growth and unemployment in Sri Lanka compared to the world contest As found by the IMF Global economic growth is projected to fall from an estimated 3.5 percent in 2022 to 3.0 percent in both 2023 and 2024. The rates increases are due to policies adopted by central banks to fight inflation. This introduces a burden on economic activities. Also, the challenge of unemployment in developing and less developed countries is increasing significantly (World Economic Outlook Update, 2023). According to the International Labor Organization (International Monetary Fund, 2021). The number of global unemployed people is now estimated to be 201 million in 2021 and 192 million in 2022 (International Monetary Fund, 2023). It is a slight increase from previous years. However, this number has significantly affected the labor market and the global economy. Also, the impact of the COVID-19 epidemic cannot be forgotten. In recent years, unemployment for the young working-age population can be seen in many regions of the continent. It has become an emerging challenge for those regions. Northern Africa (30 % youth unemployment rate in 2021), Arab states (27 %), and Southern Asia (13 %).

Accordingly, when we closely monitor the situation in Sri Lanka, according to the reports of the Central Bank of Sri Lanka (2022), the unemployment rate decreased from 5.1% reported in 2021 to 4.7% in 2022. The unemployed population also decreased from 0.440 million in 2021 to 0.399 million in 2022. As a result, the male unemployment rate remained unchanged at 3.7 percent, while the female unemployment rate decreased from 7.9 percent in 2021 to 6.5 percent in 2022. Furthermore, as indicated by the reports of the Central Bank of Sri Lanka, General Certificate of Education. The unemployment rate and above category has decreased significantly to 7.8% in 2022 compared to 9.1% recorded in 2021. Moreover, according to Central Bank of Sri Lanka reports, the youth unemployment rate (15-24 years) in Sri Lanka is also reported to be 26.5% in 2021, which will decrease to 22.8% in 2022. Looking at unemployment rates by gender, the male unemployment rate remained unchanged at 3.7% in 2021 and 2022, while the female unemployment rate decreased from 7.9% in 2021 to 6.5% in 2022. Skill mismatch, skill shortage and early school leaving are the main causes of youth unemployment. But the political, social and economic instability of the respective country can also affect it (Msigwa and Kipasha, 2013).

1.2 Graduate employability

Graduate employability can be defined as the compilation of a series of soft and hard skills and abilities that a graduate can obtain to achieve and meet a desirable job requirement and succeed in his/her career (Y. Chen, 2017; Hosain *et al.*, 2021). In focusing on graduate employability, universities are bound to public bodies to provide specific data on graduate outcomes. It's kind of building pressure in the university system. Furthermore, many universities' educational qualifications, should meet the learning outcome standards required by external accrediting agencies, are a driving force when consider about the employability of graduate students (Jackson, 2012). For example, for business education curricula, employability should be achieved in relation to learning certification standards set by AACSB (2011), a US-based business school organization. Critics argue that, when combined with other legislative, political and economic pressures to address skill development in higher education, this outcomes-based focus is leading to a Universalist approach (Jackson and Chapman, 2011; Marginson, 2006) which may not truly reflect the needs of various stakeholders or accurately reflect individual employability.

1.3 Role of higher education institutes for graduate employability

Accordingly, in the analysis of the above-mentioned facts, unemployment can be solved by creating the expected skills of the current job market, the primary objective of this research is to identify the skills demanded by local and foreign employers and incorporate them into the learning outcomes of higher education in Sri Lanka. Many young people are engaged in tertiary and vocational education. It

improves the value of human resources in the country's economy. We can observe that the problem of unemployment among the younger generation is more serious than among the adults in developing and developed countries (Dagume & Gyekye, 2016).

When we consider the relationship between higher education and employment, it is understood that it is a very strong and direct relationship. This relationship has attracted the intense attention of researchers since the 1960s. Accordingly, researchers have published an increasing number of studies examining the relationship between higher education and employment (Cai, 2012). Until the 1990s, much attention was paid to the process of transition from education to the professional sphere. This change in the research can be referred to the use of the work success as an indicator to the quality of the education in general and higher education specifically (Teichler, 2009).

1.4 Landscape of Sri Lankan labors

Today, higher education is provided by both the Sri Lankan government and the private sector. Annually, about 20,000 graduates from public universities under the University Grants Commission and about 3,500 from non-government higher education institutions (Fernando *et al.*, 2022). According to the years 2014 and 2015, there is no significant difference in the overall employment status of graduates of public universities and non-government institutions. The overall employment rate for state university graduates is 65.5%, while the employment rate for non-state graduates is 66% (University Grants Commission, 2018).

After that, graduates who complete their education from public universities and private universities enter the job markets in Sri Lanka and abroad. According to the Sri Lankan Labor Force Survey conducted by Department of Census and Statistics (DCS) in 2022, the economically inactive population has increased compared to 2021 resulting in a decrease in the labor force. In line with the increase in household population, the economically inactive population increased from 8.581 million in the previous year to 8.615 million in 2022, while the labor force representing the economically active population decreased slightly from 8.553 million in 2021 to 8.547 million in 2022. Along with these developments, the Labor Force Participation Rate (LFPR), which is the proportion of the household population in the labor force, slightly decreased to 49.8% in 2022 compared to 49.9% in 2021 (University Grants Commission, 2018).

Departures for overseas jobs have recorded a significant growth of 154.4% from 122,264 in 2021 to 311,056 in 2022. Economic difficulties in the country led to a significant increase in departures for foreign jobs in 2022. Departures under all skill categories, namely professional, middle level, clerical and related, skilled, semi-skilled, unskilled and housemaid, increased with major contributions from unskilled, skilled and housemaid categories (Central Bank of Sri Lanka, 2022).

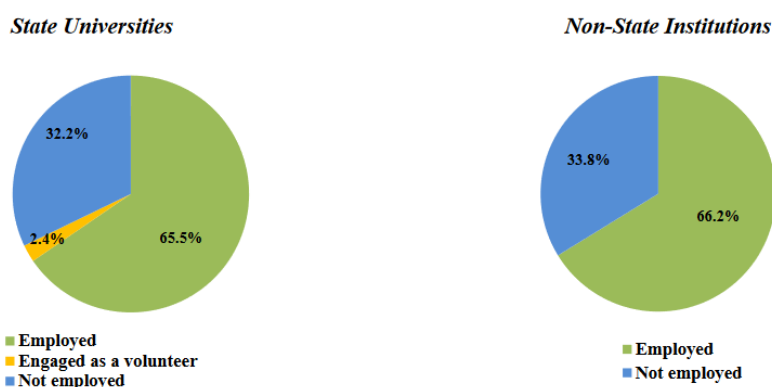


Figure 1: Employment Status of Graduates.

2. Research Methodology

A major function of higher education is to improve the employability of graduates. Employers today look for graduates with balanced with good academic credentials, soft skills such as communication skills, adaptability, problem solving and interpersonal skills (Ken *et al.*, 2012). This emphasis on skills leads to the importance of identifying employability skills and incorporating them into higher education (Markes, 2006). Also, the employability skills they expect from graduates vary depending on the industrial sector, employers and country. Based on the available literature, this paper reviews the employability skills required for different industries in Sri Lanka and selected countries. The main industry categories selected to conduct this research are as follows. Agriculture, Tourism/Hotel/Hospitality, Accounting Management, Information and Communication Technology, Manufacturing and Construction.

Currently, the Sri Lanka Bureau of Foreign Employment (SLBFE) classifies occupations according to several categories: professional, skilled, semi-skilled, middle-level, clerical, unskilled, and housemaid. These categories are without any correspondence to international occupational classifications. In order to better address issues of potential mismatch between the availability of migrant workers' skills and the demand for jobs, the SLBFE, with the support of the International Labor Organization (ILO), is in the process of harmonizing its occupational classifications with international standards (International Labor Organization, 2019). According to this classification SLBFE introduced separate job lists for each occupation category in Sri Lanka. Accordingly, in relation to those job lists, graduate students are included in the professional and middle-level occupation categories (International Labor Organization, 2008). Accordingly, according to the data reports of Sri Lanka Bureau of Foreign Employment, 2022, regions of the world selected as the destination of their work by the majority of Sri Lankan graduates from 2004 to 2022 were considered for this research. While selecting the regions for our study, North America, Asia-Pacific, Africa, Europe, Asia, Middle-East and other regions were considered (as mentioned previously) and out of that three regions were selected for the final analytical study. The majority of Sri Lankan graduates had chosen the three regions Asia, Europe and Middle East.

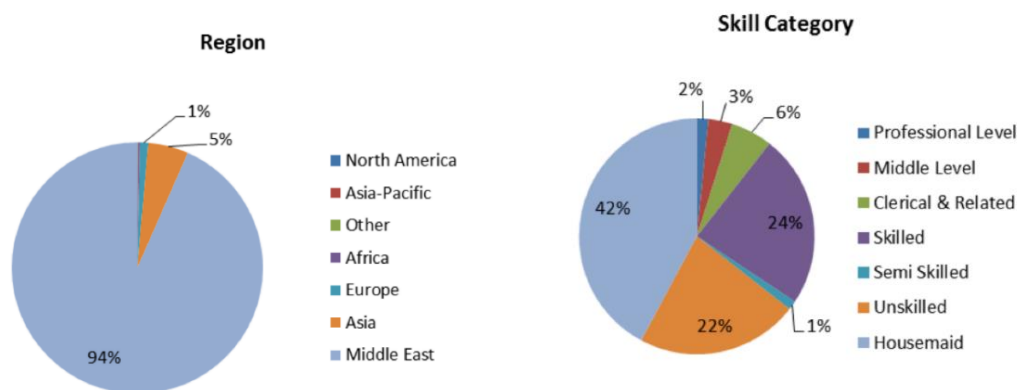


Figure 2: Departures by Region and Skill Category, 2012.

Various well-known electronic libraries were searched to achieve the objective of this study: Acm Digital Library, Science Direct, IEEE, Springer, Emerald, IMF Reports, World Bank Reports and other resources. Here, two main steps were followed to search for research papers. Key words used in the first step: employability skills in Sri Lanka, graduate performance in Sri Lanka, graduate skills in Sri Lanka, expectations of employers in Sri Lanka, perspectives of employers in Sri Lanka, higher education in Sri Lanka and performance appraisal. Key words used in the second step: job skills, graduate performance, graduate skills, employers' expectations, employers' perspectives, higher education and performance appraisal. Papers from the past 20 years were downloaded and distributed

among the authors to read and categorize. 72 Papers were collected from the existing literature. After that, appropriate information was extracted from the papers, including the name of the papers, name of the journal, year of publication, purpose of the study, research methodology, context, and results. After the initial categorization process, papers unrelated to the topic were excluded and we considered only 61 papers for further analysis. There we recognized that some of the papers we collected were not within the scope of our research. Therefore, they were not considered for further analysis. 32 of papers were removed during the preliminary analysis. After two steps in the filtering process, the resulting research papers were categorized based on: Sri Lankan industries, skills desired by Sri Lankan employers, region, and skills desired by employers in considered region. In selecting the countries for this research process, 10 countries selected by the Sri Lankan workers to engage in their jobs in the last 23 years were used. The collected data were analyzed to draw conclusions.

3. Results and Discussion

3.1 Agriculture

Assessing the employability skills of agricultural graduates from the employer's point of view is very important for aligning academic programs with industry needs. Employers seek Sirisak graduates with a combination of theoretical knowledge and practical skills to meet the challenges in the agricultural sector. Graduates have a strong foundation in basic agricultural principles, with experience gained through internships or research projects. According to the Mahaliyanaarachchi (2005), The main requirements that employers expect from an agricultural graduate are Knowledge and skills of the job, Job commitment, good working knowledge in the English Language, Knowledge in Information Technology, Ability to meet deadlines for assigned tasks Punctuality, Maturity to handle responsibilities, Ability to use available resources effectively, Ability to work well with minimum supervision, Honesty General intelligence Ability and willingness to Work hard is annoying. The ideal graduate should demonstrate a thorough understanding of sustainable practices, innovative approaches and the ability to contribute to the growth and efficiency of the agricultural industry (Sahlberg, 2007). Employers want agricultural graduates who can combine academic achievements with real-world relevance, fostering a seamless transition into the workforce (Robinson, 2006).

3.2 Tourism/Hotel/Hospitality

Tourism is one of the fastest growing forest services industries in the world. Challenges facing tourism include taxation, travel promotions, safety, infrastructure, and cross border set of laws among others. Accordingly, in order to meet the needs of the tourism industry, people must be given skills to be able to cope with the changing conditions of the business world (Markes, 2006). It appears that graduates are currently ill-prepared to meet the needs of employers. The following studies attempted to identify the skills required to operate in the tourism industry. Nolan *et al.*, (2010) conducted a study among Irish hotel employers and students and identified important competencies in this field as: customer service, interpersonal skills, professionalism and maintaining ethical standards. The above findings reveal that skills gaps exist between graduates' skills and industry expectations. As stated by Ross (1995), a study was conducted among tourists, graduates and employers of hotels to determine the expectations of the hospitality industry. The key parameters considered for this study are industry outlook, employee competency, quality and skill gap.

The findings indicate that customer service, multi-skilling, communication and providing services without categorizing customers are the key skills sought. These results identify a skills gap and suggest that industry and training providers need to work together to produce a globally competitive workforce. In addition to the above, Faith *et.al* conducted a study comparing employers' expectations of worker skills in the tourism industry and the skills acquired by learners of the Culture, Arts, Tourism, Hospitality and Sports Skills Education and Training Authority (CATHSSETA). Accordingly, it is clear

that employers expect higher level of skills than the level provided to learners in the CATHSSETA program. Although many skills are identified for the tourism industry, the most important skills expected of a graduate are communication, professional knowledge, language and management skills.

3.3 Accounting

Accounting graduates must possess several skills necessary to function as providers of and act upon financial information in their profession (Zureigat, 2015). A recent study explains that accounting education is currently not meeting the needs of the labor market and the needs of employers. In 2015, a survey conducted by Qasim explored the skills Saudi employers are looking for in accounting graduates from Saudi Arabia. According to Qasim, technical and general skills are required to carry out the accounting profession effectively (Zureigat, 2015) Critical reasoning and thinking, problem solving and decision analysis, verbal and written communication, teamwork, business ethics, time management, negotiation, planning, computer literacy and leadership are important for an accounting graduate. Meanwhile, another study was conducted in Malaysia to identify the relationship between employer satisfaction and employability using UNITEN accounting graduates (Shamsuddin *et al.*, 2016). The job skills considered for this study are categorized as technical, functional, communication, organizational and business management skills. The results show that employers are satisfied with the employability skills of graduates (Shamsuddin *et al.*, 2016). Also, employers assume that all graduates have good computer skills and can improve their computer skills with minimal training (Gibbs *et al.*, 2011). The following table shows the skills that employers in different countries expect from accounting graduates. The most important skills expected of an accounting graduate are numerical and interpersonal skills, MS Office and communication.

3.4 Management

Nowadays, employers are not only looking for graduates with specific knowledge. People who have the skills to act intelligently and manage situations intelligently. Therefore, only graduates with better skills can survive in the job market. Although graduates excel in their abilities, they lag behind when it comes to the skills required for employment. Many studies have been conducted to identify the competencies required for business graduates. As stated by Ken *et al* (2012), the research was conducted to explore the relationship between the skills important to the banking industry in Malaysia and the actual performance of graduate students and employers' perceptions. The skills considered for this study are resourcefulness, written and verbal skills, honesty, diligence, knowledge acquisition, teamwork, computer skills, value enhancement, adaptability, problem solving and reliability. Findings revealed that graduates are well trained in their areas of specialization but unfortunately lack soft skills (Ken *et al.*, 2011). Another study was conducted in Kuwait to explore the level of importance of employability factors (Abdullah *et al.*, 2014). Employability factors include graduates' knowledge, soft skills, personal abilities and teamwork. The results revealed that the curriculum should be adjusted to respond to market needs. According to Herath and Ranasinghe (2011), ICT skills, English language proficiency and relevance of practical knowledge are most important for business graduates. The most important skills expected of a business graduate are specific knowledge, management skills, diversity awareness, global understanding, personal characteristics and computer skills.

3.5 Information and Communication Technology

It focuses on the ability of Information and Communication Technology graduates to adapt to the skills environment. It also looks at their ability to use their skills to create results that lead to employment. According to Saad and Majid (2016), the most important skills demanded by employers are problem solving, ability to handle tools, teamwork and presentation skills.

3.6 Manufacturing

According to Banadir *et al* (2011), a serious shortage of skilled Saudi workers has emerged in the Kingdom of Saudi Arabia, especially in the private sector. Research results explain the skills gap on three factors. Work ethics, specialized knowledge and general skills. In 2015, According to the (Svirina *et al.*, 2016; Little *et al.*, 1987), research has been done among Indian manufacturing enterprises and, which found that employers have little understanding of their needs and skill requirements for the future. However, the most important competencies to consider in curriculum development are professional skills, technical skills, and systems thinking.

3.7 Construction

The construction sector plays a major role in the national economy of every country. But compared to other sectors, the construction sector is quite complicated due to its existing nature. So, it can never be restricted to the classroom. Accordingly, students should always be exposed to industry. The technologies, machinery and tools available here are constantly being innovated in the field of construction is the main challenge. Due to this, the expectations of the industry are also continuously changing. Many studies have been conducted to identify the gap between employers' expectations and students' perceptions of the construction industry regarding the knowledge and skills necessary to perform effectively in the construction industry. A new engineering graduate should have an understanding of engineering design and construction standards, work attitude, technical and managerial skills, personal attitude and engineering knowledge (Shyamalee *et al.*, 2010). Likewise, construction knowledge such as estimating, scheduling, plan reading, and safety are critical requirements for graduates (Bhattacharjee *et al.*, 2013). According to Sedighi, a study was conducted in Australia to identify employer preferences for graduates and the factors influencing them. Identified five most important skills required in a construction management firm including knowledge of health and safety regulations, interaction of contract documents, listening skills/attention to detail, knowledge of building codes and regulations, and time management (Saqib. 2001). Taiebat and Ku K (2009), reveals that the USA construction industry is looking for graduates with deep conceptual knowledge of BIM who are skilled in using Building Information Modeling software. Olawale (2015), noted that teamwork, communication and leadership are the most sought-after skills by employers. Rohani believes that responsibility, positive attitude and teamwork are the 3 most important qualities for the architecture industry (Attributes of Graduate Architects,) Interpersonal skills along with practical building knowledge and time management are also important for construction management graduates (Haynes *et al.*, 2002). The most important skills identified are industry-specific knowledge, time management, and interpersonal and intrapersonal skills.

Table 1: Graduate Employability skills

Sector	Country/Region	Required Skills
Agriculture Forestry and Fishery	Sri Lanka	Knowledge and skills of the job, Job commitment, Working knowledge in the English Language, Knowledge in Information Technology (IT), Ability to meet deadlines for assigned tasks, Punctuality, Maturity to handle responsibilities, Ability to use available resources effectively, Ability to work well with minimum supervision, Honesty, General intelligence, Ability and willingness to work hard
	Middle east	Practical Farming Experience Crop Management Skills Adaptability to Regional Agriculture Practices Problem-Solving Abilities
	Asia	Problem-solving, Mechanical and repairing Interpersonal Time management Health and physical stamina
	Europe	Technical Knowledge Hands-On Practical Experience Problem-Solving Abilities Adaptability Communication Skills
Tourism/Hotel/Hospitality	Sri Lanka	Adaptability skills, Computer skills, Customer service skills, Oral communication, Practical skills, Management skills, Industry knowledge, Creativity, Work experience, Events Management skills, Academic grades, Research skills
	Middle east	Problem solving, technology, languages and culture knowledge, and leadership skills
	Asia	Leadership, Professional management, technical skills, professional skills classes, on-campus internship
	Europe	Computer skills, responsibility at work, the ability to acquire new knowledge, team working, communication skills, Problem solving, Knowledge, Interpersonal Skills
Accounting	Sri Lanka	Management skills and work experience intellectual skills and personal qualities, Analytical skills, Communication skills and Accounting and technical skills
	Middle east	Ethics, Leadership, Negotiation, Communication, Critical Reasoning & Thinking, Problem & Decision Analysis, Team Working, Time Management, Computer Skills

	Asia	Assessing the scale's psychometric properties, Technical and Functional Skills, Communication Skills, Organizational & Management Skills, Assessing the scale's psychometric properties
	Europe	Numerical Skills, transfer of knowledge and education, Team Work
Information and Communication Technology	Sri Lanka	Business analysis & process Engineering, Database design & administration, Hardware engineering & maintenance, Customer service, System analysis, Programming, Systems/Application support, Project management, Network implementation, System design, System application testing, Communication Skills, Team work, Interpersonal Skills, Creative thinking skills, Professional ethics, Proficiency in English language Technical Skills; SQL Server, MS Windows, MySQL, Oracle, NET, PHP, Linux, C#, C++, Java
	Middle east	Technical Proficiency in ICT, Programming and Coding Skills, Cybersecurity Awareness, Project Management, Communication and Collaboration Skills
	Asia	Problem Solving, Tool Handling Competency, Presentation Skill, Team Working
	Europe	Programming and Coding Skills Multilingualism, Cross-Cultural Communication and Collaboration Skills, Cybersecurity Awareness Technical Proficiency in ICT
Manufacturing	Sri Lanka	Work Ethics, Systematic Thinking, Professional Skills, Communication Skills, Interpersonal Skills, Problem Solving Skills, Teamwork skill
	Middle east	Work Ethics, Specialized Knowledge, Generic Skills
	Asia	Teamwork skill and Critical Thinking
	Europe	Technical Proficiency in Manufacturing Processes, Quality Control and Assurance, Problem-Solving and Continuous Improvement, Health and Safety Compliance, Team Collaboration and Communication Skills
Construction	Sri Lanka	Engineering design and Construction standards, Working attitude, Technical and Management Skills
	Middle east	Technical Knowledge, Construction Project Management, Practical Site Experience, Health and Safety Awareness, Adaptability and Cultural Sensitivity
	Asia	Responsibility, Positive Attitude, Team Work, Time Management

	Europe	Time Management, Team-Work, Communication and Leadership, Interpersonal Skills, Engineering Design and Construction standards, Working Attitude, Technical and Management Skills, Knowledge of Health & Safety Regulations, Interpreting Contract Documents, Listening Ability, Time Management, Knowledge of Building Codes and Regulations
General	Sri Lanka	Team Working, Communication, Leadership, Critical Thinking, Problem Solving
	Middle east	Previous Experience, International Experience, Stable Employment, Arabic Language Skills
	Asia	Teamwork, Communication and Presentation Skills, Interpersonal Skills, Problem-Solving, Computer and IT skills, Numerical Skills and Graphical Design
	Europe	Language Proficiency, Cross-Cultural Communication, Adaptability and Flexibility, Critical Thinking and Problem-Solving, Teamwork and Collaboration
Management	Sri Lanka	Management Skills and Work Experience, Intellectual Skills and Personal Qualities, Analytical Skills, Communication Skills, Accounting and Technical Skills
	Middle east	Leadership and Decision-Making Skills, Strategic Thinking and Planning, Cross-Cultural Communication, Project Management, Team Collaboration and Interpersonal Skills
	Asia	Communication, Specific Knowledge, Honesty, Adaptability, Resourcefulness, Teamwork Ability, Diversity Awareness Ability, Global Understanding Ability, Numerical Skills, Problem-solving Skills, Computer Skills, Evaluation Skills, Management Skills, Technical Skills Communication Skills, Personality Traits
	Europe	Problem-solving Skills, Multilingualism, Computer Skills, Cross-Cultural Communication, Evaluation Skills

4. Conclusion

This research study attempted to conduct a detailed exploration across various industries such as agriculture, tourism/hotel/hospitality, accounting, management, information and communication technology, manufacturing and construction with a strong focus on graduate employability in Sri Lanka from the employer's point of view. The backdrop of economic challenges on a global scale makes it imperative to address unemployment, especially among the youth. The findings highlight the unique skills sought by employers in Sri Lanka and the industry-specific nature of degree requirements, so it is important for higher education institutions offering study grants and undergraduates to consider this (Niwunhella *et al.*, 2023) For example, the agriculture sector prioritizes a blend of theoretical knowledge and practical skills, while the tourism/hotel/hospitality industry places high importance on

customer service, multi-skilling and effective communication. In accounting, numerical and interpersonal skills, proficiency in MS Office and communication are considered crucial by employers. The role of higher education institutions in responding to these dynamic talent demands is evident from previous research. (Chatterton and Goddard, 2000). The complex relationship between education and employment requires a delicate balance, and ensuring that academic curricula align with the ever-evolving needs of domestic and foreign industries should be a key function of higher education institutions. However, research also highlights the potential dissonance between academic outcomes and employer expectations, and the need for a nuanced approach that aligns academic standards with the dynamic needs of the job market must be considered. (Bray *et al.*, 2020)

An examination of the employment sector in Sri Lanka has seen notable changes, particularly in the number of people seeking opportunities abroad. This trend highlights the need to reassess and adjust the skill sets that graduates must possess to succeed not only locally but also in the global job market (Ramanayake and Wijetunga, 2018). Our meticulous research methodology, including an extensive literature review from various electronic libraries, elucidates the employability skills required for Sri Lankan graduates in industry markets in the domestic and various overseas regions.

As such, addressing the employment gap in Sri Lanka requires concerted efforts from educational institutions, policy makers and industry stakeholders in our future planning. Continuous dialogue, curriculum refinement and strategic initiatives can bridge the gap between the quality of academic majors, graduate skills and industry needs, and cultivate a workforce equipped not only with academic knowledge but also with the practical skills employer's desire (Ahmad *et al.*, 2023). This research clarifies the importance to the ongoing discourse on increasing graduate employability in Sri Lanka's and the world's dynamic job market, laying the groundwork for well-informed decisions and effective interventions.

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EMPLOYABILITY OF GRADUATES OF SRI LANKAN UNIVERSITIES: A SYSTEMATIC REVIEW

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Abstract: This systematic review examines the employability of graduates from Sri Lankan universities, emphasizing the critical need to align educational offerings with industrial demands for national development. Studies consistently underscore the challenges in securing employment, particularly in the arts and social sciences compared to engineering, science, and management disciplines. Despite commendable efforts by governmental agencies and academic institutions, obstacles persist, particularly in fields like management and the arts. International research emphasizes the importance of aligning academic courses with corporate standards. While public universities have expanded higher education, a significant gap remains between graduate competencies and industry expectations, necessitating curriculum enhancements focused on employability and relevant skills. Studies reveal a weak correlation between educational quality and labour market outcomes, highlighting the need for improved Human Resource Management practices and enhanced digital and English language proficiency among graduates. Sri Lanka's traditional learning style, coupled with a competitive educational environment and a mismatch between graduate skills and business ideals, exacerbates employability challenges. Factors influencing graduate employability include training, workforce exposure, professional certifications, gender-related dynamics, language proficiency, and soft skills. Despite efforts to enhance entrepreneurship and interpersonal abilities in educational institutions, the outcomes often fall short of market requirements. Addressing graduate unemployment requires collaborative efforts among academia, government, and industries to navigate the complex interplay of sociological, financial, and educational variables. Long-term solutions are crucial to fostering economic growth in Sri Lanka.

Keywords: University graduates; Employability; Underemployment; Employer expectations; Knowledge gap; Work-based learning

1. Introduction

Sri Lanka, a vibrant island nation in South Asia, has made significant strides in expanding its higher education sector over the past few decades. With a strong emphasis on education and human resource development, the country boasts a network of universities and institutions offering diverse academic programs across various disciplines. However, alongside this growth in tertiary education, concerns have arisen regarding the employability of graduates entering the workforce.

The transition from academia to employment represents a critical juncture for graduates, yet the mismatch between the skills acquired through traditional academic curricula and those demanded by employers has become increasingly evident. As industries undergo rapid transformations driven by technological advancements and globalization, there is a pressing need for graduates to possess not only domain-specific knowledge but also transferable skills such as critical thinking, communication, problem-solving, and adaptability.

Against this backdrop, stakeholders within Sri Lanka's education ecosystem have recognized the imperative to enhance graduate employability. Efforts have been made to bridge the gap between academia and industry, with initiatives ranging from curriculum reforms and experiential learning opportunities to partnerships with businesses and vocational training programs. However, despite these endeavors, challenges persist, including the need for greater alignment between educational offerings and labor market demands, the cultivation of soft skills alongside technical expertise, and the promotion of entrepreneurship and innovation among graduates. In light of these dynamics, this review seeks to provide a comprehensive analysis of the employability landscape within Sri Lankan universities. By examining the factors influencing graduate employability, evaluating the effectiveness of existing interventions, and identifying potential areas for improvement, this study aims to contribute to ongoing discussions and initiatives aimed at enhancing the prospects of Sri Lanka's graduates in the ever-evolving job market.

2. Objectives

General Objective

- To comprehensively analyze the current state of employability skills among graduates in Sri Lanka, identifying areas for improvement, and devising actionable strategies to enhance their readiness for the dynamic job market.

Specific Objective

- To identify the key employability skills demanded by industries in Sri Lanka across various sectors.
- To evaluate the effectiveness of internship and practical training programs in Sri Lankan universities in bridging the gap between academic learning and practical job requirements.
- To examine the role of career guidance and counseling services offered by universities in assisting students to develop employability skills and make informed career choices.
- To investigate the extent to which Sri Lankan universities integrate soft skills development into their curricula and extracurricular activities.
- To assess the impact of industry-academia collaborations and partnerships on enhancing graduate employability in Sri Lanka.
- To analyze the influence of technological advancements and globalization on the changing nature of employability skills required by employers in Sri Lanka.

- To explore the perspectives of graduates regarding their perceived readiness for the job market and their experiences in transitioning from university to employment.
- To identify barriers and challenges faced by graduates in accessing employment opportunities in Sri Lanka, including regional disparities and socioeconomic factors.
- To examine best practices and successful models implemented in other countries for enhancing graduate employability and assess their applicability to the Sri Lankan context.
- To provide recommendations for policy makers, educational institutions, and industry stakeholders to improve the employability outcomes of graduates in Sri Lanka.

3. Methodology

Literature Review: In this method, researchers systematically search academic databases, journals, reports, and other relevant sources to gather existing knowledge and findings related to graduate employability. They critically analyze and synthesize the literature to understand the current state of employability skills, emerging trends, challenges, and best practices. This method helps researchers build a solid foundation of theoretical frameworks and empirical evidence to guide their study.

Surveys: Surveys involve designing structured questionnaires that are administered to a sample of participants selected to represent various stakeholders, including students, recent graduates, employers, and university faculty. Researchers use quantitative analysis techniques to analyze survey responses, such as descriptive statistics, correlations, and regression analysis. Surveys provide researchers with quantitative data on factors influencing graduate employability, such as skills acquisition, job search experiences, and employer expectations.

Interviews: In interviews, researchers engage in open-ended discussions with individuals who possess valuable insights into graduate employability, such as university administrators, career counselors, employers, and alumni. Researchers develop interview protocols to guide the conversation and probe deeper into specific topics of interest. Interviews allow researchers to capture rich qualitative data, including personal experiences, perceptions, and recommendations for improving graduate employability.

Focus Groups: Focus groups bring together a small, diverse group of participants with similar backgrounds or experiences to explore specific topics related to graduate employability. Researchers facilitate group discussions using a semi-structured format, encouraging participants to share their perspectives, insights, and experiences. Focus groups generate interactive discussions, enabling researchers to uncover common themes, differing viewpoints, and shared challenges regarding employability skills development.

Case Studies: Case studies involve in-depth examination of real-life examples of successful or innovative approaches to enhancing graduate employability. Researchers select relevant cases, such as specific university programs, industry partnerships, or employment initiatives, and collect detailed data through interviews, document analysis, and observation. Case studies provide researchers with rich, contextualized insights into the factors contributing to successful employability interventions, as well as the challenges and lessons learned.

4. Data Analysis:

Data analysis entails processing and interpreting quantitative data collected through surveys, institutional records, or secondary sources. Researchers use statistical software to analyze data, applying various statistical techniques such as regression analysis, factor analysis, or cluster analysis. Data analysis helps researchers identify patterns, trends, and relationships within the

data, enabling them to draw meaningful conclusions and insights related to graduate employability.

Observation: Observation involves researchers directly observing events, activities, or phenomena related to graduate employability, such as career fairs, employer interviews, or classroom interactions. Researchers may take field notes, record observations, or use video/audio recording to capture relevant information. Observation provides researchers with firsthand insights into the dynamics of employability-related processes, interactions, and behaviors, complementing other data collection methods.

Benchmarking: Benchmarking entails comparing the performance, practices, and outcomes of Sri Lankan universities with those of peer institutions or international benchmarks known for their excellence in graduate employability. Researchers collect data on key indicators, such as graduate employment rates, alumni outcomes, and employer satisfaction surveys, and analyze them in comparison to established benchmarks. Benchmarking helps identify areas of strength and improvement, guiding efforts to enhance graduate employability within the Sri Lankan context.

5. Discussion

The importance of employability in graduates is paramount, particularly within the context of Sri Lanka, where the transition from education to employment significantly impacts individual livelihoods and the broader socioeconomic landscape. A review of universities in Sri Lanka underscores the critical role of enhancing employability skills among graduates for several compelling reasons.

First and foremost, improving employability equips graduates with the necessary competencies to thrive in a rapidly evolving job market. Sri Lanka, like many other countries, is witnessing technological advancements, globalization, and shifts in industry demands. As such, graduates need not only domain-specific knowledge but also transferable skills such as critical thinking, communication, problem-solving, and adaptability to remain competitive and adaptable in the workforce.

Moreover, enhancing employability contributes to economic growth and development at both the individual and national levels. Employable graduates are more likely to secure meaningful employment, thereby reducing unemployment rates and poverty levels. They become productive contributors to the economy, driving innovation, entrepreneurship, and overall productivity. By nurturing a skilled workforce, Sri Lanka can attract investment, foster sustainable development, and enhance its global competitiveness.

Furthermore, addressing graduate employability is crucial for fostering social inclusion and reducing inequalities. Sri Lanka faces challenges related to regional disparities, gender imbalances, and socioeconomic inequalities, which can exacerbate barriers to employment for certain groups of graduates. By prioritizing employability, universities can ensure that all graduates, regardless of background, have equal access to opportunities for personal and professional growth, thus promoting social mobility and cohesion.

Additionally, enhancing employability strengthens the relevance and reputation of Sri Lankan universities both domestically and internationally. Employers seek graduates who possess not only academic qualifications but also practical skills and industry-relevant experience. By aligning curricula with industry needs, fostering partnerships with businesses, and providing experiential learning opportunities, universities can enhance their graduates' employability outcomes,

thereby enhancing their reputation and attracting prospective students and collaborators. Furthermore, investing in employability benefits lifelong learning and career advancement. In today's knowledge-based economy, learning does not end with graduation but continues throughout one's career. By instilling a culture of lifelong learning and equipping graduates with the skills to adapt to changing demands, universities empower individuals to pursue continuous professional development, explore new opportunities, and achieve personal fulfillment in their careers.

6. Conclusion

The importance of employability in graduates cannot be overstated within the context of Sri Lanka. By prioritizing employability initiatives, universities play a pivotal role in shaping the future prospects of graduates, driving economic growth, promoting social inclusion, enhancing institutional reputation, and fostering lifelong learning. Through collaborative efforts involving policymakers, educators, employers, and other stakeholders, Sri Lanka can build a robust ecosystem that nurtures the talents and aspirations of its graduates, ultimately contributing to a more prosperous and equitable society.

In conclusion, the review of universities in Sri Lanka highlights the critical importance of enhancing employability skills among graduates. The transition from education to employment is a pivotal phase in individuals' lives, significantly influencing their personal and professional trajectories, as well as contributing to broader socioeconomic development.

The significance of employability in graduates cannot be understated, particularly within the dynamic and competitive job market of Sri Lanka. By equipping graduates with the necessary skills, knowledge, and attributes to succeed in their chosen fields, universities play a central role in shaping the future workforce and driving economic growth.

Moreover, addressing employability is essential for promoting social inclusion and reducing inequalities within Sri Lankan society. By ensuring that all graduates have equal access to opportunities for personal and professional advancement, universities contribute to building a more equitable and cohesive society.

Furthermore, prioritizing employability strengthens the relevance and reputation of Sri Lankan universities both domestically and internationally. By aligning curricula with industry needs, fostering partnerships with businesses, and providing experiential learning opportunities, universities enhance their graduates' competitiveness in the global labor market.

In conclusion, investing in employability initiatives is not only beneficial for individual graduates but also essential for the sustainable development and prosperity of Sri Lanka as a whole. Through collaborative efforts involving policymakers, educators, employers, and other stakeholders, Sri Lanka can build a vibrant higher education ecosystem that empowers graduates to thrive in an ever-changing world, ultimately contributing to the country's continued growth and success.

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IMPORTANCE OF GRADUATES' EMPLOYABILITY AND ENTREPRENEURIAL SKILLS AMID THE UNEMPLOYMENT IN SRI LANKA

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Abstract: Sri Lanka is experiencing an acute economic situation, and now it is much more vital than ever before to deal with the growing unemployment rate. It is vital to shed light on the contribution of expertise of graduates in employment and entrepreneurship in order to reduce the magnitude of unemployment as impact. The aim of the research is to conduct detailed examination and the analysis of problems that may occur during the process of anticipation and resolution of workforce resilience. The theme of the event is to come up with key recommendations to elevate graduates' employability and entrepreneurship potential when facing severe levels of unemployment among the youthful people in the country. Research relies on literature review from 2000-2023 based on 35 research articles to determine how unemployment can affect the economy and impact both policymaker's and citizens' attitudes. In order to develop the workforce that is resilient, investigation of the important variables like skill mismatches, government initiatives, as well as vital education system reforms is conducted. The subsequent research gets down to the most crucial factors that play a role in minimizing unemployment by improving the professional abilities of job seekers. Of great importance, the research highlights the need to understand that general skill is no longer the only thing that determines success in the work market. As concerns unemployment, integration of an entrepreneurship module is one of the ways of ensuring that graduates are market-relevant and hence are able to provide for themselves one way or another, specifically in terms of their employability. The study finds a need for reform in the educational system; highlighting how action learning as well as multiple integrative pedagogies can be used to address skills gaps. The main area of entrepreneurship educational activities is widening the scope of advanced skill sets of undergraduate and graduate students. Moreover, universities should understand the role of effective entrepreneurial education as one of the key tools for the increased employment and life expectancy which in turn make the socioeconomic growth of the countries. The study anticipates a revolutionary effect on Sri Lankan economic development by conquering graduate's unemployment based on the above considering recommendations.

Keywords: Career readiness; Education system reforms; Entrepreneurial skills; Graduates' employability; Unemployment; Workforce

1. Introduction

Sri Lanka is currently facing an uncertain future because of the continuous "Triple Crisis" which is fuel, food, and fiscal (Sosale et al., 2023). Therefore, the continuous enhancement of education and skill sets would be essential to Sri Lanka's economic revival. Better employment is being produced as Sri Lanka moves from a rural to an urban economy, particularly in the services sector.

According to Yorke (2006), the definition of employability is a collection of accomplishments, skills, knowledge, and character traits that increase graduates' chances of obtaining a job and succeeding in their chosen fields, which benefits the workforce, the community, and the economy. Furthermore, Employability is essentially about three skills: securing a job, keeping a job, and finding a new job when needed (Tomlinson, 2017).

Most of the research has discovered a strong and positive correlation between economic progress and entrepreneurship. According to Sautet and Adusei (2013) the rate of self-employment, the number of new start-ups, and economic progress were found to be strongly correlated. Higher levels of competition and economic development are essential since entrepreneurship stimulates economic activity through the production of novel products and services (Rastogi, 2000). The process of entrepreneurship is to come up with fresh, creative ideas that boost competitiveness, change companies, and ultimately accelerate economic growth (Baumol, 2014). Entrepreneurship has a crucial role in reducing unemployment and economic recession, authorities adopt measures that encourage it (Minniti, 2016). Entrepreneurs must concurrently manage their inclinations and a variety of unknown, unanticipated difficulties. Thus, theories of entrepreneurship highlight the fact that, while not exceptionally ordinary people, entrepreneurs may be seen as vital agents of economic progress and are role models in society (Mahmood & Hanafi, 2013).

Therefore, numerous topics have been covered in the literature on graduates' employability and entrepreneurial skills, many of which center on the variables that affect entrepreneurial intention (Succi & Canovi, 2020). It is well acknowledged that university education systems must offer a learning environment that might act as a launchpad for new businesses founded by graduates of these institutions. Consequently, it's important to determine undergraduates' intentions about entrepreneurship (Kodisinghe & Weerakkody, 2016). Therefore, it has been suggested that graduates in this situation broaden their career foundation. By creating more jobs, entrepreneurship would assist these recent graduates in advancing their careers and reducing the existing unemployment problem (Norasmah, 2004). From now on, the present study stresses a few keywords such as unemployment, skill mismatch, education system reforms, and government Initiatives below by elaborating on the literature.

2. Literature Review

2.1 Unemployment

The biggest socio-economic issue facing developing countries including Sri Lanka is unemployment. It is not a recent problem that graduates have a high unemployment rate (Nooriah Yusof et. al, 2013). The increase in job cuts has been made worse by the economic crisis and other recent economic downturns, but supply-side factors have also frequently contributed to the rising number of unemployed students (Jayasingha & Suraweera 2020).

Recent data indicates that the young population's unemployment rate increased from 15.4% in 2016 to 22.5% in 2018 in Sri Lanka. This was down to 19.6% by July 2018 - a negligible percentage (Census and Statistics Department - Sri Lanka, 2018). Because of this, unemployment has a negative effect on people's wellbeing, society, and the economy (Selenko & Pils, 2019). (Patel & Choga, 2018) reports, in addition to having a negative impact on wages and professional performance, youth unemployment causes significant mental and physical suffering (Jayathilake, 2020). An increase in young unemployment in Sri Lanka is a challenge to the country's social and economic growth. Concurrently, the GDP has grown at a slower rate, and in 2017 the inflation rate increased from 0.9% to 3.7% (Central Bank

of Sri Lanka, 2019). As a result, the youth population is under increasing pressure to meet their diverse requirements due to slower economic development and inflation (Selenko & Pils, 2019).

Graduating students' unemployment must be carefully addressed to avoid wasting this talented labor supply. Academic credentials alone can no longer guarantee employment right out of college; instead, graduates must have a positive outlook on the dynamic nature of the labor market (Morshidi et al. 2004; Tomlinson, 2017). It has been suggested that graduates in this situation broaden their employment boundaries by looking into entrepreneurship as a potential career foundation (Clarke, 2018). By creating more jobs, entrepreneurship would assist these recent graduates in advancing their own careers and reducing the existing unemployment problem (Norasmah, 2004). Most entrepreneurial students agree that entrepreneurship may help address the issue of jobless graduates (Salmah 2006). According to Muhammad Hazrul (2012), the creation of an entrepreneurship module to give students market-relevant entrepreneurial skills so that graduates may support themselves in their careers is one way to lessen this issue (Andrews & Higson, 2008). This was a great support to recent graduates who are starting their own businesses and to generate graduates who demonstrate entrepreneurial traits and overcome the serious issue of unemployment.

The success of entrepreneurship education and training is acknowledged as a key component in assisting young people in developing an entrepreneurial mindset. These elements will shape the desire to launch a business of their own in the future. Therefore, by developing more successful entrepreneurs to serve as role models, reducing back on obstacles for aspiring entrepreneurs, and lessening the stigma associated with failure, the government can also help to foster entrepreneurship (Wang & Wong, 2004).

In order for higher education institutions to provide graduates with these kinds of competencies, a clearer image of the labor market must be presented to the graduates (Okolie et al., 2020). The industrial applicability of their programs is a major factor in helping their grads get jobs. Though employability is one of the areas in which the state university system in Sri Lanka places a lot of emphasis, it has been observed that graduates from this system do not possess the necessary skills (Jayasingha & Suraweera 2020).

2.2 Skill Mismatch

Researchers indicate that there is a discrepancy between the number of graduates and graduates who find employment, nevertheless. This gap has been caused by a mismatch between company expectations and graduate competencies. There is a significant disparity between the number of graduates and hired graduates worldwide, even though graduate employability is the most beneficial element for the growth of the economy (Clarke, 2018; Jayasingha & Suraweera 2020).

However, university graduates must acquire employability skills to secure job, claims (Jothirathne, 2013; Ornellas, 2019). Additionally, his research showed that procedural skills are the least developed in universities, whereas personal skills are the most developed. His research showed that, when it came to employability abilities, employers and undergraduates had quite different opinions of graduates compared to the former. The study's findings also revealed that employers' perceptions of graduates' employability abilities tend to vary depending on the age group of the employers.

It is advised that other graduates use the proposed employability model. Furthermore, Sosale et al., (2023) state that for Sri Lanka's population to continue being internationally competitive, it is imperative that they acquire the technical competence and higher-order cognitive abilities that are in demand in both domestic and international labor markets. Because of this, Sri Lanka will have to make significant changes to its current processes and system for developing skills to properly align it with emerging jobs, increase its market relevance, and create an efficient, accessible, and inclusive system of education and training that will enable it to skill, reskill, and upskill its labor force (Tomlinson, 2017). Every year, more graduates from public and private higher education institutions enter the workforce; sadly, this growth outpaces the need for their skills now (Okolie et al., 2020). There are instances where employers' needs do not align with the talents of recent graduates especially because of economic shifts. As a result,

graduate unemployment in Sri Lanka has grown to be a national concern (Weerakkody & Kodisinghe, 2016). As a result, it is crucial to concentrate on graduates and comprehend the variables that influence their desire to open a firm in the future. Additionally, it's critical to identify the driving forces behind the establishment of new companies.

2.3 Education System Reforms

It has been observed that graduates from this system do not possess the necessary skills (Jayasingha & Suraweera 2020), graduates, employability is one of the areas in which the state university system in Sri Lanka places a lot of emphasis. Patel and Choga (2018) reported that youth unemployment causes significant mental and physical suffering for an individual in addition to having a negative impact on wages and professional performance of the workforce of the country. When the graduates are unemployed, the time which they have been investing in their higher education as well as the cost bared by the taxpayers of the country (in case of government universities) or their parents (in the case of private universities), has been rendered unnecessary and made no impact on a country's output.

Though the contribution of Sri Lankan graduates to the national economy remains negligible, despite massive investment in them, studies looking into this important problem are scarce according to studies by Jayasingha and Suraweera (2020). However, there are many studies that have been conducted in the Asian Region as well as all around the by searching for possible solutions for graduate unemployment while encouraging entrepreneurship studies within the university curriculums themselves.

A study by Pardo-Garcia and Barac (2020) has described different initiatives for enhancing employability and entrepreneurship education. According to that study, graduates will strengthen their professional network with employers through annual career fairs. Additionally, field visits to different organizations, guest speeches from industrial experts, industrial mentoring, and international case studies competitions will be beneficial for the undergraduates to get exposed to the cooperate world.

Al-Suraihi et al., (2020) conducted a study to review past studies regarding entrepreneurial orientation and how it affects Malaysian undergraduates. This study demonstrated that the entrepreneurial orientation programs have been positive impact on the graduates' intention towards entrepreneurship (Rana-singhe et al., 2019). The studies of Laguna-Sánchez et al., (2020) reviewed an undergraduate training programme, that provides entrepreneurship training with traditional teaching, and it ended with the preparation of business plans as groups under the supervision of an industrial mentor this training program has been much more influential in enhancing the generic interpersonal and systemic skills of graduates than generic instrumental skills (Succi & Canovi, 2020). As a specific kind of organization, universities are crucial in spreading the entrepreneurial culture, promoting entrepreneurship as a viable and desirable human behaviour, and assisting and encouraging entrepreneurial behaviour among their staff members, researchers, and students. A university can teach entrepreneurship and cultivate its students' entrepreneurial mindset by utilizing transversal methodologies and enterprising educational activities.

Graduating students invest in their education, and they cannot get their money back when they are unemployed. The government's investment in higher education is thereby rendered unnecessary and has an impact on a country's output. Like Sri Lanka, graduates receive free education from public institutions, a benefit funded in large part by the GDP of the respective nations. Nevertheless, despite massive investment in producing graduates, their contribution to the national economy remains negligible. Studies looking into this important problem that exists in Sri Lanka are scarce (Jayasingha & Suraweera 2020).

2.4 Government Initiatives

In the global environment, graduates occupy the most prominent roles in both the public and private sectors, greatly assisting in the advancement of their nations. Additionally, there is a considerable disparity in graduates' employment. There is a significant disparity between the number of graduates and

employed graduates in Sri Lanka. It indicates that the rate of unemployment and underemployment among recent graduates is high. It's a serious problem that impacts developing nations like Sri Lanka (Jayasingha & Suraweera 2020). Governments are becoming increasingly interested in and attentive to entrepreneurship as an essential component of their responsibility. Several governmental efforts have been implemented globally to enhance entrepreneurship.

According to Larsen et al., (2016), the government, companies, and academic institutions in Sri Lanka created important regulations that helped create university–enterprise collaboration (UECs); as a result, this partnership framework promotes graduates' employability and entrepreneurship as an integral part of the greater economic recovery strategy. Sri Lanka has decided to offer tax breaks to encourage UEC for research and development. When a company contracts with a university or research institute to conduct research, they can receive a tax savings of 300 percent of the expenses for research and development.

Under the Intellectual Property Rights (IPR) The Technology Grant Scheme, administered by the National Science Foundation, aims to encourage technologically driven innovations in Sri Lanka, transform research and development outputs from universities and research institutes into commercially viable products and services, and encourage universities, research institutes, businesses, and individuals to start new technology companies (Rastogi, 2000). In addition, the Private-Public Partnership Programme was introduced by the National Research Council of Sri Lanka to promote research and development (R&D) for economic development.

Universities in Sri Lanka are working to support innovations, establish company incubators, and foster an entrepreneurial culture among students and other stakeholders. University-Industry (U-I) partnership has been mostly operated by individual academics, department heads, deans of faculties, and research teams. In accordance with this, the University of Colombo, and the University of Moratuwa have launched endeavours to broaden their projects and educational curriculum in entrepreneurial education for undergraduate as well as graduate students. Entrepreneurship educational programs focus on qualifying undergraduates and graduates with a wide spectrum of abilities including marketing, financing, company plan development, and networking with local business pioneers, for instance through arranging mentors. Numerous international institutes and organizations actively support global entrepreneurship through financing, technical help, and oversight. International organizations and governments from various nations work to promote entrepreneurship as a means of achieving economic progress (Al Shobaki et al., 2018; De Silva and Koggalage, 2021). Governments ought to act to encourage entrepreneurship and aid in the expansion of companies. Developing entrepreneurship is now essential to growing the economy to a sustainable level.

3. Recommendations

The study stresses a few recommendations made on all above concerns. Raising students' self-awareness of their personal responsibility to critically reflect on their own learning, develop ability to evidence acquired skills, and persuasively articulate such to employers during job interviews and in the workplace can all help close skill gaps. To close skill gaps, higher education institutions (HEIs) may need to know which skills students have fully developed or not at graduation. Action learning and multiple integrative pedagogies can be used to close skill gaps. The perception of graduating students' employability may be negatively impacted by their poor self-rating in comparison to employer judgments of their presence of abilities. Students' ability to explain their abilities clearly and persuasively to prospective employers should be embellished otherwise it may be impacted if they are perceived as having low proficiency in a particular area.

Moreover, the study recommends that it is required to introduce pedagogical strategies such as company plan development, exposure to industry, and business institutions, as well as mentorship and coaching remain essential experiential methods for enhancing learning and translating entrepreneurial curricula. In today's job markets, a degree with strong marks focused mostly on discipline-specific knowledge is

no longer enough for career success. Work experience should be highly valued since they view it as a trustworthy indicator of readiness for the workforce and reflect opportunities to upgrade with new employment opportunities.

Further, improving entrepreneurship-related instruction at universities is necessary to encourage entrepreneurship and prepare graduates for impending crisis conditions (Maritz et al., 2020). Governments ought to act to encourage entrepreneurship and aid in the expansion of companies. Make suggestions to the public and commercial sectors, academic institutions, governments, and other stakeholders regarding the creation and implementation of successful entrepreneurship education initiatives. Furthermore, it is needed to initiate a procedure wherein the

suggestions can be deliberated upon at the international, regional, national, and local levels and executed with the participation of significant key stakeholders. More experiential teaching techniques that enhance information transfer and help students form new perspectives and mindsets for creating wealth through the expansion of small and medium-sized businesses and technology advancements should be adopted by entrepreneurial educators.

Finally, economic Parenting: the goal of economic parenting is to encourage entrepreneurship because the future of economic sustainability is uncertain. In relation to this, the present study recommends that improving entrepreneurship-related instructions at universities is necessary to encourage entrepreneurship and prepare graduates for impending unemployment and crises.

4. Conclusion

The study concludes that integration of different pedagogies and application of action learning methods is critical for bridging the skill gaps of the graduates in Sri Lanka. Upon the conclusion, undergraduate and graduates who satisfy the admission criteria and showcase a wide range of skills such as marketing, finance, business plan formulation and networking with local potential stakeholder should be the focus of these entrepreneurship training programs. Additionally, a good education on entrepreneurship must be seen as a fundamental contributor to leading life expectancy and employment which are the crucial determinants of socio-economic development of a country. With these suggestions in place, the study reveals that Sri Lanka's economic growth will outreach and surpass the unemployment rate of graduates.

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**UNIVERSITY-INDUSTRY PARTNERSHIPS FOR
SUSTAINABLE DEVELOPMENT**

ICSD 038

**UNIVERSITY-INDUSTRY PARTENERSHIPS FOR SUSTAINABLE
DEVELOPMENT – BIBLIOMETRIC ANALYSIS**

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Abstract: The main purpose of this paper is to analyze the interest in the field of university-industry partnerships for sustainable development. The research methodology involves conducting a bibliometric analysis based on a quantitative research method, in the form of an inventory of publishing activities in the chosen field for study. The analysis consisted of querying the database available on the Web of Science platform, which includes journals, scientific papers, books, and other documentation. The query resulted in displaying a total of 65 scientific documents existing in the database. The results obtained from the analysis of the data collected from Web of Science using VOSviewer software highlight the most cited articles, journals, and authors, as well as the existence of strong connections between universities and industries for sustainable development. The United States and China have been the primary producers of publications in this domain, each with seven works, followed by Australia (4) and England (3). The keyword-based analysis highlighted frequently used terms such as "University-industry collaboration," "sustainability," "triple helix," "management," and "innovation." The most cited author in this field is Etz-kowitz H. from the International Triple Helix Institute in the United States, and one of the most cited articles is co-authored with Zhou, C.Y. from Hohai University, proposing a Triple Helix model of university-public-government for sustainable development, complementing the university-industry-government Triple Helix for innovation. This bibliometric analysis not only emphasizes the present but also tracks the evolution of researchers' areas of interest in the field of the university-industry relationship for sustainable development.

Keywords: University; Industry; Sustainable development; Bibliometric analysis

1. Introduction

In the current era, marked by major challenges related to climate change, natural resource degradation, and the imperative of sustainable economic development, the close relationship between universities and businesses becomes a key element in ensuring sustainable development. This collaboration not only reflects the evolution of how society addresses environmental issues but also represents an essential mechanism for generating and implementing innovative solutions needed to confront the complex challenges we face both presently and in the future.

Universities, as centers of knowledge and innovation, become the driving force propelling progress in the field of sustainable development. Through advanced research and education focused on environmental issues, these institutions are capable of generating solutions and shaping young professionals ready to tackle sustainability challenges. (Sisto & López, 2015; Bellei, Poblete, Sepúlveda, Orellana & Abarca, 2013). Simultaneously, close collaboration with businesses brings the practical and applied dimension of academic research, facilitating the transfer of knowledge and technologies into the real world. Thus, universities become catalysts for innovation, and businesses become essential partners in implementing solutions developed in the academic realm. (Azagra-Caro & Consoli 2016)

In a context where the impact on the environment and natural resources becomes increasingly urgent, the university-business collaboration becomes a pillar of sustainable development strategies. This relationship not only contributes to finding viable solutions to environmental problems but also to the training of a workforce prepared to address sustainability challenges in various economic sectors. As global awareness of the imperative to tackle climate change grows, numerous organizations are pledging to diminish their environmental footprint and actively contribute to a sustainable future. Nonetheless, accomplishing these objectives goes beyond merely establishing targets and adopting new technologies. It necessitates a workforce possessing the skills and knowledge essential for steering the shift towards a greener and more sustainable business model. This is precisely where the concept of employees' green upskilling becomes crucial. (Genghini, 2023)

Thus, the current importance of the relationship between universities and businesses cannot be underestimated, as this collaboration not only facilitates technological and scientific progress but also ensures that sustainable development becomes a tangible and viable reality for current and future generations. The predominant body of literature addressing industry–university relationships relies heavily on empirical methodologies such as case studies, quantification of patents generated, bibliometric analyses, or extensive surveys (Fontana et al., 2006; Abramo et al., 2009). Notably, some literature underscores the positive impact of scientific outcomes on the economic domain (Beise and Stahl, 1999) and elucidates how numerous innovations would be unattainable without the significant contributions of academics. Another facet of the literature investigates the importance of academics, particularly from an industry perspective, as an external fount of information for novel ideas and the completion of innovations (Fontana et al., 2003).

Given these aspects, we consider it necessary to conduct a bibliometric analysis on university-industry partnerships for sustainable development. Through this analysis, we aim to highlight the volume, impact, and evolution of scientific works in this field, emphasizing the significance of this partnership and the outcomes achieved by various researchers in their respective works. Such an analysis will yield significant benefits in terms of assessing and guiding research, identifying trends, sources of influence, and directions for future development.

In the following sections, we will explore the evolution of research in the field of university-industry partnerships for sustainable development, identifying trends and significant

contributions of researchers and institutions. Through this analysis, we aim to highlight the increasing importance of the university-industry relationship in the context of sustainable development and to identify research gaps to guide future research efforts and policies in this vital area for the future of our planet.

Our bibliometric analysis will focus on four main directions and aims to answer the following questions: In which journals are the works on the chosen topic published? Who are the relevant contributors in researching the analyzed relationship? From which countries are the authors (countries of origin)? What are the keywords of these studies? How are these works cited in the literature?

Thus, through the conducted analysis, we will highlight the most cited articles, journals, and authors. We will also analyze the most frequently cited keywords and their evolution over time to demonstrate the temporal evolution of interest in the analyzed field. In addition to the bibliometric review, we will summarize and synthesize the content of the most cited articles briefly to provide an overview of the content of these articles and offer researchers insight into the field and the main topics addressed in this literature.

2. Methodology and data

In this article, a bibliometric analysis was conducted using the VOSviewer software to meet the analytical needs of various entities such as countries, institutions, journals, and authors. This tool proved instrumental in highlighting the evolution of the influence of university-industry partnerships for sustainable development. Based on the analysis, bibliometric maps were generated to facilitate the examination and understanding of relationships and interconnections among various elements in the field of scientific research, such as articles, authors, keywords, or research areas.

The data used in this analysis were extracted from the Web of Science database. Considering two concepts within the thematic scope of the Web of Science, namely universities and industry, searches were performed for articles, papers, and book chapters that analyze collaborations between these entities. The Web of Science database provided 1626 academic works related to these topics. From these, we selected articles specifically addressing the significance of this partnership in sustainable development, narrowing down the number of articles and papers to 65. The data, including records and references, were collected through a .txt file, which was later uploaded into the VOSviewer software for analysis.

The procedure used in identifying works for bibliometric analysis consists of the following steps:

1. Searching in Web of Science-Clarivate for the main subject "university-industry partnership for sustainable development": The first phase involves conducting a detailed search within the Web of Science-Clarivate platform, focused on the main subject.
2. Extracting the found results: After identifying relevant results, they were extracted to obtain an appropriate list of academic works.
3. Inputting data into VOSviewer: The extracted information, including records and associated references, was collected in a .txt file. This file was subsequently loaded into the VOSviewer software, providing the necessary data for bibliometric analysis.
4. Analyzing data according to multiple criteria: After loading the data into VOSviewer, the analysis was conducted considering various relevant criteria. These criteria may include, but are not limited to, the frequency of occurrences, connections between different works, and others.

3. Result and discussion

This paper aims to present information from the literature, highlight the publication year of the majority of the research, identify authors dedicated to analyzing the relationship between universities and industry with an impact on sustainable development, identify collaborations between co-authors based on

their countries, analyze research trends in this field using keywords, and ultimately, showcase the most cited works and rank journals with the most prolific publishing activity.

By addressing key research questions, namely: "In which journals are the works on the chosen topic published? From which countries are the authors (countries of origin)? What are the keywords of these studies? How are these works cited in the literature?", the presentation continues with the analysis of articles using the information provided by Web of Science and the exposition of the results of the bibliometric analysis, organized into the following categories:

- Description of literature data;
- Publication activity by author;
- Publication activity by country;
- Co-occurrence of keywords;
- Analysis of the most cited works;
- Analysis of specialized journals.

3.1. Description of literature data

The selected set of publications is diverse, encompassing a variety of formats and types of works in the field of university-industry collaboration for sustainable development. Table 1 illustrates the types of publications among the total of 65 documents published in the research areas included. According to the table, the majority of publications are articles (37 in total), representing 57%, followed by 27 conference papers (42%). Additionally, there are 3 review articles and 1 book chapter. Therefore, there is a diversity of publication types reflecting the complexity and breadth of the research. However, we believe that a thorough analysis of these information sources is necessary to identify potential directions for future research.

Table 1: Publication type

Type	Number
Article	37
Proceeding paper	25
Review Article	3
Book Chapters	1
Early acces	1

Source: Own processing, using data provided by WOS (Web of Science).

Interest in researching the collaborative relationship between universities and the industrial sector with implications for sustainable development emerged late, in 2010, and fluctuated in terms of the number of publications from year to year, reaching its highest level in 2021 (12 works). Regarding the citations of these articles, an increased interest in this field is observed, particularly after 2018, with a noticeable upward trend in citations over the last 4 years (Figure 1).

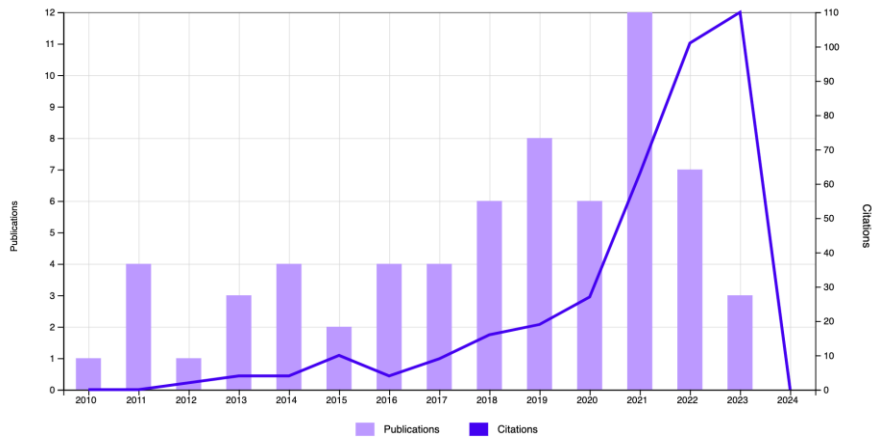


Figure 1: Annual publications and citations
 Source: Own processing, using data provided by WOS (Web of Science).

These statistics highlight that research on the collaborative relationship between universities and the industrial sector with implications for sustainable development has gained prominence and increased interest, particularly after the COVID-19 health crisis, during which the interest in analyzing the benefits of such collaboration has seen a rise.

Research in the field of the collaborative relationship between universities and the industrial sector with implications for sustainable development covers various directions, as highlighted by specialized literature from multiple domains. Figure No. 2 illustrates the top 10 thematic areas identified through publications that address the aforementioned relationship. "Education Educational Research" is the domain with the most publications (18), representing 28%, including research focusing on changes in the educational field to meet the needs of the industrial sector. It is followed by "Green Sustainable Science Technology" (17) and "Environmental Sciences" (14), encompassing articles that emphasize the effects of university-industry collaboration on technology and the environment.



Figure 2: Research areas
 Source: Own processing, using data provided by WOS (Web of Science).

This distribution indicates that studies regarding the collaborative relationship between universities and the industrial sector with implications for sustainable development span a broad spectrum of fields, covering technological, environmental, educational, management, and business aspects. This diversity reflects how researchers and professionals explore and investigate this relationship from various perspectives.

3.2. Publication activity by author

The analysis of author co-citations has provided the opportunity to identify the most cited authors in the analyzed field, examining both author citations and co-citations in publications. Graphical representations obtained through the VOSViewer application enable the highlighting of the most influential authors in this domain, serving as valuable support in the documentation process. Figure 3 presents the co-citation map, with authors as the unit of analysis. By setting the minimum number of citations per author to 5, 25 authors meeting this condition were identified out of a total of 2,198. The larger the node (circle), the more cited the author. Additionally, it is important to note that the thicker the connection between nodes, the stronger the connection, and the co-citations of these authors are more frequent. These authors were grouped into 4 clusters: (red, green, blue, and yellow).

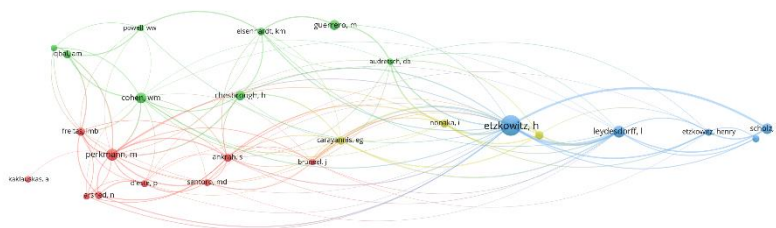


Figure 3: Co-citation of authors
Source: Own processing using VOSviewer, 2023.

Therefore, based on this analysis, we can address one of the research questions Who are the relevant contributors in the study of the analyzed? by identifying authors with the greatest impact in this field, relying on the number of citations. This ranking includes names such as: Etzkowitz, H., Eydesdorff, L.; Perkmann, M.; Scholz, R.W.; Cohen, W.M. and Guerrero, M.

3.3. Co-occurrence of keywords

Figure 4 illustrates the graphical representation of the keyword map used by authors, with a minimum keyword occurrence threshold set at 3. This representation reveals a wide diversity of terms proposed by authors in this field, reflecting a variety in specialized literature. Only 8.6% of these terms are found in at least 3 works. The most frequently encountered keyword is "innovation," appearing 17 times and having 54 connections to other keywords such as "University-industry collaboration," "sustainability," "triple helix," "management," etc., being most frequently used in 2018. "University-industry collaboration" ranks second in the most used keywords in the analyzed studies, with 13 appearances and 42 connections to other keywords such as "innovation," "sustainability," "sustainable development," "artificial intelligence," "research-development," etc., being most frequently used in 2020. "Sustainability" is the third most common keyword proposed by authors, appearing 9 times and having 30 connections to other keywords such as "innovation," "university-industry collaboration," "industry," "triple helix," "management," etc., being more frequently used in 2020.

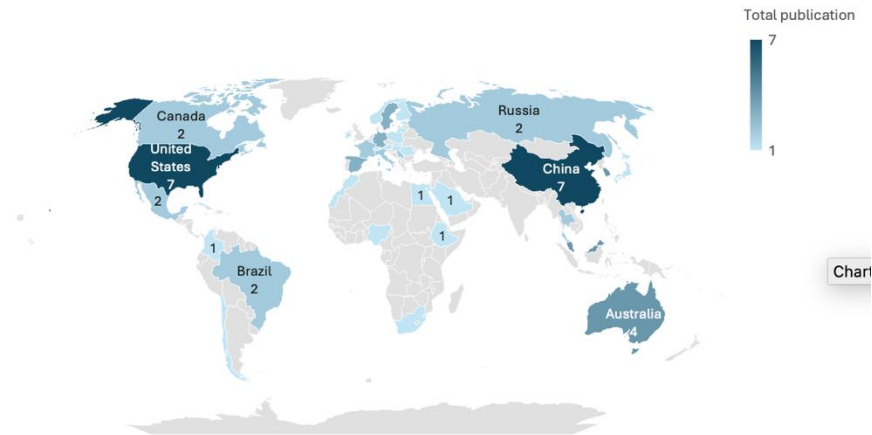


Figure 5: Prolific countries/regions

Source: Own processing, using data provided by WOS (Web of Science).

In Figure 6, obtained using VOSviewer, the most intense and close collaborations among the 9 out of 48 countries are illustrated by setting the minimum number of documents per country at 2, along with the period during which these collaborations occurred.

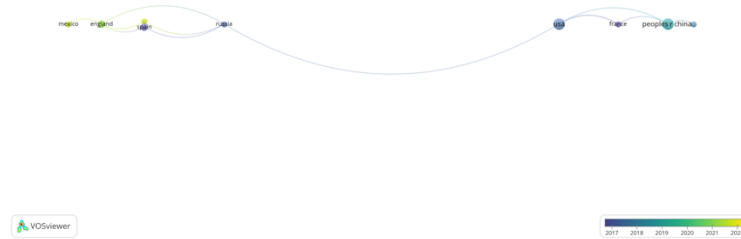


Figure 6: Country collaboration of co-authors

Source: Own processing using VOSviewer, 2023.

The nodes in Figure 5 represent countries/regions, with the size of the nodes symbolizing the number of publications, and the connecting lines between two nodes indicating a collaborative relationship between the two countries.

England has the most collaborations 4, even though it doesn't have the highest number of articles; those distinctions belong to the USA and China (each with 7 works) but only 3 collaborations. Researchers from England have collaborated with those from countries such as Spain, Russia, Brazil, and most recently, Mexico. Meanwhile, researchers from the USA have opted for collaborations with France, Russia, and the most frequent and recent collaborations being with China. In the case of China, the connections between nodes are shorter and thicker (indicating more intense and frequent collaboration), especially with those from the USA, France, and Canada.

3.5. Analysis of the most cited papers

To identify the shortcomings in the research on university-industry collaboration from the perspective of sustainable development and outline future research directions, we conducted an analysis and synthesis of the most relevant research papers on this topic. We used the same

article database as in the bibliometric analysis, covering the period from 2018 to 2023. Initial searches and filters yielded 36 articles, from which we chose to present the top 10 based on the number of citations. Thus, following this selective analysis, we arrived at a total of 9 relevant articles, with one being excluded as it was not pertinent to the analyzed theme. The main conclusions of this analysis are presented in Table 2 below, with the articles arranged in descending order based on the number of citations.

Table 2: List of most cited works

Nr.	Numele autorilor	Titlul lucrării	Anul publicării	Numărul citărilor	Numele jurnalului
1	Fischer, B., Guerrero, M., Guimón, J., & Schaeffer, P. R	Knowledge transfer for frugal innovation: where do entrepreneurial universities stand?	2021	51	Journal of Knowledge Management
2	Van Vliet, K., Pellenq, R., Buehler, M. J., Grossman, J. C., Jennings, H., Ulm, F. J., & Yip, S	Set in stone? A perspective on the concrete sustainability challenge	2012	45	MRS bulletin
3	Yang Song, Jean-Michel Sahut, Zhiyuan Zhang, Yifan Tian, Lubica Hikkerova,	The effects of government subsidies on the sustainable innovation of university-industry collaboration,	2022	32	Technological Forecasting and Social Change,
4	Scholz, R. W.	Transdisciplinarity: science for and with society in light of the university's roles and functions.	2020	28	Sustainability science
5	Zhou, C., & Etkowitz, H.	Triple helix twins: a framework for achieving innovation and UN sustainable development goals	2021	23	Sustainability
6	Bjursell, C., & Engström, A.	A Lewinian approach to managing barriers to university-industry collaboration	2019	13	Higher Education Policy
7	Lew, Y. K., & Park, J. Y	The evolution of N-helix of the regional innovation system: Implications for sustainability.	2021	10	Sustainable Developmen
8	Iqbal, J., Kousar, S., & Ul Hameed, W.	Antecedents of sustainable social entrepreneurship initiatives in Pakistan and Outcomes: Collaboration between quadruple helix sectors.	2018	9	Sustainability
9	Castro Peixoto, L., Barbosa, R.R. & de Faria, A.F.	Management of Regional Knowledge: Knowledge Flows Among University, Industry, and Government	2022	7	J Knowl Econ

Source: Own processing, using data provided by WOS

The most cited paper, with a total of 51 citations, is "Knowledge transfer for frugal innovation: where do entrepreneurial universities stand?" by Fischer, B., Guerrero, M., Guimón, J., & Schaeffer, P. R. The paper analyzes the strategic knowledge transfer practices implemented by an entrepreneurial university to foster frugal innovations in an emerging economy. It is based on a case study of the University of Campinas (Unicamp), incorporating 14 interviews and secondary data sources. The results highlight the internal capabilities of universities to promote frugal innovations and connect them to markets, as well as the surrounding innovation ecosystems in which the university is integrated and the overall institutional framework.

4. Conclusion

The present study provides a detailed analysis of the relationship between universities and industry from the perspective of sustainable development, utilizing a bibliometric framework to assess the relevance and researchers' interest in this field. The conclusions drawn from the conducted analysis reveal the global characteristics of the specialized literature, with significant contributions originating from various regions worldwide. The United States and China have been the primary producers of publications in this domain, each with seven works, followed by Australia (4) and England (3). A notable aspect is the substantial increase in the volume of articles starting in 2019, with a focus on environmental protection funding.

The keyword-based analysis highlighted frequently used terms such as "University-industry collaboration," "sustainability," "triple helix," "management," and "innovation." The most cited author in this field is Etzkowitz H. from the International Triple Helix Institute in the United States, and one of the most cited articles is co-authored with Zhou, C.Y. from Hohai University, proposing a Triple Helix model of university-public-government for sustainable development, complementing the university-industry-government Triple Helix for innovation.

This bibliometric analysis not only emphasizes the present but also tracks the evolution of researchers' areas of interest in the field of the university-industry relationship for sustainable development. However, it is crucial to acknowledge that results may evolve with the continuous update of the database, and the study recognizes the temporal and dynamic limitations associated with this aspect.

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ICSD 053

**UNIVERSITY STUDENTS' PERCEIVED EFFECTIVENESS AND
SATISFACTION REGARDING THE INDUSTRIAL TRAINING PROGRAM:
A CASE STUDY AT SABARAGAMUWA UNIVERSITY OF SRI LANKA**

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Abstract: University-organized industrial training programs serve as crucial collaborations between academia and industry, integral to holistic education systems. These programs play a vital role in producing quality labor for the industry, ensuring students' employability upon graduation, and reinforcing the symbiotic relationship between higher education and industry. Despite their widespread implementation across various universities and degree programs, the effectiveness of such programs, levels of satisfaction among students, challenges faced by students while engaging in them, and students' suggestions to enhance their effectiveness are underexplored. Therefore, the objectives of the current study were to explore the perceived levels of effectiveness and satisfaction among students who participated in industrial training programs, as well as to unveil challenges faced by students and their suggestions for enhancing the effectiveness of such programs. This research employed a case study approach, selecting 50 students through a simple random sampling technique from the B.Sc. Food Business Management degree program at Sabaragamuwa University of Sri Lanka, who had recently completed a 7-month industrial training at well-established organizations. Data were collected through semi-structured telephone interviews. Perceived effectiveness and satisfaction were measured using pre-validated scales and analyzed through descriptive statistics, while challenges and suggestions were gathered through open-ended questions and analyzed using content analysis. Results indicated that while the majority perceived the program as effective and were satisfied, overall effectiveness and satisfaction levels were moderate. Key challenges included limited practical application of theoretical knowledge, insufficient time to adopt work culture, and a lack of financial support. To enhance program effectiveness while addressing these challenges, participants suggested bridging the gap between theory and practice in the curriculum, extending the program's duration, and developing a sustainable funding program for all trainees. In conclusion, this research sheds light on the underexplored aspects of industrial training programs, emphasizing the need for a more comprehensive understanding of challenges faced by students and offering valuable insights for enhancing the effectiveness of these programs.

Keywords: Industrial training programs; Perceived effectiveness; Satisfaction; Sri Lanka; University students

1. Introduction

Holistic education is a very popular topic today, although its roots extend back nearly forty years ago to the 1980s. It emerged as an answer to the dominant worldview of mainstream education, focusing on preparing students to successfully face any challenges in their academic and future professional careers through sustaining positive social behaviors, fostering healthy relationships, and providing hands-on experiences (John, 2017). Moreover, holistic education fosters sustainable development by nurturing individuals' intellectual, emotional, and social capacities. By emphasizing interconnectedness and practical experiences, it cultivates resilient and adoptable citizens who can actively seek suitable career opportunities challenging the unemployment issues in dynamic labor markets (Spychalsky, 2023). The holistic education is more crucial at the level of university education due to its ability of creating well rounded graduates who are not only successful as future employees, but also as future citizens (John, 2017).

University-industry collaboration is a milestone in holistic education systems because it bridges the gap between academic learning and real-world applications where the essence of the concept of holistic education relies (Ankrah and Tabbaa, 2015). By partnering with industries, universities can provide students with hands-on experiences, practical skills, and industry insights, enhancing their holistic development (Nkrumah, 2015). This collaboration fosters a dynamic learning environment where students can apply theoretical knowledge to solve real-world problems, develop innovative solutions, and gain valuable workplace skills. Additionally, it promotes interdisciplinary collaboration, fosters entrepreneurship, and prepares students for successful transitions into the workforce, contributing to their holistic growth and long-term success (Ankrah and Tabbaa, 2015).

Although university-industry collaboration was initially more prevalent in advanced economies, particularly at the beginning of the 21st century, it has now widely expanded into emerging economies as well (Nkrumah, 2015). Wickramasinghe and Malik (2018) investigated the nature of university-industry collaboration in Sri Lanka, exploring the perspective of a developing country on the concept. They revealed that the technological demands of industries from universities in developing countries differ from those in developed countries. This relationship is more concerned with adaptation, enhancement, incremental changes, and adjustment to local circumstances rather than technological innovations. Moreover, they concluded that resource constraints in developing countries do not completely inhibit university-industry collaborations, as such collaborations are naturally demanded by the economy and society of the country. Weerasinghe and Jayawardane (2018) examined the importance of these collaborations in sustaining innovations within the country, while Esham (2008) presented suitable strategies to develop such collaborations within Sri Lanka.

Industrial training programs offered by various organizations for university undergraduates are a crucial practical application of university-industry collaboration. Esham (2008) also identified conducting industrial training programs as an effective strategy to strengthen university-industry collaboration. These programs, also known as internship or in-plant training programs, provide students with practical training relevant to their fields of study and career interests. They help students acquire various skills, sustain innovative talents, and ensure future employability across different job prospects (Amarathunga, 2022; Reddi and Naidu, 2022). Moreover, Joseph and Matilda (2022) as well as Kukreti and Dani (2020) identified industrial training programmes are vital for all the higher educational institutes despite of field of studies.

According to Dissanayaka et al. (2023), industrial training has a significant impact on the academic performance of students as it provides an opportunity for students to apply their theoretical knowledge in a practical setting, which can enhance their understanding of the subject matter. Moreover, through industrial training, students are exposed to new techniques and technologies that they might not have encountered in the classroom while they also can develop essential soft skills such as communication, teamwork, and problem-solving, which are valuable for their future careers (Anjum, 2020; Mendis and

Arachchige, 2015). In addition to them, industrial training also enables students to establish connections with professionals in their field, which can lead to future employment opportunities (Apriyani et al., 2023; Rodzalan and Saat, 2012). However, Tanius (2016) concluded that equal collaboration of universities and employers in the industry are crucial to increase students employability skills and employment opportunities at the industrial training programmes.

Jamaluddin et al. (2013), Dasgupta (2021), and Rosyidah et al. (2020) have identified universities, faculties, undergraduate students, and host organizations as key stakeholders of any industrial training program. Among these stakeholders, undergraduate students are the most important, as they are the primary beneficiaries, with all other parties involved contributing to the students' betterment (Gay, Umasugi and Rasid, 2021). Therefore, the perception of undergraduate students regarding industrial training programs is crucial for evaluating the effectiveness of such programs and identifying challenges faced by students while engaging in them (Jayasekara and Alahapperuma, 2021). According to the available literature, the general perception of students regarding such programmes are generally positive and inspiring throughout the globe (See Gay, Umasugi and Rasid, 2021; Jayasekara and Alahapperuma, 2021; Karunaratna and Perera, 2019; Ranganathan, Karim and Li, 2012; Subbiah et al., 2017). However, these perceptions are heavily depend on the context and situation, as these two factors essentially bring different circumstances to the general perception of students (Gay, Umasugi and Rasid, 2021).

Among different facets of undergraduates' perception regarding the industrial training programmes, perceived effectiveness is a paramount measure of perception (Jayasekara and Alahapperuma, 2021). Measuring the perceived effectiveness of industrial training programs as perceived by undergraduates is essential for refining educational strategies. By understanding students' perspectives, institutions can tailor programs to meet their needs, enhance learning outcomes, and bridge the gap between academic knowledge and practical application, fostering holistic development (Subbiah et al., 2017). Karunaratna and Perera (2019) investigated the factors impact on perceived effectiveness of industrial training programmes as perceived by undergraduates. According to the results, they determined that university (departmental) support, pre placement activities and host companies' support are key factors which determine the perceived effectiveness. In addition to these, effectiveness of developing three types of skills (i.e. academic skills, personal skills and enterprise skills) were considered as measures of the perceived effectiveness of industrial training programmes in the same study.

Nevertheless, undergraduate students' level of satisfaction is one of another key facet of the students' perception regarding the industrial training programmes (Andin, 2015). The level of satisfaction among undergraduate students regarding industrial training programs holds immense importance as it serves as a barometer for program effectiveness, reflecting how well the training aligns with students' expectations and educational goals. Understanding their satisfaction levels enables institutions to make necessary adjustments, ensuring a more enriching and impactful learning experience that prepares students for future career endeavors (Wijayakiruthika and Maheswaranathan, 2015). Moreover, Chen, Shen and Gosling (2018) found that there is a correlation between industrial training programme satisfaction and future employability where Liu (2021) revealed that satisfaction regarding the industrial training programmes leads to enhance the intention of students to retain at their current jobs ensuring their future employability. Further, Ruslan et al. (2021) identified individual factors, job characteristics, organizational environment, contextual factors, and career potential as the key determinants of satisfaction regarding the industrial training programmes. Apart from that, Caraig (2018) found that there is a direct relationship between performance at the industrial training programmes and the level of satisfaction on those programmes.

However, almost all undergraduate students perceive the industrial training programs they participate in as effective and become satisfied. Despite this, numerous challenges are associated with engaging in such programs (Gay, Umasugi, and Rasid, 2021). While universities and organizations face their own challenges in organizing these programs, the challenges faced by students are often overlooked. Many

policymakers believe it is mandatory for all students to participate in industrial training programs regardless of the challenges they face (Pillai and Usoff, 2007). According to Unadam and Mohamad (2022), many of these challenges are associated with knowledge, skills, and work ethics, while Hamdan and Rahman (2020) revealed that these challenges are departmental (university)-related, workplace/organizational-related, and personal-related matters. However, Olumese (2016) argued that such challenges and issues cannot be generalized worldwide, as students in different countries, study fields, and industries face unique challenges based on the context. Therefore, suitable solutions to overcome these challenges cannot be generalized, and customized investigations are required to reveal appropriate solutions.

The major objectives of current study were to measure the university students' level of perceived effectiveness and level of satisfaction regarding the industrial training programmes they participated and identifying the challenges faced by students engaging such programmes along with their suggestions to overcome those challenges and increase the effectiveness. Although few studies have investigated only some of identified concepts within the Sri Lankan context (See Dissanayaka et al., 2023; Jayasekara and Alahapperuma, 2021; Karunarathna and Perera, 2019; Mendis and Arachchige, 2015; Wijayakiruthika and Maheswaranathan, 2015), according to the best of our knowledge, none of them has not investigated the overall picture of the issue considering the university students perspective. Therefore, the current study would provide valuable insights for enhancing the effectiveness of these programs while increasing the level of students' satisfaction, solving existing challenges.

2. Methodology

The current study followed a mixed-methods research approach with a case study research design. Furthermore, it was conducted as exploratory research using cross-sectional primary data. The population of the study consisted of final-year undergraduates enrolled in the B.Sc. (Hons.) Food Business Management degree program at the Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka. These students had recently completed a 7-month industrial training program at various well-established organizations throughout the country. The respective organizations for students were contacted directly with the involvement of the university. The sample consisted of 50 undergraduates selected using simple random sampling techniques. Primary data were collected through semi-structured telephone interviews. The socio-demographic characteristics of the sample are presented in Table 1. Pre-validated scales were utilized to assess students' perceived effectiveness (Karunarathne and Perera, 2019) and level of satisfaction regarding the industrial training programs (Craig, 2018). Both scales used 5 points Likert scale for assess the level of perceived effectiveness and satisfaction. As the Cronbach's alpha value for both scales were 0.867 and 0.932 respectively, scales had acceptable reliability and therefore the results of further analysis were interpretable. The data were analyzed using descriptive statistics in SPSS software. Associated challenges and suggestions to improve the current conditions were assessed through open-ended questions, and the data were analyzed using content analysis techniques in NVivo software.

Table 1: Socio demographic characteristics of the Sample (N=50)

Variable	Categories	Frequency (n)	Percentage (%)
Gender	Male	11	22.0
	Female	39	78.0
Ethnicity	Sinhala	40	80.0
	Tamil	7	14.0
	Muslim	3	6.0
Monthly family income	<30,000 LKR	12	24.0
	30,001- 60,000 LKR	22	44.0
	60,001-90,000 LKR	10	20.0
	90001- 120,000 LKR	4	8.0

	>120,001 LKR	2	4.0
Place of residence during the industrial training	Home	7	14.0
	Out of home (Paid a rent)	33	66.0
	Out of home (Didn't pay a rent)	10	20.0
Category of the organization from where the industrial training received	Government	4	8.0
	Semi-government	6	12.0
	Private	40	80.0
Status of receiving an allowance from the organization during the training period	Didn't receive an allowance	29	58.0
	Received an allowance but not enough to cover basic living expenses	13	26.0
	Received an allowance which enough to cover basic living expenses	8	16.0
Belief regarding the effectiveness of the industrial training programme	Programme was effective	43	86.0
	Programme was not effective	7	14.0
Belief regarding the satisfaction of the industrial training programme	Satisfied regarding the programme	40	80.0
	Not satisfied regarding the programme	10	10.0

According to the sample characteristics, approximately 4/5 of the students were females, and around similar proportion belonged to the Sinhala ethnicity group. Furthermore, the majority of the students were from families who receive lower-middle income per month. However, two-thirds of the sample had to stay away from home during the industrial training period and were required to pay rent. While around 4/5 of the students received their industrial training at private organizations, only 16.0% of the sample received an allowance from the organization, which was sufficient to cover basic living expenses during the training period.

3. Results and discussion

Descriptive statistics for perceived effectiveness of industrial training program and satisfaction regarding the industrial training program are given in the Table 2. Results indicated that although the majority of the sample perceived the program as effective and were satisfied, overall effectiveness and satisfaction levels were only in moderate level. Additionally, perceived effectiveness and level of satisfaction regarding the industrial training programmes displayed a significant and moderately positive correlation ($r=0.443$, $p<0.01$; Two tail).

Table 2: Descriptive statistics of for perceived effectiveness of industrial training program and level of satisfaction regarding the industrial training program

Construct	Mean	Standard Deviation (SD)
Perceived effectiveness	3.02	0.332
Development of academic skills	3.05	0.211
Development of personal skills	3.11	0.435
Development of enterprise skills	2.89	0.089
Level of satisfaction	3.18	0.597

The findings regarding the level of effectiveness were quite below the findings of Karunaratna and Perera (2019) while level of satisfaction also was below to the findings of Carraig (2018). The reason for this disparity can be the difference of the field of studies and the context of the investigation. However, it is clear that, both perceived effectiveness and level of satisfaction are not in a high range hinting a possible gap between university students expectations and what actually they receive practically.

According to the content analysis results regarding the challenges faced by students while engaging industrial training programmes, six key themes were identified. Table 3 presents the key themes identified with their respective frequencies and percentages of responses.

Table 3: Key themes of challenges identified from the content analysis

Theme	Frequency	Percentage (%)
Limited practical application of theoretical knowledge	45	90.0
Insufficient time to adopt work culture	43	86.0
Lack of financial support	40	80.0
Exploitation of labour by organizations	23	46.0
Lack of support from supervisors	20	40.0
Issues related to the placement	15	30.0

According to these key themes, the major challenge was the limited practical application of theoretical knowledge, followed by insufficient time to adapt to work culture and a lack of financial support. Students believed that, despite studying more than 50 subjects during their university careers, the majority of these subjects are not applicable in practical scenarios. They felt they have missed out some important practical knowledge and skills more applicable in the work environment. As around 9 out of 10 students claimed this challenge, it is particularly significant. Furthermore, more than 4 out of 5 students believed the available time is not enough to adapt to work culture, as the induction process takes longer than expected. Therefore, they found it challenging to become familiar with work tasks, responsibilities, and cultural norms within a shorter period of time. Moreover, 4 out of 5 students claimed they faced financial difficulties while engaging in industrial training programs. This issue should be essentially considered, as the majority had to pay rent for accommodation and did not receive enough allowance to cover basic living expenses. In addition to these, challenges such as the exploitation of labor by some organizations, lack of support from supervisors, and placement-related issues have been identified as common challenges regarding industrial training programs by Hamdan and Rahman (2020), Pillai and Yusoff (2007), and Unadam and Mahomad (2022).

Further, content analysis led to identify 5 key themes regarding the suggestions to overcome challenges and increase the effectiveness of programmes. Table 4 presents those key themes with respective frequencies and percentage of responses.

Table 4: Key themes of suggestions identified from the content analysis

Theme	Frequency	Percentage (%)
Bridging the gap between theory and practice in the curriculum	43	86.0
Extending the program's duration	42	84.0
Developing a sustainable funding program for all trainees.	39	78.0

Considering the students' choices in placement	21	42.0
Developing a proper policy regarding work hours and work days	18	36.0

The three major themes of suggestions; bridging the gap between theory and practice in the curriculum, extending the program's duration, and developing a sustainable funding program for all trainees, were well aligned with the three major challenges faced by undergraduate students. Here, they strongly demanded a proper curriculum revision as soon as possible to overcome the issue of disparity between theory and practice. Furthermore, students requested an increase in the duration of the industrial training program, at least up to one year, to adapt to the work environment leisurely and obtain maximum benefits from the program. Additionally, students suggested, starting a fund in collaboration with both the university and industry to provide equitable allowances for all trainees, enough to cover basic living expenses. Apart from these, consideration of students' choices in placement and developing proper work policies have been also identified as key ways to increase students' perceived effectiveness and level of satisfaction regarding industrial training programs by Caraig (2018), Karunarathna and Perera (2019), and Liu (2021).

4. Conclusion

The current study sheds light on identifying the perceived effectiveness and level of satisfaction regarding industrial training programs as perceived by university students, while exploring the challenges faced by university students who engaged in such programs. Further, suitable suggestions are provided to increase overall perceived effectiveness and satisfaction levels to overcome these challenges. Findings imply the need to revise curricula to meet industry knowledge and skill requirements. Additionally, results emphasize the areas requiring consideration when planning industrial training programs, taking into account university students' concerns to achieve higher levels of effectiveness and satisfaction. Future research could reevaluate students' perceived effectiveness and satisfaction levels regarding such programs after implementing the possible measures suggested by the current study.

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ICSD 201

**A COMPREHENSIVE STRATEGY FOR ENHANCING UNIVERSITY-INDUSTRY
SYNERGY THROUGH INCUBATOR AND ACCELERATOR PROGRAMS
CATALYZING INNOVATION AND GROWTH IN SRI LANKA'S AGRO-
INDUSTRY SMALL AND MEDIUM-SIZED ENTERPRISES**

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Abstract: This paper presents a strategic framework designed to enhance the growth and innovation of Small and Medium-sized Enterprises (SMEs) in Sri Lanka's Agro-industry. It acknowledges their critical role in the national economy and unique challenges, especially in innovation and sustainable development. The study proposes a novel approach through university-industry incubator and accelerator programs, aiming to establish a practical strategic framework, identify critical success factors, and assess the impact on SME growth in the Agro-industry sector. The methodology involves a comprehensive review of global best practices in incubator and accelerator models, adapting them to the Sri Lankan context in consultation with local industry and academic experts, ensuring practicality and applicability. The proposed framework includes developing robust university-industry partnerships, creating structured resource allocation systems with seed funding and research facility access, and offering comprehensive business and technical support. It emphasizes sustainable agricultural practices, techno-entrepreneurial skill development among students, addressing SME innovation challenges, and leveraging digital transformation for increased agro-industrial productivity. The anticipated outcomes include boosted SME innovation, enhanced graduate employability with training in sustainable agro-industrial practices, and a dynamic innovation culture in agriculture. The conclusion highlights the strategic framework's potential to support SMEs and contribute to the sustainable development of Sri Lanka's Agro-industries. The paper emphasizes the synergy between educational institutions and industry for fostering an environment conducive to SME growth and innovation, positioning Sri Lanka's Agro-industry for future challenges and opportunities.

Keywords: Agro-Industry SMEs; Student employability; Agri Innovation; Incubator and accelerator programs; Sustainable agriculture

1. Introduction

Sri Lanka's economic crisis, food security, and the looming impact of climate change show a need to be proactive about existential challenges and opportunities. Prices of most food items have steadily climbed since the last quarter of 2021 and reached a record high in September 2022, pushing the year-on-year food inflation rate to nearly 95% (Npg et al., 2023). A primary strategy for fulfilling Sri Lanka's development potential and ensuring long-term food security is sustained agricultural growth. This can be achieved via agribusiness incubation and acceleration, particularly in SMEs.

SMEs are pivotal in a developing country's economy (Analoui and Karami 2003; Soleh 2008). SMEs comprise a large part of the Sri Lankan economy, accounting for 80% of all businesses (Rathnasiri 2014). This paper explores the potential of Graduate Research and Scholar Exchanges, Robust University-Industry Partnerships, Policy and Issue-related Engagement, and Structured Resource Allocation for Innovation.

The agro-business environment in Sri Lanka has multiple barriers that obstruct the contribution of research and development to achieve a differentiation strategy. A solid financial basis is required for SMEs in developing countries like Sri Lanka, and the lack of such is a significant constraint (Amaradiwakara and Gunatilake 2017).

Ravesteijn and Sjoer (2010) identify that innovation, recognizing opportunities, and contributing to economic growth are general norms of entrepreneurial activities. Therefore, promoting these activities and skills through incubator programs will allow SMEs to develop further and be more sustainable.

Acceleration and Incubation programs can support enterprise skill development and also have the means to support small entrepreneurs in growing. Universities are well-placed to link the youth with forward-thinking environments that expose them to advanced technology, mentorship, and investments.

2. Main body – Discussion

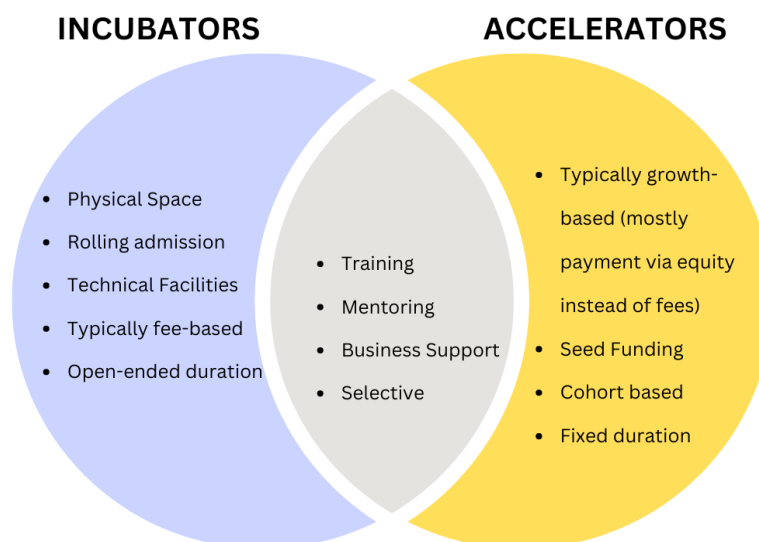


Figure 1: Incubator and Accelerator Characteristics – Venn Diagram
Source: (Bone et al. 2017).

Incubators are predominantly physical workspaces, with the physical space being central to the model's essence. The additional features include what is stated in Figure 1, which broadly includes business support services and investor access. The services provided by Incubators tend to have flexible terms, where new businesses can have more ad hoc and easy access for an open-ended duration, which is around two years (Bone et al. 2017). They tend to be partly self-funded through membership fees but can also be public or university-funded (Bone et al. 2017). In a Sri Lankan context, SMEs that are unlikely to scale rapidly would benefit the most from such incubator programs because they are based on rent instead of equity, which is less competitive than an accelerator program.

Accelerators are a newer discovery than incubators. Accelerators are also for a more limited duration, usually between three months to one year. Accelerator services are offered through an intensive cohort-based program, are competitive, and tend to prioritize services over physical space (Bone et al. 2017). Due to the business model being based on equity from the startups that are being supported, Accelerators tend to be more selective than incubators and highly growth-driven. This rapid pace allows companies to scale or fail faster, minimizing the prolonged waste of resources (Bone et al., 2019).

2.1 Graduate Research and Scholar Exchanges

2.1.1 Incubator-Linked Research Projects and Accelerator-Driven Career Launchpad

The Universities offer well-equipped computer laboratories to entrepreneurs, highly skilled human resources, and specialists in particular sectors. This also creates a space where students can apply the knowledge they have learned to actual business situations, encouraging student entrepreneurship. A significant advantage for universities is strengthening ties with the business community by bringing research findings and technology advancements to market through commercialization channels (Hasan, 2020).

In Sri Lanka, this would allow graduate students in universities to pursue agro-industry projects supported by incubators, with a clear path to market. This would also increase their research's commercial relevance and value to potential employers.

A favourable impact on participating startups' growth, including turnover, employees, and productivity, was observed. Another observation was the increase in high-quality jobs surrounding the incubator site (Bone et al., 2019).

Accelerators can provide intensive mentorship and industry connections for students, increasing their employability and providing a faster transition from academia to industry.

Accelerators positively impact the broader business ecosystem they belong to, acting as a career Launchpad. A commercial dataset was analyzed to study the impact of launching an accelerator and its effects on the amount of investment going to non-accelerated companies in the area. What was established through this experiment, is that the launch of an accelerator is correlated to a significant surge in the number and value of investments made by VCs into non-accelerated seed and high-tech companies, when compared to non-accelerated seed but non-high-tech firms (Bone et al., 2019).

2.2 Robust University-Industry Partnerships

2.2.1 Incubator Collaboration Spaces

Create spaces within universities where industry professionals from SMEs and students can collaborate, fostering innovation and leading to job creation. Lasarado et al. (2016) show that university-affiliated incubator and accelerator programs are connected with faster sales as well as job growth. This is as opposed to those programs which are not connected to a university.

Inculcating a culture of entrepreneurship within Sri Lankan universities is essential. Mainly because the graduates will be technologically knowledgeable, and that is a foundation that can contribute significantly to the high-tech startups and export sector with competitive products and services. An entrepreneurial mindset has no specific timeline for development; hence, it can be persistently cultivated at any stage of life (Murnieks, Mosakowski & Cardon, 2014).

Students would have access to leadership from top public and private sector firms, which would broaden their horizons to implementation and business practices that would otherwise not be explored at a university level. Inspiration and vision go a long way in young minds, and Incubator Collaboration Spaces would be a prime opportunity to create them.

2.2.2 Accelerator Programs for Spin-offs

A high-profile spin-off from a recent global context is the separation of PayPal from eBay.

A business may spin off to better manage the segments of the business with higher long-term potential and to concentrate its resources. Companies that want to simplify their operations frequently spin off subsidiaries with the possibility of having two types of spin-off related to different triggering events: "opportunity spin-off" and "necessity spin-off" (Molteni, 2019).

In Sri Lanka, it is possible to encourage the creation of university spin-offs through accelerators, providing employment opportunities, and retaining talent within the country. The crippling adversity triggered by the economic crisis has resulted in Sri Lankan citizens migrating to other countries to survive and in order to support their families back home. At least one family member in every ten households intends to migrate, while around 2% have already migrated (Npg et al., 2023).

The collaboration between universities and incubators tends to go beyond just funding; as universities directly manage and support spin-offs with other local businesses. Therefore, this would allow for more SME opportunities to sprout out of larger-scale ideas in the agro-sector. For example, Climate Smart Agriculture (CSA) is being promoted through the Ministry of Agriculture and the government of Sri Lanka (International Climate Change Forum, 2023). Potential spin-offs include digital infrastructure facility providers. Currently, digital infrastructure still needs to be appropriately introduced to farmers. These include decision support tools, mobile apps, and computer GIS mapping.

2.3. Policy and Issue-related Engagement

2.3.1 Policy Incubation

The plight of entrepreneurship education in South Asia has been dramatically and negatively impacted by the lack of resource availability and the lethargic approaches of policymakers (Ghina, 2014).

It is not just businesses that require incubation because supporting policies are paramount for SMEs in Sri Lanka to have sustained growth. Incubators can be used to test and develop policies supporting SME growth and innovation, with the engagement of knowledgeable professionals and students who can become policy experts. Introducing procedures to establish a more favorable business environment for SMEs, so that they have a competitive advantage, especially in accessing the globalized business environment. Organizing customized supportive programs, policy adjustments, restructuring institutional settings, and reforms would be vital to achieving the future goals of the industrial sector (Prasanna et al., 2021)

Enabling policy on climate-smart agricultural practices at the national and local levels and establishing a carbon credit system in the agriculture sector would reduce challenges to farmers in Sri Lanka (International Climate Change Forum, 2023).

2.3.2 Accelerators for Policy Implementation

Accelerators can help rapidly deploy and scale successful policy-driven initiatives, creating new job roles and demand for professionals who understand these policies.

Policymakers should consider university incubators and accelerators as a pipeline for policy generation and policy reforms by offering financial and legislative support and introducing incentives to the commercial sector for their active participation. University incubators could be a national innovation tool, a research commercialization tool, or a tool for generating knowledge and transferring it to industry. This would allow the entrepreneurial community to be competitive in an international context (Hassan, 2020).

2.4 Structured Resource Allocation for Innovation

2.4.1 Incubator Funding for Student Startups

Allocate funds for student startups within incubators, encouraging entrepreneurship and providing graduates with alternative career options in Sri Lanka.

The development of Entrepreneurship needs to be improved in the education system. It is more complex than other subjects, as it is a blend of skills, knowledge, and attitudes, which requires a deep and exciting practical focus to succeed. The meaning of entrepreneurship has been restrained to the starting of a classical business when, in actuality, it is vast in range. This is a primary reason for a student's need for more understanding of the importance of entrepreneurship and loss of interest in pursuing this path from an early age. (Kalugalagedera & Kaushalya, 2017).

Public-private partnerships could be used to fund these student incubators, which would result in automatic base funding for the student startups while further exposing them to potential investors. This would allow students an entrepreneurial path prior to graduation, thus being able to pursue business straight out of university. They would leave with a business already begun, acting as an alternate career option and an addition to Sri Lanka's SME sector.

2.4.2 Accelerator Support for Scaling Innovations

If Sri Lanka is to overcome the middle-income trap and attain a greater income index, its economic transformation must be based on innovation (Hewage, 2019).

Use accelerators to provide the resources and expertise needed to scale student and faculty innovations, leading to job creation and economic growth. The most recent Accelerator program adopting a holistic approach and explicitly targeting the Agricultural Industry is the 'Govilab AgriTech Accelerator'. In order to support farmers entails not only finding and assisting startups with innovative ideas but also collaborating with a range of stakeholders, such as other international development organizations, the private sector, and the government, to expand the nation's agri-technology and startup ecosystem. This will result in long-lasting and significant changes throughout the agriculture value chain. This program is a prime example of accelerator support in scaling innovations because the program's first phase will involve focus group discussions and stakeholder consultations to identify particular issues faced by smallholder farmers and how these are related to government priorities (Lbo, 2024).

3. Conclusion

The strategic framework to enhance the growth and innovation of SMEs in Sri Lanka's Agro-industry requires holistic intervention, and utilizing the available University infrastructure allows for a space that connects education, youth, private sector, and government. Incubator and accelerator programs will allow innovation through undergraduate programs, which will pave career paths for students. As a result, Sri Lanka will face less brain drain and utilize local talent to create innovative solutions and establish SMEs. This will directly boost the agriculture industry, impacting the country's GDP. Retaining

intelligence surrounding agriculture-related technologies within Sri Lanka will pave the way for patents and trademarks, resulting in a more significant influx of foreign currency to the island.

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ICSD 211

A CONCEPTUAL FRAMEWORK TO DEVELOP MARKET AND INDUSTRY-ORIENTED CEYLON CINNAMON-INCORPORATED PET FOOD PRODUCTS: A NATIONAL UNIVERSITY EXPERIENCE

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Abstract: This study explores a methodical framework to develop pet food products incorporated with Ceylon cinnamon (*Cinnamomum zeylanicum*) extract, a herbal and health-promoting medicinal ingredient. The proposed framework addresses the growing market needs for nutritionally sound, innovative pet food options as series of complete diets for dogs and cats. This framework, aims (i) to analyze the current industry demands and trends of pet food production in the global market including Sri Lanka and (ii) to investigate customer (human) willingness and consumer (animal) sensory preferences to identify the key factors driving the demand for Ceylon cinnamon-incorporated pet food as an alternative to cassia (*Cinnamomum cassia*) - incorporated pet food which retains numerous biological toxic factors. An innovative nutritional model which is optimally incorporated with Ceylon cinnamon and Cassia will be tested across all age categories. The formulated recipes will undergo rigorous testing to ensure their sensory attributes, nutritional composition, safety and their effectiveness on pet's performance and hematological parameters. The final approach aims to create a well-rounded framework that addresses both industry needs and customer expectations. The developed framework will be meant to provide promising results, demonstrating a range of Ceylon cinnamon-incorporated pet food products that meet industry standards. The developed nutritional formulae will be intended to exert improvements in pet health and will improve the Ceylon cinnamon brand in the pet food market.

Keywords: Cassia; Ceylon cinnamon; Conceptual framework; Industry demand; Pet food

1. Introduction

Pet food are the food materials that are intended for consumption by domestic pets. They are specifically formulated to meet the nutritional needs of dogs and cats, or any other animals specified as pets. Dogs and cats are capable of digesting a variety of food. This remarkable adaptability of pets promotes the incorporation of ingredients with different nutritional composition successfully in their commercial dietary formulae (Dilukshi *et al.*, 2009). Recent developments in the global commercial pet food industry have brought the adequacy and safety of commercially produced food from both small and large-scale facilities into the spotlight. While purchasers have access to numerous resources for gathering nutritional information for their dogs and cats, the reliability of such information is not consistently supported by rigorous scientific interpretation.

International pet food market was estimated as 100 billion USD and is expected to grow at a compound annual growth rate of 4%. The demand for pet food, mainly dog and cat food by growing consumer inclination toward the adoption of pets along with rising concerns on pet's health. Figure 1 shows the composition of global pet food market.

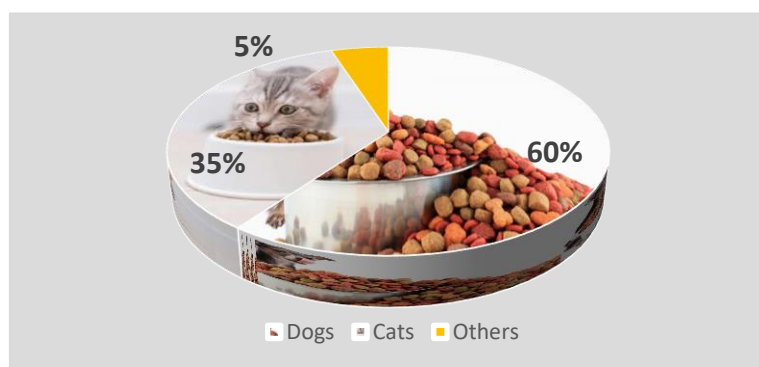


Figure 1: Composition of the global pet food market
Source: (International Trade Center, n.d.).

Increasing rate of pet ownership globally, especially from the growing middle class and developing middle income countries, act as main demand driver (Figure 2 and 3 represent that the world pet food exports and world pet food imports in 2022).

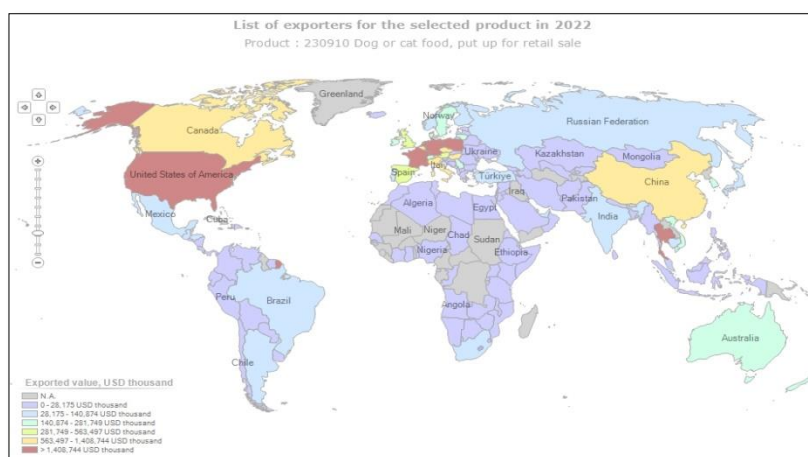


Figure 2: World pet food exports - International Trade Center (ITC)
Source: (International Trade Center, n.d.).

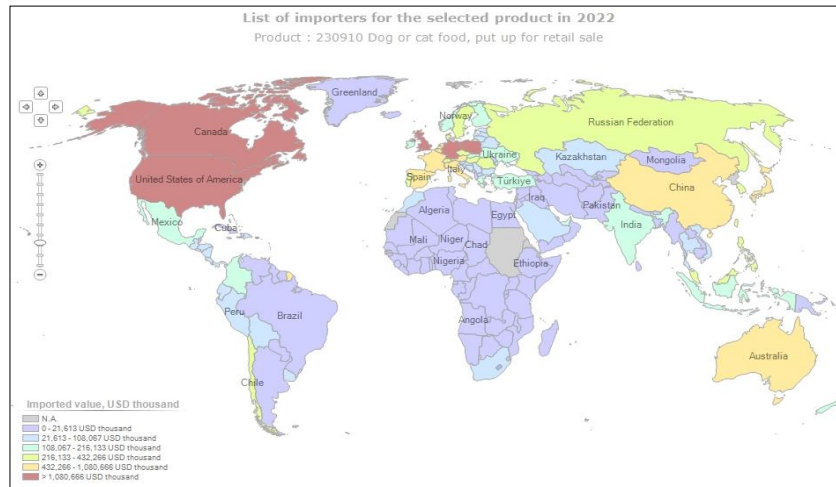


Figure 3: World pet food imports - International Trade Center (ITC)
Source: (International Trade Center, n.d.).

Health concerns, urbanization and limited domestic space available for pets places promising demand for nutritious and balanced diet. Further, growth of household income seems to be linked with exploration of new pet food types enriched with vitamins, minerals, probiotics, antioxidants and other natural raw materials.

Pet food value chain is characterized by main two segments; (i) the upstream which is comprised of raw material suppliers and manufacturers and (ii) the downstream members who are known to as distributors, retailers and consumers. The raw materials which are used for pet food production include meat and meat byproducts, cereals and their byproducts and additives such as appetizers, flavors and sweeteners, vitamins, minerals, and enzymatic preparations.

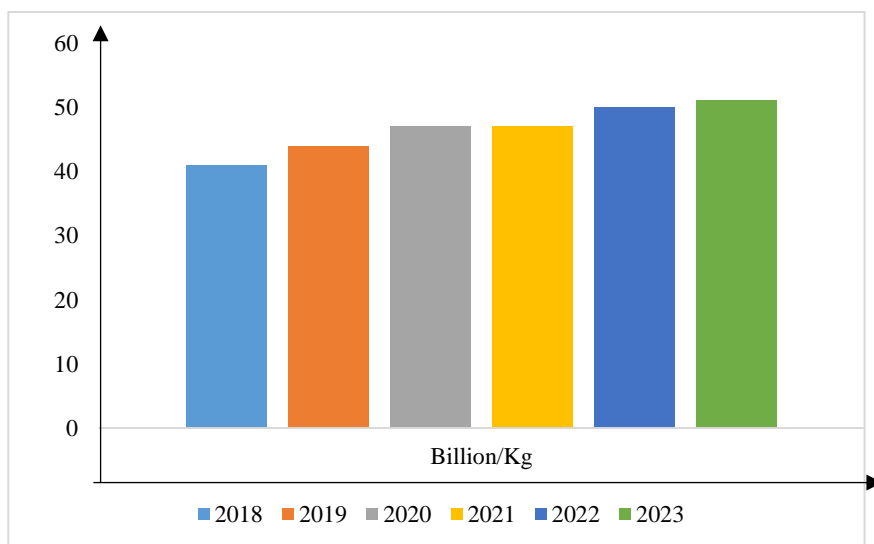


Figure 4- Pet food production trend 2018 – 2023
Source: (International Trade Center, n.d.).

Dog pet food type dominated in the market with a revenue share of more than 42.1% in 2023. Figure 4 shows the way of pet food production trends increased from 2018 to 2023. This is attributed to the growing adoption of dogs as household pets and rising household expenditure towards healthy dog food due to an increase in concerns of owners about their dog’s health. As dogs are carnivorous, their meals are largely meat-based.

Anually, Sri Lanka imports large quantities of dog and cat food of different brands from different countries (Figure 5). Figure 6 represents the major players in the pet food market in Sri Lanka. However, pet food production is not satisfactory in Sri Lanka. To address this drawback, new nutrition-rich pet food formulae will be formulated using different raw materials where local spice materials will be used as a mode of value addition.

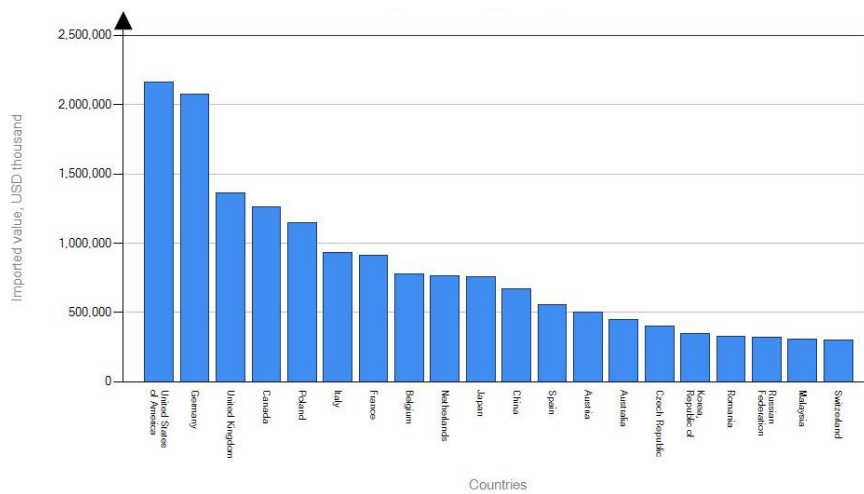


Figure 5: Importers for the pet food (dog/cat) in Sri Lanka (2022)
Source: (International Trade Center, n.d.).



Figure 6: Major players of pet food market in Sri Lanka.

As outlined by the Association of American Feed Control Officials (AAFCO), the formulation of most commercially produced pet food are designed to align specific nutritional objectives while supporting growth, maintenance, gestation and lactation. These objectives are derived from scientific studies that establish minimum requirements or safe upper limits for various physiological states. The targeted nutrients encompass calories (energy), protein, fat, carbohydrates, vitamins, and minerals that are essential for sustaining life and, whenever feasible, enhancing performance. Given the focus on achieving precise nutrient targets, different ingredient combinations can be employed to achieve the desired mix and meet specific nutrient-based goals (Zicker, 2008). AAFCO regulations for pet food

include requirements regarding product names, flavor designations, guaranteed analysis, nutritional adequacy statements, proper ingredient names, and other aspects of labeling (Dilukshi *et al.*, 2009). Various plant based resources are incorporated by the current pet food industry to gain more health benefits. In modern animal feeding, cinnamon-like condiments exhibiting health benefits are also incorporated. The herbs that are commonly used include picorhiza, garlic, cloves, slippery elm, neem fruit and leaves, sophora flavescens, nutmeg, cinnamon, ginger, peppermint, sage, thyme, mustard and fenugreek. These plants are used widely as digestive stimulants, antidiarrhoic, antiseptic, anti-inflammatory, antiparasitic and appetite stimulants in human and animals (Tipu *et al.*, 2006). Cinnamon is a condiment which is commonly used as an aromatic condiment and a flavor additive.

In contemporary times, the most pet owners are interestingly prioritizing health and functionality in their food choices, placing a greater emphasis on products that offer health benefits to their pets. Reflecting this trend, pet food options infused with cinnamon are now available in the global market. The majority of these products are formulated using cassia cinnamon (*Cinnamomum cassia*; Chinese cinnamon) which is known to have a significant coumarin content. Besides, the most expensive and the rare cinnamon variety in the world is known as “Ceylon cinnamon” which is native to Sri Lanka. Ceylon cinnamon (*Cinnamomum zeylanicum syn. Cinnamomum verum, Cinnamomum zeylanicum blume*) as a lighter, brighter and spicier flavor than cassia cinnamon and it has 63 times less coumarin (0.004%) than cassia so it is safer to use in large quantities. However, a notable concern arises from the coumarin content present in Cassia cinnamon, which has the potential to adversely affect health. Cassia cinnamon can contain up to 1% coumarin (Blahová and Svobodov, 2012). In this study, the adverse effects were addressed by substituting Ceylon cinnamon with cassia cinnamon.

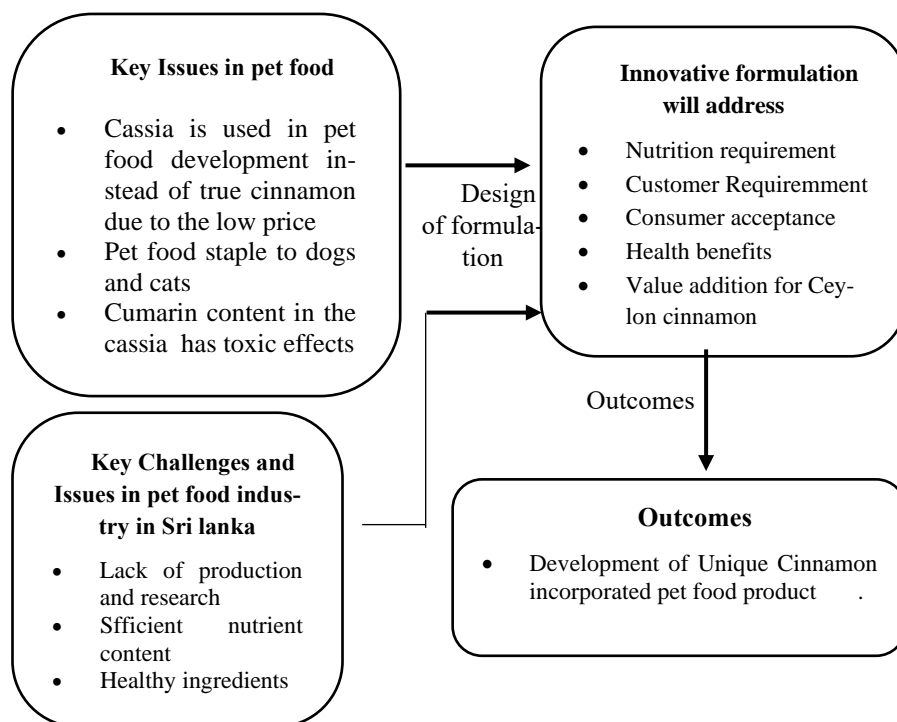


Figure 7: Conceptual framework of the project design.

Ceylon cinnamon, is also known as *Cinnamomum verum* or true cinnamon, contains only a minute amount of coumarin, approximately 0.004% (Blahová and Svobodov, 2012). Although there are pet food produced incorporating cassia cinnamon, there is no evidence for incorporation of Ceylon cinnamon into pet food. Moreover, as a tropical plant, Cinnamon is one of the most popular spices used daily by people all over the world (Rao and Gan, 2014). Previous reports showed that the antidiabetic,

antioxidant, anti-inflammatory, lipid-lowering antimicrobial, anticancer, and cardiovascular-disease-lowering compounds contained in cinnamon extracts (Ravi Kumar *et al.*, 2011; Rao and Gan, 2014). Main limitation in using plant-based materials such as cinnamon into pet food is insufficiency in tested safety (ŠTRBAC *et al.*, 2021). Furthermore, limited research has been conducted on the potential of using herbs on various disease conditions of pet animals (Gupta *et al.*, 2019). Therefore, it is important to study the safety of using cinnamon like plant herbs into pet food. The main objective of incorporating cinnamon into pet food is to increase the nutritional and health benefits of pet animals.

Therefore, the aim of this study is to bridge the existing gap by creating innovative functional pet food using Ceylon cinnamon for dogs and cats that could be utilized to promote the health while fulfilling their nutritional needs. Figure 7 shows that the conceptual framework of the project design.

2. Materials and methodology

2.1. Ethical approval

The ethical approval to conduct the research using both dogs and cats will be sought from the Ethics Committee for Animals, Sabaragamuwa University of Sri Lanka prior to conducting the experiments.

2.2. Pet food preparation

2.2.1. Ingredient selection

Ingredients selection will proceed after a comprehensive literature review. Low cost, nutrient rich ingredients and several non-nutritive feed additives will be used to formulate a series of diets for dogs and cats. A separate sets of diets will be formulated to facilitate phase feeding (e.g. Pups and kittens vs. adults)

2.2.2. Diets

For each pet type (e.g. Dogs and cats) and to a particular age group (Pups/kittens or adult dogs/cats) a basal diet (A) will be formulated. Another two diets will be formulated incorporating either Chinese (B) or Ceylon (C) cinnamon bark oil (CBO) at 5 mg/kg as fed. The effects of a commercially available pet diet (D) also will be compared along with.

2.3. Sensory evaluation of formulated sample

2.3.1. Customer acceptability

The prototype product's sensory evaluation will be conducted using a 5-point hedonic scale and 30 untrained panelists performed to evaluate the colour, smell, texture, shape of the product and appearance of the formulation.

2.3.2. Consumer (animal) acceptability

Palatability test will be performed using two pen free choice test (Dilukshi *et al.*, 2009; Aldrich and Koppel, 2015).

2.4. Test for animal performance

Two animal experiments will be conducted separately for dogs and cats. Each experiment will be designed to have both kids and adult phases. The Latin square model will be used to frame the animal performance testing of individual pet food formulas (Table 1). The experiment will run for 6 weeks. Same age, uniform pets (four Dogs and four cats) from the same sex (preferably) breed will be selected for the study (A1, A2, A3, A4). Feed intake, weight gain and feed conversion ratio (FCR) will be recorded weekly for the entire test period.

Table 1: Latin square model for four- week experiment

Weeks	A1	A2	A3	A4
1 st week	A	B	C	D
2 nd week	B	C	D	A
3 rd week	C	D	A	B
4 th week	D	A	B	C

2.4.1. Evaluation for haematological parameters

2.4.1.1. Blood glucose level evaluation

Blood glucose levels of the pets will be evaluated using handheld blood glucose meters (Gupta *et al.*, 2019).

2.4.1.2. Determination of serum coumarin concentration

Thin-layer chromatography (TLC) and reversed-phase high-performance liquid chromatography (RP-HPLC) with fluorescence detection will be used to identify the serum coumarin content.

2.4.1.3. Blood pressure evaluation

Blood pressure levels of the pets will be evaluated weekly using a barometer.

2.4.1.4. Determination of electrolyte concentration in blood serum

Blood will be taken on 1st (day-1), 3rd and 6th week of the experiment from the animal, centrifuged to separate serum and the serum will be sent for electrolyte analysis (Dilukshi *et al.*, 2009).

2.4.1.5. Blood profile evaluation

Blood will be collected (during 1st (d-1), 3rd and 6th week) and will be compared between treatments for blood cell counts, packed cell volume (PCV) and hemoglobin concentrations.

2.5. Analysis of the experimental diets

2.5.1. Physico-chemical analysis of pet food

2.5.1.1. Texture analysis

Textural properties of the experimental diets will be evaluated using Brookfield CT3 Texture analyser

2.5.1.2. Colour evaluation (L*, a*, b*)

The external colour will be evaluated using a chromometer for lightness (L*), redness (a*) and yellowness (b*).

2.5.1.3. Proximate analysis and gross energy evaluation

Proximate analysis will be carried out for all the experimental diets formulated. The moisture (oven drying method, AOAC 990.19), ash (AOAC, 900.02), crude protein (AOAC 955.04), crude fat (Soxhlet method AOAC 920.39), and crude fiber (AOAC 978.10) contents will be determined. Gross energy of feed will be measured using a bomb calorimeter.

2.5.2. Functional properties

Antioxidant activity, DPPH Radical Scavenging Assay and the total phenolic content will be determined

2.5.2.1. DPPH Radical Scavenging Assay

The free radical (FR) scavenging activity of CBO will be assessed using the standard procedure with slight alterations (Kokilananthan *et al.*, 2022). Ascorbic acid will be used as a standard solution

2.5.2.2. Total phenolic content (TPC)

Total phenolic count will be determined using a slightly altered Folin-Ciocalteu method (Kokilananthan *et al.*, 2022). TPC will be calculated using a gallic acid standard curve and will be represented in milligrams of gallic acid equivalents (mg GAE/g extract).

2.5.3. Shelf life evaluation of the test diets

Performing shelf-life evaluation by total plate count and yeast and mold count methods to evaluate the stability of the product. Moisture content is measured using the oven drying method (AOAC 990.19). Water activity will be measured using a water activity meter. pH will be measured using a pH meter. The storage conditions of pet food will be determined using different packaging conditions (Aluminum foil, vacuum package, refrigerated conditions).

2.5.4. Cost-benefit analysis

Cost of production for all dietary formulations will be conducted.

2.6. Data Analysis

All the analytical data will be measured in triplicates in this study (n=3) and the results will be presented as mean \pm standard deviation (SD). Performance results will be analyzed in Latin Square Design. Sensory results of the study will be analyzed using Non-parametric Friedman test using Minitab Software Version 20 package. Tukey's test at 5% significance level will be used to determine the treatment effect.

3. Discussion

This innovative concept framework for university-industry collaborative research activities involves establishing a structured approach to facilitate partnerships between academic institutions and industry players. First, it involves identifying common areas of interest between universities and industries during the idea generation step. The process involves setting up formal collaboration agreements with university and industry parties. Then, roles and responsibilities are defined for each party, and resources are allocated effectively to support collaborative research activities, such as those involved in designing pet food for Cinnamon incorporated. The project objectives, timelines, and deliverables are clearly identified. Research works are conducted under clear agreements and project proposals, aimed at achieving the targeted research outcomes.

Prototype preparation is conducted based on trial and error, considering organoleptic and physical properties of the final product. After confirming the product through physicochemical and functional analysis, the framework facilitates the transfer of knowledge and technology generated through collaborative research to industry partners. Finally, market launch is established, and the effectiveness and impact of university-industry collaborative research initiatives are evaluated continuously. This evaluation is conducted through surveys, interviews, or case studies to assess outcomes such as scientific advancements, economic benefits, and societal impact. The process framework is indicated in Figure 8.

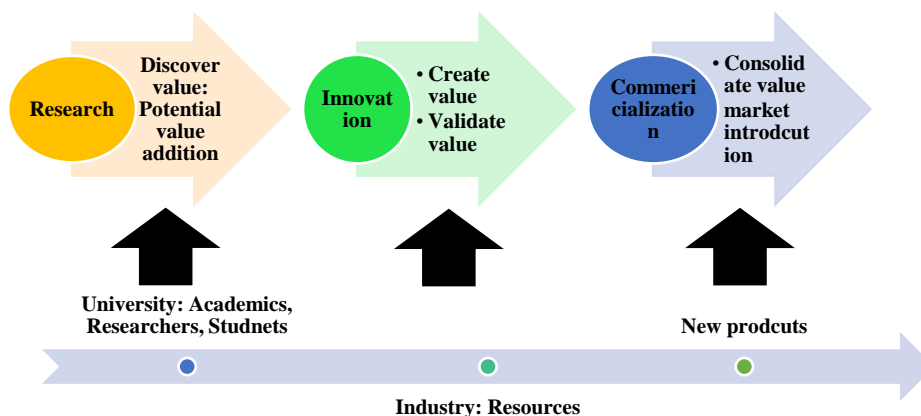


Figure 8: The conceptual framework of the process.

3.1. Nutritional standards

The final formulation of the pet food will meet the nutrient requirements recommended by the American Association of Food Control Officials (AAFCO) guidelines (Netnews *et al.*, 1992). Table 2 shows the basic nutrient content of dog foods.

The final formulations will meet these requirements and will provide complete standard nutrition to satisfy the daily nutritional needs of the animal.

Table 2 : AAFCO standard for pupps nutrition requirement (% , as fed)

Calculated Composition	AAFCO STD
ME ¹ (kcal/kg)	3600
Dry matter, %	90
Moisture, %	10
Crude Protein, %	20.3
Ether Extract, %	7.65
Crude Fiber, %	5.13
Ash, %	NS
Calcium, %	1.08
Total P,%	0.9
L-Lysine, %	0.81
DL Methionine, %	0.32

¹Metabolizable energy.

(Source-Official Pulication – AAFCO).

3.2. Sensory evaluation

Sensory evaluation will provide a complete detailed profile for consumer acceptance of the product. As pet food buyers in the market, people will pay more attention to its nutritional value, price, pellet shape, color and appearance. By targeting these properties, sensitive results will provide more effective insights for refining the final preparation.

Sensory evaluation in animals will provide detailed information on animal preferences for the new formulation over commercially available products. Firth approach, the rate of consumption and consumption rate will establish the sensory acceptance of the final pet food formulation.

3.3. Testing animal performance

For the animal performance testing step, the designing framework have plan to use animals of the same breed, age, and sex to minimize errors in results across evaluated categories. The animals will be housed in the same location, maintaining constant environmental conditions throughout the experimental period. During the evaluation period, the equipment and instruments will be used after calibration and steady conditions will be maintained to obtain optimum results from the experiment. Physical performance results will demonstrate the effectiveness of the new formula, while blood profile analysis will confirm the safety of the product, highlighting the health benefits of Ceylon cinnamon.

Proximate analysis, functional property analysis and textural analysis of the processed final product will provide comprehensive evidence that it contains the required nutrient content to meet animal nutrient requirements. In addition, it exhibits significant antioxidant activity due to the presence of cinnamon and other ingredients. Furthermore, the texture profile and other properties are perfectly matched with the customer requirements.

4. Conclusion

The final approach endeavors to establish a comprehensive framework that caters to both industry requirements and customer preferences. This framework will be designed to yield promising outcomes, showcasing a variety of pet food products infused with Ceylon cinnamon that adhere to industry benchmarks. The formulated nutritional formulas aim to enhance pet health and bolster the reputation of the Ceylon cinnamon brand within the pet food market.

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ICSD 213

**ACADEMIA-INDUSTRY COLLABORATION FOR THE DEVELOPMENT OF
ACCESSIBLE EDUCATION**

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Abstract: Accessible education is crucial for the long-term resilience of economies and societies. This paper presents a case study of a Sri Lankan Academia-Industry collaboration to design and develop accessible educational courses to a diverse audience. The selected case outlines the development and implementation of the “Project Management Skills” programme, an asynchronous online learning programme launched on open.uom.lk, the University of Moratuwa’s open learning platform. The key areas of focus in this paper are to identify the challenges that arise over the course of Academia-Industry partnerships in education, and the processes required to oversee such collaborations, particularly from the perspective of maintaining quality and standards. The study presents an analysis of data gathered from key informant interviews with resource persons, as well as project documentation such as meeting minutes and progress trackers. Key findings indicate that Industry usually participates in the roles of sponsor or resource persons, while the University oversees the instructional and pedagogical aspects of the programme, as well as its overall management. The key challenge is to balance the diverse expectations, standards, work norms, competencies and constraints of the University and Industry resources. This paper presents a multi-stage review model and a clearly defined network of collaborative Academia-Industry roles as potential solutions to the challenges that arise during the delivery of collaborative educational programmes.

Keywords: Accessible education; University-Industry collaboration; Quality assurance; Online asynchronous education; Course design

1. Introduction

Accessible education is central to sustainable development as it fosters strong and resilient economies and societies. This is exemplified by the inclusion of ‘Quality Education’ as a Sustainable Development Goal of the United Nations. This climate presents an invaluable opportunity to explore the potential of Academia-Industry collaboration to deliver accessible education, especially in emerging nations such as Sri Lanka. Academia-Industry links in Sri Lanka are usually short-term and informal, but there is opportunity to grow deeper connections and collaborations (Larsen et al., 2016).

Academia-Industry collaboration in education primarily takes the form of research and curriculum partnerships. Literature on curriculum partnerships have long focused on engineering educational programmes and highlight industry involvement in facilitating experiential learning through capstone projects or internships (Lucietto et al., 2021). However, there is a comparative dearth of studies on how Academia-Industry curriculum partnerships can be utilized to develop and deliver course content in a manner that merges the best of both worlds.

This paper aims to address this knowledge gap by exploring the intricacies of Academia-Industry collaboration to facilitate accessible education, as well as the key challenges that arise in such collaborations and how they can be resolved. It does so through a case study of the “Project Management Skills” program delivered on open.uom.lk, the University of Moratuwa’s open learning platform. The study presents an analysis of data gathered from key informant interviews with resource persons, as well as project documentation such as meeting minutes and progress trackers.

2. The “Project Management Skills” Program and Accessible Education

The Project Management Skills Program consists of twelve courses. The courses were developed based on the Project Management Body of Knowledge or PMBOK (6th edition and 7th edition) as well as the new Exam Content Outline for the Certified Associate in Project Management (CAPM) credential of the PMI, USA effective from October 2022. Four courses of the programme were launched on the 23rd of June 2023. At the 8-week mark, the programme had recorded more than 2300 student registrations and around 150 course completions (Thoradeniya et al., 2023).

The development and delivery of the “Project Management Skills” programme displays a clear intention to facilitate inclusive education. This is especially reflected in the three options that will be provided to students for undertaking the courses.

The program is currently offered as a series of *Audit Courses*. As a policy, all Audit Courses on open.uom.lk platform are offered free-of-charge (FOC), and are sponsored by DP Education. The objective is to provide a student with the required knowledge and skills of a subject. In the future, the programme will also be offered as a series of *Credit Courses* leading if desired to a *Conversion Master’s Degree* qualification at Level 6 of the Sri Lanka Qualifications Framework (SLQF) (Ministry of Higher Education, 2012). This is equivalent to the 4th year of the undergraduate honours degree. The objective is to provide students who have completed 3-years of undergraduate education in any field of study, such as the humanities, commerce, technology, or natural sciences an opportunity to top-up to an equivalent honours degree in Project Management while also broadening their scope of employment.

The Project Management Skills programme is also made accessible and inclusive due to its method of delivery. The programme is delivered in asynchronous online mode. Online delivery of the programme enables accessibility to the course regardless of the student’s geographical location, allowing students to complete courses from the University of Moratuwa while living in various parts of the country (or even the world). This is supported by two changes that took place because of the COVID-19 pandemic. First, the use of smart devices for learning (e.g., phones, tablets and laptops) became more prevalent among students in Sri Lanka. Second, the Telecommunications Regulatory

Commission and Telcos facilitated free-of-charge data usage for e-learning activities, making online learning much more inclusive and equitable (Bower et al., 2015).

Asynchronous mode encourages self-directed learning which provides more flexibility to the student in terms of their commitment of time (Davis, Gough and Taylor, 2019; Alzahrani et al., 2023). This enables students to undertake courses while studying or working full-time. Additionally, asynchronous mode circumvents the problem of unstable internet connections in remote areas that can cause interruptions leading to a poor learning experience.

3. The Academia-Industry Collaborative Team

The process began with identifying and appointing suitable persons to the team (Awasthy et al., 2020). A key feature of this educational program is that the traditional role of Lecturer (referred to as Content Developer in the project) was undertaken by industry professionals to a large extent. They are responsible for developing and delivering the content of the course. If more than one Content Developer is assigned to a course, a Content Lead is appointed to handle coordination between the Content Developers.

It is recommended that industry partner selection in academia-industry collaboration should address criteria such as genuine interest and commitment (Barnes et al., 2002). For the Project Management Skills program, the primary selection criteria for Content Developers from industry professionals were their familiarity with the subject matter. The majority of Industry Content Developers had qualifications such as the Project Management Professional (PMP) from the PMI, USA. Additionally, two Authorized Training Partners of the PMI, USA, collaborated in the capacity of Content Developer and External Reviewer. The professional qualifications and experience of the Industry Content Developers, coupled with previous experience in teaching PMI curriculum delivered additional value to the program (Edmondson et al., 2012).

Another key role in the team is that of the Course Coordinators. They are academic staff from the University of Moratuwa whose primary responsibilities in the project include formulating the scope and sequence of the course (i.e., course details and structure), providing pedagogical support and ensuring that the quality of the course meets the university's standards (Kenny et al., 2005). The Intended Learning Outcomes (ILOs) for the courses, as well as the course topics were developed collaboratively by the Course Coordinator and Content Lead, supported by senior academics in the team and a senior member of the PMI Colombo Sri Lanka Chapter.

The Content Developer is the central figure, supported by Course Coordinators, External and Language Reviewers, as well as the Centre for Open and Distance Learning (CODL). In online education, an instructor would traditionally perform four roles: Pedagogical, Social, Managerial and Technical (Berge, 1995; Morris, Xu and Finnegan, 2005). In this instance, the content developers are either supported in these roles or are completely removed from some roles as others fully take on some of these responsibilities. For example, CODL as the overall coordinating body, takes on the Social and Managerial roles as well as the uploading and management of content on the Learning Management System (LMS). Other elements of the technical role are undertaken by the University's Centre for Information Technology Services. It leaves the Content Developer primarily with the Pedagogical role, supported by the Course Coordinator.

This was an important feature, as it reduced the burden on the Content Developers who are often Industry Professionals who work full-time on other jobs, and/or may not have the competencies required for all four roles (Thoradeniya et al., 2023). Figure 1 illustrates the network of Academia-Industry collaboration for the development and delivery of the Project Management Skills program.

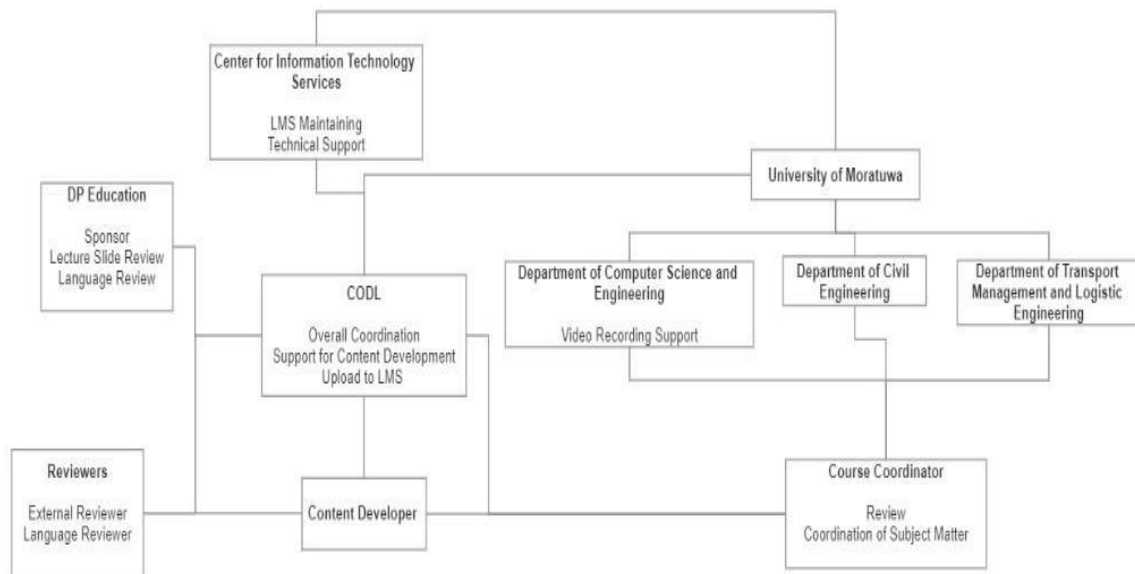


Figure 1: Network of Collaborative Parties.

The Technical Assistance provided was appreciated by the Content Developers, who cited their lack of technical knowledge. Additional help in video editing was requested by one Content Developer. Technical assistance was initially provided with instructional videos on specific activities (e.g., the creation of lecture videos using three different types of software), and then individual requirements on request. While most Content Developers chose to record the videos using their own devices and in their own spaces, the university also provided recording equipment and access to the recording studio on request. Additionally, a workshop on video preparation was conducted on a face-to-face basis early in the content development process.

A perceived downside of collaboration was the inconsistency in subject matter and presentation due to the involvement of multiple Content Developers for the same course. A suggested solution was greater involvement in subject matter coordination by the Course Coordinator.

3.1 Communication

Awasthy et al. (2020) note the importance of establishing effective communication in university-industry collaboration.

It is important to note that the team had convened in person on only one occasion (to attend a workshop) but have otherwise worked together online and have weekly meetings to keep track of the progress of the individual content developers. Collaborating remotely allowed for the team to include busy industry professionals, as well as team members who live and work overseas. The key mediums for collaboration were weekly progress update Meetings on the Zoom platform as well as the use of shared folders and documents on Google Drive. Communication lines were also open via phone, email and group chats on WhatsApp.

Evans et al. (2023) noted that communication styles between academia and industry are different, and that this gap needs to be bridged. The case study confirms this statement to some extent. The meetings were viewed by Academia as an important medium for discussions, review and monitoring while Industry Content Developers had mixed views.

While many Content Developers noted positively that meetings allowed discussions on how to improve content and was a useful medium to receive comments from Academia experienced in the

delivery of asynchronous online education, a recurring suggestion for improvements to the meeting included adjustments to the frequency and length of meetings. Some Industry Content Developers noted moments of repetition and lack of structure leading to feelings of unproductivity, as well as “financial loss”, or the opportunity cost of time spent at meetings. In general, this indicated a difference between Academia and Industry in the perceived value of the time spent on meetings. In response to the feedback of the Industry Content Developers, CODL reduced the number of weekly meetings by forming clusters (i.e., combining the teams from multiple courses which have common team members), which saw a positive reaction from the Content Developers and led to shorter meeting times, less repetition and better productivity overall.

3.2 Multiple review process

A key concern from the perspective of Academia is the adherence to the University’s requirements and standards on content delivery (i.e. quality assurance) (Porter et al., 2023). Industry professionals who undertake the role of Content Developer may be unfamiliar with pedagogical requirements, as well the standards (e.g. plagiarism and copyright rules) stipulated by the University. Hence, to maintain quality of content, CODL implemented a content development process which included reviews at multiple stages (Figure 2).

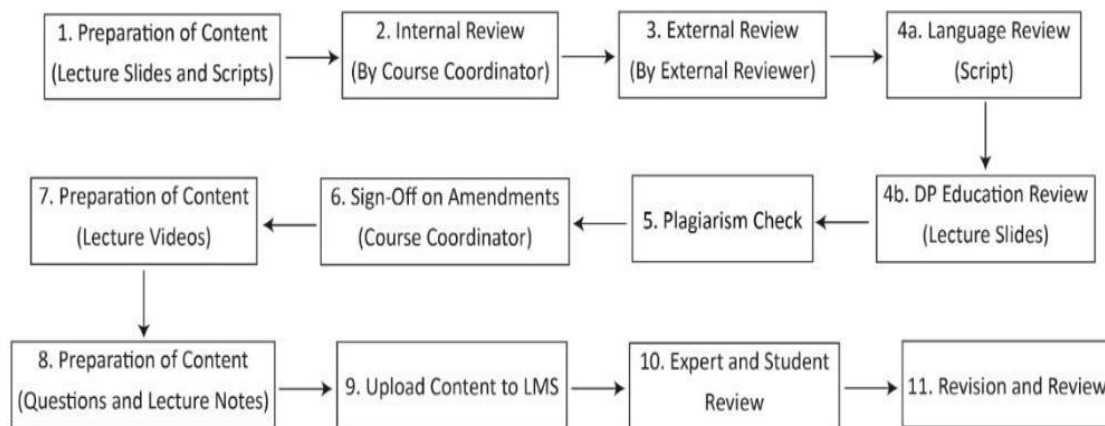


Figure 2: The Content Development Process.

The Content Developer was first required to prepare the Lecture Slides and Script for the lecture, which were subsequently reviewed by the Course Coordinator (Internal Review) who provided feedback on accuracy and completeness of content, as well as pedagogical issues. An External Reviewer, typically an industry professional, next reviewed the content for accuracy with a focus on practical application and perspectives. The Content Developer was expected to address the feedback from the internal and external reviews.

Asynchronous online courses require lecture videos to be pre-recorded. Rather than “lecturing on the spot”, the Content Developers were asked to prepare a script of the lecture which they could then use to record the video. The script allows for greater oversight of the content, and enables corrections to be made prior to video recording, thus saving time for the busy industry professionals. The lecture script is also made available to the students as a part of inclusive education. Although the medium of instruction is English, many students who enrol in the course are not native English speakers and may lack proficiency to efficiently grasp concepts in a secondary language. The Script allows students to read along with the video and refer to any terminology or phrases that they do not understand. To ensure that the scripts use simple and correct English, a Language Review is conducted on the request of the Content Developer.

The DP Education Team conducted review of the presentation slide decks to ensure that the slides reflect the standard formatting required on the open learning platform. A plagiarism check was conducted to ensure that the content meets the University’s standards for copyrighted material. The Course Coordinator then conducts a final review of the lecture slides and scripts, ensuring that suggested amendments have been incorporated by the Content Developer, and grants approval for the Content Developer to make the recording of the lecture video.

Once the Content Developer provides the recorded lecture videos, lecture notes, and formative assessment questions, the content is uploaded to the Learning Management System (LMS). A select group of industry experts and students were then given access to the course on the LMS, and their feedback on the content, as well as the user/learning experience were taken into account and necessary amendments were made prior to releasing the course.

This process is conducted with the intention of producing a quality learning experience and requires the collaboration of multiple parties from both Industry and Academia. Table 1 provides a summary of the tasks and roles of the various parties involved in this Academia-Industry collaboration.

Table 1: Summary of Academia-Industry collaboration in the “Project Management Skills” program

	Academia	Industry
Accessible Education	CODL: - Asynchronous delivery - Language Review of scripts	DP Education: - Sponsorship
	CITS: - LMS Maintenance - Technical Support	Telcos: - Free-data usage
Managerial	CODL: - Overall programme management and coordination	
Curriculum and Content Development	Course Coordinators: - Mapping ILO to CAPM ECO - Pedagogical support - Review and approval of content (Internal and Final Reviews)	Project Management Institute (PMI): - PMBOK (6 th and 7 th Editions) and CAPM as basis for program curriculum
	CODL: - Compliance with content creation guidelines (overall) - Copyright checks	PMI Colombo, Sri Lanka Chapter: - Mapping ILO to CAPM ECO - Review of content (External and Expert Review)
	Department of Computer Science & Engineering: - Support for recording lecture videos (studio space and equipment on the request of the content developer)	Industry professionals: - Resource persons for creating and delivering content - Review of content (External and Expert Review)
		DP Education: - Compliance with content creation guidelines (powerpoint slides)

4. Conclusion

Collaboration with industry in developing and delivering professional educational programmes adds value to students as it elevates understanding of subject matter by supplementing theory with the practical experiences and applications of industry professionals. This is especially important for “applied subjects”, such as Project Management, Engineering and so on.

The case study highlighted how education can be made accessible and inclusive with Massive Open Online Courses (MOOCs), especially if they are delivered free-of-charge through sponsorship, given data-usage exemptions by the Telecommunications industry, and delivered in asynchronous mode to maintain learning flexibility.

The key challenges that arise in Academia-Industry collaboration stem from differences in expectations, both in terms of the content and delivery that is expected, as well as on how collaboration and communication is conducted. The allocation of clear roles and responsibilities, as well as the implementation of a multiple, collaborative review process can overcome many of these challenges while utilizing the strengths of both Academia and Industry, to make up for the lack of competencies or constraints faced by either party.

Further work along this line of research can include investigations into establishing success factors or best practices for Academia-Industry collaboration in developing and delivering MOOCs.

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BLENDED LEARNING

ICSD 006

COMBINING GLOBAL CITIZENSHIP EDUCATION WITH THE ENCOURAGEMENT OF INCLUSIVE ART REPRESENTATION

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Abstract: This study examines how university-industry relationships might facilitate the influence of arts, humanities, and sustainable development. The project looks into how academic and industry collaborations affect how gender, race, and identity are portrayed in art, with a focus on the impact of social and political movements. The research explores issues related to how feminism shapes gender representation, LGBTQ+ inclusion in art, ethical considerations in artistic representation, and the use of art as a tool for political resistance and activism. It focuses on the intersections of global citizenship education and artistic expression. Along with evaluating the effects of intersectional activism on gender, race, and identity representation while taking into account concerns of class, disability, and other dimensions it also discusses the difficulties and constraints associated with advancing diverse representation in the arts. The study's methodology places the impact of political and social movements on the arts throughout history in perspective by using historical analysis, the document finds, and references. The findings shed light on how collaborations between academics, institutions, and businesses may support global citizenship and sustainable development by transforming the creative landscape to be more inclusive and socially conscious. The study uses a multidisciplinary methodology that includes documented findings, historical analysis, and a thorough evaluation of the literature. Political and social movements have influenced art throughout history, and this effect can be traced via historical analysis

Keywords: University industry partnerships; Political movements; Gender; The arts; Humanities; Feminism

1. Introduction

The intersection of artistic expression, humanities, and sustainable development promotes innovation, critical thinking, and responsibility for social and environmental issues. The humanities provide a lens for understanding the world, while human expressions represent the human condition. The relationship between academia and business influences artistic expression, allowing artists to experiment with new media and technologies. This collaboration also promotes inclusive representation of gender, ethnicity, and identity, leveraging industry resources and technology development. The blurred lines between academia and industry demonstrate the dynamic potential of collaborative projects.

2. Objectives of the Research

- ***To Identify the Partnerships between academia and business on how gender, race, and identity are portrayed in art*** – Academic and industrial partnerships significantly influence the artistic expression of gender, ethnicity, and identity, promoting dialogue, challenging norms, and promoting diversity, equality, and representation in a broader social context.
- ***To explore the social and political movements' influence on creative expression*** – craftsmanship is a powerful medium for expressing social and political events, capturing moments of societal change and dissent. It serves as a graphic narrative of social progress, reflecting the evolving human experience.
- ***To examine the points where creative representation and global citizenship education converge***– Global citizenship education and artistic expression are interconnected, promoting shared responsibility and understanding among cultures. Art transcends boundaries, addressing social, environmental, and cultural aspects. Integrating creative expression into education fosters awareness, promotes cultural diplomacy, and fosters socially conscious global citizens.
- ***To identify the challenges associated with advancing diverse representation in the arts*** – Cultural barriers, such as prejudices, customs, and traditional beauty standards, hinder diverse artistic expressions. These barriers restrict creativity, limited creatively, and create a cycle of poor visibility. Addressing these challenges requires promoting social discontent and mindfulness.

3. Research Areas

3.1 Gender Representation Art in Global Citizenship Education

Gender is a cultural and social description of masculinity and femininity, influenced by women's advancements and feminism in the twentieth century. Feminist art has re-appreciated women's representation as subjects, artesian, and recipients, challenging established gender roles and stereotypes. Artists like Cindy Sherman and Nan Goldin have reshaped modern art by challenging gender stereotypes in performance art, digital media, and textiles. The Guerrilla Girls, Barbara Kruger, and Louise Bourgeois have all used feminine materials to expose the sexiest subtext and challenge social and political standards, securing a proud niche for women in the art world. Intersectional activism, a concept introduced by Kimberle Crenshaw, involves artists challenging oppressive structures in art by addressing social identities like race, gender, class, and sexual orientation. This approach requires critical thinking and representation, promoting a more inclusive and diverse representation of women. The University is implementing a multidisciplinary approach to include women in global citizenship education, focusing on gender-responsive pedagogy, inclusive language, faculty training, diverse representation, student organizations, and research projects. This strategy aims to develop informed and responsible global citizens, contributing to a more just, prosperous, and sustainable society. India's National Council of Education Research and Training (NCERT) also recognizes gender sensitivity in curriculum development. (APCIEU, 2018) Handicrafts play a crucial role in challenging stereotypes and fostering a sense of belonging for the LGBTQ+ community. Craftsmen's work can promote representation, activism, documentation, and raising awareness of LGBTQ+ concerns, preserving stories for future generations. Eccentric craftsmanship, dating back to ancient Greece, symbolizes acceptance and celebration of same-sex interest. Despite advancements in LGBTQ+ rights, universal

acceptance is still necessary. In the 20th century, quirky handicrafts emerged to address LGBTQ+ concerns and campaigns. Robert Rauschenberg, a renowned theoretical expressionist artist, developed the assembly approach in the 1950s, using visual codes to convey strangeness in his works like Rebus. David Wojnarowicz, a renowned author, producer, and advocate for LGBTQ+ rights, utilized his artistic talent to raise awareness about the HIV/AIDS crisis through powerful narratives. The post-Stonewall LGBTQ+ subculture in the 1970s and early 1980s featured themes such as drug addiction and the AIDS crisis. Surrealist photographer Claude Cahun challenged orientation jobs and female subjects in self-representation. Openly gay artist Félix González-Torres created aesthetic works in the 1980s and 1990s, addressing sorrow, grief, and loss. Feminist Hannah Höch used photomontages to expose gender inequalities and queer concerns. Singaporean artist Jimmy Ong focused on sexual identity and gender roles in traditional Chinese family environments. American photographer Catherine Opie explored queer people's relationships through sexual identity. The LGBTQ+ community history continues with efforts for global equality, using various forms of art to challenge identity formations and perceptions. (Soo, 2020) Artists like Mickalene Thomas, Zanele Muholi, and Tourmaline use their craft to highlight issues and raise awareness, particularly among LGBTQ+ individuals. Their design sparks conversations about activism ethics and inclusion, promoting a more welcoming society. Craftsmanship is crucial in the fight for LGBTQ rights, promoting cultural understanding and acceptance of diverse individuals. Writing, music, and visual art are essential tools in this fight, fostering understanding, compassion, and acceptance while challenging heteronormativity.

Global Citizenship education should foster awareness of diversity and understanding, including LGBTQ+ perspectives. Collaboration between teachers, program designers, administrators, and the LGBTQ+ community is crucial for integrating LGBTQ+ representation, promoting empathy, and strengthening diversity. Teaching sensitive teachers is also essential. The convergence of art and ethics highlights creators' obligations as well as the broader impact of their work.

- **Artists' Moral Obligations:** Artists frequently encounter ethical quandaries regarding the content of their work and its impact on viewers. This includes considerations such as possible injury, offending others, and representation accuracy.
- **Societal Impact:** Art has a profound impact on societal values and norms. As a result, creators must consider the broader implications of their work

Limits to Artistic Expression

What constitutes acceptable art is a multidimensional question influenced by various cultural, social, and political settings.

- **Cultural Sensitivities:** Art that addresses sensitive cultural issues can be perceived in a variety of ways, triggering discussions about cultural respect and appropriation.
- **Controversial and hurtful Material:** Art viewed as provocative or hurtful sparks debate about the boundaries of artistic expression. This includes works that have the potential to inspire hatred, violence, or discrimination.

The role of the state in work guidelines is a controversial issue that strikes a balance between protecting creative freedom and protecting cultural values. Even when state-run institutions justify this in the name of public safety or quality improvement, their control must be clear as an infringement on speech. Distributors and the public are influenced by ethical reflection and must align their ethical and commercial objectives. Creative expression requires a balance between creative freedom and moral responsibility, which must be constantly readjusted in response to social upheaval and economic development. Maintaining this balance requires speaking out and advancing policy. Artists must use subjective approaches and metrics to understand how their work impacts the crowd and society.

We must also consider the broader implications of the data, keeping in mind how they influence collective action, social change, and challenges to established norms. Critical reasoning and reflection are required to assess material impact and focus on quality and value satisfaction. (Cropley, 2019).

3.2 Art as a Tool for Political Resistance and Activism

Art has been a powerful tool in political opposition, serving as a platform for communication, mobilization, and emotional connection within social movements. Activists use various art forms, such as protest songs and street dramas, to resist authoritarian governments and forms of dominance. Art impacts the mobilization process by improving communication and visibility, promoting emotional connection and solidarity among participants, and attracting resources. It can also help socialize members of resistance movements by guiding art-work production, discussing complaints and collaborating with other social movement organizations. Art has played a significant role in creating culture and supporting a more equal society throughout history. When dominant discourses and power structures collide, art can be revolutionary, questioning common beliefs and authorities. It can also be a means of recovery for nations devastated by political conflict. Art challenges boundaries and restrictions imposed by powerful people, influencing the thinking of others. Artists like Hannah Hoch, Hans Arp, Marcel Duchamp, and Tristan Tzara have used art as a technology to develop socialism and communism. Artists can create change on their own or participate as activists in political situations. In a positive trend, artistic expression acts as a social component, influencing society in many ways, including fostering responsibility, exposing society, and critically examining progress. (MyArtBroker, n.d.) (Wilcox, 2009)

4. Connection of the Study of Global Citizenship

The intersection of creative expression and global citizenship education creates a rich tapestry of learning, social consciousness, and creativity. Global citizenship education, with its focus on fostering a sense of shared responsibility for a globalized society, recognizes the unique alliance in the expressive power of the arts. Imaginative expressions enable meaningful dialogue between many societies, ideas, and global perspectives.

Performance becomes a means of understanding and considering universal themes across boundaries. Artists create visual stories that address social, environmental, and cultural themes while reflecting the complexities of our planet. Global citizenship education, which prioritizes the cultivation of ethical and compassionate perspectives, is consistent with the ability of art to evoke emotion, stimulate critical thinking, and enable rapid reflection on our shared humanity.

Artistic expression also bridges social strategies, bridging knowledge gaps and fostering humanity. The collaboration of artists around the world raises the bar for global citizenship by demonstrating the diversity of human experience and promoting mutual respect.

The Global Citizenship curriculum offers a broad approach to teaching and learning in education, including creative expression. We challenge students to creatively engage with global issues and develop mindfulness and organization when dealing with them.

These intersections enhance the educational process and contribute to the development of a globally aware citizenry. Creative expression becomes a special tool for determining judgment, dispelling stereotypes, and promoting shared responsibility for the economy and the wider global sphere. The dialogue between global citizenship education and creative expression demonstrates the incredible possibilities that emerge when creativity becomes the cornerstone of global awareness and understanding.

How Education for Global Citizenship Affects Artistic Expression

Global Citizenship Education (GCED) serves as an important catalyst to shape and influence creative expression by weaving the diverse narratives of a globalized society into a cross-border embroidery. Fundamentally, GCE instills in participants a heightened awareness of global challenges, a sense of collective responsibility, and a will to promote positive change. This educational framework has a profound impact on creative expression, enabling technologists to engage with and address global concerns, translating their vision into practical expression.

GCED specialized people provide an inspiring global perspective to raise the aspirations of veterans and help them find inspiration in diverse cultures, stories, and global events. This in-depth understanding explores topics related to citizenship, environmental sustainability, social diversity, and fundamental freedoms in works of art. As global citizens, artisans take on the role of storytellers, exploring the complexities of our interconnected global communities and providing perspectives on persistent issues plaguing humanity.

Additionally, GCED fosters a sense of empathy and integration, leading artisans to consider universal aspects of human interaction. This unique center promotes art that transcends social boundaries by creating connections and fostering understanding between people from diverse cultural backgrounds. Professionals must generally amplify marginalized voices and emphasize their commitment to diversity and civil rights in their work.

GCED focuses on critical thinking and a deep understanding of global frameworks that prepare professionals to engage in provocative and socially conscious creative processes. It encourages individuals to challenge established norms, reject stereotypes, and think of themselves as global citizens at work. In this approach, global citizenship education becomes a major force shaping the content, purpose, and outcomes of creative expression, fostering powerful synergies between education and creative expression in the pursuit of a more just and practical society. (Penny Enslin, 2013)

4.2 Art's Function in Promoting Social Consciousness and Understanding Around the world

Craft remains a powerful process that promotes understanding and social awareness around the world, informing shared human encounters that transcend etymological, social, and geological barriers. As a common language that communicates the complexities of our interconnected world, its ability to fill in, frame perspectives, and evoke empathy is critical. Through various media, craftsmanship serves as a mirror reflecting excellence, combat, and diverse societies, forming an overall global story.

Its primary function is the craftsmanship's ability to evoke emotion and provoke thought. Visual representations, whether in the form of compositions, models, visual and sound installations, etc., have the power to evoke automatic responses in viewers and encourage them to consider the nuances of different countries and social structures. Crafts serve as a platform to connect people by introducing them to new environments, traditions, and stories, and fostering a sense of humanity.

Talent also plays an important role in elevating marginalized voices and social issues. Artists regularly use their platforms to confront fundamental injustices, promote shared rights, and draw attention to global issues. This support develops social consciousness by stimulating conversation and enabling viewers to critically examine their role in larger social structures.

Innovative ways to express yourself can question established norms and spark conversations about civil rights. Institutions, exhibitions, and public art serve as tools for activism, enabling practitioners

to engage with and address cultural issues. The powerful interplay of social awareness and craftsmanship promotes a holistic consciousness that transcends borders and inspires individuals to actively participate in the global conversation.

Instructively, handicrafts become a means of fostering global responsibility and social responsiveness. Integrating the arts into educational curricula can help people develop respect for diverse perspectives and become empathetic global citizens in the future.

In essence, the role of art in promoting global understanding and social consciousness is its ability to awaken, challenge, and connect. Craft as a powerful force for good contributes to a common understanding of human interdependence and the desire for a more compassionate and global society. (Correia, 2020) (Penny Enslin, 2013) (III, 2022) (Team, 2023)

5. Methodology

5.1 Historical Analysis

Artistic expression in the United States is significantly influenced by political and social events, shaping social scenes and highlighting the impact on human expression. Key age and creative responses reflect cyclical movements, highlighting the development of women's freedom, LGBTQ+ empathy, and ecological activism. (Chatterjee, 2023) (Seitz, 2003) (Thippawong, 2021) During the Vietnam War, artists transformed cultural movements into innovative works, reflecting on political and social changes. Craft activities, such as spray painting and road building, served as activism conduits during times of social uncertainty. Innovations like queerness, feminist craft, and Afrofuturism expanded creative expression. (Elen Riot, 2019)

5.2 Document Finding

The report analyzes the relationship between university and industry collaborations and their impact on the craft sector. It highlights the convergence of cutting-edge ideas, the proliferation of creative media, and the impact on representation and broadcasting. Collaborations with businesses encourage artisans to explore new materials and techniques, influencing how race, orientation, and identity are expressed in handicrafts. They also contribute to global perspectives and diversity in trade, resulting in craftsmanship reflecting a deep understanding of global challenges. Challenges include balancing industry requirements with creative respect, and the training effect of university-industry collaborations on publishing education. The report encourages coordinated efforts to overcome barriers between academic creativity and public understanding, fostering a more inclusive skill set. The report highlights the revolutionary impact of university-industry collaboration in modern technology, contributing to a more diverse, inclusive, and globally educated creative expression. (Becker, 1974) (Wages, 2019) (Association, 2009)

5.3 Literature Review

This literature review explores the complex relationship between creative expression and cultural inclusion, focusing on the diversity and expression of human expression. Scholars like Nochlin and Pollock highlight institutional barriers limiting female artists' recognition, while Kobena Mercer exposes biases in depicting racial and ethnic minorities. (Nochlin, 2015) (Pollock, 2003)

Variability in Creative Expression - *Kimberlé Crenshaw's* research has emerged from multiple perspectives as an important framework for understanding the nuances of expression. Scholars emphasize the importance of examining how race, sexual orientation, and other factors intersect in creative narratives. Ringer Trapp also noted the importance of considering the unique power components of images and techniques. (Crenshaw, 2017)

Writing tends to be the tireless work of corporate gatekeepers who propagate homogeneity in the craft world. Researchers such as *Howard Becker and Sarah Thornton* analyze how existing structures limit the diversity of creative expression by favoring particular styles, disciplines, and artisans. (Becker, 2008) (Thornton, 2008)

The concept of “group,” explored by writers such as *David B. Morris*, is examined to understand how systematic criteria influence the selection and presentation of art, typically through experts and narratives deemed important. (Morris, 2022)

The literature review examines the challenges and open doors of LGBTQ+ representation in human expression. The work of researchers like *Jonathan D. Katz* and *Amelia Jones* examines the actual erasure of queer voices and the growth of LGBTQ+ labor activism. (Hide/Seek: Difference and Desire in American Portraiture, 2011) (Lamm, 2023)

Scholars like *Rosemary Garland*, who studies how disability narratives subvert traditional notions of portraiture and aesthetics, contribute to the conversation about disability representation in art. (Garland, 2017)

Researchers such as *Nicholas Mirzoeff* examine how virtual entertainment stages and online networks work with new technologies of creative expression and recognition for marginalized groups, examining the impact of computerized environments on expanding representation. (Mirzoeff, 2023)

This essay focuses on the multifaceted exchange of authenticated legacies, intricate details, and institutional designs that contribute to a unique dialogue about change and representation in artistic expression. The analysis provides a basis for understanding the challenges and possible consequences of encouraging more diverse and holistic creative philosophies as the field evolves. By engaging with these important revelations, researchers, artists, and institutions can work together to create a more diverse and equitable future for human expression.

6. Obstacles and Limitations.

Creative industries face challenges like underrepresentation, institutional obstacles, and limited access to assets, stereotypes, and market tensions. To create a more inclusive environment, coordinated efforts are needed to remove barriers and promote diverse creative voices. Addressing these issues is crucial for creating differentiated and engaging creative discipline. (Janet Johansson, 2023) Creative expression can transform stories about class, disability, and humanity, but presents challenges and opportunities. Artists can challenge stereotypes, and challenge financial bases, manual failures, and disability. Diversity and cultural bias can also be addressed. Constructive research can break down stereotypes and foster intergenerational dialogue, contributing to complex artistic scenes. (Jones, 2022) (Keri Watson, n.d.)

7. Findings

- **Perspectives from the Literature Review, Documented Results, and Historical Analysis** - The university industry’s relationship with diversity is influenced by political and social changes, collaboration, and literature reviews. It’s crucial to dispel stereotypes and promote inclusion in creative narratives. Collaboration and ongoing discussions are needed to create a diverse and representative creative scene, reflecting the human experience complexity.
- **Changes in the creative environment brought about by partnerships** – University-industry collaborations are transforming creative philosophy by providing access to advanced workspaces, fostering multidisciplinary research, and blurring traditional boundaries between creativity and craftsmanship. These initiatives challenge long-held beliefs and expand crea-

tive discourse, inspiring artists from diverse societies. Despite tensions between creative autonomy and industry demands, these initiatives promote innovation.

8. Contribution to GCED and Sustainable Development

Universities and industry are collaborating to advance machine development and promote inclusive and socially conscious work. This collaboration dismantles traditional barriers to human expression, promoting diverse perspectives and fostering a unique work ethic. It also tests and normalizes standards, allowing artists to challenge assumptions and stereotypes. Collaborations also leverage innovation to raise social awareness, combining cutting-edge technologies with creative ones. This creates new avenues for socially aware communication, fostering empathy and consciousness across social and geographic boundaries. The collaboration also creates a global perspective, combining craftsmanship with diverse social outcomes. These efforts have significant implications for education, global perspectives, and cultural awareness. As the creative landscape evolves, the collaboration between academia and industry is crucial for shaping a more inclusive, socially conscious, and dynamic future for human expression. The university industry's artistic expression activities are transforming into powerful professionals, promoting global citizenship and real-world change. These efforts involve collaborations between academic institutions and businesses, fostering empathy, social consciousness, and responsibility to solve global problems. Veterans are becoming social ambassadors, bridging social gaps and contributing to an interconnected global community. The integration of academia and industry promotes economic processes, reducing biological impact and promoting sustainable practices. Creative expression can also foster public awareness and support for sustainable practices. Collaborations also foster socially engaged technology initiatives, addressing local and global problems in education, healthcare, and social values. These efforts foster a generation of professionals who understand the role of human expression in developing social responsibility and support.

9. Conclusion

The research report emphasizes the positive impact of partnerships between academia and business on humanities, arts, and sustainable development. It highlights the intertwining of technology and art, encouraging social conscience and global creative exchange. Balancing artistic individuality with industry demands is challenging, but these partnerships support sustainable development. The study suggests actions like encouraging diversity, writing comprehensive laws, prioritizing intersecting stories, funding arts education initiatives, and supporting neighborhood and grassroots projects to create a vibrant, diverse, and socially conscious artistic environment.

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ICSD 017

**SUSTAINABILITY EDUCATION FOR TOURISM UNDERGRADUATES:
ASSESSING THE IMPACT OF INCORPORATING A SUSTAINABLE TOURISM
MODULE ON STUDENT LITERACY**

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Abstract: Over the past few decades, sustainable development has garnered significant attention in the tourism sphere and is increasingly considered a collective responsibility of all stakeholders within the industry. In this context, Higher Education Institutes (HEIs) with a focus on tourism education have been identified to play a crucial role, especially given their critical role in transforming students into prospective employees within the tourism industry. Globally, HEIs have been making notable progress towards creating sustainably conscious graduates by including dedicated sustainable tourism-specific modules embedded in degree programs. Despite these significant strides, there remains a critical lacuna of how such sustainable tourism-specific interventions by HEIs impact and influence student perceptions and behaviors, especially from the viewpoint of developing countries. Hence, this research addresses this gap by critically evaluating the perceptions of undergraduate students pursuing a degree in event, tourism, and hospitality management who had recently completed studying a sustainable tourism-specific module at a Sri Lankan HEI. This empirical study adopts a qualitative approach where information is collected using semi-structured, in-depth interviews from undergraduate students. The results of this empirical study show that a dedicated sustainable tourism module positively influenced the student's technical, analytical, and ethical literacies pertaining to sustainable tourism. The results further elucidated that incorporating collaborative field visits with industry partners positively enhanced student sustainable tourism literacy, given their ability to provide students with a real-life outlook on how sustainability is incorporated into business operations in the tourism and hospitality industry.

Keywords: Sustainable tourism; Sustainability education; Tourism education; Tourism pedagogy; Sustainable tourism education; Core literacies

1. Introduction

Over the past few decades, the tourism industry has made remarkable progress in becoming a pivotal contributor to the global economy (Peng, Saboori, Ranjbar and Can, 2023). Corresponding to this phenomenal growth, Higher Education Institutes (HEIs) have started identifying tourism as a major science to be taught within higher education, resulting in a plethora of HEIs embedding tourism-specific components in their product offerings (Malihah and Setiyorini, 2014). Despite this progression, tourism education providers are often critiqued for their traditional and inadequate teaching approaches and failures in identifying the real needs of the tourism industry (Anderson and Sanga, 2019; Hsu, 2018). In this light, education for sustainable tourism has emerged as a facet that requires urgent attention within the broader tourism pedagogy.

With sustainable tourism becoming a mainstream form of tourism, the focus of research being conducted on the concept has also drifted from mere interpretation to understanding the fundamentals of operationalising the concept across various contexts (Pernecky, 2023). Accordingly, past studies have identified the central role played by the education sector in supporting sustainable tourism development through dedicated sustainable tourism-centric educational offerings (Boyle, Wilson and Dimmock, 2015). HEIs are at the forefront of spearheading this change by integrating sustainable tourism degrees and specific modules addressing sustainability-centric issues (Bowen and Dallam, 2020). Despite these notable strides, there is a scarcity of research uncovering how such efforts are contributing towards making any noteworthy changes to the students' sustainable tourism related literacy levels. Hence, this research attempts to address the above research gap by holistically evaluating how incorporating a dedicated sustainable tourism module impacts the overall literacy of undergraduate students from a student perspective based in a HEI in Sri Lanka. The main objectives of this research are two-fold. Firstly, this research attempts to critically evaluate whether a dedicated sustainable tourism module could be developed to deliver on core sustainable tourism literacies proposed by Jamal, Taillon and Dredge (2011). Secondly, this study assesses the impact of delivering a sustainable tourism module on the various facets of sustainable tourism literacies from a student perspective.

2. Literature Review

2.1 Sustainability Development

Sustainable development refers to meeting the needs of future generations while making economic decisions in the present, and it has become a pivotal criterion in policy decision-making in many countries (Gordon, 2003). Moreover, to streamline the global sustainability efforts, the United Nations proposed Sustainable Development Goals (SDGs). Since then, all UN member states have continued to engage in sustainability endeavors while using the SDGs as a blueprint for implementing and monitoring their sustainability commitments (Slocum, Dimitrov and Webb, 2019).

2.2 The Evolution of Tourism Pedagogy

Throughout history, tourism education programmes have been responsible for producing employable graduates with networks and connections specific to the industry through holistic education (McIntosh, 1983). The rapid transitions within the tourism business model have highlighted the need for a transition in tourism education to provide students with specialized abilities (Mínguez, Martínez-Hernández and Yubero, 2021). Many countries have established national benchmark statements for tourism education where contemporary subject areas in tourism programmes, including ecotourism, responsible tourism, and sustainable tourism management, receiving significant emphasis from education practitioners (Munar, 2007). Even among these niche segments, the growing focus on sustainability remains the most noticeable trend in tourism pedagogy (Bowen and Dallam, 2020).

2.3 Sustainable Tourism Pedagogy

The current circumstances of the global tourism industry demand sustainable tourism to be the central focus of the tourism curriculum. Sustainable Tourism encompasses tourism's natural, cultural, and so-

cial aspects (Honey, 1999; Moswete and Thapa, 2015). Moreover, sustainable tourism has been identified as a critical aspect and a tool to support achieving the 2030 SDG agenda (Rasoolimanesh *et al.*, 2023). Sustainable tourism is often referred to as the ethical component of tourism education, and HEIs are required to ensure that graduates have the knowledge and abilities to act as responsible guardians for the growth of sustainable tourism (Dredge *et al.*, 2013). Tourism education research has discovered how students' sustainability attitudes can be influenced by incorporating sustainability considerations throughout their curriculum (Slocum, Dimitrov and Webb, 2019).

Learning programmes emphasizing sustainable tourism need to incorporate both theoretical and practical knowledge (Tilbury, 2011). Moreover, given the close linkage between SDGs and sustainable tourism, HEIs are responsible for supporting the achievement of these long-term goals by creating awareness and behavioural transformations among their student communities (Slocum, Dimitrov and Webb, 2019).

2.4 Core literacies of Sustainable Tourism Pedagogy (STP)

Education for sustainability needs to draw from transformative teaching and learning approaches to emphasize critical reflection on values and the active participation of students in making changes toward achieving true sustainability (Boyle, Wilson and Dimmock, 2015). Sustainable tourism education mainly plays two roles. First, it guides tourism toward sustainability awareness; second, it focuses on providing high-quality education that fosters critical thinking (Slocum, Dimitrov and Webb, 2019). New pedagogical techniques have been identified to develop student capacity to solve complex problems within tourism pedagogy (Hales and Jennings, 2017). For instance, Mínguez, Martínez-Hernández and Yubero (2021) state that sustainable Tourism Pedagogy (STP) is an action - and change-oriented pedagogy that tackles sustainability from sociocultural, political, and environmental angles. Accordingly, Jamal, Taillon and Dredge (2011) proposed that tourism students must be able to develop six core literacies, as elucidated in Table 1, to acquire a comprehensive understanding of sustainable tourism.

Table 1: Types of Sustainable Tourism Literacies

Literacy	Description
Technical literacy	Theories, concepts, and frameworks that provide foundational, technical knowledge related to the sustainable development of tourism
Analytical literacy	Skills, techniques, and personal qualities necessary to engage in problem-solving, issue identification, and critical inquiry
Ecological literacy	Awareness of the connections between people and their environment and the consequences that decisions and actions have on these relationships
Multi-cultural literacy	Appreciation of the different cultures, values, interests, and power relations that exist between stakeholders with an interest in sustainable tourism
Policy and political literacy	Creating an appreciation for how sustainable tourism is planned and managed, how decisions are made, and how implementation occurs, as well as the profile and how the influence and power of stakeholders become drivers, are paramount to education.

Ethical literacy	Development of values and ethical positions within students' thinking, and how these values may be gained through theoretical learning and practical wisdom [phronesis] through experience and collaborative learning in a community service-learning context.
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Source: Jamal, Taillon, & Dredge (2011, cited in Mínguez, Martínez-Hernández and Yubero, 2021, p. 3)

The various facets of STP suggest that students should be able to demonstrate practical and applied skills in solving multiple challenging issues regarding sustainable tourism (Jamal, Taillon and Dredge, 2011). Therefore, STP should be closely linked to active and participatory learning processes as it pushes students to think systemically, clarify values, ask insightful questions, envision more positive futures, respond through applied learning, and investigate the dialectic between tradition and innovation (Tilbury, 2011). However, various experts have demonstrated a lack of success in implementing broader STP due to inadequate methodologies, the absence of additional curriculum assessment, and the demand for more critical perspectives within traditional academia (Ayikoru, Tribe and Airey, 2009). Furthermore, Mínguez, Martínez-Hernández and Yubero (2021) highlight that there has not been notable debate on the importance of tourism pedagogy and whether students are being nurtured on the skills and cognitive thinking required, particularly in promoting and operationalizing sustainability.

2.5 Sustainable Tourism Education in HEIs

Recently, several researchers have conducted studies on sustainable tourism pedagogy in HEIs. An exploratory study by Rezapouraghdam, Alipour, Kilic and Akhshik (2022) identified critical learning components in education to develop sustainable tourism in Northern Cyprus. Farsari (2022) examined the curriculum and provided insightful information on the instructional methods for promoting sustainable behaviours and awareness in the tourism industry based on a Swedish Masters Programme. Nonetheless, the current expanse of literature needs to capture how incorporating a sustainable tourism-specific module in a degree programme impacts student literacies at HEIs. Moreover, despite sustainable tourism becoming an increasingly important area of study within Sri Lanka, there was a dearth of studies exploring sustainable tourism pedagogy in the context of the Sri Lankan HEIs (Shanika, Jayawickrama and Perera, 2023). Accordingly, this study attempts to address this literature gap on sustainable tourism pedagogy through a Sri Lankan HEI case study.

3. Methodology

3.1 Study scope

The basis for this empirical research is derived through the reflections of a student cohort who recently completed a sustainable tourism-specific module as a requirement of their undergraduate degree specializing in event, tourism, and hospitality management at a leading HEI in Sri Lanka. Tourism and Sustainable Development is taught as a mandatory module during the 3rd year of a 4-year degree programme. Overall, this module consisted of 3 Intended Learning Outcomes (ILO) where at the end of the module, students were expected to understand the necessity of planning for tourism in line with sustainable planning principles and approaches (ILO-1), explain the concept and theories of sustainable development and its importance within a sustainable tourism industry (ILO-2), and assess tourism planning need and take initiatives and pathway for sustainable tourism development (ILO-3). The three ILOs directly correlated with three STP literacies proposed by Jamal, Taillon and Dredge (2011), namely, technical literacy, analytical literacy, and ethical literacy. A summary of how the respective ILOs and STP literacies interlink is elucidated in Table 2.

Table 2: Overview of Core Literacies and ILOs

ILO	Linked Literacies
ILO 1	Technical Literacy, Ethical Literacy
ILO 2	Technical Literacy, Analytical Literacy
ILO 3	Analytical Literacy, Ethical Literacy

The module consisted of 3 assessment components, namely a group report (AC 1), group presentation (AC 2), and end-semester examination (AC 3) to assess the achievement of the ILOs from a student perspective. The two in-semester assessments required the students to undertake the compilation and presentation of a review article on sustainable tourism. The students were expected to identify the meaning of sustainable tourism, methods of operationalizing sustainable tourism, challenges and opportunities in pursuing sustainable tourism, and the linkage between sustainable tourism and the achievement of the SDGs from an academic and practical perspective. The theoretical knowledge required to perform relevant assessments was provided through extensive lectures and in-class interactive activities by the respective lecturer. Specifically, this module comprised 45 teaching hours and was supplemented with additional consultation hours at students' request for individual or group meetings. The module leveraged several pedagogical strategies throughout the semester, such as group discussions, stimulus activities, critical incidents, case studies, and reflexive accounts, to enhance the student's overall learning experience (Tilbury, 2011).

Moreover, the assessment was linked with a 3-day field visit to 11 pre-selected hospitality businesses in Kandy district, Sri Lanka, to assist students in gaining an in-depth understanding of sustainable tourism from a practical perspective (Arcodia, Abreu Novais, Cavlek and Humpe, 2021). Overall, the module focused on active learning, where interactive and participatory exercises remained a focal point of consideration (Clark, Stabryla and Gilbertson, 2020). The end-semester examination was presented in a case study format, with the primary aim of assessing the student's knowledge of identifying the symbiotic relationship between sustainable tourism and SDGs. Case studies are increasingly considered preferential evaluation tools, especially within management pedagogy, given their potential to make students use their critical and analytical skills to solve practical problems (Raza, Qazi and Umer, 2020). During the examination, the students were expected to create a sustainable tourism policy while linking it with SDGs.

3.2 Research Design

This research employed an exploratory case study approach (Nguyen, 2019). The main aim for employing this methodological consideration was due to this research's aim of capturing students' reflections and assessing their levels of cognitive processing of the respective module's desired learning outcomes (Nilsson and Jakobsson, 2011). Semi-structured in-depth interviews were used as the primary data collection method to allow students to reflect and verbalize their learning experience about the module (Ribeiro *et al.*, 2023; Zhang, 2023). This study used a convenience sampling method where the batch to whom the module was delivered (comprising eight students) was sent an open request to participate in the interview, and seven students consented freely to share their reflections on the module learnings (Vidergor and Ben-Amram, 2020). Given the fact that this is a new degree programme the above batch was the only student group to have studied the Tourism and Sustainable Development module at the respective HEI, making them the only student cohort that possessed a substantial depth of understanding of the module's content (Boddy, 2016). Therefore, the selected sample remained highly representative of the overall population under consideration.

Two authors conducted the interviews conjointly and took place virtually via the Zoom platform. The module lecturer (i.e., an author of this study) refrained from participating in the interviews to ensure

that student reflections were not influenced and were as authentic as possible (Väänänen *et al.*, 2018). The reflective dialogue comprised seven questions, each aligned with a core literacy of STP to elicit student reflections (Bogo *et al.*, 2013). Clarifying probes were utilized only when the interviewers required further self-disclosure from the respondents to an inquired structured question (Robinson, 2023). Moreover, in line with the university's ethical considerations, all students were individually informed of the study aim, and informed consent was obtained before commencing each interview (Ribeiro *et al.*, 2023). Subsequently, all interviews were digitally recorded and transcribed for analysis purposes (Bogo *et al.*, 2013).

Finally, a thematic analysis was performed to identify and interpret emerging patterns within the data on the individual learning experiences of the students (Zhang, 2023). The emerging themes were formed by the three perceived sustainable tourism pedagogy literacies tested in this study (Slocum, Dimitrov and Webb, 2019; Jamal, Taillon and Dredge, 2011). The findings section below presents a consensus of identified student reflections categorically divided into three areas to showcase the literacies gained by the students by undertaking the Tourism and Sustainable Development module (Rezapouraghdam, Alipour, Kilic and Akhshik, 2022).

4. Findings & Discussion

4.1 Technical Literacy

According to Jamal, Taillon and Dredge (2011), technical literacy refers to the overall awareness and understanding of multiple theories and concepts of sustainable tourism from a technical perspective. The study's findings reveal that the sustainable tourism module assisted the students in gaining the necessary awareness of different concepts and theories related to sustainable tourism as evidenced by the below statement from Interviewee 05:

“Sustainable tourism involves utilizing industry resources without compromising the ability of future generations to use those resources.”

Sustainable development highlights making current economic decisions without compromising the needs of future generations (Gordon, 2003). This statement justifies that the students understand the core of sustainable tourism by emphasizing concepts such as not compromising the needs of the future generation.

Further, Interviewee 01 explains sustainable tourism as:

“Sustainable tourism considers the triple bottom line—economic, social, and environmental impacts—balancing the needs of visitors, industry, host community, and the environment for a positive impact on all stakeholders.”

Sustainable tourism focuses on tourism's natural, cultural, and social aspects (Honey, 1999; Moswete and Thapa, 2015). The above statement proves that students have received broader awareness of sustainability as the interviewee discusses the multidimensionality of sustainable tourism.

Teaching sustainable tourism necessitates that students advance from merely memorizing facts and concepts to a level of learning where they must apply the knowledge to solve complicated problems and assess the sustainability of choices (Posch and Steiner, 2006). SDGs are one such facet that addresses the challenges faced by the world (Slocum, Dimitrov and Webb, 2019). The student responses on how sustainable tourism contributes towards achieving SDGs showcased mixed results. Interviewee 03 mentioned:

“Implementing sustainable initiatives in a hotel can serve as an example, demonstrating practices like recruiting staff without gender discrimination, providing equal opportunities for both genders and addressing any disadvantages females might face. This directly links with SDG 5, which focuses on gender equality”.

Similarly, Interviewee 06 highlighted:

“For example, in achieving SDG 8 through sustainability, hotels can offer jobs with proper working hours and adhere to relevant labour laws. This approach aligns with achieving SDG 8 and is beneficial for the hospitality industry in contributing to the broader SDG”.

Many respondents highlighted that sustainable tourism contributes towards achieving SDGs 5, 8, and 12. However, it was observed that in comparison to the understanding of sustainable tourism as a concept, the application of sustainable tourism for achieving SDGs could be further improved.

4.2 Analytical Literacy

Jamal, Taillon and Dredge (2011) describe analytical literacy as skills, techniques, and personal attributes essential for problem-solving, issue identification, and critical inquiry. Consequently, most students have acknowledged that the sustainable tourism module has substantially impacted their critical examination of the sustainability concept within the tourism industry. Furthermore, it has enhanced their understanding of how these concepts can be applied to identify and address challenges.

For example, Interviewee 02 stated:

“Concepts like Sewage Treatment Plants were new to me, and I learned about their significance in sustainability. Understanding how sustainability activities impact hotels, including aspects like monitoring carbon dioxide through plants in rooms, was enlightening. The module provided insights into mitigating sustainability issues and taking actions to protect the environment. From an educational perspective, understanding the impacts on the three phases—community, planet, and profit—has been crucial. Now, we consider these factors when working on projects or within an establishment, a perspective we did not have before. If starting a new business, incorporating sustainability concepts is deemed important despite initial high costs, as many people nowadays overlook sustainability due to financial concerns.”

Whereas Interviewee 03 mentioned:

“As an undergraduate soon entering the corporate sector, I recognize the growing importance of sustainability within businesses. Many organizations are adopting sustainability initiatives, making knowledge in this area valuable for employability. Learning about sustainability has improved my knowledge and enhanced my prospects for securing a job.”

These statements indicate that sustainable tourism education is vital in developing analytical literacy, including communicative, creative, and initiative skills (Mínguez, Martínez-Hernández and Yubero, 2021).

Further, incorporating a field visit was unanimously acknowledged as a valuable component contributing to enhancing sustainable tourism knowledge. Participants recognized that sustainability is not just a theoretical concept but is actively practiced in many establishments (Camargo and Gretzel, 2017). The field visit was instrumental in bridging the gap between theoretical learning and practical insights, allowing for a better understanding of the industry's dynamics. As an illustration, interviewee 01 mentioned:

“The assignment focused on insights gathered from interviews with hotel managers, exploring sustainability challenges and opportunities. The module centered on species, sustainability, and responsible tourism concepts, applying them to the Sri Lankan tourism industry. The field visit to Kandy provided real-world insights into the hotel industry's awareness and knowledge. This experience prompted reflection on our role in contributing to a more sustainable tourism industry. The interconnected nature of fieldwork and the assignment was crucial for our learning.”

Moreover, interviewee 02 mentioned:

"We learned that sustainability is not just a theory; it is actively practiced in many establishments. The field visit helped us realize how sustainability practices and initiatives are actively implemented."

The above statements indicate a positive impact of a dedicated sustainable tourism module, especially with the inclusion of a field visit, on the development of analytical literacy, practical skills, and a deeper understanding of sustainable tourism among the participating undergraduate students.

In addition, many respondents in the study recognized tangible skill development aligned with the sustainable tourism module. For instance, interviewee 01 stated:

"Developed leadership skills, specifically in taking the lead and engaging in direct conversations with high-profile industry individuals. Enhanced communication skills, particularly in face-to-face interactions, posing insightful follow-up questions, engaging in meaningful dialogues, and navigating different perspectives. The field visit played a crucial role in refining conversational skills in a real-world context, practicing effective communication with diverse backgrounds. The main benefits that come to my mind are the networking opportunities and connections established during our field visit. I still maintain contact with hotel managers, which has been valuable."

Leadership, communication, and networking skills were notably highlighted as supplementary skills gained through the module. Moreover, the field visit also played a pivotal role in refining conversational skills in a real-world context for the respondents.

4.3 Ethical Literacy

The research findings suggested that studying a sustainable tourism-specific module had a direct positive impact on the ethical literacy of the students. As Jamal, Taillon and Dredge (2011) elucidate, developing values and ethical positions within students' thinking is a key desired outcome of engaging in STP. Accordingly, all respondents in the study agreed that the module enlightened them on their commitment to the tourism industry and the broader society in general.

For instance, Interviewee 01 stated:

"The upcoming generation, including myself, needs to learn and incorporate sustainable practices to ensure the industry's longevity. Failing to do so raises questions about what we can offer future generations of tourists, making it a pressing concern from a tourism perspective."

Whereas Interviewee 03 highlighted:

"Learning about sustainability provides opportunities to contribute as a responsible citizen. This includes fostering sustainability initiatives within the industry and contributing to the long-term viability of businesses."

These statements evidence that sustainable tourism education contributes to the creation of better and more conscious prospective employees for the tourism industry (Malihah and Setiyorini, 2014). The findings also suggested that the module had resulted in positive mindset and behavioural shifts among several students. For example, Interviewee 05 mentioned, *"I am actively engaged in energy savings and related practices now."* Interviewee 06 mentioned, *"I used to waste a significant amount of water and energy, but I have actively reduced this through practical changes,"* showcasing that the module's education had transcended beyond typical technical and analytical literacy and has paved a path toward positive and tangible changes among the student community. The findings further identified that the module's field visit highly influenced the gaining of such phronesis as it enabled the students to witness sustainable tourism from a practical perspective (Jamal, 2004).

Interestingly, the findings also suggested that the module learnings had created a knowledge trickle-down effect with the students incorporating their learnings into their extra-curricular activities as highlighted below by Interviewee 04:

“The knowledge gained from the module prompted changes in my behaviors. I used the awareness gained from the module to initiate projects like tree planting programmes and guest lectures in high schools on responsible traveling.”

This statement asserts that a positive learning experience for a student, especially in an area like sustainable tourism, could result in trickle-down engagement, resulting in the subject knowledge being disseminated among a broader population (Saucier, Miller, Jones and Martens, 2022).

5. Conclusion

The findings of this study suggested that incorporating a dedicated sustainable tourism module positively impacts undergraduate students' sustainable tourism literacy. The research findings unequivocally supported the claim that the inclusion of sustainability into course curricula directly impacted students' technical knowledge of the subject spectrum (Perera and Hewege, 2016). While all respondents showcased signs of grasping the core technicalities of the subject effectively, several students showcased complications in drawing relationships between baseline technical knowledge and more profound technical knowledge, such as applying sustainable tourism conceptual knowledge toward achieving the SDGs. Moreover, the incorporation of the module also contributed to ameliorating the broader analytical skills of the undergraduates, especially in terms of applying their technical knowledge in real-life scenarios. Interestingly, the student learnings during their field visit were highlighted as the key driver in enhancing their analytical literacy over in-class learning. The module also positively contributed to the ethical sustainable tourism literacy with many students claiming positive viewpoints and behavioural changes regarding their personal and prospective work life. Overall, the findings asserted that the successful delivery of a curated sustainable tourism module could become a highly effective pedagogical tool in sustainable tourism knowledge enhancement in HEIs.

This study proposed several recommendations for HEIs. Firstly, tourism educators must transcend beyond traditional education approaches to cater to multiple facets of student literacies to create holistic and industry-ready tourism graduates. Secondly, HEIs must also strive to balance in-class and external learning methodologies by incorporating elements such as field visits in feasible areas of study to enhance student learning experiences. Thirdly, HEIs must explore avenues for industry collaborations with leading companies within the sustainable tourism spectrum, ideally through initiatives such as guest lectures and short-term sustainable tourism apprenticeship programmes to bring in different and practical worldviews on sustainability to augment the broader educational offering.

Despite providing significant insights, this case study remains universally inconclusive due to several limitations. The study sample was limited to 7 respondents representing only one HEI, given the newness of the subject area and lack of student cohorts studying the module. Future research could explore this phenomenon in a broader context with a more prominent and representative sample. Moreover, the study was conducted as cross-sectional research, with data being collected only at the end of the module. Future research could also investigate the possibility of engaging in longitudinal research to conduct a comparative study of pre- and post-studying of a sustainable tourism-centric module to compare the literacy and mindset changes.

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ICSD 077

THE EFFECTS OF USING BLENDED LEARNING IN ENGLISH AS A SECOND LANGUAGE CLASSROOM

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Abstract: With the advancement of technology, the education sector tries to improve the quality through the combination of traditional and digital platforms of learning. As a result, the modern classroom tends to implement blended learning for better outcomes. This paper aims to demonstrate that the application of blended learning encourages second-language learners of English to enhance their language skills with enthusiasm, motivation, and attention. The research paper analyses the studies that have been previously done on the impacts of blended learning on students and teachers in second language classrooms of English. The literature shows that this learning approach makes students to be active, autonomous, and responsible for self-driven learning. In a blended setting, students are expected to be in charge of their learning and success while teachers become facilitators to guide them through lessons and digital platforms. Nowadays, universities and educational institutions create online learning management system (LMS) such as Blackboard, Canvas, and Moodle for students to access necessary course resources, quizzes, and assignments in addition to traditional classroom sessions. These systems are created with the expectation of delivering top-notch education experiences for students through modern learning strategies. In conclusion, second language learners of English can gain better language development through blended learning.

Keywords: Blended learning; Second language learners of English; Technological advancement; Active learner

1. Introduction

Technological evolution has created new opportunities in every field to boost productivity and efficiency. Modern-day inventions and innovations ease the lives of humans and create competition to improve existing levels. The education sector has been greatly influenced by technology, which makes the relevant authorities always aware of upcoming improvements. The use of traditional and online platforms separately in modern society does not encompass the passion to learn. Especially those from Generation Z who have experienced the virtual platform from birth require a dynamic learning atmosphere to attain success. As a result, the education sector has been using ways to upgrade learning and teaching strategies. Apart from the traditional and online learning systems, the use of blended learning in classrooms has given students and teachers a different view of how to understand the subject matter easily.

It is important to explore whether blended learning can be implemented in every learning and teaching environment. Learning English as a Second Language has been incredibly crucial in society, given its importance to career, educational, and societal development. The traditional classroom lessons are not sufficient to gain fluency in English. For instance, students learn English as a second language at school to pass the exams; therefore, they specifically focus on writing and reading skills. In Sri Lanka, English is taught as a subject with other subjects in a larger syllabus (De Silva and Palikakkara, 2020, p. 45). Hence, the students have to encounter barriers when mastering the language due to a lack of interaction and proper communication in the classroom.

According to Zhang and Zhu (2018, cited in Albiladi and Alshareef, 2019, p. 232), blended learning promotes an approachable, adaptable, active, collaborative, supportive, and motivating learning and teaching condition. Therefore, blended learning can support learning and teaching English as a second language. The objective of this paper is to show that the application of blended learning in the English as a second language classroom brings positive reinforcement for students to advance their language skills by being responsible and autonomous. Also, it discusses the positive impacts of using learning management systems (LMS) like Canvas, Blackboard, and Moodle as a strategy of blended learning for second-language learners of English. The research article is primarily written using previous studies and literature. The research contributes to the understanding that blended learning with modern online tools should be implemented in second language classrooms for better progress. The paper is divided into three sections: What is blended learning?, e-learning platforms, and blended learning in English as a second language classroom.

2. What is blended learning?

With the advancement of technology, every sector begins to flourish with endless opportunities. The educational sector specifically highlights replacing conventional study methods with modern and contemporary applications. In modern society, the learning and teaching processes are not only limited to traditional and online methods, but techniques with more enhanced features to make the study process fascinating and appealing. Therefore, universities and educational institutes consider developing fully-fledged learning environments for better outcomes. To overcome the issues related to education, blended learning is a successful option (Yu, 2015, p. 7). This system has been successfully implemented in universities worldwide to create chances for students and teachers to explore and investigate the untouched areas of subjects with clarity and enthusiasm.

People often get confused with hybrid learning and blended learning. Hybrid learning equally allocates time for face-to-face and online styles while blended learning allows more time to interact in the classroom with a few online elements (Ataby, 2021, p. 27). Blended learning allows the integration of online strategies into in-person learning processes to maximize the ef-

fectiveness of students (Yu, 2015, p.6; Yana, 2018, p.84). Moreover, it has the potential to deliver collaborative learning; constructive learning and computer-assisted learning (Lalima and Dangwal, 2017, p.129). Then, students can develop their communication skills when interacting with others, understand facts on their own rather than being a passive learner and familiarize with modern technology and incorporate it with traditional education methods to get better results. According to Bhatia (cited in Avazmatova, 2020, p. 508), blended learning has advantages such as, the development of professional skills, flexible learning opportunities to cater to students' needs, the ability to access online resources, and effective group learning. To successfully implement this system, appropriate attitude, utmost effort, handy budget and highly motivated learners and teachers are required (Lalima and Dangwal, 2017, p.129). The contribution from both learners and teachers is essential for the success of blended learning. The responsible bodies must make sure that educators are well-trained and thoughtful to handle the platform with minimum errors and deliver productive lessons. Students, on the other hand, ought to maximize their potentials using the improved resources and be motivated to be a part of the learning process.

Moreover, this system enables learners to be self-driven to produce and use the knowledge rather than becoming passive learners (Sheerah, 2020, p.199). Therefore, students become responsible, autonomous and motivated to study using their own methods and critically reflect on learning (Gördeslioğlu, and Yüzer 2019, p. 20). This system allows learners to be more attentive and analytical about the subject matter and gradually attain new truths and realizations.

2.1 E-learning Platforms

Educational institutions always thrive to excel in their relevant fields using modern and convenient resources. In order to provide a better learning experience, educators tend to use modern technology, especially social media platforms such as Twitter, Whatsapp, and YouTube. For instance, during the COVID-19 pandemic, many online tools like Zoom, Microsoft Teams were used to deliver lessons and share necessary resources. Teachers also created Whatsapp groups to share documents and activities among students. It was helpful for learning and teaching processes to continue without disruption amid the lockdown. The use of these platforms has undoubtedly improved the quality of education. Social media has been recognized as a crucial ICT element for learning. The main advantages of using social media for education are that it enhances students' collaboration and promotes peer education. But it is a concern whether all social media platforms are appropriate and relevant for students' development. Furthermore, due to its wide spread, teachers are unable to monitor and supervise students' social media usage (Baquero and Escortell, 2022, p. 4486).

To avoid those aforementioned issues and to enhance the learning experience, the universities have now implemented Learning Management Systems (LMS) such as Blackboard, Canvas, and Moodle. The integration of web-based technology and learning management systems improves learners' communication, critical thinking, creativity, and collaboration (Ramalingam, Yunus and Hashim, 2021, p. 1437). The current youth (Generation Z) is known to be digital natives, while teachers become digital immigrants (Elaoufy, 2023, p. 24-25) therefore, blended learning will interest and benefit students.

Canvas LMS is one of the most used electronic learning systems that provides numerous options and features to enhance learning and teaching processes (Ataby, 2021, p. 27). The use of Canvas assists educational institutes in managing learning and provides a platform for both students and teachers to have productive interactions and collaborations in one place. Due to their unique features and applications, Canvas, Moodle, and Blackboard are able to host different types of materials, including documents, videos, audios, and ways to do assignments (Ataby, 2021, p. 30; Truong, 2021, p. 129; Alhussain, 2017, p. 297).

These digital applications are designed to provide access to course modules, outline, assignments, and quizzes for both learners and educators. In addition to classroom interaction, students are able to use the resources available on these platforms, as they can be accessed through computers, laptops, and smart devices anywhere and anytime (Yana, 2018, p. 84; Kamlesh and Chetankumar, 2019, p. 15). These platforms provide the opportunity for teachers to create and share content with students and to interact with them inside and outside of class. For example, lecturers can publish discussion board activities on Canvas, Blackboard, or Moodle where students get the chance to present their ideas about a topic and review the answers of other students. Therefore, students can engage in their studies outside of their traditional classroom. The discussion board is a tool that is important for collecting feedback or questions about the topics discussed in class (Ataby, 2021, p. 29). Through Blackboard LMS, teachers can post updates about the course for students to read as announcements (Alhussain, 2017, p. 298). It reminds students of upcoming submissions and exams; therefore, they can prepare in advance to perform well.

Moreover, if the learners need extra help from the teachers, support sessions can be arranged via Collaborate Ultra, a tool available on the LMS to conduct online classes. During the COVID-19 pandemic, the online sessions were done using Collaborate Ultra. Hence, the platform became a successful alternative to physical classes because it allowed students to attend lectures through smart devices (Elsamanoudy, Fayz and Hassanien, 2020). This is a web conferencing and collaborative online teaching tool. It does not need to be installed as it is browser-based. Collaborate Ultra is user-friendly and can be used in various online teaching sessions such as lectures, seminars, and tutorials (Hill, 2019, pp. 1-2). When the teacher creates the sessions, students can easily log in and participate in the lecture. Features like chat, microphone, 'raise hand', and polling are provided for students to interact with the teacher and other colleagues. Teachers can use 'share screen' and 'whiteboard' options to conduct lectures effectively. During group activities, the teacher can divide the students into different groups and allow them to discuss freely outside of the main room. Moreover, when doing presentations, the lecturer can make the participants presenters and allow them to share the screen. Most importantly, if the lecturer chooses to record the session, students can later view the recording to understand the lesson better.

These learning management systems are convenient and trustworthy when the assignments are being submitted and marked. Teachers can post assignments and receive them through the assessment tab (Alhussain, 2017, p. 298). Especially, university students have to submit their assignments or exams through these platforms to avoid the hassle of handing over many hardcopies, and then the lecturers can detect the plagiarism rate of the submitted work through Turnitin, plagiarism detection software. Therefore, students learn to be mindful and hardworking to produce original and credible work. Then, teachers can use the grade book to release assignment marks (Alhussain, 2017, p. 298). LMS tools can help all the stakeholders, including parents, students, and teachers evaluate the progress and predict the performance of the student (Kamlesh and Chetankumar, 2019, p. 17). These platforms teach students to be disciplined in academia.

To sum up, a virtual platform, including social media and the Learning Management System (LMS), can take the traditional learning environment to a whole new level of opportunities and explorations. LMS is capable of directing learners to achieve the desired outcome through its modern features and tools.

2.2 Blended learning in English as a second language classroom

Learning English as a second language has not been an easy task. The learners need to engage in continuous learning and actively use the language to be fluent. But many learners assume

that it is impossible to master English; therefore, they are reluctant to learn it. Moreover, English is taught in second language contexts, targeting general written examinations. Students are expected to use correct grammar, vocabulary and sentence structure which makes the learning process detestable and challenging. Due to the pressure of achieving examination standards, users are not focused on improving communication and listening skills. Additionally, the learners are not given proper exposure and practice to improve their language abilities (Raja and Selvi, 2011, p. 41).

Non-native speakers of English learn English as a second language (ESL) or English as a foreign language (EFL). Learning English has been marked as of high importance in developing countries because of its ability to reach for well-earned occupations. Hence, improving the English language standards at the school and university levels is important to produce competent users (De Silva and Palikakkara, 2020, p. 43). Therefore, educational institutes test new ways to improve the levels of English teaching and learning. Blended learning has become the latest tool to make learning and teaching English productive and successful in the classroom. The importance of applying blended learning to language learning should not be overlooked, given the fact that a language should be learned to speak in active, interactive in-class communicative sessions. A language can be improved using both traditional and online aspects. Learning English as a second language has been a challenge for many users. But social media and online platforms have eased the struggle of acquiring English by introducing appropriate activities and clear explanations. Nowadays, many YouTube channels are dedicated to English language teaching. The learners can improve their language skills easily and quickly. It is found that watching English YouTube videos has the potential to develop students' listening comprehension (Sembiring and Katemba, 2023, p. 161) and communication skills (Muslem, Fata and Sautri, 2022, p. 428).

Past studies have shown that both teachers and students are given better experiences through blended learning to understand their roles in education. Banditvilai (2016) conducted research to understand the effectiveness of using blended learning to improve the language skills of students. The participants of this study were sixty English major undergraduates from Kaset-sart University, Thailand. The research was done by dividing the students into two groups: Group 1 (the control set), who studied English in a classroom setting, and Group 2 (the experimental set), who learned the subject both in-class and using additional online activities. According to findings, extra online work enhances the language skills of students compared to traditional learning. Moreover, the new process has transformed the class from teacher-centered to student-centered allowing the students to be responsible and in charge of their learning. Hence, the students form meaning and knowledge using their own experience and information.

Teng and Zeng (2022) conducted a study on a Chinese middle school to investigate the effect of the application of blended learning on improving oral proficiency. The experimental group of 46 students followed blended learning along with a four step method for teaching speaking: pre-speaking, while-speaking, post-speaking, and extension practice, and was tested with a pre-test, an immediate test, a delayed post-test, and an interview. The control group consisted of 45 students who followed traditional learning and took the same tests. According to the scores of the two groups, blended learning had significant impacts on oral fluency and accuracy. The main reason for the improvement of oral fluency and accuracy is the noticeable increase in students' self-regulation. According to the study, regulation happens in three stages: object-regulation, other-regulation, and self-regulation. For object-regulation, the students benefited from the virtual platform by using the features of online-based learning to understand the input and reflect on the outcome. For other-regulation, the participants were able to get support, guidance, and feedback from teachers and friends both in-class and virtually for

the activities they could not complete on their own. For self-regulation, they became autonomous without the assistance of teachers and peers and became motivated to search for necessary online tools and increase interaction in the classroom to better their language learning (Teng and Zeng, 2022, p. 289).

Madarina et al., (2020) conducted a research to explore the advantages of using blended learning on improving writing skills of university students through focus group interviews. The participants are six ESL second-year students from Universiti Sultan Zainal Abidin, Malaysia, who have followed writing skills courses for two semesters through blended learning. The data from the interview was understood using inductive thematic analysis. According to findings, blended learning has supported students to improve their writing skills, self-esteem and most importantly increased motivation to learn writing lessons.

A study done by Menggo and Darong (2022) shows that blended learning has a positive effect on students' English proficiency, motivation, autonomy, and ICT skills. This research is designed as a quantitative explanatory type with a pre-test and post-test. The participants are 198 students from the Department of Primary School Teacher Education at the Catholic University of St. Paul Ruteng. Twelve blended learning sessions were undertaken, with six in-person classes and six virtual classes on Zoom. According to the results, blended learning builds up students' English proficiency with a mean score of 82.57 on the post-test, motivation (80%), autonomy (88.57%), and ICT skills (71.43%).

According to a study (Ahmad, 2021) done on EFL/ESP (English for Specific Purposes) teachers and students at Saudi universities, utilizing full in-person classes or full online sessions is not successful given the effectiveness of blended learning. The majority of the participants have responded that blended learning presents various approaches for learning and teaching with the combination of both online and traditional platforms. The findings indicate that teachers from the old generation can improve the quality of teaching by integrating online resources in the classroom. Learners are enthusiastic about interacting with dynamic teachers in the class and incorporating visual aids to enhance the learning process at any given time.

Another qualitative study (Ramalingam, Yunus and Hashim, 2021) explores the application of blended learning with web-based technologies in an ESL classroom and the influence it has on improving students' 21st century skills. According to the experiment, the students perceive blended learning to have a positive impact on their learning, including improving teamwork skills, creativity, critical thinking, and communication. The participants acknowledge that virtual-based blended learning exercises can enhance their soft skills. All in all, the students express positivity about experiencing the enhanced version of their learning approach.

In addition to social media platforms, the use of the Learning Management System (LMS) in the classroom has positive impacts on the learning process. A study (Lien, 2023) has been conducted to understand EFL teachers' and students' perceptions towards the implementation of LMS in blended courses. Web-based survey questions and interviews were used to gather data from 130 EFL students and 12 EFL teachers at a public university in Central Vietnam. The results explain that LMS provides advantages for both EFL teachers and students. They are; clear course organization and management, different teaching ways, accommodating teaching and learning tasks and enhanced interaction and autonomy of students.

Truong (2021) has done a study to examine students' thoughts on the application of Moodle-based LMS in learning and teaching speaking skills at Van Lang University. This quantitative research has used 24 English-major students as participants and deployed a questionnaire to gather their thoughts. According to the results, the majority of the participants have claimed that the use of LMS improves speaking skills, including grammar, pronunciation, and vocabu-

lary. The final remark of the study is that, despite in-person classes being crucial for speaking improvement, the learning should be supplemented with LMS to gain better speaking proficiency. According to Manan and Emzir (2020, cited in Truong, 2021, p.129), the use of Moodle LMS in blended learning can help improve ESP students' speaking skills.

A study (Gördeslioğlu, and Yüzer, 2019) has been done to investigate if a course can be structured using BlackBoard Learn LMS to develop learning and the listening and speaking lessons. The research was performed in the second semester at Koc University, Istanbul with 88 candidates from course 2 of Listening and Speaking. These participants began the course as false beginners. The administrators' expectation for students is to complete the proficiency exam within a year. Therefore, the researchers implemented BlackBoard Learn to maximize the chances for students to achieve better results despite the time factor. The new learning method was applied with the intention of providing good exposure to the target language and directing the learners to be motivated and autonomous. The findings reveal that the online platform has positively impacted on successfully completing listening and speaking tasks. Most importantly, online speaking activities have helped students to be more confident and relaxed, particularly for those who may be shy to express in a traditional classroom.

All in all, research shows that blended learning can be implemented in ESL/EFL classrooms to enhance the learning experience. Both teachers and students express positive attitudes towards blended learning with social media tools and LMS.

3. Conclusion

The research paper concludes that a blended learning system is beneficial for second language learners of English to improve language skills. Learning management systems can enhance learning and teaching through the use of unique and useful tools, as well as the integration of classroom lessons. Blended learning can inspire students to make exceptional learning choices and be productive in their knowledge creation. However, in order to make the blended learning approach more convenient and user-friendly, proper training and exposure should be provided.

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TRANSFORMING SRI LANKA'S IT EDUCATION WITH ONLINE ASYNCHRONOUS LEARNING

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Abstract: Sri Lanka's university system still firmly believes in conventional classroom teaching and assessments where only a limited number of students can be facilitated annually. This creates a bottleneck in meeting the growing demand for skilled individuals, especially in the Information Technology (IT) sector. Even the leading universities are unable to meet the infrastructure needed to increase the number of IT graduates owing to existing economic constraints. Thus, a revolutionary change in the delivery of education is essential. The Open Learning Platform of the University of Moratuwa, open.uom.lk, is a major step towards this change. The platform provides free of charge and open access to quality education in essential topics in IT. The courses were designed in collaboration with IT industry professionals, where representatives had significant influence on course structure and programme content, ensuring the output from this platform meets the requirements of the industry. Attention has been paid to develop the knowledge, skills, and attitudes of the participants to enable them to enter the industry with confidence upon successful completion of the programme. The Trainee Full Stack Developer programme of the open.uom.lk has received an overwhelming response with over 250,000 registrants to-date and overall positive reception by the IT industry and industry consortia such as Sri Lanka Association for Software Services Companies and Computer Society of Sri Lanka. This study evaluates the key points to consider in designing online asynchronous study programmes to meet the human resource requirements of the industry.

Keywords: online learning; asynchronous learning; academia-industry collaboration

1. Introduction

The concepts of online learning, e-learning and distance learning have been the focus for many studies on pedagogical delivery and effectiveness (Johnson, Hornik and Salas, 2008; Mahdizadeh, Biemans and Mulder, 2008; Moore, Dickson-Deane and Galyen, 2011; Parkes, Stein and Reading, 2015).

In Sri Lanka only around 30% of those who qualify for higher education from GCE Advanced Level (A/L) Examinations secure placements in either public or private sector Higher Education Institutions. The time between completing the GCE A/L Exams and the release of results is about five months and university selection is nearly a year.

A key policy area of Vistas of Prosperity and Splendour (National Policy Framework Vistas of Prosperity and Splendour 2019), the National Policy Framework of the Government of Sri Lanka (GOSL), is to promote a Technology-based society in Sri Lanka, by developing a global innovation hub and promoting IT entrepreneurship. The Sri Lankan IT industry has grown rapidly and is considered the fastest growing industry sector in the country.

However, the scarcity of skilled manpower is a major bottleneck faced by the IT industry (National IT-BPM Workforce Survey - ICTA 2019). To solve both these problems a programme to provide learners in Sri Lanka skill enhancement was designed, developed, and deployed online free of charge. On completion of the course, they will have the qualifications to enter the IT industry as an intern. While the main objective of the programme is to provide new skills to students who are school leavers, it can also be useful in up-skilling those already studying in higher educational institutes to gain industry relevant skills and re-skilling graduates to move into IT fields.

University of Moratuwa (UoM) with faculties of Engineering and Information Technology and its strong linkages to the IT industry working together with DP education foundation, a strong proponent of free and open online education in this country, designed the Trainee - Full stack developer (TFSD) programme to address these problems.

While there are many resources and courses online where it is possible to learn programming, there was a need to create a course specifically tailored to the needs of Sri Lankan learners. UoM is the most sought-after premier learning institute in the country and has widespread recognition in the country. A certification from the UoM will be trusted by both learners and the IT industry employers in providing high quality courses which meet the needs of the local IT industry. Enhancing both the learners' technical and soft skills have been a focus of the courses from the beginning.

Having relevant soft skills such as adaptability, communication, and teamwork are essential requirements to participate in the IT industry. The TFSD programme has a course component entirely focused on enhancing soft skills to improve the learners' attitudes, in addition to these skills promoted throughout the other courses as well.

Collaborations with industry have guaranteed that the programme will fulfil the objective of producing learners who will meet the need of the human capital requirements of the IT industry. Endorsement by Computer Society of Sri Lanka (CSSL) and the recognition from Sri Lanka Association for Software and Service Companies (SLASSCOM) is further assurance for the quality of the course. The voluntary support from IT professionals, UoM academics and the financial support from DP Education foundation has enabled the University to provide this course free of charge to all learners without depending on state funding.

The TFSD program, launched on 22 February 2022 to coincide with completion of the Advanced level exams in 2022, has over 250,000 students as of 12 February 2024.

2. The Open Learning Platform

The TFSD course is hosted on the Open Learning Platform (Nanayakkara *et.al.* 2022), which utilises the Moodle learning management system (Moodle.org). Moodle is an open-source learning management system which was developed using pedagogical principles. It is also the platform that is being used at the UoM as the eLearning platform. Moodle provides a variety of plugins, which is software that adds new functions, enabling the inclusion of additional interactive teaching and learning activities and to make the management of the course easier. These plugins can be categorised into activities and resources. Activities generally enable interactions with students, among students, and/or with the teacher. This includes forums, assignments, and quizzes etc. Resources allow the teacher to provide access to content such as a file, folder, page, book, or a URL to an external website. The Open Learning Platform utilises the full spectrum of the Moodle plugins.

The Moodle - plugins such as quiz activities, file, page, and book resources, H5P tool, along with the CodeRunner activity, and the embedded Trinket tool have formed the complete Open Learning Platform which is now being used actively by thousands of students. Further, the completion of TFSD is marked by a capstone project which is conducted in fully automated manner using GitHub classroom allows the Open Learning Platform to handle large volumes of project submissions without burdening the instructors.

One of the main objectives of the Open Learning Platform is to provide a self-learning portal to the students. We identified the need to automatically grade the programme code the students develop as part of their learning activities. CodeRunner (Lobb and Harlow, 2016; Croft and England, 2020) is an automated programming assessment plugin for Moodle, that is also used in internal courses at the Faculty of Engineering at UoM. CodeRunner allows the teachers to set the assignment as a Moodle quiz (Figure 1).

The screenshot displays a Moodle quiz question titled 'Question 1'. The question text asks to 'Modify the following code snippet to add two numbers'. An example table shows 'get_number()' returning 'Enter number now: 12' and 'Enter number now: 23'. The student's code in the 'Start answer' field is as follows:

```
1 get_number()
2
3 // Only add the code segment between the dashes
4 -----
5
6 * Add the code segment between the dashes
7 *
8 *
9 *
10 *
11 *
12 print(a+b)
```

Below the code editor is a 'Check' button. At the bottom, a table shows the test results:

Test	Input	Expected	Got	Result
✓ get_number()	12	Enter number now: 12	Enter number now: 12	✓
✓ get_number()	23	Enter number now: 23	Enter number now: 23	✓
✓ get_number()	28	Enter number now: 28	Enter number now: 28	✓
✓ get_number()	28	Enter number now: 28	Enter number now: 28	✓

The table concludes with 'Passed all tests: ✓'. A 'Finish attempt...' button is visible at the bottom right.

Figure 1. An example CodeRunner quiz activity that illustrates a programming assignment given to students, the answers provided by the student, and the results generated by evaluating the test cases.

The teacher can set the coding language of the programming assignment, the conditions for passing the assignment and the test cases needed to evaluate the assignment, among other options. Once a student submits their answer to a question as a programme code, it is executed in an isolated environment in a sandbox server (referred as the JOBE server) and evaluated against the test cases set by the teacher. Depending on the grading criteria, the student receives a mark for their submission as soon as this evaluation is completed, which generally occurs within a few seconds. Therefore, the student receives immediate feedback for the activity allowing the student to learn constructively.

Providing hands-on programming experience is another main objective of the courses provided at the Open Learning Platform. As a result, we identified the need to allow the students to code on the platform itself (on a web browser) without installing any additional software or programming environments. We have used Trinket (Kurniawati, Kusumaningsih and Sophan, 2018) which is a web-based tool that allows the user to write python code, execute code, and generate outputs, inside the browser (Figure 2). We use trinket to provide the coding playground that allows users to code, engage in self-evaluation and build on their knowledge by themselves. Trinket is added to the Moodle course as an embedded web resource.

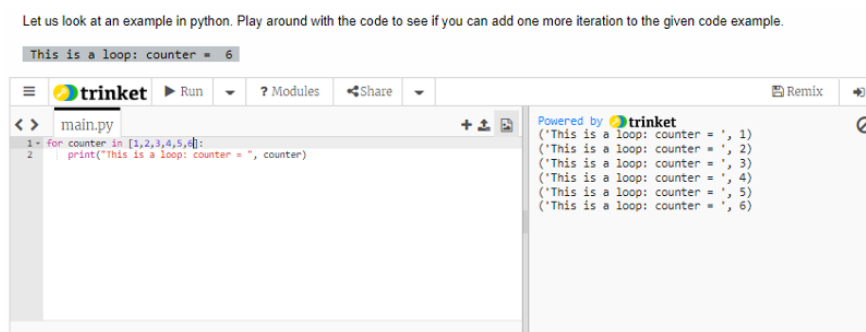


Figure 2. Trinket is embedded as a tool inside a lecture note to allow the student to try and execute a program code within the web browser and to observe outputs.

The Moodle learning management system, the plugins such as quiz activities, file, page and book resources, H5P tool, along with the CodeRunner activity and the embedded Trinket tool makes up the complete Open Learning Platform which is now being used actively by thousands of students.

2.1 Content Arrangement

Providing interactive content to the users is crucial in a self-paced learning platform. In the Open Learning Platform – UoM, we use the H5P - HTML5 Package (H5P) framework to offer interactive content to the students. H5P is a free and open-source content collaboration framework based on JavaScript that can be used in Moodle, the learning management system used in the Open Learning Platform – UoM.

H5P makes it easier for the course conductors to create HTML5 content directly from the browser window. Further, H5P is mobile-friendly, allowing the users of our platform to enjoy the same interactive learning experience using smartphones and tablets.

H5P enables the creation of interactive content like interactive videos, presentations, games, and many more. We extensively use interactive videos on our platform. Using interactive videos in H5P allows us to add many different types of questions and informational resources to the lecture videos. For example, we can add multiple choice, fill-in-the-blank questions, pop-up text, and interactive summaries (Figure 3).

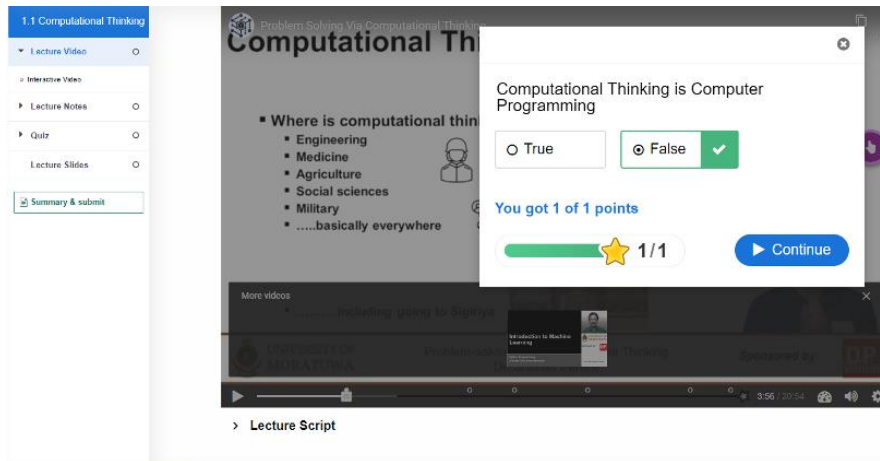


Figure 3. An example where the student is asked an interactive question during the lecture.

In addition to making the videos more engaging, we can encourage the students to learn the lessons thoroughly using the interactions and features offered by H5P. For instance, we can add interactive questions with adaptive behaviour in the middle of the lecture video. Typically, the lecture video is paused for the question, and the correct answer allows the student to proceed with the video. However, if the wrong answer is given, we can configure it to direct the user to the place where the answer to the question is presented. Furthermore, H5P allows disabling video fast forwarding to encourage the student to watch the complete video and prevents them from skipping watching the video.

At the end of the interactive video, the students are shown a summary of the interactive questions they answered, along with the marks they obtained for each question.

Hence, using H5P provides formative assessment opportunities for the students while making it enjoyable to watch the lecture video.

As thoroughly evaluating the students' programming skills is essential when conducting IT courses, in the Open Learning Platform – UoM, students are given programming assignments at the end of each programming course. In addition, at the end of the TFSD Program, the students are given a capstone project to assess the knowledge students gained via the program.

We conduct this capstone project using GitHub Classroom, which provides an exciting learning environment for the students by facilitating automatic grading and instant feedback. In an assignment created using GitHub Classroom, we can provide a template repository with the initial code base for students to start the coding. Further, the GitHub Classroom facilitates auto-grading. We can configure automatic test cases to evaluate the code committed by the students. If all tests succeed for a commit, a green checkmark will be displayed for the students. If not, a red X will be displayed. Hence, the students can check their work as soon as they commit the code to an assignment repository. Furthermore, students can see the entire history of test runs.

They are also allowed to view the details of the evaluation, such as compilation errors and test case failures which provide the students with a great learning experience. GitHub Classroom also facilitates the course conductors to monitor the students' progress for the given assignment. For example, the course conductors can check how many of the enrolled students have accessed the assignment, the commit history of each student, how many points each student has gained, and which students are struggling. Hence, employing GitHub classrooms has enabled the Open Learning Platform to conduct coding projects in a more scalable and sustainable manner.

3. Discussion

Collaborations with industry have guaranteed that the programme will be fulfilling the objective of producing learners who will help fulfil the human capital requirements of the IT industry.

With rapidly growing participation numbers, one of the major challenges was the grading of assessments. Adding any manual grading component was impractical at such a large scale. Therefore, all the assessments had to be designed with provisions for auto-grading and using a variety of question types supported by the Moodle platform. The programming assessments were prepared using the CodeRunner question type, which supports auto-grading and feedback.

It should be emphasised that the platform has successfully adopted auto-grading techniques, so that it minimises the requirement for any manual grading effort. The process of completing all six courses of the programme is automated, so that the certificate for each course is generated in real-time once all the assessment requirements are satisfied by the participant. The assessments are constantly being reviewed and necessary changes are made so that the authenticity of evaluations is preserved to the extent possible through the platform.

Due to the asynchronous nature of the courses, retaining the interest level of the participants was also a major challenge. Unlike in live delivery of lectures, the risk of reduced participant engagement was considerably high. This was addressed at the stage of video content development by using example use cases to relate to the lesson content. After the video production interactive content was added to the video lesson using the resources provided by the H5P content arrangement module.

We were also faced with the socio-cultural factor connected with the unfamiliarity of the method of delivery of the learning programme. The participants are mostly used to teacher-centred education rather than learner-centred education. This is rather a broader issue that must be addressed at different stages of the education system. We expect this learning program would be a step towards making a positive change. In this program there are multiple communication channels to the participants, so that they are provided with the necessary the assistance.

Further details on the adopted methodology with comprehensive analysis have been presented in Thoradeniya *et.al.* (2023).

3.1 Achieving the learning outcomes

The main objective is for the participant, on completing the course, to have the skills and knowledge required to enter the IT industry as an intern or at an entry level. The course aimed to provide a foundation so anyone, even if they lacked any previous experience or knowledge of programming will be able to complete the course via independent learning.

A dedicated team of analysts ensured the course was benchmarked against the best programmes currently available worldwide. Constant guidance from the experts in education ensured the quality and relevance of the course material. The experts from the IT industry helped shape the programme so that it produces industry-ready personnel upon successful completion.

The TFSD programme consists of six courses which aim to methodically build knowledge and skills as a full stack developer.

- Python for Beginners (Introduction to programming)
- Web Design for Beginners (Introduction to web technologies)
- Python Programming (Foundation for advanced programming)
- Front-End Web Development (Single page application development)
- Server-Side Web Programming (Handling and serving data)

- Professional Practice in Software Development (Attitude development and capstone project)

The course content was designed to be delivered with recorded videos and supplementary reading materials. Each lesson consists of one or more recorded videos, lecture notes, lecture slides, interactive activities, and self-assessments. The script for each video lesson was included so that the participants can carefully follow the lesson and extract as much information as required by everyone make it more accessible to students who are not fluent in English so they can use translation applications if they find a word or section difficult to understand. The video lessons include embedded interactive content which helps to keep the participant engaged and prevents students from skipping the video. The lecture note provides additional information on the lesson, links to further reading resources, and may consist of built-in programming exercises using Trinket (Kurniawati, Kusumaningsih and Sophan, 2018) to help the participant to enhance their skills and internalise the content that is covered in the respective section.

Each section contains assessments to monitor and evaluate student progress of the courses. The assessments may include quizzes and programming exercises using auto-graded CodeRunner. The participants are required to attempt the quizzes and obtain a satisfactory grade to proceed to the next section. The assessments are similar to the assessments available on leading online learning platforms such as Coursera, Edx, Udemy, and Udacity. However, there are no peer-graded assignments on our platform. Most of the assessments are auto graded, but there are few assignments which are manually graded by our instructors to ensure that the students completing the course have the required skill set. Unlike in other platforms, we have a team from the Centre for Open and Distance Learning (CODL) - UoM to continuously monitor and give support for the learners to enhance their learning experience.

The main advantage of our platform is we provide all the course content and certificates for free making it accessible to the local students who otherwise would not be able to afford similar courses. Similar existing platforms have free courses or financial aid programs with certain limitations. We have designed our course content considering the local school syllabus to ensure the course is accessible for students from different education levels.

3.2 The response from the community

There has been an overwhelmingly positive response from both the industry and the society at large. Two years after the release of the course there have been over 250,000 registered users who have enrolled in the course. Industry professionals have engaged with the course enthusiastically and are eager to employ the students who completed the programme as interns. Even after the initial release there has been a steady increase in enrolments and a steady increase in the number of students participating and completing the course.

Figure 4 indicates a steady growth of the number of total registrations on the platform.

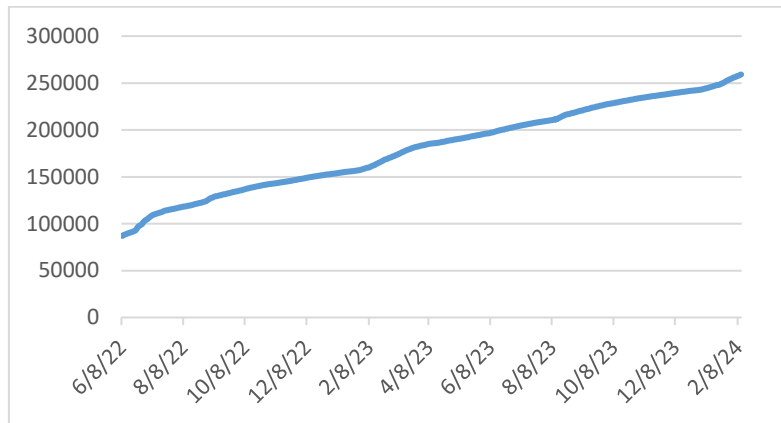


Figure 4. Total registrations during the period June 2022 - February 2024.

Inspections of Figure 5 shows the rising numbers of completions on the platform for the first two courses, Python for Beginners and Web Design for Beginners. Constant attempts are made to further increase the number of completions in all courses on the platform by aiding the participants to recover from any situations where they find it difficult to proceed.

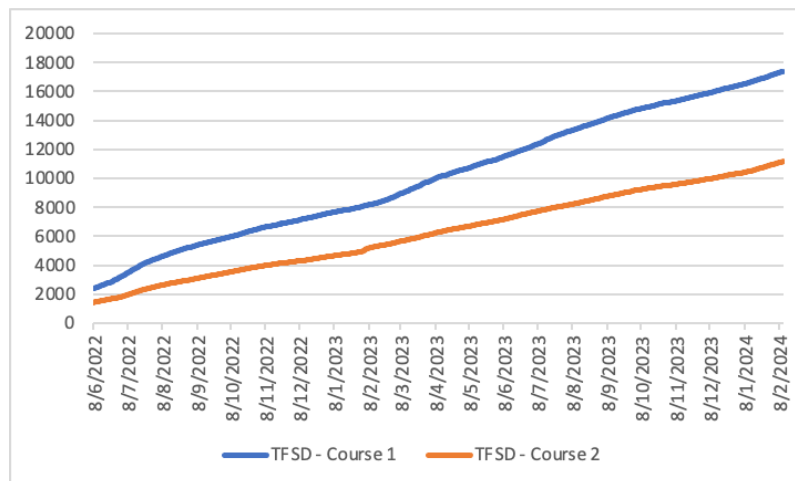


Figure 5. TFSD Course completions (Python for Beginners and Web Design for Beginners) during the period June 2022 - February 2024.

Further analysis on completion behaviour has been discussed in Karunarathne *et.al.* (2023) and Rana-singhe *et.al.* (2023).

4. Future developments

Our current aim is to continuously improve the programme to maintain both quality and satisfaction of the students. There is a forum and support email students can use to contact us about any errors that occur in the system such as videos failing to load or auto-grading not happening quickly enough.

We are closely monitoring the user’s behaviour as they progress through the course. Steps are taken to analyse the user data and identify any bottlenecks or problems areas in the course and then take steps to remedy these bottlenecks. Surveys were also sent to students who had completed the course as well as to students who are still engaged in the course to get feedback on their experience. Their feedback was compiled and analysed and will be reflected on when taking steps to improve the course in the future.

We are planning on introducing more IT related courses in the future including more courses in data science, quality assurance, information security and cloud computing in addition to other courses which are still in development.

The next step is to provide a platform on open.uom.lk for students who have completed the TFSD programme to create a profile where they can upload their CV and other relevant credentials. IT company recruiters would be given access to view these student profiles who they can then contact if they wish would ask them to interview with them with the intention of hiring them in the future. This platform will promote the students who have completed the programme to potential employers and allow these students to get gainful employment and help IT companies find employees which they have a dire need for.

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BLENDED LEARNING: A COMPREHENSIVE OVERVIEW OF STRATEGIES, BENEFITS, AND IMPLEMENTATION CHALLENGES

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Abstract: Blended learning is the term used for the educational practice of combination of traditional face-to-face interactive teaching in a classroom with digital learning tools. This practice has gained significant attention in educational settings worldwide. This paper provides a comprehensive overview of blended learning, examining its various strategies, associated benefits, and implementation challenges. The paper begins by defining blended learning and elucidating its evolution and history. Thereafter it elaborates on the key components and prominent models of blended learning and explains how by leveraging the strengths of both face-to-face instruction and online learning, blended learning offers a flexible and adaptable approach to meeting the diverse needs of learners in today's digital age. Blended learning encompasses a diverse range of instructional strategies that leverage both conventional instruction and online learning activities to create dynamic and engaging learning experiences. An attempt has been carried out in this paper to provide an insight into various strategies commonly employed in blended learning and its benefits. Despite its numerous benefits, the implementation of blended learning is not without challenges. This paper identifies key implementation challenges and explains how by addressing these challenges and considerations thoughtfully and proactively, educational institutions can maximize the benefits of blended learning while mitigating potential risks and ensuring that all students have equitable access to high-quality educational experiences. Furthermore, the paper illustrates real-world applications of blended learning initiatives taken by various institutions and highlights emerging trends and future directions. In conclusion, through a thorough analysis of existing literature, empirical evidence, and best practices, this paper has synthesized key insights to offer a nuanced understanding of blended learning's potential to transform educational practices and enhance learning outcomes. It emphasizes the need for continued exploration, adaptation, and refinement of blended learning approaches to meet the diverse needs of learners in the digital age.

Keywords: Blended learning; Pedagogy; Online learning; Active learning; Personalized learning; Implementation challenges

1. Introduction

There is always demand for both technology and traditional teaching and learning methods. As a result of this, the art of combining digital learning tools with more traditional face to face teaching and learning gave birth to the term “Blended Learning”. Blended Learning deals with the blend of different; web-oriented technologies; pedagogical methods and instructional technologies with face-to-face teaching (Driscoll, 2002).

1.1 Definition

The simplest definition of the term *blended learning* is the use of traditional classroom teaching methods together with the use of online learning for the same students studying the same content in the same course. It is a “thoughtful fusion of face-to-face and online learning experiences” (Garrison & Vaughan, 2008). Wikipedia offers the following definition: “Blended learning, also known as hybrid learning, is an approach to education that combines online educational materials and opportunities for interaction online with traditional place-based classroom methods.”

1.2 Evolution of Blended Learning

Blended learning is talked about now more than ever. This system has evolved over time in response to the intersection of educational needs, technological advancements, and pedagogical theories. The roots of blended learning can be found in early experiments with incorporating technology into traditional classroom instruction. In the 1960s and 1970s, educators began using computers for instructional purposes, albeit in limited capacities. These early efforts laid the groundwork for the integration of technology into education and set the stage for the emergence of blended learning. The rise of distance learning in the early years of 21st century, facilitated by innovations such as correspondence courses and televised lectures, contributed to the evolution of blended learning. Distance education models, which combined remote instruction with periodic face-to-face interactions, provided a precursor to the hybrid instructional approaches characteristic of blended learning. The advent of digital catalysed the development of online learning platforms and resources. Learning Management Systems (LMS) emerged as key tools for delivering and managing online content, enabling educators to supplement traditional classroom instruction with digital resources and activities. Over the past one decades, blended learning has become increasingly mainstream in educational practice, fuelled by advances in technology and shifting pedagogical paradigms. Educators have embraced a variety of blended learning models. The COVID-19 pandemic accelerated the adoption of blended learning worldwide, as schools and institutions grappled with the need to transition to remote and hybrid learning modalities. The widespread reliance on digital tools and platforms during the pandemic underscored the importance of blended learning as a means of ensuring educational continuity and resilience in the face of disruptions to traditional schooling.

The evolution of blended learning reflects a convergence of historical, technological, and pedagogical factors, culminating in its widespread adoption as a flexible and adaptive instructional approach. From early experiments with integrating technology into education to the mainstream adoption catalysed by the COVID-19 pandemic, blended learning has undergone a dynamic evolution, shaped by the changing needs and contexts of contemporary education.

2 Models of Blended Learning

In recent years, the education field has gone through significant changes. As teachers strive to help students engage with their learning in deep and meaningful ways, new strategies help them achieve the goals. Blended learning models represent an innovative way to encouraging hybrid learning and thereby promoting student success. There are a variety of models of blended learning. Each model offers unique configurations and structures that can be tailored to suit specific educational contexts, learning objectives, and student needs.

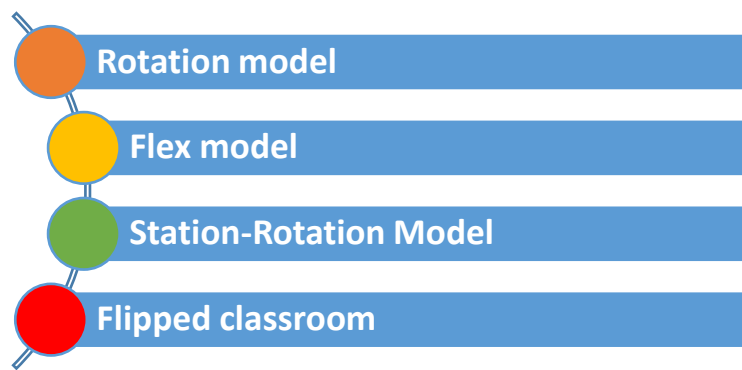


Figure 1: Models of Blended Learning.

2.1 Rotation model

In this Model of Blended Learning students rotate between traditional classroom activities and online learning stations, such as virtual lectures, interactive tutorials, or multimedia resources. This rotation of students is done either on a fixed schedule or at the instructor’s discretion. The rotation schedule can be adjusted based on students’ learning needs and progress.

2.2 Flex model

This model offers students flexibility in scheduling and pacing their learning activities, with a combination of face-to-face instruction, online coursework, and independent study. This model allows learners to have control over their learning.

2.3 Station-Rotation Model

This model is similar to the rotation model, but students rotate between different learning stations within the classroom, each offering a distinct learning activity or modality.

2.4 Flipped classroom

The motto of this model is “online learning, offline application.” With a flipped classroom, lectures and practical homework elements are reversed. In this model, traditional instruction is delivered online outside of class time, allowing in-class sessions to focus on active learning, collaborative activities, and application of knowledge. Learners study new content at home before the class, and in-class time is devoted to active learning and applying the newly learned skills. This can be accomplished in the form of discussions, case studies, or project work. The instructor’s task is to guide the learners by answering questions and supporting them in the application of course concepts.

3 Pedagogical Principles in blended learning

Blended learning is grounded in pedagogical principles that aims at optimizing learning experiences, fostering engagement, and promoting student success. The following are key pedagogical principles that underpin effective blended learning:

3.1 Active Learning

The pedagogical principle of active learning emphasizes student engagement, participation, and interaction in the learning process. In a blended learning system this active learning can take various forms such as collaborative problem-solving activities, group discussions, peer teaching, and hands-on projects. Online learning components can facilitate active learning by providing opportunities for students to explore content through interactive simulations, multimedia presentations, and self-assessment quizzes.

3.2 Personalization

Personalization is the system of tailoring instructions for students as per their individual needs, preferences, and learning styles. In a blended learning context, personalization can be achieved through adaptive technologies, differentiated instruction, and learner-centered approaches. Online learning platforms can offer personalized learning pathways, adaptive quizzes, and content recommendations based on students' performance, interests, and prior knowledge.

3.3 Flexibility

Flexibility refers to providing learners with choices and opportunities to customize their learning experiences according to their schedules, preferences, and pace of learning. Blended learning offers flexibility by allowing students to access course materials, resources, and activities online anytime, anywhere. Students can engage in self-paced learning, review content as needed, and revisit challenging concepts at their own convenience, enhancing autonomy and ownership of learning.

3.4 Integration

Integration involves seamlessly integrating online and face-to-face learning components to create a cohesive and holistic learning experience. Blended learning models should ensure that online and offline activities complement each other, reinforce learning objectives, and provide multiple pathways for achieving mastery. Integration can be achieved through careful instructional design, alignment of learning activities with course objectives, and scaffolding of learning experiences across modalities.

3.5 Reflection and Metacognition

Reflection and metacognition involve promoting self-awareness, critical thinking, and self-regulated learning skills among students. Blended learning encourages students to reflect on their learning experiences, monitor their progress, and identify areas for improvement. Online tools, such as blogs, discussion forums, and reflective journals, can facilitate metacognitive processes by prompting students to articulate their thoughts, reflect on their learning goals, and assess their understanding of course concepts.

3.6 Engagement and Motivation

Engagement and motivation are essential for fostering a positive learning environment and sustaining students' interest and commitment to learning. Blended learning offers opportunities for active engagement, interactive learning activities, and multimedia-rich content that captivate students' interest and promote intrinsic motivation. Gamification, simulations, and multimedia presentations can enhance engagement by making learning experiences interactive, immersive, and enjoyable.

3.7 Feedback and Assessment

Feedback and assessment are integral components of the learning process, providing students with guidance, support, and opportunities for reflection and improvement. Blended learning facilitates timely and constructive feedback through online quizzes, assignments, peer reviews, and automated grading systems. Formative assessments can be integrated into online learning activities to monitor students' progress, identify misconceptions, and tailor instruction to address individual learning needs.

4 Benefits of Blended Learning

Blended learning offers a balanced approach that harnesses the strengths of both traditional and online learning modalities, resulting in a more effective and engaging educational experience for students and it also offers educational institutions a versatile and effective approach to delivering high-quality education that meets the needs of 21st-century learners. Students' contentment has also been described to

be greater in blended learning courses as compared to only classroom teaching. Moreover, online components of blended learning encouraged the expansion of critical thinking skills among students (Dziuban et al., 2006; Owston et al., 2006). Institutions can create dynamic learning environments that foster student success, engagement, and lifelong learning. The various benefits are:

4.1 Enhanced Learning Outcomes

Blended learning combines the strengths of both traditional face-to-face instruction and online learning, leading to improved learning outcomes. By incorporating interactive multimedia content, collaborative activities, and personalized instruction, blended learning engages students more effectively and facilitates deeper understanding and retention of course material.

4.2 Interactive learning process

Theoretical materials can be challenging if not boring. It's one thing when learners sit and listen to a speaker for a few hours and it's radically different when they learn that same information by clicking on buttons, participating in a dialogue simulation, taking a game-like course, and so on. This promotes active participation and engagement among students. Acquiring new knowledge can be fun, and blended learning provides lots of tools to make it so. This active engagement fosters a sense of community and motivates students to stay committed to their studies.

4.3 Learner Autonomy and Flexibility

Being able to control and schedule an individual learning path is essential for learners. Blended learning offers flexibility in terms of time and location. Students can access course materials and participate in learning activities online at their own pace and convenience, reducing scheduling conflicts and accommodating different learning styles and preferences. In blended learning, learners can access courses 24/7 – whenever they want it and have opportunity. This flexibility increases accessibility for students with varying schedules, commitments, or geographical constraints.

4.4 Faculty Development and Collaboration

Blended learning encourages faculty members to explore innovative teaching methods and incorporate technology into their pedagogical practices. Institutions can support faculty development initiatives to enhance digital literacy, instructional design skills, and online teaching competencies. In the view of Motteram (2006), blended learning not only supports educators in developing significant skills but also offers an opportunity to reflect on an online forum about their pedagogy. Collaborative opportunities for sharing best practices and resources can foster a culture of continuous improvement and innovation among educators.

4.5 Data-Driven Decision Making

Blended learning platforms provide valuable data and analytics on student engagement, performance, and learning progress. Institutions can leverage this data to identify trends, assess the effectiveness of instructional strategies, and make data-driven decisions to improve teaching and learning outcomes. By monitoring student progress in real-time, instructors can intervene early to provide additional support or enrichment opportunities as needed.

4.6 Preparation for the Digital Age

The digital age has brought about significant changes in how we live, work and interact with the world. Blended learning equips students with digital literacy skills and prepares them for success in the increasingly digital workforce. By leveraging online tools and technologies, students develop critical skills such as information literacy, digital communication, collaboration, and problem-solving, which are essential for thriving in the digital age.

Overall, blended learning offers educational institutions a versatile and effective approach to delivering high-quality education that meets the needs of 21st-century learners. By harnessing the benefits of both

traditional and online learning modalities, institutions can create dynamic learning environments that foster student success, engagement, and lifelong learning.

5 Implementation Strategies

Implementation strategies for blended learning encompass a range of steps and considerations aimed at effectively integrating online and face-to-face instruction to enhance student learning outcomes, engagement, and overall educational experience. These strategies involve careful planning, pedagogical design, technological support, faculty development, and ongoing evaluation to ensure successful implementation.

- a) Conduct a comprehensive needs assessment to understand the specific educational objectives, learning goals, and student needs within the context of the institution or program.
- b) Set clear and measurable goals for the implementation of blended learning, aligning them with the overall mission, vision, and strategic priorities of the institution.
- c) Provide faculty with professional development opportunities and training in blended learning pedagogy, instructional design principles, and technological tools and platforms.
- d) Offer workshops, seminars, and online courses to familiarize faculty with effective strategies for designing, delivering, and assessing blended learning experiences.
- e) Assess the institution's technology infrastructure, including access to hardware, software, internet connectivity, learning management systems (LMS), and digital tools.
- f) Ensure that technical support services are readily available to assist faculty and students with any technological issues or challenges that may arise during the implementation of blended learning.
- g) Design courses and instructional materials that integrate online and face-to-face components in a coherent and meaningful manner.
- h) Utilize instructional design principles, such as backward design, active learning, and universal design for learning (UDL), to create engaging and effective blended learning experiences.
- i) Develop multimedia resources, interactive activities, and online assessments that align with the learning objectives and promote student engagement and achievement.
- j) Provide orientation sessions and support services to familiarize students with the blended learning environment, expectations, and resources available to them.
- k) Offer academic advising, tutoring, and technical support to assist students in navigating the blended learning experience and addressing any academic or technical challenges they may encounter.
- l) Establish mechanisms for monitoring and evaluating the implementation of blended learning, including ongoing assessment of student learning outcomes, faculty and student satisfaction, and overall effectiveness.
- m) Collect feedback from faculty and students through surveys, focus groups, and course evaluations to identify strengths, areas for improvement, and opportunities for innovation.
- n) Use data analytics and learning analytics to track student progress, identify trends, and make data-informed decisions to enhance the quality and impact of blended learning initiatives.
- o) Foster a culture of continuous improvement and innovation by encouraging experimentation, collaboration, and sharing of best practices among faculty and instructional support staff.
- p) Encourage faculty to explore emerging technologies, pedagogical approaches, and instructional strategies that can enhance the effectiveness and efficiency of blended learning.
- q) Allocate resources and support initiatives that promote innovation and excellence in blended learning across the institution.

By implementing these strategies, educational institutions can successfully integrate blended learning into their programs and courses, creating dynamic and engaging learning experiences that meet the diverse needs of students, faculty, and stakeholders while promoting student success and achievement.

6 Challenges and Considerations

While blended learning offers numerous benefits, it also presents various challenges that educational institutions, faculty, and students must address. Some of the common challenges are elaborated below-

6.1 Resistance to change

It is normal to have a fear of the unknown and resist changes. But once the individual becomes familiar with the new technology and recognizes the enormous benefits, this issue becomes immaterial. Faculty and institutional stakeholders may face resistance or reluctance to adopt and embrace new pedagogical approaches, technology integration, or changes in instructional roles and responsibilities. This resistance or reluctance is mostly because of faculties lack of experience, confidence or training in designing, delivering, and assessing blended learning experiences. Though, adjusting to new instructional pedagogies has always been tedious and challenging tasks that necessitate greater struggles (Akbulut, 2009) yet, it induces novelty in the arena of education and supports learners to involve in educational process. To overcome this resistance to change Institutions should offer professional development opportunities, training programs, and ongoing support to help faculty develop the knowledge, skills, and confidence needed to effectively implement blended learning in their courses.

6.2 Alignment of Goals and Methods

One of the challenges of blended learning is to ensure that the goals and methods of online and face-to-face components are aligned and coherent. This means that you need to have a clear vision of what you want your learners to achieve, and how the different modes of instruction will support that. You also need to consider the balance and integration of online and face-to-face activities, and how they will complement and reinforce each other. To avoid confusion and inconsistency, you should use a common framework and language to design and communicate your blended learning plan.

6.3 Technological Constraints

Inadequate access to technology, digital literacy skills, and technical support may hinder students' ability to fully engage with online learning materials and activities. Not having reliable, high-speed broadband available at home, it becomes difficult for some students to use a variety of software for learning. Limited data and bandwidth can also pose particular barriers for learners with disabilities. For example, learners with dyslexia, blindness, cerebral palsy, and other reading barriers, who typically utilize online resources to read accessible books and supplemental educational materials at school, lose access to the digital books they depend on for learning without adequate data or bandwidth at home. Additional barriers exist for learners who are deaf or hard of hearing who need to simultaneously stream videos of virtual instruction alongside interpreters, requiring smooth, reliable video transmissions to understand the lesson and fully participate. Special arrangements need to be done by the institute for such students and solve this issue.

6.4 Reliability and Accessibility of Technology and Infrastructure

Proper care must be taken to choose the appropriate tools and platforms that suit the specific learning objectives, content, and audience. Also need to test and troubleshoot your technology before and during the course, and provide technical support and guidance to your learners and instructors. You should also be prepared for any contingencies or emergencies that may disrupt your blended learning course, such as power outages, network failures, or health crises.

6.5 Engagement and motivation

Another challenge of blended learning is to keep your learners engaged and motivated throughout the course. This can be difficult, especially when learners have different preferences, backgrounds, and levels of readiness for online learning. Students may face distractions, feelings of isolation, or difficulty managing their time effectively. To overcome this challenge, as a faculty, you need to design your blended learning course in a way that appeals to different learning styles, provides feedback and support, and creates a sense of community and collaboration. You also need to monitor your learners' progress and participation, and intervene when necessary to address any issues or concerns. This can help keep students motivated and focused.

6.6 Assessment and evaluation

A fourth challenge of blended learning is to design and implement effective assessment and evaluation strategies that measure your learners' outcomes and satisfaction. This means that you need to align your assessment and evaluation methods with your learning goals and methods, and use a variety of tools and techniques to collect and analyze data. You also need to provide timely and constructive feedback to your learners and instructors, and use the results to improve your blended learning course. You should also consider the ethical and legal implications of collecting and storing data online, and ensure that you protect your learners' privacy and rights.

6.7 Professional development and support

A fifth challenge of blended learning is to provide adequate professional development and support to your instructors and staff who are involved in the design and delivery of the course. This means that you need to train and mentor your instructors and staff on how to use the technology, design the content, facilitate the interactions, and manage the course. You also need to create a culture of collaboration and innovation, and encourage your instructors and staff to share their experiences, challenges, and best practices. You should also recognize and reward their efforts and achievements.

6.8 Quality assurance and accreditation

A sixth challenge of blended learning is to ensure that your course meets the quality standards and accreditation requirements of your institution, sector, or industry. This means that you need to follow the policies and procedures that govern your educational context, and demonstrate that your course meets the expectations and criteria of your stakeholders. You also need to seek feedback and input from your learners, instructors, staff, peers, and external reviewers, and use them to enhance your course quality. You should also document and showcase your course design, delivery, and outcomes, and share them with your community.

7 Conclusion

Blended learning offers a dynamic and adaptable approach to education, combining traditional and online elements to enhance student engagement, personalize learning experiences, and improve outcomes. Technology allows for active learning, collaboration, and flexibility, potentially transforming teaching and learning across diverse contexts. However, successful implementation requires strategic planning, faculty development, robust technological infrastructure, and ongoing support. Overcoming challenges like digital equity, student motivation, and faculty training is crucial to unlock the full potential of blended learning for student success and educational innovation. Moving forward, continuous research, collaboration, and strategic implementation are essential to ensure this approach benefits all learners in a supportive and inclusive learning environment.

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**INVENTION AND INNOVATION - SUSTAINABLE
ENVIRONMENT/ SUSTAINABLE CONSTRUCTION/ WASTE
MANAGEMENT**

ICSD 031

**THE IMPACT OF THE WORK ENVIRONMENT ON EMPLOYEES'
MENTAL SATISFACTION IN GREEN AND NON – GREEN
APPAREL FACTORIES IN SRI LANKA**

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Abstract: The establishment of green apparel buildings is an efficient method of minimizing the negative impacts of industrial development. As a result of the insufficient knowledge of potential benefits and disadvantages, apparel factories in Sri Lanka are not likely to take on a green approach. This study aims to identify the factors that affect employees' mental satisfaction in the industry as well as the impact on environmental benefits, employee perception and performance, and economic impact through Indoor Environmental Quality (IEQ) and its maintenance cost to the apparel factory. A mixed approach was used for the study. A green factory building, and a non-green factory building were selected as the sample for the study. Using questionnaires, data was collected from 90 randomly selected apparel sector employees from both factories. In addition, semi-structured interviews were conducted with fifteen professionals in the green building construction and apparel industry. The results demonstrated that the environment and the company's employees benefit from the green apparel industry. Green apparel buildings provide employees with improved lighting, fresh air, cosy surroundings, and stunning natural views. Employee productivity, mental satisfaction, and health are all improved. Employees of non-green buildings are not benefited by IEQ; rather, it can be developed psychologically by promoting worker productivity and quality of work. Maintenance cost can be varied through different IEQ. The expenses are closely related to how much attention is put on various design components, demonstrating a sophisticated strategy for balancing the project's architectural demands with its financial constraints. Understanding the limitations of green and non-green factories is necessary for achieving a balance that enhances employee productivity and well-being in the apparel industry. Green apparel buildings are required to improve brand equity and lower employee turnover and absenteeism rates by improving strategies which can enhance productivity through awareness programs regarding the green building concept.

Keywords: IEQ; Employees' mental satisfaction; Green apparel buildings; Non – green apparel building; Maintenance cost; Productivity

1. Introduction

Under the sustainability idea, various organizations are concerned about the application of environmental planning to manage the gap between limitless human needs and limited resources (Abeyrathna, 2021). A green building is a building that is meant to be efficient in the consumption of natural resources while saving energy, decreasing detrimental environmental effect, and increasing user quality of life (Rupasinghe, 2019). In Sri Lanka's construction sector, the concept of green building developed recently by enhancing the IEQ and green buildings can have a greater impact on the health and productivity of the people within it (KGAS Waidyasekara, 2012). Nowadays most of the building constructions are done according to the green concept and many Sri Lankan green buildings have achieved the certification of awards, according to the Environmental Classification Systems for green buildings. When moving towards sustainable construction, a developing country like Sri Lanka has numerous obstacles (Kaizer, 2020). Although green buildings have been proposed to improve health and productivity by creating satisfying and comfortable interior environments, further research is needed to verify the contentions (Zhonghua Gou, 2012). Based on previous studies, the goal of this study is to evaluate the effects of green building practices on green motivation, mental satisfaction, and sustainable performance; explore the effects of green motivation and job satisfaction on sustainability performance; and investigate the mediating role of green motivation and job satisfaction on the relationship between green human resource management practices and sustainability (Hany Hosny Abdelhamied, 2023). This study is intended with a focus on sustainability to explore the advantages and challenges of using green building techniques and to identify options for overcoming challenges that may be affecting employees' mental health. Followings are the objectives,

- I. Identify the factors of green buildings that affect the mental satisfaction of employees of the apparel sector in Sri Lanka.
- II. Analyzing the factors, that affect the mental satisfaction of employees in apparel factories to productivity enhancement.
- III. Identify the impact of maintenance costs involved in Indoor Environmental Quality of the green apparel buildings in Sri Lanka.
- IV. Propose recommendations to enhance the mental satisfaction of employees.

2. Literature Review

This literature review focuses on Employees' mental satisfaction, identifying research problems and factors influencing the process. It will find the relationships among indoor environment, human comfort, and performance, and include a discussion on sustainable development, focusing on sustainable green factory buildings and their values through increasing building employee comfort, health, and productivity.

2.1 Overview of sustainable construction practices in Sri Lanka.

Sustainable development is the process of achieving current requirements without compromising the capacity of future generations to meet their own needs. Sustainable development ties together awareness of the carrying capacity of natural systems with the social challenges facing humanity. Environmental, social, and economic factors are the three most crucial sustainability indicators (BAWP Bombugala, 2010). The concept of the "green economy," which is an organized strategy for sustainability, is where the term "green industry" originates. The green garment industry is considered by all environmentally friendly aspects. When compared with conventional industries, the green factory is less harmful to the environment. A green factory doesn't focus only on production. A green factory's top priorities are human health, safety, and environmental sustainability (Charles Hall, 2019). Studies have found physical differences between people working in environments with plants or natural views compared to those without them. When there is a view of nature at work, employees report suffering from headaches and other diseases with less frequency (McFarland, 2017). Behavioral environment, which is produced by interactions between people and their physical surroundings and includes control, privacy, and pressure, has an impact on psychological comfort (Divya Jain, 2023). Physical work place characteristics like lighting, temperature, the existence of windows, and free ventilation have a significant impact on employees'

attitudes, behaviors, satisfaction, performance, and productivity (Abeyrathna, 2021). Additionally, studies have found that employees who performed their duties in offices with windows or indoor plants experienced better levels of job satisfaction (McFarland, 2017). The main goal of "green factory building" is to reduce the overall negative impact on the environment, natural resources, and human well-being (Kaizer, 2020).

2.2 Relationship between comfort, satisfaction, and productivity

The relationship between productivity and environmental happiness is confirmed by plenty of studies. Physical characteristics can make a person feel satisfied or unsatisfied and might make it easier or harder for them to complete tasks at work (Woo, 2010). Healthy workplaces that promote employee health and well-being can be a goal in and of themselves, but they may also have intended or unforeseen effects on other objectives, including risk, costs, employee happiness, productivity, and corporate image. In contrast, values like the benefits of sustainability for health and happiness. Green buildings are supposed to be healthier than non-green buildings, because of its focus on the triple P of people, planet, and profit. Connections between healthy work environments and other values are much less studied (Rupasinghe, 2019). Green garment manufacturers provide a safe working environment, higher internal environmental standards, and a comfortable working environment. Interior designers of green garment manufacturing facilities consider maximum natural airflows (Kaizer, 2020). Since people have been spending more time indoors recently, IEQ is receiving more attention (Woo, 2010). The acoustic conditions, air quality, architectural details, controllability, ergonomics, lighting conditions, maintenance, Odor, space planning, thermal conditions, and ventilation qualities are several IEQ elements of the designed workplace environment (Rana Elnaklah, 2020). Psychological factors can have an impact on how people feel about the environment. In this process, people make subjective and intuitive average judgments about their environment. As a multifaceted concept, job satisfaction is generally considered to include employee perceptions of both external and internal job elements. Some factors that contribute to job satisfaction are rewards, payment, work environment, advancement opportunities, guidance, organizational procedures, and relationships with coworkers (Chandrasekara, 2019). Improved IAQ may increase occupant satisfaction and perceived productivity, according to several post-occupancy studies (Rana Elnaklah, 2020). The relationship between office design and a few indicators of business performance defined in terms of individual performance and team effectiveness has received the most attention in research on the relationships between IEQ and worker satisfaction and, to a lesser extent, workplace performance. The success of green environmental planning depends on the development of healthy working environments, maintaining ideal temperatures, setting up pleasant and stress-free working environments, and resource utilization (Zhonghua Gou, 2012). The current study's goal is to determine the effects of having green areas at work on employee satisfaction with work, general quality of job characteristics, and psychological factors. This study's hypothesis is that people who spend more time in natural or environment settings throughout the period of the workday, or who have windows looking out into greenery or live Plants in their office, will score higher on assesses of mental health, quality of life, and job satisfaction. In general, productivity can rise when people react to a more favourable work environment (Woo, 2010). Although some studies show a strong relationship between green buildings and improved occupant satisfaction, others showed a poor or no relationship (Ayşe Müge Öz, 2015).

2.3 Maintenance and the Indoor Environment Quality

The concept of "green building" concentrates on the design and construction of buildings that use resources more efficiently, as well as on reducing and avoiding negative effects and creating a more comfortable and healthier environment for people. As a result, green buildings are distinguished from non-green buildings by their specific focus on maintaining human health, the environment, and resources around the building lifecycle (Rupasinghe, 2019). Comfort in the environment includes psychological, physiological, and physical aspects. Physical comfort increases psychological and physiological comfort and is a necessary condition for environmental comfort. Physical comfort encompasses building conveniences like access, maintenance, and service, as well as building safety and health codes,

standards, and norms (Woo, 2010). The IEQ elements that are related to maintenance, Odor, thermal comfort, ventilation qualities, air quality, acoustics, and lighting, both artificial and daylighting have an impact on the well-being of the employees (Young Ki Kim, 2022). Workplace efficiency appears to be influenced by a multitude of interrelated factors, especially physical settings such as office layout and environmental comfort. Investing in the design, construction, and maintenance of the built environment to improve working conditions may be the most economical way to increase productivity because recruiting employees is significantly more costly than maintaining and operating buildings (Woo, 2010). Measuring maintenance performance involves not only doing quality work but also making sure that the work effectively reduces the chance of a plant, piece of equipment, or facility failing. The difference between the planned and actual costs of maintenance is referred to as a deviation in the maintenance budget. A larger discrepancy shows poor decision-making, which results in ineffective maintenance performance (Dananjaya Wijesinghe, 2018). To meet this challenge, the apparel industry has been implementing several strategies, including total productive maintenance and lean manufacturing (Rupasinghe, 2019). Green Apparel factory remains cooler because of the vegetation. When the trees grow and the green carpet expands, shading of the building and grounds will keep the building, on average, 1 to 2°C colder. Because endemic and adapted species were chosen, less watering and maintenance are needed. Additionally, rare, endangered, and medicinal species were planted. The building's green roofs are home to a variety of local grass and a few medicinal herbs. This vegetation needs minimal maintenance. No drop of water that enters the site is lost without offering some benefit (Foundation, 2009).

3. Research Methodology

A questionnaire survey and semi-structured interviews were used to collect data in both qualitative and quantitative methods to meet the goals of the study. The information given in this study was in a sample of two Kurunegala apparel factory buildings, one of which was "Green", and the other was "Conventional". A qualitative data study approach was used to explore the research questions. Qualitative research helps to understand a phenomenon's significance.

3.1 Conceptual Framework

As indicated in Figure 1, this research study defines the features in work environment and the Employees' mental satisfaction of green and non – green apparel factories in Sri Lanka. The following variables are specifically mentioned in this study:

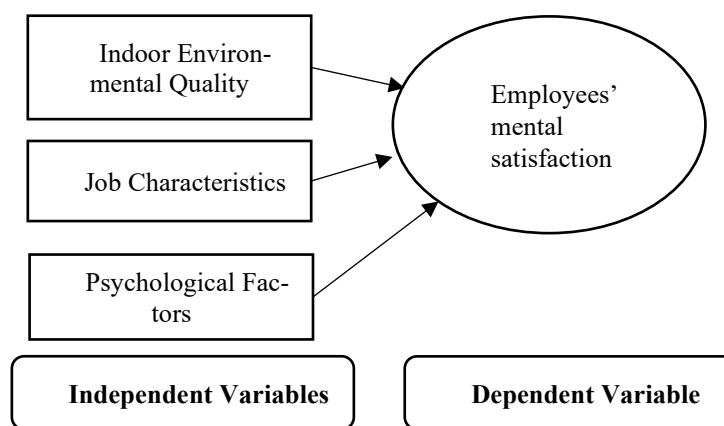


Figure 1: Conceptual Framework.

3.2 Data collection

The questionnaire was reflecting to collect data to identify the relationship and the impact between the independent variables, the specified factors in the work environment that derives the employees' mental

satisfaction and the dependent variable, identified, and developed during the literature review. The questionnaire was distributed among the employees who were directly involved in the apparel industry. All the questionnaires were distributed through Google forms and the language was Sinhala. The questionnaire was distributed online, which saved time, zero paper wastage, and improved the efficacy and efficiency of the responses. The semi-structured interview was conducted to collect comprehensive data, for this study, a semi-structured interview with open-ended questions was used. The participants came from different backgrounds and had varying levels of information and knowledge. To acquire relevant responses, it was necessary to change the format and language a little. This interview questionnaire was prepared as 6 questions. The first and second questions are prepared to investigate, the recommendations to enhance the mental satisfaction of Employees. The third and fourth questions, analyse the sustainable green building construction and the last two questions are to find out the challenges occur when implementing healthy work environment to enhance the mental satisfaction of employees in apparel sector in the Sri Lanka.

3.3 Data Analysis

To accomplish the objectives, the statistical analysis method was applied, and at the same time, responses obtained from the interview survey were expressed through content analysis to illustrate the connection between the features of the work environment and employees' mental satisfaction. During the interviews, the practicability of these variables for the Sri Lankan context was verified. The interviewees' opinions regarding the applicability and significance of the variables were verified, and this allowed the data collection and analysis process to proceed. The quantitative data from the questionnaire's closed-ended questions was analysed statistically using SPSS software, and the qualitative data from the questionnaire's open-ended questions and semi-structured interviews was analysed using a content-analysing technique with frequency tables (Freihoefer, 2012). The correlation analysis was used to establish the relationship between the study's independent and dependent variables. To confirm the relationship between the independent variables and dependent variable, analysed data from a questionnaire survey in Likert scale format using SPSS software. The influence or impact between the dependent and independent variables was evaluated using regression analysis. This was done to figure out which independent variable affects the dependent variable the most. Using SPSS software, the same set of data that was obtained through a questionnaire and used for the correlation analysis was examined in the regression analysis.

Where,

- Y = The dependent Variable
- X_i = The independent variable
- a = Constant
- B_i = Unstandardized Coefficient B value
- St. e = Unstandardized Coefficient Std. Error Value

$$Y = a + \beta_i X_i + St. e$$

Figure 2: Linear Regression.

The content analysis method was used to analyse qualitative data from literature reviews and semi-structured interviews. The data which was extracted via the responses to the open-ended questions which were included in questionnaire survey was also analysed through this analysis.

4. Discussion

Considering the frequencies and the percentage of the respondents' results were gathered, majority of respondents were Machine Operators with a percentage of 32.20% and 20% of employees who are working administrative based, 16.7% of other employees including senior level and the minor level, 14.40% of sewing machine operators, 7.80% of supervisors, 5.60% of the shear operators and with the least percentage 3.30% of completion operators.

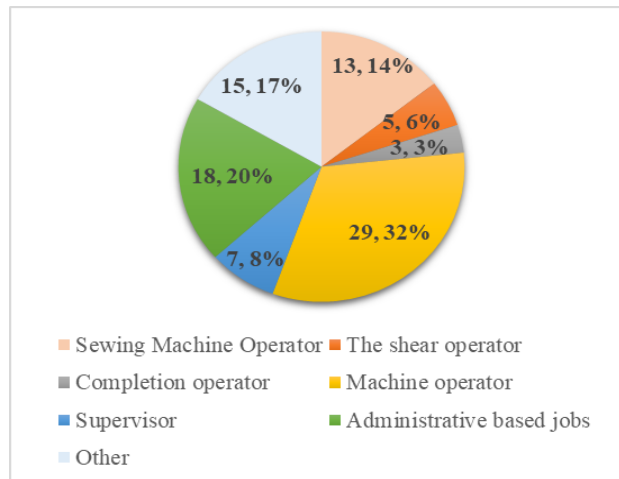


Figure 3: Respondents Summary of Questionnaire Survey.

Purposive sampling was used to select experts and experienced professionals from the targeted population for the semi-structured interview because it fully reflects the accomplishment of the third and fourth objectives. Based on the results of the Pearson correlation calculation using the statistical software SPSS, it was obvious that there was a relationship between the indoor environmental Quality, Job characteristics, psychological factors, and employees' mental satisfaction in green apparel building. When the significance level is less than 0.05, it means that the relationships between those variables are meaningful.

Correlations					
		AIE	AJC	AIV	ADV
AIE	Pearson Correlation	1	.731**	.603**	.584**
	Sig. (2-tailed)		<.001	<.001	<.001
	N	69	69	69	69
AJC	Pearson Correlation	.731**	1	.573**	.663**
	Sig. (2-tailed)	<.001		<.001	<.001
	N	69	69	69	69
AIV	Pearson Correlation	.603**	.573**	1	.478**
	Sig. (2-tailed)	<.001	<.001		<.001
	N	69	69	69	69
ADV	Pearson Correlation	.584**	.663**	.478**	1
	Sig. (2-tailed)	<.001	<.001	<.001	
	N	69	69	69	69
** Correlation is significant at the 0.01 level (2-tailed).					

Figure 4: Correlation analysis of Independent and Dependent variables in green apparel factory.

Based on the results of the Pearson correlation calculation using the statistical software SPSS, it was obvious that there was a relationship between the Job characteristics, psychological factors and employees' mental satisfaction in non - green apparel building. When the significance level is less than 0.05, it means that the relationships between those variables are meaningful except indoor environmental quality,

Correlations					
		AIE	AJC	AIV	ADV
AIE	Pearson Correlation	1	.420**	.275*	.277*
	Sig. (2-tailed)		<.001	0.022	0.021
	N	69	69	69	69
AJC	Pearson Correlation	.420**	1	0.219	.400**
	Sig. (2-tailed)	<.001		0.071	<.001
	N	69	69	69	69
AIV	Pearson Correlation	.275*	0.219	1	.554**
	Sig. (2-tailed)	0.022	0.071		<.001
	N	69	69	69	69
ADV	Pearson Correlation	.277*	.400**	.554**	1
	Sig. (2-tailed)	0.021	<.001	<.001	
	N	69	69	69	69

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Figure 5: Correlation analysis of Independent and Dependent variables in non- green apparel factory.

The impact of each identified factor on employees' mental satisfaction of the apparel sector was tested using regression analysis, and the numerical results obtained using SPSS software show that each identified factor has a significant impact on dependent variable.

Coefficient						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error			
1	(Constant)	0.628	0.404		1.552	0.126
	AIE	0.186	0.15	0.174	1.238	0.22
	AJC	0.52	0.148	0.479	3.499	<.001
	AIV	0.094	0.112	0.099	0.843	0.403

a. Dependent Variable: ADV

Figure 6: Regression Analysis of Green Apparel Building.

With a beta value of 0.520 and a variance of 52.0%, job characteristics and employees' mental satisfaction of the green apparel factory building are positively correlated.

Coefficient						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error			
1	(Constant)	0.843	0.433		1.948	0.056
	AIE	0.026	0.115	0.025	0.229	0.819
	AJC	0.287	0.109	0.283	2.632	0.011
	AIV	0.445	0.093	0.486	4.783	<.001

a. Dependent Variable: ADV

Figure 7: Regression Analysis of Non - Green Apparel Building.

The beta value of 0.445 indicates a 44.5% variance between the employees' mental satisfaction of the non- green apparel building and the psychological factors, providing further evidence of a positive relationship between both.

That the precise architectural design of the building determines the fixed costs or cost ranges for components like thermal comfort, acoustic quality, interior environmental quality, spatial comfort, and visual comfort. The expenses are closely related to how much attention is put on various design components, demonstrating a sophisticated strategy for balancing the project's architectural demands with its financial constraints. Regarding indoor environmental quality, thermal comfort, acoustic quality, spatial comfort, and visual comfort, the client's budget determines fixed costs or cost ranges. Designers or the project team's capacity to pinpoint cost factors depends on their ability to fully comprehend the design, considering the building's features, aesthetics, and structural elements. With the constraints set by the client, this information serves as the foundation for providing knowledgeable insights into the related financial considerations.

The maintenance cost of a green building compared to a normal building allocates 20% + budget. Encouraging employees to adopt more sustainable practices requires a multi-faceted approach. Following strategies are the most favorable options which have identified through the interviews,

- a) Fostering a culture of sustainability within the organization through clear communication of environmental goals and values is crucial.
- b) Education and training programs on sustainable practices equips employees with the knowledge and tools needed to integrate eco-friendly habits into their daily routines.
- c) Incentivizing sustainable behavior, such as through recognition programs, rewards, or competitions, can motivate employees to actively participate.
- d) Involving employees in decision-making processes related to sustainability initiatives and seeking their input can create a sense of ownership and engagement, making the adoption of sustainable practices more likely to succeed.

5. Conclusion

The results showed that all existing relationships between the dependent variable employee mental satisfaction and the independent variables, indoor environmental quality, job characteristics, and psychological factors were interpreted as significant positive linear relationships with higher level of intensity with both factories but the statistical analysis highlights the important effect that the work environment has on indoor environmental quality and job characteristics, which in consequently impacts employees' mental satisfaction. Although green buildings greatly enhance appropriate environmental factors, non-green buildings typically do not have these elements, which negatively affects employee mental satisfaction.

However, the study finds that non-green buildings may have more developed psychological factors related to work performance and the high quality of work. Limitations in implementing sustainable practices into practice could unintentionally create environments in non-green factories that encourage the development of certain psychological factors linked to output quality and work performance. Finding solutions to close the gap between green and non-green factories and achieving a balance that combines the best features of both strategies to improve overall employee productivity and well-being in the apparel industry requires an understanding of these limitations.

6. Recommendations

This study covered several aspects related to indoor environmental quality which will be beneficial to the green aspects. Therefore, the following recommendations will assist in implementing those systems in the Sri Lankan apparel industry to minimize waste. The future growth of the green apparel factories is mostly dependent upon the combined efforts of manufacturers, purchasers, legislators, and the government, which must play a strong supportive role. High-quality building components are necessary to achieve sustainable building and improve building performance. In the rainy season, for example, it can save heat energy by increasing the air impermeability of your windows; to lower interior noise, require good sound insulation. Better performing windows are therefore required, which will raise the initial cost. In this situation, clients consider good cost performance rather than sustainability. It is a fact that

small businesses can only implement fundamentals. Measures for building development, but the only companies with enough capital are large ones to consider the development of green buildings. As a result, actions must be taken to raise stakeholders' awareness of sustainability from small businesses; it is their duty to develop a mature green building market and to spread awareness of and interest in green building.

7. Further Research Directions

Based on research, the maintenance cost of indoor environmental quality (IEQ) in green apparel buildings has become a variable factor in the Sri Lankan context. The ongoing maintenance costs associated with maintaining these standards can vary, even though green apparel buildings prioritize sustainability and offer superior IEQ through features like improved air quality, natural lighting, and ergonomic designs. By regular monitoring, inspection and the maintenance schedules can uphold the IEQ in green apparel building. The long-term maintenance costs required to sustain these environmental standards. According to the statistical data analysis, Indoor environmental quality and the job characteristics have greater impact to the green building employees' mental satisfaction than non-green building employees, but psychological factors show a greater impact on non-green building employees. Based on that, the green concept has certain limitations, it's positive but when applied it can be negative. Future research should evaluate the performance of green buildings across various counties using a variety of classifications. While there are several obstacles to overcome in the implementation of green building, green building has a great potential to reduce greenhouse gas emissions and energy use.

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ICSD 043

**INVESTIGATING THE PRACTICALITY OF GREEN ROOF AS A HEAT
MITIGATING TOOL FOR URBAN CONTEXT IN
SRI LANKA**

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Abstract: Over the past few decades, there has been a significant acceleration of global warming. The land that was once moist and had permeable layers has changed due to increased global warming. The result of this change is the phenomenon known as the Urban Heat Island (UHI), which is defined as higher temperatures in cities than in their rural surroundings. The UHI effect is primarily caused by the widespread use of artificial, heat-absorbing materials in urban structures, which have replaced the natural greenery that was formerly present with large expanses of concrete. Alternative solutions are becoming more and more popular as traditional green spaces in urban landscapes become less and less in number. Notably, using green roofs has become more popular as a long-term solution to reduce the heat island effect in many countries. In the urban setting of Sri Lanka, this paper investigates the viability of using green roofs as a heat mitigation technique. The study combines expert interviews conducted in a semi-structured manner with surveys of the literature, all of which are qualitatively analyzed. The results clearly show the impact of the global warming and UHI effect on increasement of urban temperature and how beneficial green roofs are at lowering that effect and energy efficiency compared to other buildings. It also revealed that the practicality of green roofs in reducing surface temperature and heat island intensity in urban areas. Additionally, the study highlights significant obstacles such as high initial cost, maintenance problems, un-wareness, environmental barriers to Sri Lanka's adoption of green roofs and provides suggestions for resolving these issues. The scenario that has been envisioned highlights the practicality of green roofs as an effective means of mitigating urban heat in Sri Lanka.

Keywords: Global warming; Green roof; Practicality; Urban heat island effect; Sri Lanka

1. Introduction

In many parts of the world, the average temperature and exposure to direct heat are already rising due to global climate change. The effects of global climate change will have an impact on people's living and working conditions and pose health risks to millions of people. Due to heat absorption in concrete structures and tar-sealed roads, modern urban development can also raise local temperatures by several degrees (Tord Kjellstrom et al., 2009). According to the temperature analysis of Scientists of National Aeronautics and Space Administration's (NASA) Goddard institute for space studies average global temperature is increased by 1.1° Celsius since 1880 (Administration, 2010). International Panel on climate change (IPCC) collected data on climatic observations across the world and evidence warming of global climate is unequivocal. Current projection estimates that the increase of global climate at the end of this century will 1.8°-4° Celsius (Bharwani, 2011). Heat stress in urban areas is increasing during heat waves, which are predicted to become more frequent and intense with increase of greenhouse gases (Petra M. Klein, Reid Coffman, 2015).

Climatic changes may cause increases the surface temperature in Sri Lanka that are more rapid than the rate of global warming. In Sri Lanka, according to high emissions scenario, annual mean temperature of Sri Lanka is projected to rise by about 3.7°C on average from 1900 to 2100 (Climate and Health Country Profile, 2015).

A significant and expanding component of Green Infrastructures is green roofs. Green roofs have been around for a very long time. The Hanging Gardens of Babylon circa 500 BC, Mesopotamian ziggurats, and early Roman architecture are some of the oldest examples (Berardi et al., 2014b). The thermal effects of green roofs on the urban environment are another widely used argument to promote their implementation (Eleftheria Alexandri, Phil Jones, 2006). Urban vegetation plays an important role in sustainable development and mitigates urban heat islands (Bowler et al., 2010).

The Followings are the objectives of the research.

1. Identifying the impact of the global warming and urban island effect on increasement of urban temperature.
2. To assess the practicality of green roofs in reducing surface temperatures and heat island intensity in urban areas.
3. Identify the Practicality of Green Roofs Considering Energy Consumption and Reduction in Cooling Demand on Urban Buildings in Sri Lanka.
4. What are the barriers for not implementing green roof as an energy saving method in Sri Lanka.

2. Literature Review

A. Global Warming

The fundamental principle of global warming can be understood by considering the energy of radiation from the sun that warms the surface of the Earth and the thermal radiation from the Earth and atmosphere that is radiated out of space (Houghton, 2005).

The greenhouse effect is a crucial aspect of global warming, where solar radiation absorbs at Earth's surface and is absorbed by the atmosphere, causing infrared radiation to be radiated away. This heat is retained by atmospheric gases, similar to glass in a greenhouse, allowing heat to enter but restricting its exit. This effect raises Earth's temperature, enabling life to thrive. (Khasnis & Nettleman, 2005). Greenhouse gases (GHGs), including carbon dioxide, methane, nitrous oxides, and chloro-

fluorocarbons (CFCs), have exhibited a significant increase over the past century, primarily as a consequence of rapid industrialization (Khan et al., 2015).

The most immediate and visible effect of global warming is an increase in global temperatures (Awanthi & Navaratne, 2018). According to the World Health Organization, the warming and precipitation trends attributed to anthropogenic climate change over the past three decades have resulted in an annual loss of more than 150,000 lives (Patz et al., 2005).

The last few decades' worth of historical meteorological records demonstrate how human-caused emissions are affecting the world's climate. By the end of this century, the IPCC predicts that the global temperature is projected to have increased by 1.4 °C to 5.8 °C (Husain & Chaudhary, 2008). By the end of this century, it was predicted by many climate models that, with the current rates of population growth and GHG (Green House Gases) emissions, earth surface temperatures will rise by 1.6 to 5.8°C (Awanthi & Navaratne, 2018).

Between 1990 and 2011, Sri Lanka's greenhouse gas (GHG) emissions witnessed a 43% increase, with an average annual growth rate of 2% (Gao et al., 2014). Sri Lanka's air temperature has increased nationwide over the past 100 years. In recent decades, the warming trend has accelerated (Senaratne et al., 2009).

In Sri Lanka, statistical data indicate that Carbon Dioxide (CO₂) emissions in Sri Lanka exhibited a notable escalation from 2,658.58kt in 1965 to 18,393.67kt in 2014, growing at an average annual rate of 4.61%. Sri Lanka CO₂ emission intensity in 2018 was 0.09 tons per 1000-dollar G.D.P. CO₂ emission per capita of Sri Lanka tremendously increase from 0.53 metric tons (MT) in 1999 to 1.14 metric tons in 2018 (Wadanambi et al., 2020).

B. Urban Heat Island Effect

The Urban Heat Island (UHI) effect is a heat buildup caused by urban development and human activity, affecting the flow of materials and energy within urban ecological systems, affecting urban climates, hydrologic situations, soil properties, atmospheric environment, material cycles, biological habits, energy metabolism, and health. (Yang et al., 2016).

The UN predicts 66% of the world's population will live in urban cities by 2050, causing both positive and negative impacts on people and the environment, including urban heat islands (UHI) caused by urban landscape changes, population growth, and resource loss (Ranagalage et al., 2017).

It has a substantial impact on reducing outdoor and indoor air quality, thermal comfort, and healthiness of city citizens and occupiers, as well as raising building energy consumption (Herath et al., 2018). Predicting the influence of UHI on future internal and outdoor air temperatures aids in the development of novel approaches and regulations for the design and retrofit of current and proposed buildings (Mirzaei, 2015).

The most well-documented effect of UHI is a large rise in highest and worldwide electricity demand for HVAC (Heating, Ventilation and Air-conditioning) systems, as well as a considerable decline in air conditioning system performance (Akbari et al., 2016). Urban heat islands (UHI) are rising in Asia's rapidly expanding cities as a result of a reduction in green space in the metropolis, especially in recent decades (Maheng et al. 2019).

Due to its detrimental impact on urban ecological environment and the overall livability of cities, the UHI phenomenon has become a major research focus in various interrelated disciplines, including urban climatology, urban ecology, urban planning and urban geography (Estoque, Murayama, and Myint 2017).

C. Effect of the UHI in Sri Lanka

Sri Lanka is an Island nation with finite resources. Despite this, Sri Lanka holds the distinction of being the fifth least urbanized nation during the period spanning 1995 to 2017. As a developing nation with constrained land resources, it is very important to study the UHI situation in other areas in Sri Lanka also (Manoj & Arachchi, 2022).

Sri Lanka's largest commercial city faces challenges due to rapid urbanization, including urban warming and increased energy consumption, with the Urban Heat Island effect significantly impacting climate and energy patterns (Perera and Langappuli 2013). Based on the effects of extreme weather events and the socioeconomic losses they generate, Sri Lanka's sensitivity to climate change risks earned it a ranking of sixth in the Global Climate Risk Index 2020 (Irfeey et al., 2021). The rate of the annual temperature increase for the 1916-2015 period was in the order of 0.009°C per annual in Sri Lanka. The value was 0.008°C/per year for the wet zone, and the trend value for the Intermediate Zone was 0.009°C/per year. The effects of global warming and the El-Nio phenomenon may be one of the factors causing Sri Lanka's temperature to rise and urban heat to increase (Meegahakotuwa, Rekha Nianthi, 2018).

D. UHI Mitigation Methods

One of the results of growing urbanization is the UHI, and numerous mitigation strategies have been investigated and put out by earlier academics. Enhanced vegetation cover, implementation of green roofs, cool roofs, cool pavements, and adoption of smart growth by preserving the environment in urban areas are only a few of the mitigation strategies that have been suggested. Green infrastructure is one of the proposed mitigation solutions that is simple to deploy in cities (Planning for a Cooler Future, 2014). Green cover reduces the air temperature (Gaffin et al., 2006a) and decrease the surface temperature in urban areas (Hien Wong et al., 2003).

UHI mitigation techniques include surface lighting, enhanced tree planting, and living roof/ Green roofs construction (Gaffin et al., 2006b). Cities are becoming warmer and more prone to severe heat events due to the built environment, which includes structures like buildings and roads that absorb sunlight and radiate heat, as well as less vegetation that would normally provide shade and contain cooling moisture (Corburn, 2009). By adding more street trees, green walls, and green roofs, urban surroundings and climate can benefit from natural ecosystems (Harris & Coutts, 2011).

Another frequently discussed strategy, arguably one of the most pivotal, is urban greening, encompassing the introduction, upkeep, or enhancement of green spaces within urban areas. The potential for adapting to and reducing the effects of UHI that implementation of green roofs, cool roofs, and cool pavements have, Additionally, the implications of urban design and geometry (Rajagopalan et al., 2014).

There are eight mitigation methods mentioned as high albedo roofing materials, high albedo pavements, the proliferation green vegetation, incorporation of shade trees, pervious pavements, water bodies, urban planning and adoption of green roof (Nuruzzaman, 2015) and green roofs improve roof insulation, lessen the cooling demand on buildings in the summer, and maintain relatively cool outdoor air temperatures close to them and the extensive green roof is simpler to maintain, less expensive, and lighter than the intense green roof, it is relatively more frequently used as a thermal equipment (Aleksandrowicz et al. 2017).

Sri Lanka, a developing nation, offers greater opportunities than other engineering solutions to apply nature-based solutions for UHI mitigation. Urban built-up areas need to be converted into urban blue-green spaces. Therefore, management of urban green-blue spaces must be taken into regard (Ranagalage et al., 2020).

E. Green Roof

Roof gardens, forerunners of modern green roofs, have a long history. The Semiramis hanging gardens in what is now Syria were the first roof gardens that were ever recorded. It stands as the seven wonders of ancient world (Oberndorfer et al., 2007). One strategy to combat global climate change is to build green structures, and regulations for smart development will be essential in the future to reduce greenhouse gas (GHG) emissions. Green roofing is a common concept in green building (Irfey et al., 2011).

They are a strategy that can improve the urban thermal environment and reduce the cooling energy use. Although there is a limited amount of space for on-ground greening of urban areas, urban vegetation is proven to be efficient for lowering temperatures through transpiration (Hirano et al., 2019). A building's roof can be transformed into green by incorporating a layer of plants or other greenery over a waterproofing membrane (Kumar et al., 2021).

A green roof's surface temperature is 15 °C cooler than a typical roof's (Karachaliou et al., 2016) green roof can bring down the temperature of the urban surface by 3–6 °C (Önder & Akay, 2016). The reduction in heat might be 25% of the basic scenario if the area's buildings' roofs were covered with 75% greenery. 15% of the base case is attainable with 50% vegetation added to the surfaces, whereas only 8% of the base case heat reduction is possible with 25% greenery added (Dwivedi & Mohan, 2018).

There are some positive externalities of green roof also as mitigate urban heat island effect, purifying air and absorbing noise (Chinas' Agenda 21, 1994). They can lower the thermal burden on the rooms below by limiting the heat flux through the roof itself and potential for a green roof to reduce a building's cooling and heating load (Takakura et al., 2000).

F. Types of Green Roof and Technical Side

A growing media and vegetation can partially or completely cover a waterproofing membrane on a green or living roof. Green roofs come in two primary categories: There are two categories of roofs: dense roofs system, which are heavier and may sustain tiny trees and bushes, and extensive roofs, which are lighter and are covered in a minimal vegetation cover of flora (Santamouris, 2014). These clarifications mentioned as also intensive roofs and extensive roofs (Peng & Jim, 2013).

Intensive green roofs are typically designed as roof gardens featuring a substantial substrate depth (greater than 15-20 cm), a variety of plants species (comparable to landscapes at ground-level), significant water retention capacity (over 50%), high capital expenditures and considerable heavy weight (180-500 kg/m²). When the slope is less than 10 degrees, this type is typically built. The selection of the plants can exhibit more diversity because of the deeper soil, including tiny trees, bushes and shrubs (Cascone, 2019).

In contrast to intensive green roofs, extensive green roofs feature a shallow substrate layer depth (less than 15 cm) and are lighter overall. Due to the thin substrate layer, only a few species of plants, such as grasses, mosses, and a few succulents, may be grown on wide rooftops. When compared to intensive roofs, extensive roofing systems have a lower initial investment, maintenance costs, and water requirements (Czemiel Berndtsson, 2010).

Green roofs have a number of layers that shield the support and enhance system functionality. The vegetation, growing medium (substrate), filter layer, and drainage layer are among them (van der Meulen 2019). From bottom to top, a green roof typically comprises of numerous elements and They are substrate (growth medium or soil), anti-root barrier, a protective layer, a layer that stores and drains water, a layer that filters, and vegetation plants (Vijayaraghavan, 2016).

G. Thermal Performances and effectiveness on reducing urban temperature of green roof

3. Methodology

A. Research Approach

The research explores the practicality of green roofs as a heat mitigating tool in Sri Lanka's urban context, focusing on their effectiveness in reducing surface temperature, heat island intensity, thermal performances, and energy consumption, while identifying key barriers to their implementation as an energy-saving method.

B. Data Collection

All the objectives of this study were covered through semi-structured interviews and literature review and research conducted as qualitative research.

The semi-structured interviews were held by experts to get a useful response. There were twelve expert interviews conducted with experienced and expert green building professionals.

C. Data Analysis

Data analysis for qualitative research should apply rigorous, systematic approaches and usually entails content analysis. Interview data was recorded, and content analysis was used to examine it.

4. Discussion

The analysis of expert opinions provides a comprehensive understanding of the factors contributing to global warming and the subsequent increase in urban temperatures in Sri Lanka. The consensus among professionals underscores the urgency of addressing the impacts of global warming and the UHI effect on urban temperature rise. This not only validates the research objective of identifying the impact of global warming and the UHI effect but also emphasizes the critical need for proactive measures to mitigate these effects for the well-being of both local and global communities.

The interviews revealed a varying level of awareness among respondents regarding green roofs as a heat-mitigating tool. While most respondents demonstrated a commendable level of awareness, there was a notable opportunity to enhance understanding among those with a normal awareness level and to educate a small portion of respondents lacking awareness. This emphasizes the importance of targeted educational initiatives to promote the use of green roofs as an efficient solution for heat mitigation in industrial settings.

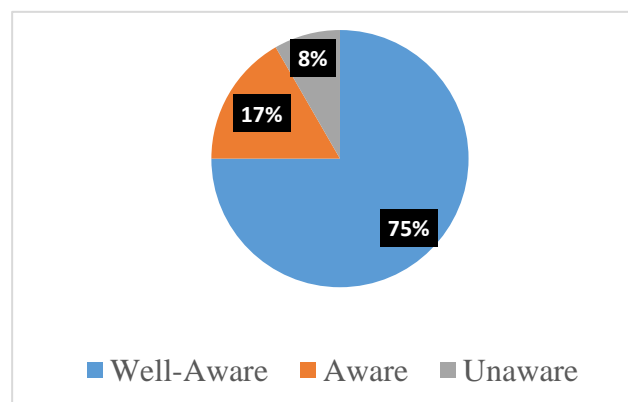


Figure 1: Awareness of the Green Roof as a Heat Mitigating Tool.

The opinions expressed by interviewees further corroborated the potential of green roofs. The green roofs are highly effective in reducing atmospheric and urban heat. The specifically highlighted studies indicate that green roofs can reduce surface temperatures by up to two to three degrees Celsius, contingent on factors such as vegetation type, substrate depth, and irrigation systems.

However, the predominant use of green roofs in Sri Lanka is more for architectural appearance and human comfort than as a heat-mitigating tool. This reflects a gap in awareness and utilization of green roofs for their full potential. Nevertheless, the practicality of green roofs, emphasizes the need for public education to overcome adoption challenges.

By practical experiences, particularly regarding a hotel in Sri Lanka, they provided valuable insights. The comparison of indoor temperatures with green roofs and vertical greenery demonstrated a significant difference of 1.5 to 2 degrees Celsius, affirming the cooling effects of green roofs. The practicality of green roofs in Sri Lanka's tropical climate, emphasizes their efficacy in mitigating heat due to direct sunlight exposure on building roofs.

The resounding endorsement of green roofs as the "best solution" by some interviewees, who cited temperature reductions of 3 to 5 degrees Celsius inside buildings, further supports the research objective. However, it is noteworthy that a more cautious perspective, considering the practical side and cost-effectiveness of green roofs is less feasible.

In conclusion, the analysis of literature and interview data collectively supports the research objective, indicating that green roofs hold practical potential in reducing atmospheric temperature and heat island intensity in urban areas. The varied perspectives underscore the need for targeted education, addressing adoption challenges, and optimizing green roof design and implementation for effective heat mitigation.

The exploration of energy-saving and heat-mitigating methods commonly employed in Sri Lanka, as revealed through the perspectives of various experts, provides valuable insights for understanding the practicality of green roofs in urban contexts. The methods mentioned encompass both active and passive approaches, ranging from traditional architectural techniques to modern technologies. The use of mechanical methods like air conditioning and ventilators, as well as passive methods such as building orientation, introduced innovative practices like cool roofs, urban greening, and reflective materials.

Architectural considerations, as emphasized play a crucial role in energy efficiency, with conceptual drawings focused on optimizing building orientation to minimize solar radiation. Additionally, the significance of sustainable materials and design features like cantilevers to mitigate heat and provided practical evidence from a hotel setting, showcasing the integration of natural ventilation and greenery for energy savings. When it comes to the energy consumption of green roofs, the experts' views align on the positive impact of green roofs in reducing energy consumption and cooling demand. The clear reduction of 10% to 15% in energy consumption compared to conventional buildings. The sentiment is that green roofs can save up to 20% on energy consumption, attributing this to the temperature-regulating properties of green roofs. Practical examples from hotels and apartments demonstrated tangible energy savings ranging from 10% to 30%.

The practicality of using green roofs in urban contexts in Sri Lanka emerged as a nuanced topic. While many experts expressed that a positive stance on the practicality of green roofs, others raised concerns. They also cited challenges in retrofitting existing buildings with common roofs and structural considerations, suggesting that promoting green roofs may be more practical for new constructions. Some highlighted water supply challenges in urban areas and differences in practicality depending on building types. The popularity of green roofs but identified barriers to widespread adoption in Sri Lanka's construction industry.

They further emphasized through the experiences shared regarding the successful implementation of green roofs in a hotel setting, proving its viability with proper planning and feasibility studies. The reiterated that practicality hinges on proper planning, knowledge, and professional engagement. In conclusion, the analysis of energy-saving methods, the energy consumption of green roofs, and the practicality of implementing green roofs in urban contexts in Sri Lanka collectively supports the research objective. The insights from various experts underscore the potential for green roofs to contribute significantly to energy efficiency and cooling demand reduction in urban buildings in Sri Lanka, provided that challenges are addressed through proper planning and professional expertise.

The investigation into the barriers for not implementing green roofs as an energy-saving method in Sri Lanka reveals a multifaceted challenge. The predominant barrier, highlighted by various interviewees, is the high initial cost associated with the implementation of green roofs. This financial challenge, cited by 66.6% of the respondents, encompasses construction and material costs. The deterrent effect of high capital costs, with offering a practical example from a hotel where leakages occurred after two decades, adding to maintenance costs.

Another critical barrier, expressed by 91.6% of the interviewees, is the lack of knowledge and awareness regarding green roofs. The insufficient understanding of installation techniques, potential risks such as water leakage, and a general lack of awareness about the benefits of green roofs. These barrier to a knowledge gap among professionals like architects and quantity surveyors, emphasizing the need for industry development.

Maintenance challenges stand out as a significant barrier, impacting 50% of the respondents. Concerns about the difficulty of maintaining green roofs, especially in the busy urban lifestyle of Sri Lanka. Additionally, the reluctance stemming from potential side effects such as insect breeding due to increased biodiversity, contributing to maintenance challenges. Environmental and climate barriers are acknowledged by 25% of the interviewees, particular. The tropical climate of Sri Lanka, characterized by high temperatures and humidity, presents challenges for plant selection and careful maintenance of green roofs. Cultural preferences and aesthetic considerations are highlighted as factors influencing the reluctance to adopt green roofs. Public interest and space constraints emerge as barriers, affecting 16.6% of the respondents. The lack of interest among people due to unawareness, limited space in plot areas, financial constraints, and a general reluctance to embrace new concepts.

In summary, the barriers against implementing green roofs in Sri Lanka are interconnected and diverse, ranging from financial concerns and lack of knowledge to maintenance challenges and environmental factors. The identified key barriers, supported by the perspectives of various experts, provide a comprehensive understanding of the obstacles hindering the widespread adoption of green roofs as an energy-saving method in Sri Lanka.

5. Conclusion

This study investigates the practicality of green roofs as heat mitigating tools in Sri Lanka's urban context. It uses literature survey and semi-structured interviews to gather data and analyze objectives. The research aims to identify the effectiveness, energy efficiency, and reduction of energy consumption of green roofs in Sri Lankan urban contexts. The study also identifies barriers to their implementation and uses content analysis to present these findings.

The study examines the impact of global warming and urban heat island effect on Sri Lanka's urban climate, highlighting their interdependence and the need for immediate action and long-term solutions to address rising temperatures, thereby enhancing the Sri Lanka's urban climate.

The study aims to explore the practicality of green roofs in reducing urban temperatures and heat island intensity. Through literature surveys and semi-structured interviews, the research reveals the ef-

fectiveness of green roofs in reducing temperature and mitigating the UHI effect in other regions. Experts also discuss practical examples and thermal performances of green roofs. The overwhelming consensus among survey respondents affirms green roofs' applicability as a workable and efficient technique for reducing urban temperatures and lowering heat island effects. The study uses semi-structured expert interviews and literature surveys to explore the practicality of using green roofs in Sri Lanka's urban areas. It highlights the potential of green roofs as a sustainable and effective tool for mitigating heat and enhancing energy efficiency. The interviews and real-world examples support the practicality of green roofs in Sri Lankan urban contexts. The study also found that other energy-saving methods can achieve higher energy consumption with green roof buildings.

Otherwise identify barriers to implementing green roofs as an energy-saving method in Sri Lanka. Through data analysis, major barriers identified include lack of awareness, knowledge, maintenance, environmental and climate issues, and public interest. The key barriers are presented as percentages. The research study focuses on investigating the practicality of green roofs as a heat-mitigating tool in the urban context of Sri Lanka. The findings highlight that a lack of awareness about green roofs within the community is a significant barrier to implementation. Professionals in the construction industry, including engineers and architects, emphasize the need to improve awareness to overcome these obstacles.

Recommendations to promote green roofs in Sri Lanka include government intervention, such as initiating programs that provide technical knowledge and financial assistance, along with incentives like tax breaks. The establishment of proper guidelines and standards for green roof projects, coupled with the development of training programs for industry professionals, is also recommended. These measures aim to enhance knowledge, provide financial support, and create a conducive regulatory environment to facilitate the adoption of green roofs. All these recommendations revealed through expert interviews.

The research acknowledges its limitations, such as a reliance on qualitative analysis based on expert opinions and a limited dataset due to the relatively uncommon nature of green roofs in Sri Lanka. Future research directions include exploring quantitative measurements of energy reduction, applying value management for enhanced energy efficiency, overcoming identified barriers, conducting cost-benefit analyses through case studies, and innovating materials to address the high initial costs of green roof installation. Overall, the study emphasizes the potential of green roofs as a sustainable construction approach to mitigate urban heat issues in Sri Lanka.

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ICSD 083

TRANSPORT OF DISSOLVED CONTAMINANT IN TEXTURALLY HETEROGENEOUS POROUS MEDIA

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Abstract: Around 80% of the rural domestic water demand in Sri Lanka is catered by groundwater, a highly sensitive element in the environment which has been increasingly affected by strong anthropogenic interference. The intrusion of saltwater into freshwater aquifers, migration of agrochemicals and fertilizers in agricultural subsurface, dissolved contaminants released from chemical industries, leachate from landfills, and leaks from fuel stations are among several potential sources of groundwater contamination. The fate and transport of such dissolved contaminants to groundwater are affected by the properties of the soil and other porous domains, including the textural heterogeneity of the porous media. Therefore, remedial measures to constrain groundwater transport of such contaminants require a thorough understanding of the control of textural heterogeneity on dissolved contaminant migration. This study investigated the transport of NaCl, used as a dissolved model contaminant, in physically heterogeneous porous media. Two clean sands with distinct particle size distributions, along with a series of mixtures thereof, were used to mimic the physical heterogeneity of the porous domains. The differently textured porous materials were packed into a two-dimensional experimental setup, and a continuous source of dissolved 0.01M NaCl was applied at the top of the tank to investigate the transport behaviour. A colour dye was used to trace the dissolved contaminant transport pathway throughout the experimental domain. The results showed a pronounced effect of soil textural heterogeneity on dissolved contaminant migration, as controlled by the change in pore size distribution. These findings also provide practical implications for designing an engineered filter bed for the effective removal of dissolved contaminants.

Keywords: Groundwater contamination; Dissolved contaminants; Physical heterogeneity; Soil texture; Transport pathways

1. Introduction

Throughout history, groundwater has been a crucial source of water supply, especially for rural and suburban populations in Sri Lanka. However, the increasing demands, inefficient utilization, and contamination pose significant threats to groundwater resources. Various sources of pollution ranging from agricultural runoff, industrial discharges, and leachate from landfills to sewage leaks, mining activities and urban runoff introduce a diverse array of contaminants. Contamination of groundwater, in particular, poses significant challenges due to the movement of dissolved contaminants through soil and porous materials is intricately influenced by the geological and hydrological characteristics of the aquifer. These contaminants often mimic the natural flow patterns of groundwater, leading to the formation of concentrated plumes. The size, speed and direction of these plumes are determined by various factors including contaminant type and solubility, groundwater characteristics, and environmental conditions.

Therefore, to effectively address pollution prevention or remediation, it is important to comprehend the dynamics of contaminant migration. The variability of soil properties in the subsurface hampers groundwater remediation efforts, highlighting the need for a thorough understanding of how textural heterogeneity affects the movement of dissolved contaminants (Guo et al., 2019). Various laboratory and field experimental studies have been carried out to dissect the complexities of subsurface environments efficiently. Numerous investigations have been conducted to explore the impact of layered heterogeneous porous media on contaminant migration. Characterizing the diverse textures of porous media and analysing differences in the volumetric compositions of these media are crucial steps for advancing engineering and research applications (Huang, Toride and Van Genuchten, 1995). However, there is a lack of comprehensive data on the migration patterns of contaminants in heterogeneous granular mixtures. This hinders our ability to establish functional relationships that could inform more effective pollution control and remediation techniques.

This study investigates the effect of soil textural heterogeneity on dissolved contaminant migration dynamics, as controlled by selected binary granular mixtures. The insights gained from the study will be instrumental in designing engineered granular filter beds tailored for the effective removal of dissolved contaminants and developing practical solutions for improving groundwater quality.

2. Experimental Methodology

Two widely available and distinctively contrasting sand types were selected to prepare four different coarse to fine binary sand mixtures to mimic the physical heterogeneity of the porous domain. The physical properties of the two sand types that were used are given below.

Table 1: Physical properties of the fine sand and coarse sand.

Sand type	Average particle diameter (mm)	Bulk density (g/cm ³)	Particle density (g/cm ³)
Coarse Sand	0.95	1.65	2.65
Fine Sand	0.18	1.84	2.65

In addition to the two-component sands, mass-weighted fractions of each component were uniformly mixed to produce two different coarse-to-fine (C: F) mixtures: 100:0, 50:50, 30:70, 0:100. The physical properties of the binary mixtures are given in Table 2.

Table 2: Physical properties of the binary mixtures.

No.	Binary Mixtures	Average particle diameter (mm)	Bulk density (g/cm ³)	Total Porosity (cm ³ cm ⁻³)
01	C100:F0	0.95	1.65	0.377
02	C50:C50	0.50	1.95	0.262
03	C30:F70	0.25	2.00	0.247
04	C0:F100	0.18	1.84	0.305

The experiments were carried out in a medium-sized, two-dimensional tank constructed from 8mm thick plexiglass, ensuring transparency and watertightness through precise glueing. The tank's external measurements were set at 0.5m in length, 0.2m in width, and 0.3m in height. Following the methodology recommended by Gibert et al. (2012), the mixtures were carefully placed inside the tank using a wet-packing approach, with a consistent focus on maintaining energy uniformity throughout the process.

Sodium Chloride with a concentration of 0.01M was injected at the top-mid surface which consisted of a 12cm gravel-packed layer (Figure 1). The solution was colour-dyed to observe the migration pathways at different time intervals. The experiments were conducted for 48 to as long as 72 hours, depending on the migration patterns.

Samples, each measuring 10ml, were extracted from the sample points at different time intervals to measure the electrical conductivity and to estimate the concentration. The contaminant concentration was expressed by assuming the following implicit analogy.

$$\frac{C(t)}{C_0} = \frac{EC(t)}{EC_0} \quad \text{---} \quad \frac{C(t)}{C_0} = \frac{EC(t)}{EC_0} \quad (1)$$

where C (mols) and C₀ (mols) are NaCl concentrations of the solution at time t and t₀ (t=0), respectively, while EC (mS/m) and EC₀ (mS/m) are the corresponding values for electrical conductivity (Porro, Wierenga and Hills, 1993).

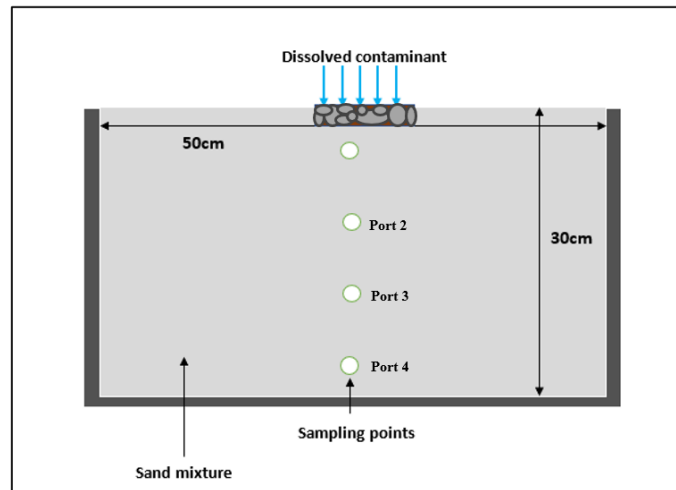


Figure 1: Schematic of the experimental setup.

3. Results and Discussion

A uniform and concentric migration pattern can be observed around the source point of the C0:F100 binary mixture system which is illustrated in Figure 2. The slow and steady migration is predominantly governed by diffusion, which is characteristic of fine-textured soils with smaller pores.

The delayed and sudden increase in relative concentration depicted by Figure 3 could suggest, that while the overall movement is slow, there may be micro-heterogeneities within the fine sand like small-scale variations in soil physical and chemical properties.

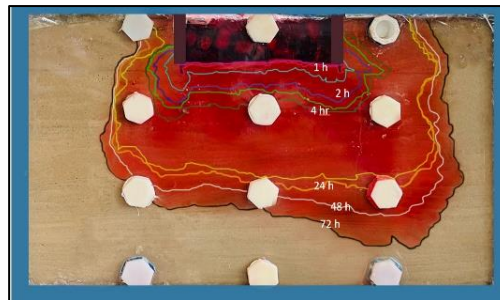


Figure 2: Contaminant flow path of C0:F100.

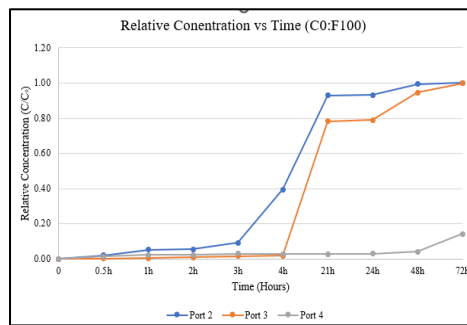


Figure 3: Measured C/C_0 vs Time for C0:F100

Figure 4 illustrates the migration pattern observed in C100:F0 binary mixture system which is more extensive, and irregular compared to the fine sand medium. The irregular shape of the spread suggests the presence of preferential paths. The larger and more connected pore spaces in coarse sand allow for rapid advection and development of preferential flow paths. This behaviour is reflected in the variable concentration trends over time in the graph depicted in Figure 5. (Tang et al., 2021).

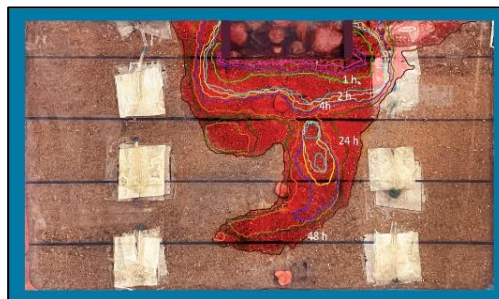


Figure 4: Contaminant flow path of C100:F0.

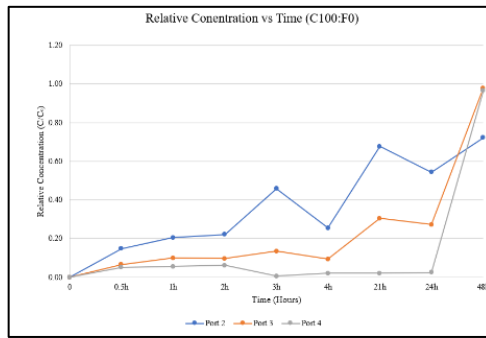


Figure 5: Measured C/C_0 vs Time for C100:F0

Figure 6 illustrates the migration pattern observed in the C50:F50 binary mixture system. This balanced mix creates a soil with intermediate textural heterogeneity resulting in varying migration patterns. The spread is uneven, with some areas showing a greater extent of movement. The graph given in Figure 7, exhibits a gradual increase, suggesting a slower migration pattern at first, followed by a steep increase, which may indicate that the contaminant encountering larger pores or a network of connected pores. It shows a gradual growth in concentration in port 4, suggesting a mix of preferential flow and diffusion.



Figure 6: Contaminant flow path of C50:F50

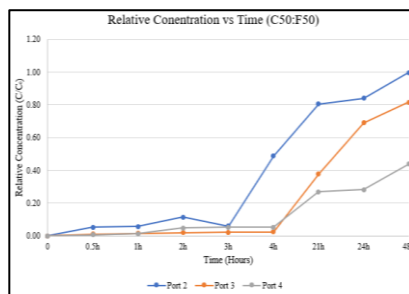


Figure 7: Measured C/C_0 vs Time for C50:F50

Figure 8 illustrates the contaminant migration in the C30:F70 binary mixture system, which exhibits a moderately heterogeneous texture that influences the dispersion of the dissolved contaminant. The tracer dye reflects a more restrained and controlled spread.

Samples from Port 2, as shown in Figure 9, reveal a steady increase in contaminant concentration over time, suggesting a consistent and moderated flow within the medium. This phenomenon is likely due to the combined influence of both fine and coarse sand particles, which modulate the migration speed and prevent rapid breakthroughs (Huang, Toride and van Genuchten,

1995). Meanwhile, the concentration at Port 3 remains relatively flat, indicating that the contaminant transport towards this port is significantly slower.

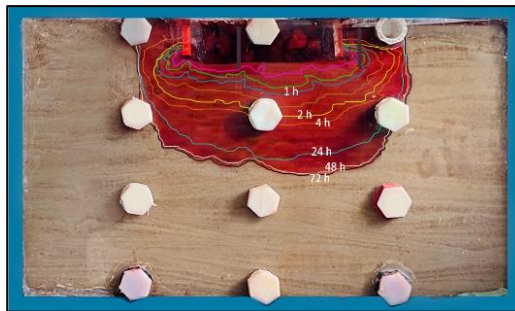


Figure 8: Contaminant flow path of C30:F70.

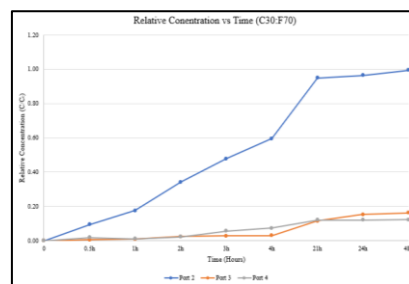


Figure 9: Measured C/C_0 vs Time for C30:F70

The experimental results have delineated the impact of soil textural heterogeneity on the migration of the dissolved contaminant. The transport behaviour varied significantly across the different sand mixtures.

4. Conclusion

This study observed the migration of a dissolved model contaminant (NaCl) in a porous system comprising uniform mixtures of coarse (C) and fine (F) textured sand. The results obtained from the experiments with the binary sand mixtures (C100:F0, C50:F50, C30:F70, C0:F100) demonstrate the effect of soil textural heterogeneity on dissolved contaminant migration. The mixture C30:F70, with optimum packing and lowest porosity, showed more constrained contaminant movement, while C100:F0 and C50:F50 were characterized by preferential and fingering flow patterns, yielding rapid contaminant migration.

Therefore, the results provide implications for designing an engineered filter bed and offer valuable insight into the use of differently textured mixtures for the implementation of remedial measures for groundwater protection.

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ICSD 095

**A REVIEW ON CLIMATE CHANGE IMPACT ON GLOBAL SUPPLY CHAIN;
MITIGATION AND ADAPTATION**

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Abstract: The global supply chain refers to the interconnected network of organizations, processes, and resources involved in the production, distribution, and delivery of things and services on a worldwide scale. It encompasses the flow of materials, information, and finances across various stages, often spanning multiple countries and regions. Climate change such as extreme weather events impact on supply chains by disrupting transportation, uncertainties in market demand or shifting resource availability. These impacts can lead to supply chain vulnerabilities, increased costs, and potential delays in production and delivery. Mitigation involves efforts to reduce the causes of climate change, while adaptation involves adjusting systems to cope with the changes that are already happening. This review was conducted by referring 30 research articles on Google Scholar and Research Gate, between 2005 and 2023 to assure how climate change impacts on global supply chains and to indicate the mitigation and adaptation strategies for climate change on global supply chains. Companies are becoming more aware of the need of strategies to mitigate these risks, incorporating sustainable practices and resilience measures to address the challenges posed by climate change in supply chain. Also, this review assessed the measures that taken to adapt to the challenges and mitigate the negative consequences, providing insights into sustainable practices for the future. Companies responded with resilience strategies, emphasizing sustainability, renewable energy, and climate-resilient models. Urgent integration of climate considerations was crucial for long-term supply chain sustainability. This high-lighted climate change's profound impact on global supply chains, emphasizing the critical need for a dual strategy of mitigation through sustainability and adaptation via innovative risk management.

Keywords: Adaptation; Climate change; Global supply chains; Mitigation; Sustainability

1. Introduction

1.1 Climate Change

Climate change is defined as a change in the state of the climate that can be identified by changes in the mean or the variability of its properties which lasts for an extended period, typically decades or longer. Its multifaceted impacts show through changed ecosystems, economies, and societies which reshapes the environment and livelihoods. As per the studies of scientists about the effects of climate change, they have identified that the climate change is approaching faster than predicted which highlighted about an immediate action (Ghadge et al, 2019). Global warming has led to climate change, which is the widely recognized phenomenon. According to the analysis, all regions will see an increase in climate change in the upcoming decades with respect to the global warming and there will be more heat waves, longer warm seasons, and shorter cold seasons for every 1.5°C increase of global warming while heat extremes would more frequently surpass essential tolerance limits for agriculture and health with every 2°C increase of global warming which indirectly impact on the economy (IPCC, 2021).

1.2 The Global Supply Chain

The global supply chain remains a fundamental component of modern commerce. It represents a complex network of interconnected organizations, processes and resources spanning the globe that provide the fundamental foundation for international trade and economic growth which facilitating movement of goods and services across vast distances and varied landscapes. It covers the flow of materials, information and finance across borders and continents. If the process of supply chain disrupted by any reason, significant consequences such as decreases of productivity, supply shortages, increases of costs, customer dissatisfaction, quality issues and market instability will be resulted and also impacted on the person who directly or indirectly depend on the expected service or products. As an example, the disruptions of the COVID-19 pandemic on supply chain can be pointed out. It also evidenced by some of research. National lockdowns slowed or even temporarily stopped the flow of raw materials and finished goods even in 2022, which has negatively impacted production (Harapko, 2022). However, the global supply chain affects by both natural and anthropogenic activities (Katsaliaki et al., 2022).

In recent decades, the supply chain operations have become an interconnected system that span continents and transcend geopolitical borders due to the expansion of global trade networks, advances in transportation and communication technologies, and the establishment of multinational corporations. Because of that, companies have to conduct their operations which sensitive to climate change, in a more robust and vulnerable environment where institutional, resource-based supply chain and stakeholder views are critical to characterizing and understanding corporate strategic responses to a sustainability issue (Katsaliaki, Galetsi and Kumar, 2022).

1.3 Impact of Climate Change on Global Supply Chain

The impacts of climate change are significantly and widely affected for every stage of the supply chain process, which includes production, transportation, distribution and extraction of raw materials for consumption (Nam Yi Yun and M. Ali Ülkü, 2023). In today's global economy, supply chains look like complex webs and a failure of any single part can have widespread ripple effects. Therefore, quickly re-replacing a damaged supply chain has become a difficult task. According to the current scenario, almost every company is exposed to small and large risks (Lee, 2018) which highlights the need of risk management mainly in global supply chain.

Risk management involves identifying, assessing, adapting and mitigating threats and uncertainties that may affect an organization's objectives. Risk management strategies attempt to anticipate and ad-

dress various risks arising from factors such as market volatility, geopolitical instability and climate change in the context of global supply chains. Mitigation strategies include reducing greenhouse gas emissions, transitioning to more sustainable and environmentally friendly practices, and reducing the carbon footprint of supply chain activities. By reducing emissions and resource consumption, businesses can reduce their contribution to climate change. Cost savings, operational efficiencies and reputational benefits can also be achieved. Likewise, incorporating sustainability into supply chain operations creates new opportunities for innovation, change and value creation in an increasingly competitive market. However, mitigating the effects of climate change alone is not enough to ensure the long-term viability of global supply chains. In addition to those mitigation efforts, building resilience and establishing adaptation strategies to reduce risks associated with climate-related issues has become an essential task. Adaptation is the ability to anticipate, respond to and recover from the impacts of climate change, thereby enhancing the adaptive capacity and resilience of supply chain systems. This includes developing climate-resilient infrastructure, diversifying sourcing and distribution channels, strengthening supply chain collaboration and coordination, and developing emergency preparedness for extreme weather events and other disruptive scenarios. These climate change mitigation and adaptation policies currently in use may further affect business operations in a somewhat indirect way (Dasaklis and Pappis, 2013).

Given the above considerations, the primary objective of this research review is twofold. That is to assess the impacts of climate change and identify mitigation and adaptation strategies. Climate change impact assessment seeks to explain the various ways in which climate change affects supply chain dynamics, from operational disruptions to strategic decision-making processes. Efforts are made to investigate best practices and emerging trends in supply chain management through identification of mitigation and adaptation strategies.

2. Methodology

A comprehensive review technique was used to thoroughly analyse how climate change affects the global supply chain and study how the mitigation and adaptation process works. It began with a thorough search of multiple academic databases. It includes well-known sites such as Google Scholar, Science Direct and Research Gate. This extensive search used relevant keywords such as climate change, global supply chains, risk management, and sustainability. It helps to reveal a variety of studies, articles, and papers that having much insight into the topic. The search was limited to published research articles between 2005 and 2023 to ensure the correctness. The selected literature was gone through a screening process and it helps to determine its application and relationship between to the topic. The same way was conducted to ensure quality of the methodology employed, and the veracity of the results provided. After this careful examination, only the most significant, reliable, and pertinent research were included in the review process. The gathered information included a various topics related to global supply chains and climate change. They were combined and carefully analysed to identify recurring patterns, areas in need of additional study, and knowledge gaps. This comprehensive study offered a solid foundation for understanding the complex dynamics at play, which in turn formed the basis for the discussion and conclusions that followed. Additionally, the methodology employed in this study included the advantages and disadvantages of past researches. By using this strict scientific frame work, it is possible to investigate the mitigation and adaptation of climate change on the global supply chain. It contributes to the growing body of knowledge in this area of study by allowing us to fully understand the subject.

3. Results and Discussion

It has been estimated that more natural disasters, such as floods and droughts, would occur because of climate change. Consequently, companies need to think about how to modify their supply chains to cope with climate change. The study of Abbass et al., (2022), has been mentioned about need of consideration about the impacts, mitigation and adaptation, according to the sectors that suffer from climate change. Also, it revealed that growth in the economy and overall productivity are significantly

influenced by the climate and as a result of its impact, Environmental policymakers at the national and international levels are currently recognizing climate change to be of utmost importance. Hence, the global supply chain plays a crucial role in economy as it bridges the key factors in each sector. A review on “Managing climate change risks in global supply chains” by Ghadge et al., (2019), highlighted about the interest of companies on global supply chain. Due to increased public awareness, government initiatives, media coverage, and international events like the 2015 Paris Summit and other climate change conferences and workshops, companies are more inclined to engage in sustainable supply chain initiatives even in situations where organizational capabilities and resources are limited. The environmental and social sustainability of supply chains is impacted by the short-term and long-term effects of shortages, delays, and disruptions because to control the risk of climate change, the interference of human is not enough in some means.

Most of the time agriculture act as a foundation of supply chain process which affected by the climate change. Researchers have discovered that several parts of the world agricultural sectors would be impacted by global climate change. As an example, the crop production is highly vulnerable to the global temperature changing trends as raised temperatures will pose severe negative impacts on crop growth finally cause at the base of the supply chain (Reidsma et al. 2009). The significant effects of climate change on global supply chains in a variety of industries have been emphasized by numerous studies. Climate change has caused extreme weather events, such hurricanes, floods, and droughts, to occur more frequently and with greater intensity (Smith et al., 2020). These events disrupt transportation networks, damage infrastructure, and lead to supply chain disruptions, causing delays in production and distribution (Jones & Warner, 2018). Also, port facilities and coastal infrastructure are vital centres in international supply systems, and they are seriously threatened by sea level rise. Storm surges and coastal floods cause delays in cargo handling and port closures for maritime trade. Furthermore, sectors like manufacturing and agriculture that depend on water-intensive processes are impacted by changes in water supply brought on by climate change (Elco et al., 2023).

Temperature increases make storage conditions worse, which affects food quality and shelf life, increases waste, and raises the possibility of the growth of microorganisms, especially in humid environments (van der Spiegel et al., 2012). The results identified significant factors that affect the probability of food safety issues under climate change in erratic and harsh weather conditions, such as rising temperatures and heavy precipitation. This means that the world food supply chain is affected by climate change (Tirado et al., 2010).

As the effects of climate change intensify, the efficiency and effectiveness metrics used to assess supply chain performance show a downward trend. A long term planned response strategy and improved decision-making abilities are required due to the complex nature of transport energy infrastructure and the rising frequency and severity of climate related disasters. Sustainomics is one of a good framework and useful tools for incorporating adaptations to climate change into plans for sustainable development. (Munasinghe et al., 2010). Methodologies, ideas, and approaches that combine climate change mitigation with sustainable development provide a number of important benefits. The issues around climate change and sustainable development are closely related. Given the importance of these connections, it is surprising that the literatures on sustainable development and climate change have not been more closely interwoven.

To address the impacts of climate change on global supply chains, various mitigation strategies have been proposed. Enhancing supply chain visibility and risk management is crucial for identifying and mitigating climate related disruptions. Advanced technologies, such as IoT sensors and predictive analytics, enable real-time monitoring of supply chain operations, allowing companies to proactively respond to climate risks. Optimizing transportation routes and logistics operations can help reduce greenhouse gas emissions and enhance sustainability throughout the supply chain (Zhang et al., 2019). In addition to mitigation efforts, adaptation strategies are essential for building resilience to climate

change impacts. Diversifying sourcing and production locations can help mitigate the risk of climate related disruptions in specific regions (Lam et al., 2020). By spreading production facilities across different geographic areas, companies can reduce their vulnerability to localized climate impacts and ensure continuity of supply.

4. Conclusion

As a conclusion, this research highlights the serious and complex effects of climate change on international supply chains and stresses the pressing need for effective mitigation and adaptation plans. The vulnerabilities present in supply chains have been brought to light by our investigation; these vulnerabilities range from a rise in the frequency of extreme weather occurrences to problems with transportation and logistics networks. To minimize greenhouse gas emissions and stop additional environmental damage, mitigation measures must be thorough and proactive, involving cooperation between governments, businesses, and stakeholders.

In addition, adaption methods are very important to maintain supply chain operations and foster resilience in the face of changing climate patterns. This entails improving risk management procedures. It expands the range of sources and distribution options. It helps the process of making strategic decisions with incorporating climatic factors. It's very important to give an equal weight to adaptation and mitigation strategies, and stakeholders may lessen the negative impacts of climate change on international supply chains. It promotes a more resilient and sustainable future. But in order to successfully handle the problems that the climate change presents, these initiatives must be carried out quickly and completely.

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ICSD 098

DEVELOPING A PROPER NANO MATERIAL TO USE IN CUISINE CLAY POTTERIES

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Abstract: Along with the emergence of civilization the clay pottery industry has an immemorial antiquity as a basic village industry. Advantages of using clay for cooking wares are, it is an environmentally and eco-friendly material with minimum harm to the environment with special characteristics such as antibacterial properties, consisting of natural minerals, non-flammable, resistant to heat, mould and rust and artistic and functional value. However, using of nonstick metal cooking wares have become popular kitchen items due to their user friendliness. Nevertheless, using of nonstick metal cooking wares causes to hygienic problems in human beings due to removing or damaging of the inside nonstick coating and high cooking temperature. In the current scenario, using clay pottery causes the occurrence of food stickiness and clinging to the inner surface of the pottery and due to that reason, it needs to season the clay pottery before use for cooking. With the broaden usage of clay potteries for cooking purpose, the advancements are required by consumers for the user-friendly purpose such as nonstick property to prevention of food stickiness to the pot, even distribution of heat, cook meals without using oil or with less oil and it should be suitable to modern kitchens and satisfy the new generation than the existing clay potteries. Therefore, this study was implemented to identify the most appropriate mineral type to use as a nano material to collaborate with clay to prepare cooking clay potteries to avoid above obstacles. Field study and literature review were done to identify the commonly used and suitable clay type for cooking clay potteries and abundant suitable mineral type in Sri Lanka to develop as a nano material by investigating their properties. Collaborating the developed nano material with clay causes to increase the nonstick property including other necessary properties in clay potteries.

Keywords: Clay cooking ware; Metal; Mineral; Nano material; Nonstick property

1. Introduction

Along with the emergence of civilization the clay pottery industry has an immemorial antiquity as a basic village industry. Mostly these clay potteries are used as cooking wares and there are advantages in using them for cuisine purposes as clay is an environmentally friendly and eco-friendly material with minimum harm to the environment. Other special characteristics of clay potteries are antibacterial properties, consisting of natural minerals, non-flammable, resistant to heat, mould and rusts and it has artistic and functional value (Amboro *et al.*, 2022). However, with the busy schedule of people, currently the using of the nonstick metal cuisine utensils, pots and pans have become popular kitchen items due to their user friendliness. The most specific thing is a non-stick layer is coated in the inner surface of the pottery and Poly Tetra Fluoro Ethylene (PTFE) and Poly Fluoro Carbon polymer (PFC) polymers are used as non-stick coating materials (Ismaeili *et al.*, 2022). Metal cooking wares are made of different substances like aluminium, cast iron, copper, stainless steel, clay, stones, glass and many metal materials (Shamloo *et al.*, 2023). According to the International Agency for Research on Cancer (IARC) has been identified these nonstick chemicals as “possibly carcinogenic to humans.” (Bansal *et al.*, 2020). At the same time, among those metal materials aluminium is considered as a cheap material and due to that reason aluminium cuisine equipment shows a high prevalence all over the world (Ruengcharungpong *et al.*, 2019). Nevertheless, using non-Anodized or non-coated aluminium pots direct to many hygienic problems because of the discharging of aluminium metal ions and other material ions to the food when cooking (Amboro *et al.*, 2022).

In the current scenario, using clay pottery causes the occurrence of food stickiness and clinging to the inner surface of the pottery and due to that reason, it needs to season the clay pottery before use for cooking. With the broaden of the usage of clay potteries for cooking purpose, the advancements are required by consumers for the user-friendly purpose due to it should with nonstick property to prevent the food stickiness to the pot, easy to wash and clean, resistance to scratch, cost effective, even distribution of heat and save on fuel, reduces the cooking time, cooks tasty meals without using oil or with less oil, suitable to modern kitchens and satisfy the new generation than the existing clay potteries (Ruengcharungpong *et al.*, 2019). Therefore, the main objective of this research is to identify the most appropriate mineral type to use as a nano material to collaborate with clay to prepare cooking clay potteries to avoid above problems.

2. Literature Review

2.1 Occurrence of hygienic problems by using nonstick metal cooking wares

When considering nonstick metal cooking wares, Metal vessels are used as substrate pots and the inner surface of these vessels are coated with PTFE or PFC polymers as layer to produce non-stick cooking wares (Coyle, 2017). Teflon is the commonly used name for Poly Tetra Fluoro Ethylene (PTFE) which is used to make non-stick cooking wares. The special characteristics of these polymers are the anti-sticking ability, mechanical properties like strength and the shallow ignitability (Ismaeili *et al.*, 2022) and the major unfavourable characteristic is the weak abrasion resistance of these polymer coatings (Hatzikiriakos, 2012). Nonetheless the main disadvantage is, the PTFE layer starts to decline when the cuisine pot heats up to 260 °C and completely decays over 350°C (Ismaeili *et al.*, 2022). Also, ageing, cleaning for long time, rubbing and abrasions lead to remove or damage the non-stick layer. Hence the lifetime of the nonstick cuisine utensil depends on the existence of PTFE non-adherent film. Another thing is anti-sticking cooking wares are ideal only for very slight foods like meat slices, sausages, and egg. Though there is an anti-sticking layer in Teflon coating wares, food sticking occurs if used heavy food and it leads to damage to the nonstick film. Therefore, it is not suitable for cooking heavy foods for long time in the same cooking ware (Coyle, 2017).

With the heating during cooking, the PTFE layer starts to decay, and it emits minor toxic fumes. The increasing of the stove firing time during the cooking causes to increase the temperature of the non-stick cooking wear and then the overheating of the nonstick coating causes to breakdown the PTFE layer (Sajid & Ilyas, 2017). With the overheating dangerous chemical gases are emitted as toxic fumes (Sajid & Ilyas, 2017) and breathing of these poisonous fumes causes the flu called “Teflon Flu” in the human body (Coyle, 2017) and for severe problems in the respiratory system (Lee *et al.*, 1997). This “Teflon flu” also known as the “Polymer Fume Flu” and reveals many indications like fever, quivering, throat difficulties (Greenberg & Vearrier, 2015). Exposure to large amount of polymer fumes causes severe damages in lungs, body pains and heart pains (Shimizu *et al.*, 2012). With the increasing of the heat, 15 numbers of toxic and cancer-causing gases are emitted during the cooking. The inhalation and the deposition of these unfavorable gases lead to cancers, issues in infertility, testicles, liver, and pancreas in the human body (Bansal *et al.*, 2020).

PFAS is a poly and perfluoroalkyl substance which is used during the preparation of Teflon (Coyle, 2017). At the same time Perfluorooctanoic acid (PFOA) and perfluoro octane sulfonate (PFOS) are the widely searched constituents of PFAS. According to probes and analysis it was identified that 98% of the community in the tested case with accumulated PFAS in their body in different levels in the United States. These chemicals are completely artificial chemicals and the accumulation in human body for long periods of time, creates bad health effects. PFAS is nondegradable and remains in the environment. These chemicals are deposited in organisms and the concentration is gradually increased during the lifetime. This is called “bioaccumulation”. Then the bioaccumulated chemicals are transferred to the top-level organism through food chains and food webs and this incident causes “biomagnification” and severe health damages occur in life beings including humans (Geiger *et al.*, 2014). However, when considering metal utensils, the usage of anodized or coated aluminum pots reduces the releasing of metal ions to the food when cooking due to the layer generated by the anodizing or coating process inside the pot. However, it is not a permanent solution, because with aging those anodized or coated layers are damaged by abrasing and scratching and cause food poisoning and then to many health disorders. The discharging of metal ions to diet depends on the cooking time, temperature, PH level of the food and other material amounts when making the aluminum alloy cooking ware. There is a high possibility to migrate lead and arsenic into food from the aluminum alloy when damage to the coating (Amboro *et al.*, 2022).

Hence, considering all above issues the clay mineral has selected for the replacive and collaborative material instead of metals due the food poisoning is not occurred by reacting with clay surfaces, high enrichment of minerals, no chemical reactions and damaging of the nonstick layer which has been applied on the metal surface.

2.2 Clay and Clay Minerals

Clay is defined as a material that is generated in a natural way and it consists of fine grain size small particles. It appears plasticity property with the water availability which leads to more flexible to be shaped and molded and become harden during drying and firing. Clay consists of “phyllosilicate” called “sheet silicate” and those sheet silicate cause to the absence or presence of plasticity, hardness, organic materials and for other characterizations (Al-Ani & Sarapaa, 2008).

Generally, the clay crystal structure is getting hexagonal structure. Clay is deposited as horizontally leveled hexagonal sheets by connecting each plate by water. It means the water consists in between two sheets of clay plates as shown in the figure and these sheets can slip over each other and due to that it showed plastic property in wet conditions. Under this condition clay does not shows the elastic but plastic property which it holds the deformed shape (Bloomfield, 2016). According to the ISO Standard 4688:1996 the grain particle size less than 0.004 mm is considered as clay (Al-Ani & Sarapaa, 2008).

Phyllosilicate or sheet silicate and materials that generate the plasticity or hardening properties in the soil are considered as “clay minerals”. Clay minerals are geologically originated by ecological configurations of soil, oceanic and continental dispositions, geothermal waves due to earth heat, hydrothermal incidents like volcanic eruptions’ sedimentations and chemical weathering.

Mostly the clay minerals are generated through the chemical weathering process in association with rocks in the presence of air, water, and vapor. Formed clay minerals exist as silicate layers in the clay. Primary and secondary are the major clay and clay minerals accumulations modes. Deposition of the clay remainders at the same location that it was created called primary deposition. Secondary clay depositions occur by transporting clay from the originated location to another site through water flow and accumulate them as a new sediment. Wetlands and lakes are considered as secondary sedimented clay rich sites (Al-Ani & Sarapaa, 2008).

2.3 Nanotechnology in Clay

The word “nano” in the term nanotechnology, implies one part of a billionth (1×10^{-9}) (Poole & Owens, 2003). There is a special terminology combining with the word “nano” according to the British Standards Institute (BSI 2005), the United Kingdom Royal Society and the Royal Academy of Engineering. Nanoscale, Nanoscience, nanotechnology, nonmaterial, nanoparticle, nanocomposite, and nanostructure are the most essential vocabulary which is used in nano related experiments and activities (European Union, 2006).

When considering the importance of having a nanomaterial with collaboration with clay, it should be highly considered regarding the compatibility of each relevant material for each other when collaborating with clay. Therefore, structural modifications should be applied for the relevant combined material as necessary to maintain proper compatibility.

However, there are many advantages of using nano particles in mixing and binding clay mineral (Awasthi *et al.*, 2019) due to nano clay consists of exceptional performances in the characteristics and properties than its native raw states. They are non-toxicity, superior surface qualities such as nonstick property, increase the catalytic performance (Isaifan *et al.*, 2013), barrier and abrasion properties, higher tensile strength, low thermal expansion, very good processing properties (Nanographi, 2024), act as nano-adsorbent to absorb harmful materials (heavy metals, dyes, antibiotics, biocide compounds, and other organic chemicals), high removal efficiency and loading of harmful chemicals in water, Remedy the corrupted water and act as a property enhancer of effectiveness and efficiency for water refinement. According to above advantages clay nanoparticles are used in different applications such as chemistry and environment for development of new materials, food, pharmaceutical, water and metal adsorption treatments, Biomaterial, agrochemicals and consumer goods and cosmetics (Awasthi *et al.*, 2019).

2.4 Synthesize of Nano Particles

There are two main strategies of synthesizing the nano particles called “Top-Down” and “Bottom-Up”. Physical manipulations are applied under the “Top-Down” method to decrease the size of the material particles into nano scale. In the “Bottom-Up” approaches, chemical transformations methods are used to synthesize the large nano structure starting from atoms and molecules (Pahwa *et al.*, 2023). Nevertheless, the binding energy is a valuable factor, and it is calculated to find the adhesion properties of aggregates substrates during synthesizing the clay composites (Du & Zhu , 2019).

When generating a nucleus by combining two separate nucleons the system energy is decreased and the change of that energy is always getting negative value (Marmie & Sheldon,

2013). That changed negative energy value is called as the Binding Energy and it can be defined as “the negative value of intermolecular interaction energy” (Du & Zhu , 2019). In another way, binding energy is described as released energy when combining a molecule or atoms with another molecules or surfaces and it is affected by the following factors such as particle size, the structural arrangements, the oxidation state of the material, chemical properties, physical properties, geometrical factors, system electronic charge density, trepidations, and type of interactions between the substrates (Radnik *et al.*, 2003). When considering the relationship between particle size and binding energy there is an Inversely Proportional relationship (Isaifan *et al.*, 2013) as shown in below Eq. (1).

$$particle\ size \propto \frac{1}{Binding\ Energy} \quad (1)$$

Therefore, the nano size particles lead to high binding energy, and it leads to strong intermolecular interactions and to more steady system.

3. Methodology

The research methodology was implemented under three main steps. They are,

- Collecting Primary and Secondary Data
- Find out the physical and chemical properties of each clay type and clay minerals.
- Identify the suitable clay and mineral types to develop the nano material to apply for clay potteries.

3.1 Collecting Primary and Secondary Data

Primary data were collected through the clay pottery industry to identify the majorly use clay types to make cooking clay potteries. Caly pottery industries at Polwatta- Minuwangoda and Gampaha Weragula areas are physically visited to experience the current existing clay industry and information were collected from Panduwasnuwara, Kurunegala and Meerigama areas in Sri Lanka regarding the clay pottery industry.

Secondary data were collected through the literature survey to identify the abundant clay mineral types available in Sri Lanka

3.2 Find out the physical and chemical properties of each clay type and clay minerals.

Physical and chemical properties of each identified clay type and clay minerals were investigated through the literature survey.

4. Results and Discussion

According to the field surveys, the Red clay and the Ball clay types were identified as major clay types which use for making clay cooking wares. However Red clay type is the abundantly use clay type due to its wide availability. It was found that red clay is used to make both cooking wares such as “Etili”, “Mutti” and non-cooking wares such as milk pots, clay lamps, terracotta etc... In this research the cooking wares are mainly considered. According to Export Development Board Sri Lanka (2021) and Belghazdis & Hachem (2021) Montmorillonite, Bentonite, Kaolinite, Graphite, Silica Sand and Quartz are identified as abundantly available mineral types in Sri Lanka.

As per the literature survey below chemical and physical properties were found out as important values in identifying the process of most suitable mineral type to make nano material. they are chemical composition/formula, crystalline structure /system, specific gravity, melting point, boiling point, flash point, liquid limit, density, triple, shrinkage, porosity, compressive strength, water absorption, thermal properties- refractoriness, thermal shock resistance, thermal conductivity, mineralogical analysis, color, molecular weight, plastic limit, plasticity in-

dex, PH value, solubility, particle size, oil absorption, odor, hardness and loss of ignition. Table 1- 7 show the refereed values for each clay and clay mineral type.

Table 1: Physical and chemical properties of Red clay

Chemical Composition-Red Clay	Silica (SiO₂) 49.98, Calcium Oxide (CaO) 17.08 , Iron (III) Oxide (Fe₂O₃) 2.85 , Magnesium Oxide (MgO) 3.36 , Aluminum Oxide (Al₂O₃) 16.39 , Potassium Oxide (K₂O) 0.33 , Sodium Oxide (Na₂O) 0.11 , Loss on Ignition (L.O.I) 5.54 (wt%)
Melting Point	1250 °C
Density	1.8 gm/cc
Shrinkage	1.11%-1.71%
Porosity	0.2894
Compressive strength	0.1931
Water absorption	0.0523
Thermal Properties- refractoriness	1054 °C
Thermal Properties-thermal	9 cycles
Thermal Properties- thermal conductivity	2.3 W/m.K
Color	Red-brown color (depend on the percentage of Ferric oxide)

Table 2: Physical and chemical properties of Montmorillonite

Chemical Composition/Formula	Al₂(OH)₂Si₄O₁₀
Crystalline Structure /system	Tetrahedral, Octahedral
Specific gravity	1.7-2
Crystal class	Prismatic (2/m)
Melting Point	1750°C
Density	2-3g/cm ³
Color	Light Cream/Off white, Translucent
Molecular weight	202.185 g/mol
Mohs scale- hardness	1-2

Table 3: Physical and chemical properties of Bentonite

Chemical Composition	[(Si 8.0) (Al 3.02, Mg 0.50, Ca 0.06, Fe 0.18, Ti 0.02, Na 0.22) O₂₀(OH)₄]
Specific gravity	2.8
Melting Point	>1200 °C
Boiling Point	381.8°C at 760 mmHg
Flash Point	184.7°C
Liquid limit	4.1
Density	2.5
(M.D.D_ Maximum dry density)	17.70g/cc
Shrinkage	1.34%
Water absorption	25.1% (O.M.C Optimum moisture content)

Thermal Properties- refractoriness	1.503 (Refractive Index)
Thermal Properties- thermal conductivity	10800 μ s/cm ²
Color	Grey to white powder or lumps
Molecular weight	360.313756 g/mol
Plastic Limit	45%
Plasticity Index	365%
PH	7.4
Surface area	87.5m ² /g
Solubility	Not soluble in water, Bentonite is a rock formed of highly colloidal and plastic clays composed mainly of montmorillonite.
Vapor	4.93E-06 mmHg at 25°C

Table 4: Physical and chemical properties of Kaolinite

Chemical Composition	Al₂(OH)₄Si₂O₅
Crystalline Structure /system	Triclinic, Phyllosilicates
Specific gravity	2.0-3.0 g/mL @ 20°C
Melting Point	1760°C
Flash Point	Not flammable
Density	2.65 g/cm ³
Thermal Properties- refractoriness	1.62 (Refractive Index)
Color	Odorless white to yellowish or grayish powder
Molecular weight	258.16 g/mol
PH	6-7 (50g/l, H ₂ O, 20°C) (slurry)
Solubility	Practically insoluble in diethyl ether, ethanol (95%), water, other organic solvents, cold dilute acids, and solutions of alkali hydroxides.
Odor	No odor
Mohs scale- hardness	2-2.5

Table 5: Physical and chemical properties of Graphite

Chemical Composition	Carbon atoms (C_n)
Crystalline Structure /system	Hexagonal
Specific gravity	2.25
Crystal class	Dihexagonal dipyramidal
Melting Point	3652-3697 °C(lit.)
Boiling Point	4290 °C
Density	2.26 g/cm ³
Compressive strength	20 – 200 Mpa (75)
Color	Black to steel grey
Molecular weight	5.315 cm ³ /mol (formula weight-288.26)
PH	5-6 (50g/l, H ₂ O) 20°C)
Solubility	insoluble in H ₂ O

Mineral Type	Native mineral
Mohs scale- hardness	1-2

Table 6: Physical and chemical properties of Silica Sand

Chemical Composition	SiO₂ – 97.5-99.8%, Al₂O₃ – 0.05-2%, Fe₂O₃ – 0.02-0.05%
Specific gravity	0.88 g/ml
Cristal Structure	Transparent crystals or amorphous powder
Melting Point	1719 °C
Boiling Point	2230 °C
Flash Point	23°C
Density	2.65 g/cm ³
Water absorption	0.10%
Thermal Properties- refractoriness	1.193
Thermal Properties- thermal conductivity	7.2-13.6 W/Mk
Color	Blue, White crystal particles-(78)
Molecular weight	60.09
PH	pH of water suspension: 6.8-7.2, 7-9 (silane treated)
Surface area	0.3-6 m ² /g
Other (Solubility)	Insoluble in water
Particle size	2-90 μm
Oil absorption	14-28 g/100 g
Odor	Odorless
Loss of ignition	0.1-0.55 %

Table 7: Physical and chemical properties of Quartz

Chemical Composition/Formula	SiO₂
Crystalline Structure /system	Crystalline form of silica.
Specific gravity	2.2-2.6
Melting Point	1610 °C(lit.)
Boiling Point	2230 °C
Density	2.6 g/mL at 25 °C(lit.)
Thermal Properties- refractoriness	n ₂₀ /D 1.544(lit.)
Color	White
Molecular weight	60.08 (Formula weight)
PH	5-8 (400g/l, H ₂ O, 20°C) (slurry)
Solubility	Insoluble in H ₂ O, acid solutions; soluble in HF
Mineral Type	Igneous

According to these findings these are the main clay type, mineral types and important chemical and physical characteristics which use for identifying the proper mineral to create nano composite for clay cooking wares.

5. Conclusion

Montmorillonite is the best clay mineral type to collaborate with Red clay to make nano composite due to its properties and naturally available nano properties. Therefore, it causes to increase the nonstick property including other necessary properties in clay potteries as suitable to the modern kitchen.

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IMPLEMENTING EFFECTIVE ENVIRONMENT MANAGEMENT SYSTEM IN SELECTED SOAP AND FOOD MANUFACTURING COMPANY

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Abstract: Selling a good or service locally is no longer the only aspect of business; organizations must adopt a forward-thinking approach for national and international competitiveness. A key foundation for success lies in effective management systems, with environmental performance now surpassing financial metrics in the industrial sector. This shift is defined by the positive or negative changes in the environment, influenced by various environmental factors. Every facet of corporate operations, from product creation to marketing, is increasingly dedicated to assessing the environmental impact of decisions. Environment Management Systems (EMS), fortified by ISO 14001, offer businesses a platform to showcase environmental stewardship. The ISO 14001 standard provides a structured method for managing environmental issues, evolving into a widely embraced administrative tool for corporate environmental management. Its goal is the seamless integration of environmental improvement throughout a company's operations. The focus of a particular research is to explore the implementation of an Environmental Management System (EMS) based on ISO 14001 in a selected soap and food manufacturing company. The study delves into the current environmental management practices, identifying limitations and risks associated with EMS in the company's processes. Additionally, it assesses the perceptions of workers and management towards EMS. Methodologically, data collection involves interviews, observations, environment audits, and surveys among employees and top management. Analysis of the findings reveals that, despite the company's environmental concerns, a proper EMS is lacking, primarily due to the perceived high cost of obtaining certification by top management. This research serves as a practical guide for companies seeking to enhance their environmental stewardship and align with global sustainability goals. The study recommends raising industry awareness about the benefits of implementing EMS and obtaining ISO certification, emphasizing the importance of proactive environmental management systems in modern businesses.

Keywords: Environmental factors; Environmental impact; Environment management system; ISO 14001 standard; Environment audit; Sustainability

1. Introduction

1.1 Background of the study

Current population growth leads to the overconsumption of biological resources, outpacing the environment's ability to replenish. This results in a daily increase in natural resource depletion and a surge in waste disposal. The escalating environmental pollution is primarily attributed to the industrial sector, urging a need for manufacturing companies to adopt eco-friendly strategies for a better balance with nature (Massoud et al., 2010).

Industries extract raw materials and energy from the environment, necessitating distribution and transportation. Throughout the industrial production process, various environmental impacts arise, including air emissions, solid waste disposal, and wastewater emissions. These inputs and outputs contribute significantly to environmental damage. Moreover, industrial products may pose potential environmental risks throughout their entire life cycle, from raw material production to end-of-life disposal.

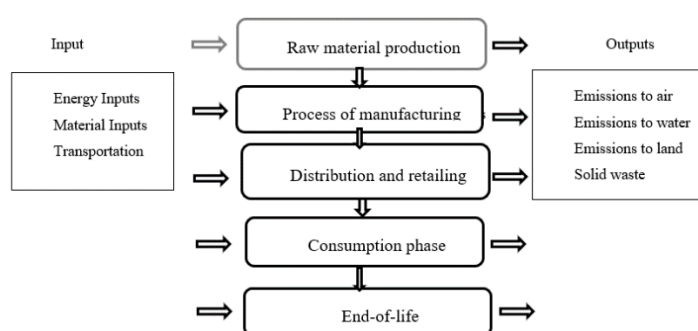


Figure 01: Industrial inputs and outputs during life cycle' (source: linkedin).

Industries extract resources, causing environmental impacts like air emissions and waste. The entire life cycle of industrial products, from production to disposal, poses potential environmental risks. Industrial activities rely on environmental inputs like energy and raw materials, producing waste in air, water, and land. This interaction results in environmental impacts. Environmental aspects refer to features of an industry's operations affecting the environment, while environmental impact is the resulting change. Examples are outlined in the Table 1. Below;

Table 1: Environmental aspect and impacts (source: Researchgate.com)

Environment Aspects	Environment Impacts
Emissions to air (GHG, Sox, NOx, PM, VOC, PAH, POC etc.)	Global warming (Biggest threat) Acid Rain Ozone Layer Depletion Health problems (7 Mn deaths due to air pollution alone)
Discharge of wastewater	Contamination of water bodies Eutrophication
Disposal of solid/hazardous waste	Contamination of land Contamination of water bodies Spread of diseases
Resources extraction	Environmental degradation
Land use	Land degradation Soil pollution

Noise generation	Noise pollution
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Inadequate environmental aspect management can lead to legal issues, liabilities, and a damaged reputation. A methodical approach should be used to solve the concerns with EAs. It is possible to refer to this as a "system," a "planned manner of doing things," or an "Environmental Management System (Edwards, 2001).

In the late 1980s, businesses, consumers, and governments alike began focusing on environmental issues. The business sector sought ways to balance economic interests with environmental impact, recognizing the complexity and consequences of environmental challenges (Fagioli, Paolotti and Boggia, 2022).

1.2 Area of investigation and Research Problem

The selected company specializes in manufacturing and distributing food, soap, and fuel/lubricants. Its main operations include Grain Processing Noodles, Papa Dam, Soap, Gingelly Roll, Bakery, and Boiler across two primary segments: food and soap. Since the Central Environmental Authority (CEA), Sri Lanka has already granted the company Environmental Protection Licenses (EPLs), it has already put in place mitigation measures with regard to the pollution brought on by sewage and contaminated emissions from furnace oil boilers. A sewage water treatment plant is under construction, and external labs verify discharge quality. Air emissions from boilers are regularly tested for particulate matter (PM), carbon monoxide (CO), and sulfur dioxide (SO₂) as per legal requirements. Selected, a food and soap production company, relies heavily on energy for grain processing and faces challenges with waste and pollution. The food sector, requiring substantial electricity, encounters issues like resource waste and increased costs. Government regulations, customer preferences for eco-friendly products, and shareholder expectations emphasize the need for a robust environmental management system to enhance corporate environmental performance (Aderemi et al., 2009; Tung, 2015; Cong and Hien, 2016). Improving the environmental performance of corporations is one way of limiting environmental damage (Matta, et al., 2003.) In this company thus needs more effective environment management system.

An environmental management system (EMS) is a systematic process designed to manage the environmental impacts of a business and reduce the environmental risk associated with business activities (Zhang, Wang and Wang, 2014). Successful EMS must offer a framework for managing a company's energy and environmental issues as well as for facilitating and encouraging ongoing knowledge production and management, which is the essential resource for preserving a company's competitiveness (Morvay and Gvozdenac, 2008).

If developed and implemented effectively, an EMS benefit business by:

- Helping to ensuring compliance with regulations,
- reducing risk,
- promoting better environmental results
- boost operational effectiveness,
- cultivate a favorable company reputation; and
- improve environmental efficiency (M, 2019)

With this scenario in mind, the aim of this research was to identify the environmental issues of the corporation and developing effective environment management system to reduce environmental damages while increasing company efficiency. Future environmental standards, influenced by systems like ISO 14001, aid businesses in reducing environmental impact. Implementing ISO 14001-compliant environmental management systems facilitates effective integration of environmental values into operations.

EMS aims to minimize energy, electricity, raw material use, and reduce waste and pollution. ISO 14001 provides a valuable framework, but actual environmental improvement relies on employee dedication, management commitment, stakeholder pressure, and adherence to environmental regulations. Therefore, this Research focused on implement effective EMS in this manufacturing company by addressing current environmental status, limitations, and risks in the company's EMS and Exploring workers' perceptions and finally provided suggestions based on ISO 14001-2015 for EMS development.

2. Methodology

The development of the research design, methods and theories used in this study will be summarized in figure 02.

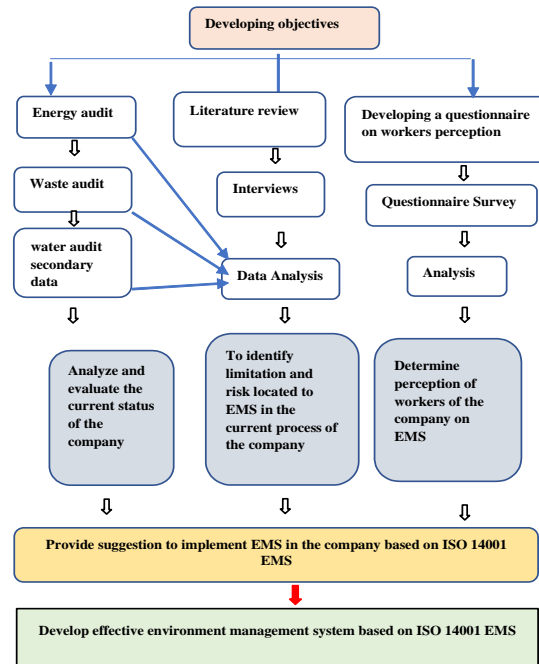


Figure 02: Research methodology flow chart.

2.1 Experimental Procedures/Methods of Data Collection

Preliminary data collection employed various techniques—measurements, key person interviews, and observation. Actions included touring facilities, gathering data on electrical appliances, water use, and waste through observation and interviewing. Site drawings depicted building layouts and electricity distribution. Power consumption measured with a multimeter or based on rated power. Appliance utilization details obtained through interviews with electricians and custodians. Generalizations and estimations made in data-scarce areas. Secondary data sources included past water audits, annual reports, books, and websites. MS Excel, Minitab were used for data analysis and statistically analysis. Text, tables, figures, and charts were data presentation methods.

2.1.1 Energy Audit

The energy audit focused on pinpointing main energy-consuming areas, quantifying electricity usage across different sections monthly, and identifying opportunities for efficiency improvements and renewable energy integration. Methodology included instrument load measurements with a clamp multimeter (Figure 03), data collection on working hours, and employee interviews to understand electricity usage patterns. Recommendations for energy conservation and management strategies were provided based on the findings.



Figure 03: Industrial Clamp multimeter.

The following analyses were carried out on the energy audit data collected (Plc, 2018). The quantity of electrical power used by the machines in each production sections is determined using equation (1):

$$P = V \times I \times pf \times \sqrt{3} \quad (1)$$

Where: P= electric power consumption in W; V = Applied Voltage in V; I= Current in A; pf= Power factor

The power factor of a machines was determined from Equation (2).

$$Pf = \frac{P_i}{P_{if}} \quad (2)$$

Where: P_i = Actual Load Current in W; P_{if} = Full Load Current on Name Plate in W

The average electrical usage per month of each machine was evaluated using Equation (3)

$$\text{Electrical power usage/month} = \frac{P \times h \times d}{12} \quad (3)$$

Where: P = Electric power consumption in W; h = Period of operation Per day in hours; d = Number of working day per year

2.1.2 waste Audit

Waste and pollution pose significant challenges for the food manufacturing industry, impacting resources, expenses, product quality, and environmental and reputational aspects. A waste audit aimed to identify main waste areas, quantify emissions, and explore improvement opportunities, including waste minimization and recycling within the company. The methodology involved on-site measurements, employee interviews, and data analysis to recommend strategies for converting waste into valuable products and enhancing production profitability.

2.1.3 water Audit

Company recent water audit report data was referred to identify company present water usage and waste water emission Company specific product water use, and Company Waste water quality. According to the available information, records, measurements and observations, company water balance was identified.

2.1.3 Questionnaire survey

A comprehensive survey, including both qualitative and quantitative questions, was conducted among a random sample of employees across various production sections and top management officers. The questionnaire aimed to assess employees' perceptions of the company's Environmental Management System (EMS). It specifically focused on understanding management issues, concerns, and challenges related to EMS standards, covering areas such as employee sentiments, achieved environmental outcomes, and the business unit's emphasis on environmental issues.

3. Results and Discussion

3.1 Energy audit

Energy audit data are given below in figure 04;

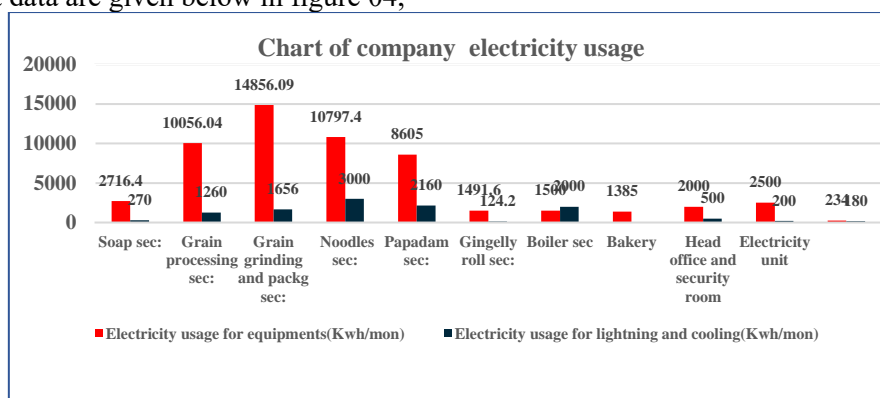


Figure 04: Chart of company electricity usage for equipment's and lightning and cooling.

Grain grinding/packaging dominates equipment electricity (26%, 14856 kWh); noodles prep leads in lighting/cooling (26.43%, 3000 kWh). Overall, grain grinding/packaging tops total usage (24%, 16512 kWh). Grain processing (17%) and papadam (15%) also contribute significantly to monthly electricity consumption.

Main energy-intensive departments are grain grinding/packaging, noodles, grain processing, and papadam. High-energy machines in these sections drive demand. Grain grinding is crucial, supplying flour for papadam, noodles, and bakery; it's highly efficient. The milling process consumes around 75% of a flour plant's total energy (Dharmarathna, 2019). The company uses 16% (11350.02 kWh/month) for cooling due to high temperatures and machinery heat. Lack of natural airflow and daylight, essential for product quality and worker comfort, is intentional to prevent quality issues and insect contamination. Thus, Company requires alternative energy for manufacturing, necessitating energy management systems to cut consumption and boost profits. Industrialists aims to enhance energy efficiency amid cost hikes and environmental demands, relying on energy for raw material transformation (Kluczek and Olszewski, 2017).

In the grain milling and food production industry, electricity costs pose a significant challenge, impacting slim profit margins. Inefficient energy use raises the carbon footprint, leads to financial losses, and hikes product prices. Despite emphasizing manufacturing, planning, marketing, and product quality, energy management is not prioritized in this company.

3.2 Waste Audit

Company tracks monthly organic solid waste and reusable wastes data. Monthly average waste emissions are detailed in in Figure 7. Grain processing contributes the highest monthly waste (24007.2 kg, 75% of total), followed by noodles production (19%). All identified wastes, including husk, udu shells, grain dust, noodles pieces, papadam, gingelly, and return products, are organic and managed within the company yard, avoiding disposal to the environment.

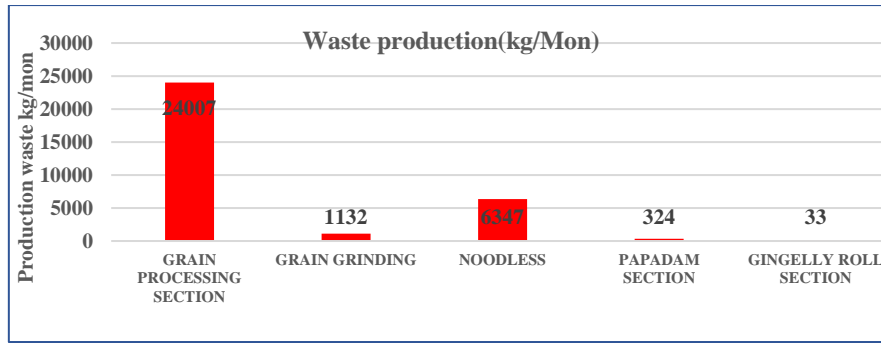


Figure 06: Chart of company production process waste emission.

Company utilizes identified wastes for animal food production, aiming to boost profits. Municipal council manages other solid wastes (food, papers, polythene), no significant documentation on company polythene waste during the research period.

3.3 water Audit

Selected manufacturing company water requirement to the factory premises is supplied by the municipal water and ground water.

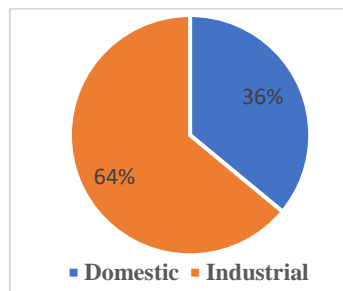


Figure 07: Company water requirements intake (source: Secondary data from company).

The company receives municipal water through four meters for industrial and domestic use. Wastewater from domestic activities goes to a central drain and an underground pit, while tea preparation waste goes to a separate pit. Industrial wastewater undergoes treatment before being discharged into a canal. Stormwater mixes with raw wastewater. Company prioritizes minimizing environmental impact, identifies inefficient water consumption as a concern. Conducted water audit with National Cleaner Production Center Sri Lanka for analysis and improvement.

During water audit measurements were done with indirect methods. According to the research data, records, measurements and observations, the following water balance can be presented (Figure 08).

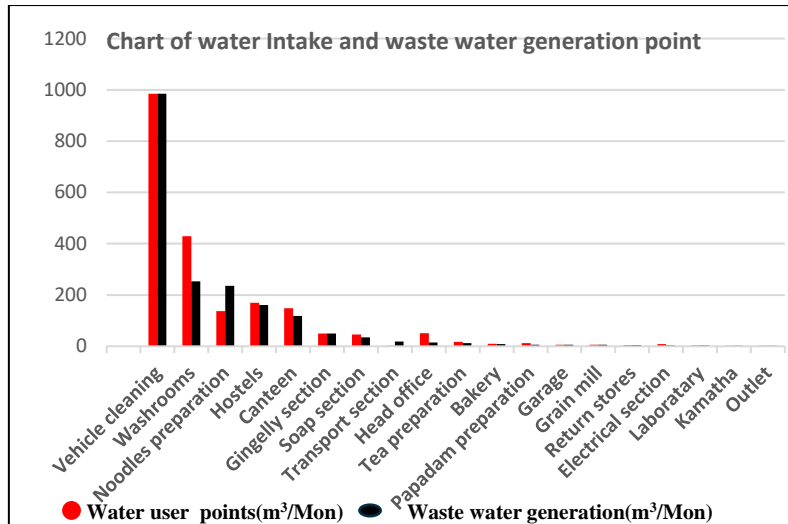


Figure 08: Company water requirements intake (source: Secondary data from company).

Premises use water for domestic and industrial purposes. In a water audit, 80% of total intake is consumed by vehicle washing, washrooms, boiler, hostels, and canteen. Highest usage is in vehicle washing (984 m³), followed by washrooms. Industrial activities (steam generation, food prep, testing) account for 64% of water intake (1507.81 m³), while domestic activities contribute 36% (863.76 m³). Wastewater audit finds vehicle cleaning as the highest contributor (51%), followed by washrooms, noodles prep, hostel, canteen, and gingelly section. Average monthly wastewater generation is 1,935 m³. Noodles prep sees higher waste water points due to steam vapor leakage.

3.4 Analysis of the questionnaire survey for company employees

The information was gathered using both an online survey and a physical interview guide. 70 participants were intended for the study. Those questioned included three senior managers, six department heads from the organization's six production divisions, and five staff members from the electricity department.

Table 9: Respondents demographics (Source: Survey Data)

Age	%	No of respondent
18-25	20	14
25-35	24.3	17
35-45	27.1	19
45-55	21.4	15
56-65	7.1	5
Gender	%	
Male	50	35
Female	50	35
Education level	%	
Up to o/l	50	35
Up to A/l	37.1	26
Graduate	8.6	6
Post graduate	4.3	3

According to survey data majority of company employees do not aware about the EMS and that is 77.1%. Only 22.9% of company employees aware on the concept (Figure 09).

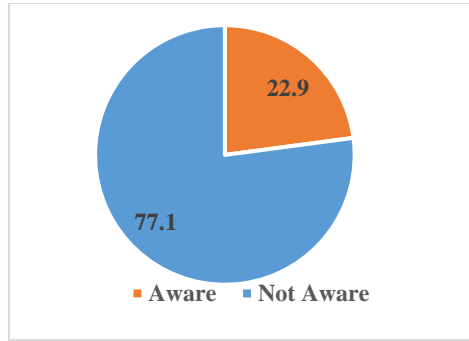


Figure 09: Awareness on EMS among company workers.

According to the data gathered through the survey, 92% of the respondents indicated they are monitoring environment impact of operation. But 80% of the respondent indicated company do not trained to implement environmental procedure.

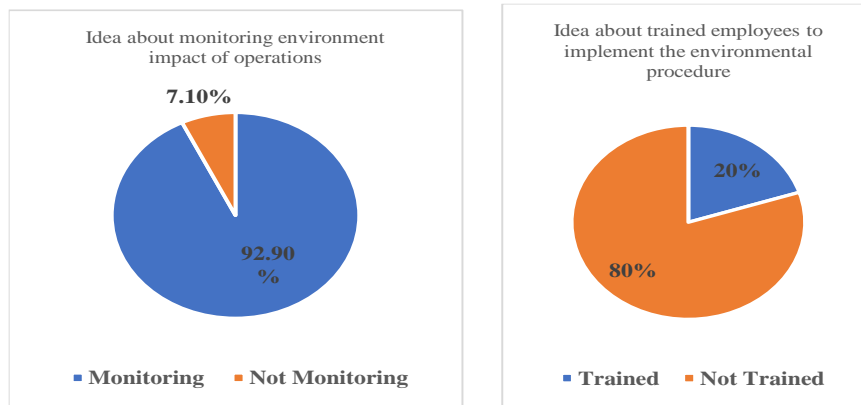


Figure 10: Idea about company monitors the environment impact of operations and trained employees to implement environmental procedure.

When discussing the overall results of the research, commitment and environmental policies of the company is weak due to the various reasons though they have environmental policies, they did not include essential components of environmental policy called prevent pollution, continuous improvement, and comply with environmental regulations. Hence, most of the time environmental policies have failed to achieve their institutional goals. As well as when implementing environmental policies, lack of time frame to implement environmental programs, lack of good attitudes of employees, lack of practical implement of environmental programs and due to the lack of authorized environmental managers of the institution have led to the failure in implementing environmental policies. The same time when considering environmental auditing data and perception of EMS on company where it is clear that most of the company sector have given considerable value for commitment and environmental policy and planning the environmental policy but they have not given considerable attention for Audit and review and external environmental communication and documentation.

4 Conclusions

Purpose of this research was the identify current environmental status of the selected manufacturing company and give recommendation to implement effective environment management system in the premises.

EMS aims to minimize energy, electricity, raw material use, and reduce waste and pollution. ISO 14001 provides a valuable framework, but actual environmental improvement relies on employee dedication, management commitment, stakeholder pressure, and adherence to environmental regulations. To

establish a robust Environmental Management System (EMS) and address current environmental challenges, key recommendations include conducting awareness programs for employees, providing training on water and energy efficiency, implementing multilingual voice announcements on conservation, installing submeters for monitoring resource usage, offering comprehensive EMS training aligned with ISO 14001 principles, incorporating essential components in the environmental policy, establishing accountable environmental task groups, conducting periodic audits, appointing an environmental officer, and fostering improved employee attitudes towards environmental responsibility. Future environmental standards, influenced by systems like ISO 14001, aid businesses in reducing environmental impact. Implementing ISO 14001-compliant environmental management systems facilitates effective integration of environmental values into operations (Nolan 2016). By following below process show in Figure 11, can obtain certified EMS based on ISO 14001-2015 any institute, in Sri Lanka.

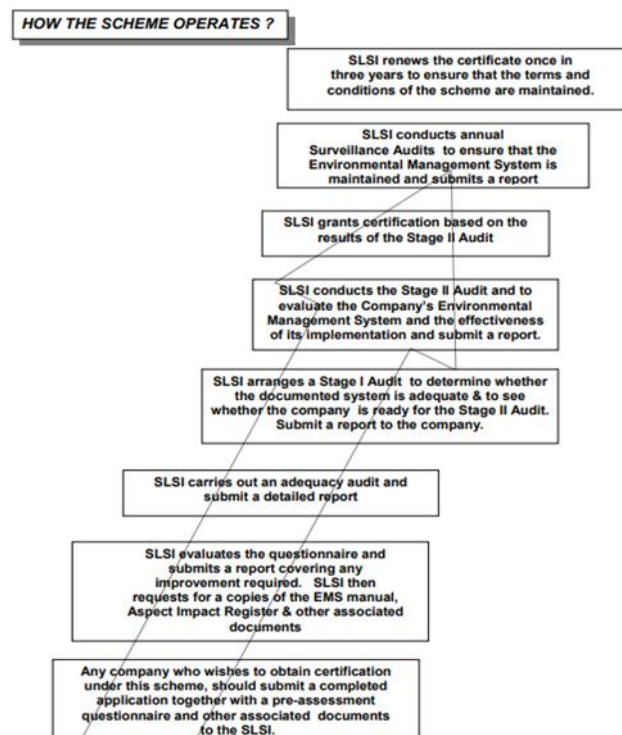


Figure 11: How the scheme operates (source: ISO Sri Lanka).

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INFLUENCE OF REUSED TYRE RUBBER (RTR) & REUSED TYRE STEEL FIBRE (RTSF) ON MECHANICAL PROPERTIES OF CONCRETE

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Abstract: Waste tyre rubber disposal has become a major issue to the environment due to the increment and durability of discarded tyres. As the tyres are non-biodegradable products, landfilling pollutes the soil, stockpiling leads to health issues and burning emits hazardous gases to the atmosphere. One solution for this issue is using of Tyre Rubber Particles in Concrete. The coarse aggregates were partially replaced by tyre rubber particles of sizes 5 mm, 10 mm and 15 mm by volume percentages of 5%, 7.5% and 10%. With the addition of reused tyre rubber particles, the compressive strength and flexural strength reduces. Hence, reused tyre steel fibers were added to concrete to compensate this strength reduction. Reused tyre steel fibre particles were added by volume percentages of 0.25%, 0.5%, 0.75% and 1%. The compressive strength and flexural strength tests were carried out by varying the percentage of reused tyre rubber particles and percentage of reused tyre rubber steel fiber. By this, the reduction of compressive strength could be mitigated by adding 0.5%-0.75% steel fibre. By adding 1% volume percentage of steel fibre, the workability reduces. For concrete mixtures with 5 mm rubber particles, 5% rubber content and 0.75% steel fiber content are the optimum combinations for mechanical properties such as compressive strength and flexural strength.

Keywords: Reused tyre rubber; Reused tyre steel fibre; Compressive strength; Flexural strength; Mechanical properties of concrete

1. Introduction

Every year around 1.6 billion tyres are produced all over the world and 1 billion waste tyres are generated. From this 100 million tyres are recycled for reuse purposes (Thomas & Gupta 2016). In Sri Lanka also, a large number of tyres are imported for a year and a huge amount of scrap tyre waste is also generated.

The used tyres are composed of materials which do not decompose under environmental conditions. The stockpiles of tyres cause many types of health, environmental and economic risks through air, water and soil pollution. Burning is one method for their decomposition, but the exhausted gases result in harmful pollutions. The coarse aggregates for concrete are vital materials needed for the construction industry. There is a continuous and increasing demand on the natural rocks used for coarse aggregates. Nowadays, there is a growing concern for protecting the environment. In order to preserve natural resources (i.e. rocks), alternative materials have to be used: they are recycled materials or waste materials. One solution for this issue is using of Reused Tyre Rubber (RTR) in concrete.

In this research, it is planning to partially replace the coarse aggregates with tyre rubber aggregates. It has been found that the addition of reused tyre rubber to the concrete increases its mechanical properties. [Aiello & Leuzzi (2010)]. Therefore, it was decided to add reused tyre steel fibre (RTSF) to the concrete expecting to prevent the decreasing of compressive strength.

Many researches have carried out to investigate the effect of RTR and RTSF on concrete. The previous researches can be divided into three categories.

- 1) Researches for investigating the effect of reused tyre rubber (RTR) on concrete
- 2) Researches for investigating the effect of reused tyre steel fibre (RTSF) on concrete
- 3) Researches for investigating the combined effect of RTR and RTSF on concrete

1.1 Researches for investigating the effect of reused tyre rubber (RTR) on concrete

Many researches have carried out to investigate the effect of RTR on concrete. Some researches have performed by partially replacing the coarse aggregates with rubber particles and some researches have performed by partially replacing the fine aggregates with rubber powder. Gesoglu, et al. (2014) investigated on the concrete with rubber added, compressive strength, modulus of elasticity, fracture energy, splitting tensile strength, and permeability were analyzed. Rubber particles were added in different percentages of 5%, 10% 20% by volume, and with the control specimen without replacement. For this case, rubbers were added in three categories, very fine (1mm), fine (4mm), and coarse particle (tyre chips). Specimens were prepared, contains only tyre chips (TC), crumb rubber (CR), fine crumb rubber (FCR), tyre chips and crumb rubber (TC +CR), and tyre chips and fine crumb rubber (TC + FCR). For the mix design, water-cement ratio 0.27 and aggregate cement ratio of 4.1 were used by weight and volume respectively.

He concluded that, the type, size, and percentage added of the rubber directly affect the above mentioned properties of the previous concrete. Minimum compressive strength of 6.45MPa was observed for the 10TC+10CR mixture and the permeability coefficient was in the range of 0.025-0.61cm/s, both were in allowable range for the previous concrete. Fracture energy shows some increment for the tyre chipped replacement and decreased for the fine rubber addition. Suggested the rubber concrete, to use in the area where heavy load-bearing is not essential.

Bompa, et al., 2017 investigated based on the partial replacement of coarse and fine aggregate with the waste tyre rubber for the varying sizes, while using the same volume replacement for both coarse and fine. Rubber replacement of 60% and control specimen were used for the grade 60 (60MPa) rubber concrete. Rubber sizes used for the testing are 0-0.5mm, 0.5-0.8mm, 1-2.5mm, 2-4mm, and 4-10mm. Compressive strength, modulus of elasticity and crushing strain test were conducted and an analytical model was performed and validated for the material properties. He concluded from the

study, that mechanical properties depend on the type of aggregate replaced other than the size and volume replacement. crushing strain enhanced due to the increment of the rubber content, because of the energy absorbed by the rubber particles, at the same time the above three testing mechanical properties were reduced. Water permeability, water absorption, water penetration and dynamic load behavior were not conducted in the study.

Raffoul, et al., 2016 investigated on the maximization of the strength properties of rubberized concrete by utilizing the percentage of waste tyre rubber in the concrete mix, amount of water, admixture, cement percentage, rubber particle surface treatment and properties. The microscopic analysis also was used. Optimum rubber percentage derived by considering compressive strength and fresh properties. The percentage of volume replacement used for the investigation varies from 0-100%. The experiment was conducted in two stages. At the first stage, the optimum mix was identified by using different water-cement ratios, various cement, admixture amount, method mixing techniques, rubber surface pre-treatment, without changing the rubber replace for fine aggregate from 40% by volume. In the second stage, both fine and coarse replaced by volume of 20%,40% and 60% (case 1) and fine or coarse replaced by volume percentage of 0%,10%,20%, 40%, 60%, 80%, 100% according to the aggregate replaced (case 2). The rubber aggregate size varied for the case 1, 0-5mm size for fine replacement, and 10-20mm size for coarse replacement of truck tyre particles were used, but for the case 2, for fine replacement between 0-5mm and coarse replacement 5-10mm sizes of car tyres were used. Grade 40 strength concrete was cast for the experimental analysis.

He concluded that by the replacement of both fine and coarse aggregate, the reduction in the strength and the workability can be minimized. The strength reduction depends on the amount of rubber replaced for the total aggregate, other than the depending on the aggregate type (coarse or fine). The 60% of the total aggregate volume replacement produces allowable workability and 7 N/mm² compressive strength in 7 days. The replacement of 40% fine aggregate, gave a 70% reduction in the control mix, at the same time only a 49% reduction in the optimal mix. The silica fume addition to the mixture, enhance the flow ability by 20% and compressive strength by 42% for the 20% of cement replacement in weight. Through, the scanning electron microscope analysis, a separation between the tyre rubber and cement slurry was observed, for the large rubber particle.

Aiello & Leuzzi (2010) investigated on partial replacement of the rubber particles of both coarse and fine aggregate separately in the ordinary concrete. The coarse aggregates were partially replaced by 25%, 50%, 75% by volume and fine aggregates were partially replaced by 15%, 30%, 50%, 75% by volume. The variation of unit weight, workability, compressive and flexural strengths were analyzed. Found that the reduction in compressive and flexural strength for coarse aggregate replacement is higher than that of fine aggregate replacement.

Xue & Shinozuka (2013) investigated on the impact load effect on the rubber added concrete column by impact test method, the energy dissipation and column displacement were calculated. 0%, 15% & 30% volumetric rubber was replaced with the range of 2-5 mm and 5-7 mm tyre rubber particles for fine and coarse aggregates respectively. In his study, the impact energy was increased with the increment of the rubber percentage. The impact force was reduced 27%-40% compared to the control column.

1.2 Researches for investigating the effect of reused tyre steel fibre (RTSF) on concrete

Many researches have carried out for investigating the effect of Reused Tyre Steel Fiber (RTSF) on Concrete by including different lengths and percentages of rubber steel fiber concrete Syaidathul et al. (2012) also examined the effect of volumetric fraction (0%, 0.2%, 0.4%, 0.6%, 0.8%, 1%) and randomly distributed fiber length varying between 20 and 99 mm on compressive strength. According to his results the volumetric fraction of 0.4% RTSFs gave the best results for compressive strength. He also examined the effect of volumetric fraction (0%, 0.2%, 0.4%, 0.6%, 0.8%, 1%) and randomly dis-

tributed fiber length varying between 20 and 99 mm on compressive strength and flexural strength. According to the results, volumetric fraction of 0.4% gave the best results for compressive strength and flexural strength.

Pilakoulas (2014) reported on application of recycled tyre based steel in structural concrete production. RTSF are very high strength steel, more flexible and better for micro crack control. He conducted tests on concrete reinforced with RTSF together with manufactured steel fibre, and results showed that inclusion of these hybrid steel fibers help to maintain integrity after failure. There is also moderate enhancement of strengths at increased RTSF volume. He further stated that strength may decrease at high fibre volume due to extra voids that may be formed.

Mastali & Dalvand (2016) investigated the effect of volumetric fraction (0%, 0.25%, 0.5%, 0.75%) on the compressive strength and flexural strength of steel fiber-reinforced self-compacting concrete extracted from discarded tyres at a constant fibre length (40 mm). the highest compressive strength and highest flexural strength were observed at 0.75% with a fibre length of 40 mm.

1.3 Researches for investigating the effect of reused tyre rubber (RTR) on concrete

A very limited number of researches done to investigate the combined effect of both RTR and RTSF on mechanical and dynamic properties of concrete. Ndayambaje (2018) found that the compressive and flexural strengths of concrete reduce with increase in crumb rubber aggregate in concrete. That is due to the weak bond between rubber particles and cement paste as well as low modulus of elasticity of rubber compared to conventional aggregates. Here 12.5% rubber volume was taken as optimum rubber volume where the reduction in compressive strength was not more than 20%. Incorporating of different percentages of RTSF in crumb rubber, 12.5% mix resulted in a little improved compressive strength where at 1.2% addition of recycled tyre steel fiber with 40 mm length, the compressive strength reduced by 10%.

Ndayambaje (2018) concluded that increase in crumb rubber substitutions in concrete reduces flexural load carrying capacity (peak load), hence reduced flexural strength. The ductility of concrete increase with increase in crumb rubber. Combining RTSF with crumb rubber resulted in a significantly increased ductility and toughness of concrete. The RTSF concrete mixes evidenced an enhanced post-crack strength behavior allowing further deflections after the peak load is reached.

Ndayambaje (2018) also tested on the dynamic properties as well and concluded that in plain concrete load carrying capacity drops all sudden when peak load is reached and it is an indicator of poor post-crack strength material. The drop weight test method was conducted on impact resistance of concrete. According to the results, substituting crumb rubber in concrete resulted in enhanced first-crack impact energy. Combining RTSF and crumb rubber in concrete showed substantially improved both first crack and post-crack energy.

1.4 Research Gap

Many researches have done to investigate the properties of concrete by separating adding RTR or RTSF to the concrete. There are very limited number of researches to investigate the combined effect of these two materials. Ndayambaje (2018) has conducted a research for investigating combine effect of RTR and RTSF, partially replacing fine aggregate with crumb rubber. In this research, the coarse aggregates will be partially replaced with chipped rubber.

2. Methodology

In this research, the mechanical properties (compressive strength and flexural strength) of concrete were tested with different mix combinations of RTR and RTSF. First, we select the materials and the specific gravity of the materials were found. Then the test cubes were casted for the mix combinations given in item 4.4 below. The 28 days compressive strength and flexural strength were tested. From

those results, a mix combination or set of mix combinations which gives the best mechanical properties were found.

2.1 Materials

Materials used in this research are:

- a) Ordinary Portland Cement (OPC)
- b) River Sand
- c) Coarse Aggregates (Max-20 mm)
- d) Reused Tyre Rubber (RTR)
- e) Reused Tyre Steel Fiber (RTSF)

RTR and RTSF are obtained from shredding of tyres which is a tyre recycling process.

Three sizes of particles were used for RTR. The particle sizes were selected as such the sizes are within the size range of coarse aggregates (4.75 mm-20 mm).

- a) 5 mm rubber – Particles which passes through 5.6 mm sieve and retained on 4.75 mm sieve
- b) 10 mm rubber – Particles which passes through 11.2 mm sieve and retained on 9.5 mm sieve
- c) 15 mm rubber – Particles which passes through 16 mm sieve and retained on 14 mm sieve

2.2 Material Properties

Specific gravity of materials were conducted using pycnometer method by taking average value after testing three samples.

2.3 Mix Design

Mix Design was done to achieve a target strength of 25 MPa with a confidence level of 95%. Grade 25 concrete is used due to its applicability for construction in all areas as it is a multi-purpose concrete mix which is commonly used for both domestic and commercial use. Water/Cement ratio was selected as 0.5 and slump range was selected as 60-180 mm. Relatively high water content and a higher slump range is selected in order to withstand the reduction in workability which occurs due to inclusion of tyre steel fibre.

2.4 Mix Combinations

Different mix combinations are due to three variables

- a) Size of rubber particles – (5 mm, 10 mm, 15 mm)
- b) Volume percentage of rubber that replaces coarse aggregates in the mixture (5%, 7.5%, 10%)
- c) Volume percentage of steel fibers from the total volume of the mixture- (0.25%, 0.5%, 0.75%, 1%)

2.5 No. of Samples

The Table 01 shows the number of samples prepared with different rubber particle sizes for each experiment.

Table 1: No. of Samples from each Rubber Particle Size

Rubber Particle Size	Cubes for determination of Compressive Strength at 28 Days	Beams for determination of Flexural Strength at 28 Days
Control Sample	1 x 4 = 4	1 x 3 = 3
5 mm	15 x 4 = 60	15 x 3 = 45
10 mm	15 x 4 = 60	15 x 3 = 45
15 mm	15 x 4 = 60	15 x 3 = 45

2.6 Experimental Procedure

Compressive Strength Test and Flexural strength Test were carried out accordance with BS1881-116:1983 and BS EN 12390-5:2009 respectively. The optimum mix combinations were selected from the results of two tests.

3. Results and Discussion

3.1 Material Properties

The following specific gravity values were found using pycnometer method.

Table 2: Specific Gravity of Different Materials

Material	Specific Gravity
5 mm Rubber	1.103
10 mm Rubber	1.148
15 mm Rubber	1.182
Steel Fibre	6.568

3.2 Mechanical Properties

3.2.1 Compressive Strength

28 days compressive strength values for each rubber particle size and for various percentages of RTR and RTSF are shown in Figure 1 to Figure 3.

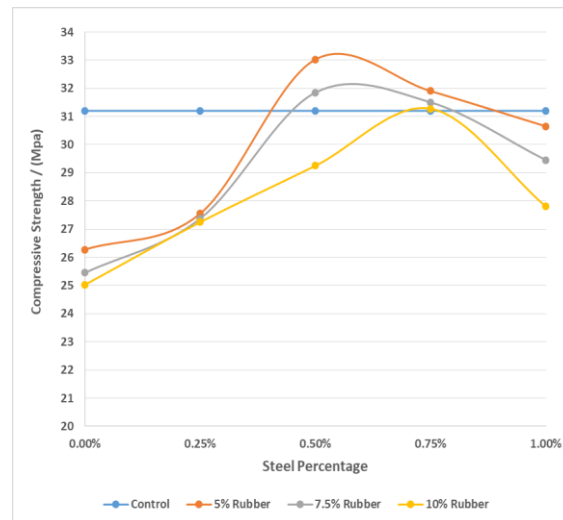


Figure 1: Variation of Compressive Strength vs Steel Fiber Percentage for 5 mm Rubber.

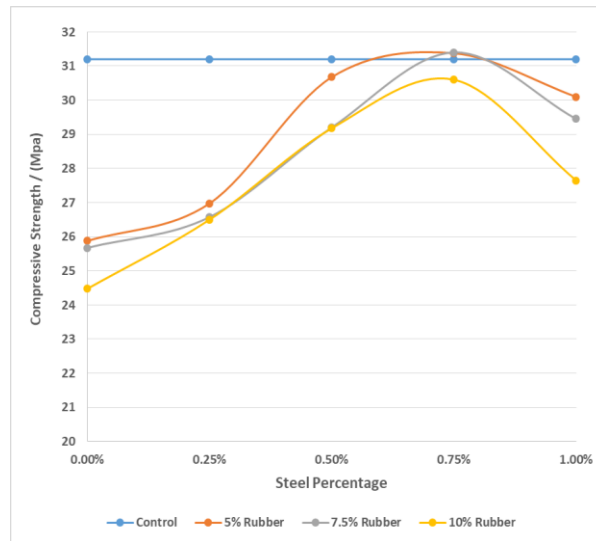


Figure 2: Variation of Compressive Strength vs Steel Fiber Percentage for 10 mm Rubber.

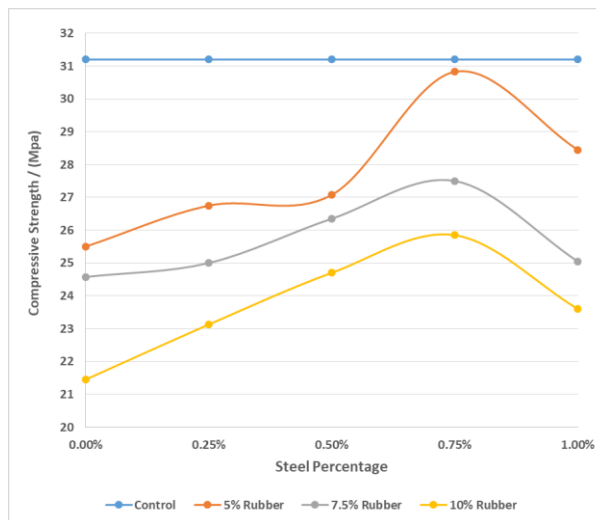


Figure 3: Variation of Compressive Strength vs Steel Fiber Percentage for 15 mm Rubber.

For all the rubber percentages of 5%, 7.5% and 10%, the compressive strength increases with the increase of steel fiber percentage and reaches a maximum point and then decreases. For 5% and 7.5% rubber content, the compressive strength is maximum when the steel fiber content is 0.5%. For 10% rubber content, the compressive strength is maximum when the steel fiber content is 0.75%.

This shows that the steel fiber can increase the compressive strength of concrete up to certain limit of fiber content. With higher steel fiber content more than 0.75%, the workability of concrete reduces and balling effect of steel fibers can be observed. Concrete cannot be properly compacted due to this balling effect. Hence the compressive strength gets reduced.

3.2.2 Flexural Strength

28 days flexural strength values for each rubber particle size and for various percentages of RTR and RTSF are shown in Figure 1 to Figure 3.

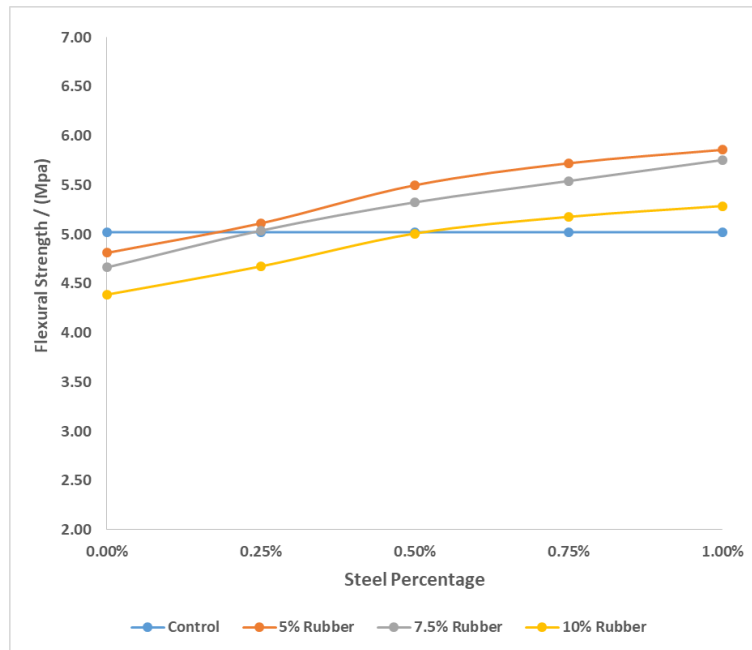


Figure 4 : Variation of Flexural Strength vs Steel Fiber Percentage for 5 mm Rubber.

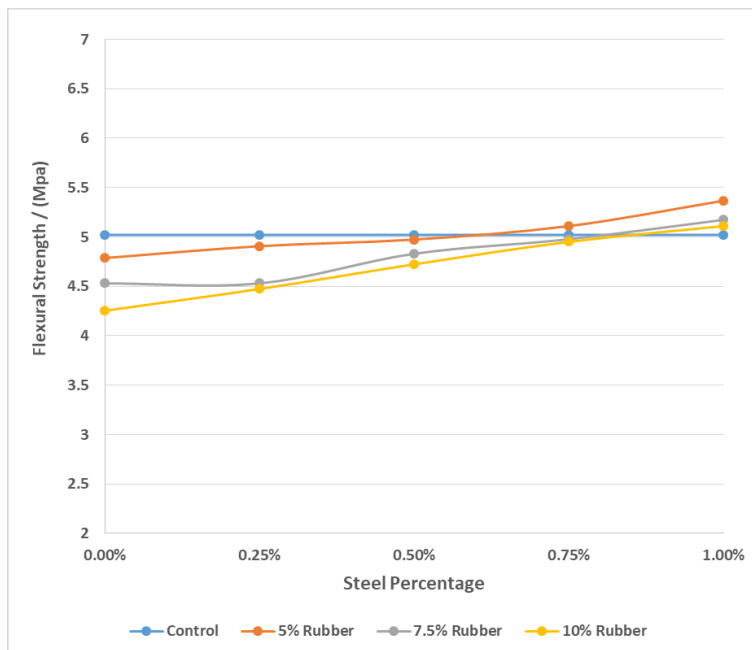


Figure 5: Variation of Flexural Strength vs Steel Fiber Percentage for 10 mm Rubber.

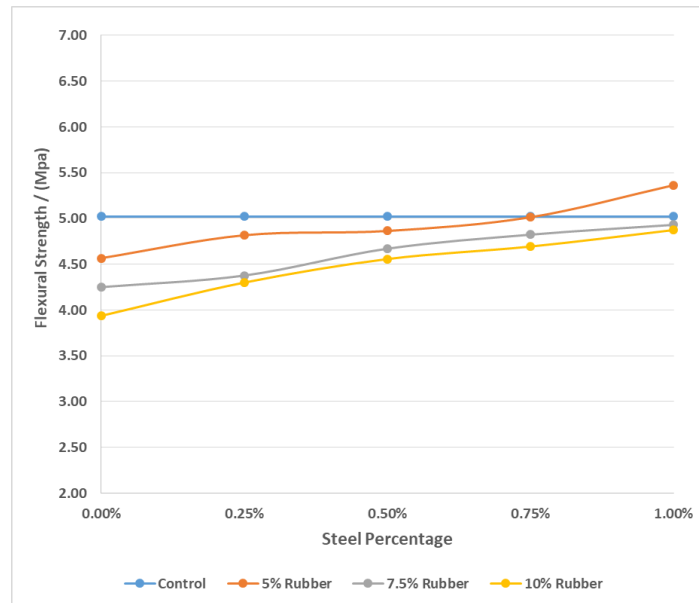


Figure 6: Variation of Flexural Strength vs Steel Fiber Percentage for 15 mm Rubber.

For all the rubber percentages 5%, 7.5%, 10%, the flexural strength increases with the increase in steel fiber percentage. Steel fiber can give an extra tension to the concrete. Therefore, the flexural strength increases with increasing of steel fiber content. For same steel fiber content, the flexural strength is higher for concrete mixes with 5% rubber content than the other two rubber percentages. The concrete-rubber bonding strength is lower than the bonding strength of concrete-aggregate. Hence when increasing the rubber content the bonding strength concrete reduces. This causes decreasing of flexural strength.

For the steel fiber contents greater than 1%, workability of concrete was reduced and balling effect of steel fibers was observed. Concrete cannot be compacted due to lack of workability. Hence the study was conducted up to 1% steel fiber content only. Finally, it was able to increase the flexural strength by adding RTSF to the concrete, despite the reduction of flexural strength occurred due to inclusion of rubber. For any rubble particle size, both compressive strength and flexural strength are optimum at a steel content of 0.75%, so the steel content of 0.75% can be selected as the optimum steel content. For any rubble particle size with the steel content of 0.75%, both compressive strength and flexural strength are optimum at rubber content of 5% for rubble particle sizes 5 mm.

4. Conclusions

With the addition of RTR particles, the compressive strength and flexural strength reduces. This reduction of compressive strength could be mitigated by adding 0.5%-0.75% steel fibre for concrete mixtures with 5 mm rubber particles. For all the RTR particle sizes of 5mm, 10mm and 15mm, 0.75% RTSF content and 5% RTR content can be taken as the optimum content for both compressive and flexural strength. Although 1% RTSF content shows more flexural strength, it is not workable. Considering RTR particle sizes, 5 mm particle size is optimum in terms of mechanical properties. Although, the compressive and flexural strengths were increased by small percentages, the dynamic properties of concrete may increase due to addition of rubber particles to the concrete.

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EXPERIMENTAL AND NUMERICAL INVESTIGATIONS OF THE STRUCTURAL PERFORMANCE OF CONCRETE FILLED DOUBLE SKIN STEEL TUBE (CFDST) COLUMNS

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Abstract: The construction industry has undergone global evolution driven by technological advancements. Among its critical components, columns play an indispensable role. Despite the array of construction methodologies, conventional concrete columns remain prevalent, yet they suffer from economic and performance limitations, spurring a quest for improvements. Concrete Filled Skin Tubes (CFST) represent a promising solution as composite structural elements. Featuring a hollow steel sheath filled with concrete, CFST facilitates efficient fabrication processes. Initially focusing on circular and square tube configurations, research has progressed to Concrete Filled Double-Skin Tubes (CFDST), boasting lighter mass and enhanced load resistance. The versatility of CFDST, including its potential for utility extension and improved seismic performance, positions it as a favoured material in contemporary construction. However, beyond physical attributes, factors such as assembly configurations and bonding integrity significantly influence the performance of these composites, necessitating further research for optimization. Advancements in Finite Element Analysis (FEA) software have revolutionized research methodologies, offering increased reliability and enabling simulations of diverse scenarios without exhaustive physical testing. This paper investigates the percentage change in axial capacity relative to controlled specimens, providing valuable insights into the current state of research. Through empirical analysis and theoretical discourse, it seeks to advance structural solutions and redefine modern construction practices, aiming to bridge the gap between conventional methods and innovative approaches. This research explores the potential of CFST and CFDST sections in addressing the limitations of conventional concrete columns, offering a pathway towards optimized structural solutions and sustainable construction practices

Keywords: Concrete filled double skin tubes (CFDST); Concrete filled skin tubes (CFST); Axial load; Strength capacity; FEA model

1. Introduction

Time to time research developers have introduced different construction techniques and materials to Civil Engineering fields. Economical soundness, sustainability, higher strengths, and construction easiness etc. were taken into the consideration of the vast variety of researchers all around the world. Traditional and conventional materials are often replaced by latest and advanced materials.

Recent discoveries such as Concrete Filled Skin Tubular (CFST) columns are subjected to consideration of the researchers to optimize further as a composite material with enhanced properties to serve the modern building construction industry which is under a rapid growth. These CFST sections consist with a concrete layer filled in a hollow steel tube. This particular configuration resulted with much higher performance in the practical civil engineering aspects, therefore it was a substitute to the traditional reinforced columns. Those sections have been widely used in High rise buildings, subways, bridges, electric light poles, etc. CFST sections were further improved by adding one more inner steel tube. A concrete infill is in place as a sandwich in between inner and outer steel tubes to form Concrete Filled Double Steel Tube (CFDST). According to Montague (1975) these CFDST was initially used in a deep-water vessel to resist external pressure.

The cross-sectional configuration of CFDST and CFST sections are depicts in the Figure 1.

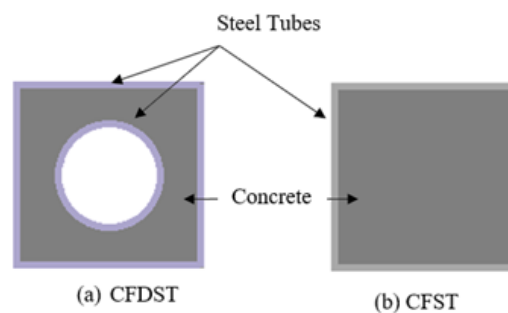


Figure 1 (a) Concrete filled Double skin Tube (CFDST) section and (b) Concrete Filled Skin Tube Section (CFST).

Alias & Jacob (2017) explains that CFDST sections are characterised by much better performance indicators of the compressive strength of the concrete and the ductility of steel in composite action than isolated. The lateral deformation under compressive loads are prevented by the inner and outer steel tubes while the concrete infill resists the buckling of the outer steel.

Experiments done by Tao, Han & Zhao (2004) confirmed the higher the slenderness ratio tends to lower the capacity of the section. (Tao, et al., 2004). The inner hollow section of CFDST makes the section lighter comparatively to CDST. Hence, the inner and outer steel tubes act as jackets, the formwork is not required as in conventional RC columns. Also, the requirement of reinforcement is not compulsory in these types of sections. Therefore, the demand of those are increasing over the traditional RC columns.

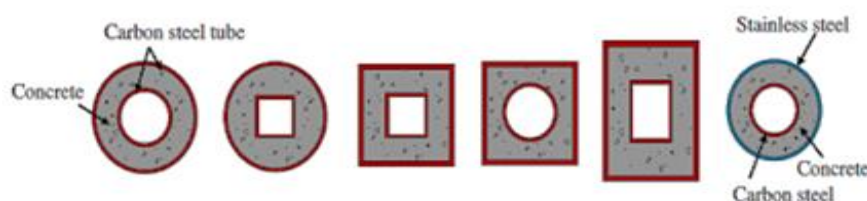


Figure 2 General Configurations of the CFDST sections (Vasugi & Elavenil, 2019).

Yuan and Yang (2013) experimented on short CFDST columns with respect to axial compressive load. The variable parameters were concrete grades, radius- thickness ratio, Hollow section ratio, and slenderness ratio (Yuan & Yang, 2013). Octagonal steel tube as outer skin with circular PVC-U pipe as the inner section was used and filled with high strength concrete. A total of nine specimens experimented with length varying from 380mm- 830mm and numerical study were done to analyze the experiment with ANSYS software. Initially, CFDST exhibits linear behavior, followed by elastoplastic deformation and a subsequent decrease in load capacity at higher deformations. Failure was not observed in the inner PVC-U tube, whereas failure in the outer section resulted from axial compression and concrete crushing. Finite element analysis revealed that concrete crushing precedes steel tube failure. Compressive capacity was unaffected for inner thicknesses greater than 3. Ultimate load increased with strength but decreased with radius-thickness or hollow section ratio.

At later stage in 2016, The behaviour of SHS outer and CHS inner subjected to compressive load was studied by Karthika & Ranjitham (2016). FEM analysis was done with the obtained experimental data and the results were compared with the analytical investigations. Reliable agreement of the FEM was obtained with the experimental data and failure modes as predicted by the FEM model agreed with the previous research results. Many researchers developed models to find the capacity of the CFDST column sections. A total of sixteen specimens was taken for a parametric study. For Group 1, variation in length was done by keeping the outer and inner area of the specimen constant while for Group 2, diameter and thickness were varied for 1000mm long specimens. When the slenderness ratio increased, capacity decreased simultaneously. An increase in the thickness ratio increased the capacity of the CFDST specimen. It was also found that increasing the hollow ratio to 0.8 ultimate capacity increased and above 0.8, it gradually decreased.

Later, Gunathilaka & Appuhamy (2019) researched CFDST columns subjected to axial compressive load to evaluate the structural performance of CFDST columns of CHS inner- CHS outer and SHS inner – SHS outer section. FEA software was used to model the CFDST specimen which was validated by the materials property obtained from different tests. The validated model was thus used to compare the performances between CFDST, CFT, and CFST columns under compressive load. From the experiment, it was found that the resistive capacity of CFDST is higher than the CFST.

Bhattarai, N (2020) further researched by testing and CFDST specimens. Axial compression test was carried out for the prepared specimens with a length of 250mm. The experiment was conducted for all different possible arrangements of Circular and Square sections to identify the percentage change in the peak load of the specimens. The deformation shape of the model was identified using the model results.

His experimental results predicted as indicated in Figure 1.5 that the CFDST sections with square outer tubes characterized by higher capacity than those of with circular outer sections.

Many researchers have conducted studies employing a single type of steel tube shape. Some investigations utilized circular hollow sections (Ekmekyapar and Ghanim Hasan, 2019), with design parameters such as the thickness of the outer and inner tubes and the concrete grade. Others opted for rectangular hollow sections (Tao and Han, 2006), emphasizing various critical steel tube shapes as design parameters.

This study addresses a gap in previous literature by focusing on the correlation of different sections of CFDST columns, which has not been extensively explored. It aims to determine the axial loading capacities of CFDST columns with various configurations, including SHS-SHS,

SHS-CHS, CHS-CHS, and CHS-SHS. Physical specimens are fabricated, measured, and tested, with additional validation through software models.

2. Experimental Investigation

2.1. Methodology of research

The experimental procedure is set to investigate the structural behaviour of CFDST columns against the varying compressive load. Figure 3 illustrate the flow diagram of the entire scope of the research.

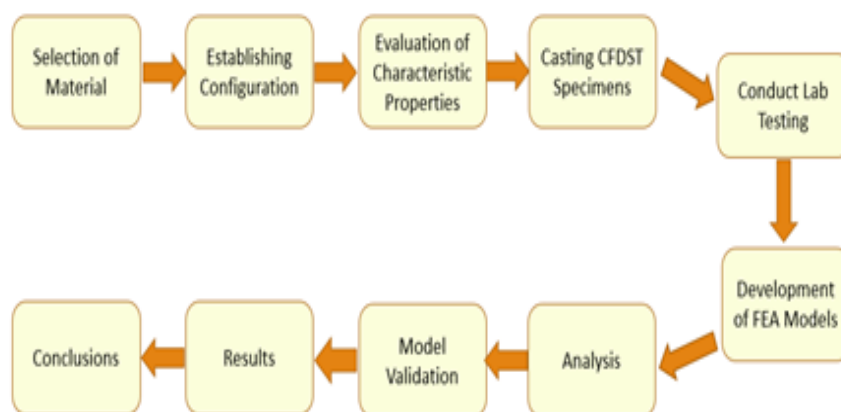


Figure 3 Block diagram of the methodology of research.

The optimum sections to be found among large variety of sectional configurations. However, limited number of Circular and square sections with different dimensions were taken with the availability and the affordability. Hence, CFDST were formed in various possible ways such as SHS-SHS, SHS-CHS, CHS-SHS and CHS-CHS. The specimens shown in Figure 2.2 shows the physical appearance of them before filling with concrete.

Table 1 Physical definition of testing specimen

SECTION DESCRIPTION		CROSS SECTION
CHS-CHS	Circular Inner-Circular Outer	
CHS-SHS	Circular Outer- Square inner	
SHS-SHS	Square Outer-Square Outer	
SHS-CHS	Square Outer- Circular Inner	

After pouring concrete between the steel tubes, the concrete was allowed to cure to reach the target strength. Test cubes were created to confirm the concrete strength. Strips of the same steel used for the tubes underwent laboratory investigation to determine initial properties such as Young's modulus and Poisson's ratio for use in upcoming calculations. The specimens were then subjected to experimental procedures under controlled conditions, with appropriate boundary conditions applied and zero eccentricity set for loading. Software models of the specimens were established using ABAQUS Finite Element Method and validated. These models were then validated against available theories and practices. Next, the validated software models were

subjected to variation of parameters to represent a large variety of testing specimens. Finally, the processed output data from ABAQUS was collected and rearranged to draw conclusions.

2.2 Selection of materials and evaluation of characteristic properties

CFDST sections consist of inner and outer steel jackets, with steel and concrete used as tubular and filler materials, respectively, due to their widespread use in the construction industry. MELWA Company Steel tubes, which adhere to SLS 375 standard for ribbed steel bars, SLS 26 for Plain bar steel, and ISO 9001 for quality management, were utilized in this experiment. A tensile test was conducted to determine the yield stress, ultimate tensile stress, and Young's modulus of elasticity for the materials. Grade 30 concrete, with a design mix proportion of cement: sand: aggregate, was proposed as the concrete infill for the CFDST members. Three concrete cubes (150mm150mm150mm) were cast to identify the characteristic compressive strength at 28 days. The concrete cubes were cured in a bathtub for 28 days to minimize cracking. A compression test was performed to determine the compressive strength of the concrete, following BS EN 12350-2:2009 standards for testing Fresh Concrete for the slump test and compressive strength test.



Figure 4 CFDST steel specimens in circular and rectangular sections are ready to undergo testing procedures.

2.3 Experimental analysis

All square CFDST specimens were subjected under axial compression in an ADR 2000 compression testing machine at University of Ruhuna. Controlled samples (CFST), Cubes, CFDST sections were subjected under axial compression and hence results were recorded. The deformed patterns of the shapes of the specimen were recorded.

All steel and concrete were subjected to undergone material property determination tests. Concrete testing cubes were casted using the same material used for make fill the steel tubes. Hence, 28 days strength was observed. Similarly, tensile tests were conducted to identify true material properties which used for FEM with ABAQUS software.



Figure 5 Axial compression of specimen and deformed shape.

3. Results and discussion

3.1 Experimental results

From the pool of samples, it is observed the actual load bearing capacity of the square sections were lower than the circular sections. The results of the circular sections were varied in between 1400-1850 kN whereas the loads of the square sections were in between 500-1600 kN.

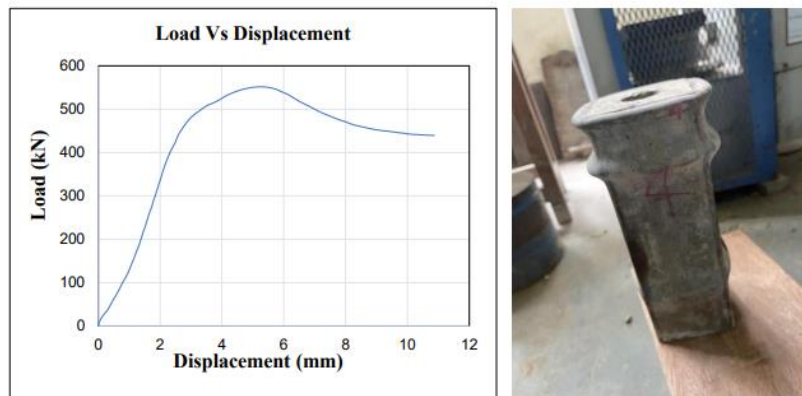


Figure 6 Load vs deflection curve of square CFDST Specimen 1.

3.2 FEM results

Validation of the ABAQUS model requires the simulation of materials property and precisely imposing the experimental conditions. The input parameters obtained from the characteristic evaluation of the material properties were incorporated into the model. It includes the strength of concrete, stress, modulus of elasticity of steel, diameters of section, thickness, etc. The result obtained from the FEA model showed a good agreement with the experimental results as shown below.



Figure 7 Deformed shape of the tested specimens.

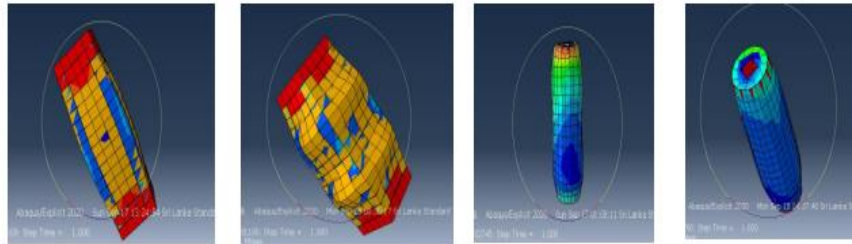


Figure 8 Deformed shape of the Abaqus Models of tested specimens.

Models were developed and validated after simulating it in software. A model can be said to be validated if the deformation shape, results for both experimental as well as a model are reliably similar (Figure 7 and Figure 8).

4. Conclusions

Several experimental and analytical studies were conducted to examine variations in the axial strength of different section layouts and to evaluate the influence of CFDST under axial loading conditions, particularly focusing on Concrete-Filled Double-Skin Tubular (CFDST) columns. The experimental findings showed the improved axial capacities of CFDST columns compared to other types and the results of FEA models were validated with the experimental results. Both experimental and FEA models showed a good comparison of axial loads, stress distributions and failure modes.

Hence, these validated FEM models could be used to make codes for calculations for practical usage of any sections. Further research may require in this circumstance for more precise details in due course.

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INVESTIGATING THE WATER ABSORPTION OF TREATED MANGO WOOD; ORGANIC WOOD PRESERVATIVES COUPLED WITH PETROLEUM OIL

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Abstract: Wood is a versatile and sustainable construction material with various desirable properties. With the rapid population growth in the modern world, there has been a significant increase in wood consumption. However, the unsustainable practice of frequent and care-less tree felling is no longer acceptable. Moreover, wooden structures face numerous threats such as water, fire, termites, fungi, and other adversaries, emphasizing the importance of wood preservation. Effective preservation techniques not only mitigate the degradation of wooden structures but also reduce maintenance costs, enhance their durability, and make a less environmental impact. The resistance to water absorption in wood preservatives is of utmost importance due to the detrimental effects of excessive water absorption. Problems such as mold growth, swelling, discoloration, structural failure, and reduced durability can arise from high water absorption. Therefore, enhancing the water absorption resistance of organic wood preservatives becomes crucial. This research paper focuses on evaluating and improving the water absorption resistance of organic wood preservatives to mitigate these issues. The findings contribute to the development of effective preservation methods and promote the long-term durability of wooden structures. The study compares the water absorption resistance of mango when it is treated with two organic wood preservatives when combined with petrol in different proportions. As the methodology first, a comprehensive literature review was conducted, followed by resource gathering. The experiment employed three replicates per sample. Wood and oil proportions (3:1, 2:1, 1:1, 1:2, and 1:3) were tested with FSWM and FSWOM separately. Results were analysed to conclude the effectiveness of the organic wood preservative and it was concluded that the best solution to minimize the water absorption is given by FSWM: Petrol, 3: 1 ratio solution. This research can guide the development of improved wood preservation techniques, promoting the sustainable use of wood in construction.

Keywords: Wood; Water absorption; Organic wood preservative; Petrol

1. Introduction

Wood is a natural, porous, and fibrous material that is derived from the stems, branches, and roots of trees and woody plants. Sapwood is the outermost layer of a tree covered by bark, and it consists of water and nutrient-transport tissues known as the xylem. The inner layer is made up of countless dead xylem tubes, and the heartwood is usually used to make wooden constructions (Ansell, 2015). Wood is a natural, renewable, and generally non-toxic material that has been widely used in various industries for thousands of years. It is derived from biomass and is environmentally sensitive (Sandberg et al., 2017). Wood offers several advantages, including easy accessibility, lightweight, high strength-to-weight ratio, predictable behavior in fires, strong performance in seismic zones, low environmental impact, and ease of use for prefabricated buildings. As a result, it is a promising construction material with numerous applications.

1.1 Wood as construction material

Wood is considered an excellent building material and the only truly sustainable resource. While other materials like concrete, bricks, or steel have gained popularity, wood remains highly valued due to its inherent characteristics. It is the oldest known building material and continues to be regarded as luxurious. Its lightweight nature, high strength-to-weight ratio, and environmental friendliness contribute to its enduring appeal in the construction industry (Coggins, 2016). In addition, water, fire, termites, fungi, and other various adversaries can damage wooden structures (Williams & Feist, 1999). So, wood preservation is very important because it can reduce the degradation of wooden structures, reduce maintenance costs, increase the durability of the wooden structure, etc.

1.2 The wood modifications

The wood modification involves altering the properties of wood through various treatments and techniques. It encompasses chemical, mechanical, physical, and biological techniques to enhance the qualities of wood. This process is important because it can improve the durability, dimensional stability, strength, fire resistance, and aesthetic appeal of wood. Wood modification techniques can make wood more resistant to decay, insects, and fungal growth, as well as reduce warping and shrinking. Additionally, it can increase the mechanical properties of wood, making it suitable for structural applications. Different types of processes, including chemical, thermo-hydro, thermo-hydrromechanical, biological, and physical treatments, can be employed to modify wood effectively (Sandberg et al., 2017).

1.3. Wood preservatives

There are numerous artificial wood preservatives available today, including borates (Borax-Boric and CCB-Copper Chrome Boron), and others (Ringman et al., 2019). However, because of their high toxicity, these artificial wood preservatives can harm both human health and the environment. Considering the toxicities of most of the artificial preservatives available on the market, natural preservatives have been developed by combining bark extract, leaf extracts, and other plant-based products.

Introduction of organic wood preservative by Pro-Green Lab, University of Moratuwa, inspired by ancient techniques, advancing sustainable wood treatment namely FSWM (Final Solution Without Mud) and FSWM (Final Solution Mud). They are patented to the University of Moratuwa UOM under local patent numbers 21911 and 21896 respectively.

1.4 Wood preservatives and water absorption

Wood preservatives should be resistant to water absorption to increase their preservative characteristics, as excessive water absorption can lead to various problems such as mold growth, swelling, discoloring, structural failure, and durability (Mendis et al., 2023). But artificial wood preservatives have a high environmental impact, thus the discovery of alternatives like organic wood preservatives with high efficiency is a must.

Petroleum oils, ranging from diesel to heavier variants, combined with chlorinated phenols, primarily pentachlorophenol, and copper naphthenate, have gained significant popularity as wood preservatives in the United state. Additionally, traditional practices have employed used motor oil as a water-repellent finish or wood preservative. Timber preservatives like pentachlorophenol exhibit enhanced performance when used in solutions containing heavy solvents such as heavy gas or heavy petroleum solvent (Henriques et al., 2008). The Nordic countries mostly use white spirit or other petroleum-based hydrocarbons as light organic solvent-borne preservatives for impregnating window and door joinery products (Salminen et al., 2014).

This research is focused to identify suitable methods to increase the water absorption resistance of organic wood preservatives by coupling them with petroleum oil. In the context of wood science, the term "absorption" refers to the overall uptake of material by wood, regardless of the specific mechanism involved. On the other hand, "adsorption" specifically denotes the process of material uptake on surfaces or interphases, achieved by the attachment of water molecules within the wood structure, as defined by the IUPAC guidelines. The commonly used term "absorption" encompasses both the uptake of water by the cell walls of wood and the phenomenon of capillary condensation within lumber (Thybring et al., 2018)

In wood research, water uptake involving both adsorption (bound water) and absorption (free water) is typically assessed using water absorption tests. However, it is important to acknowledge that these two forms of water uptake cannot be quantified separately or considered individually within the scope of these tests (Penvern et al., 2020). Nonetheless, it has been observed that approximately 25% of this overall uptake can be attributed to bound water when the cell wall material remains unchanged prior to the water absorption test, particularly in cases where hot pressing has not been employed as a treatment method.(Xu et al., 1996). Consistency in the interpretation of water absorption testing standards can be observed across various research studies.

2. Methodology

The following section presents a detailed description of the methodology employed in this research study.

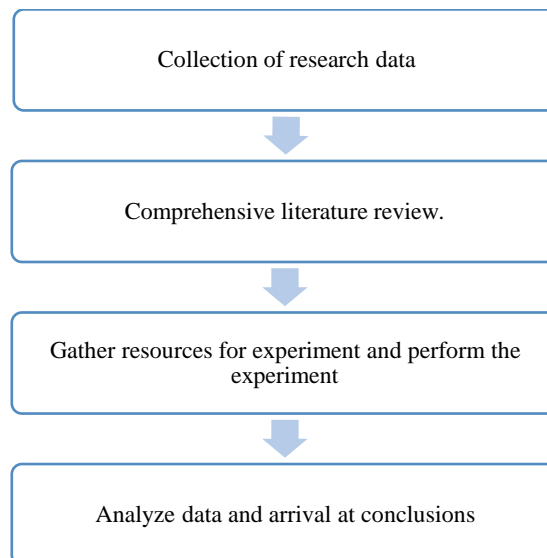


Figure 1: Methodology.

To ensure accuracy and reliability, three replicates were employed for each sample. 3:1, 2:1, 1:1, 1:2, and 1:3 proportions were applied for one wood type and one oil type coupling with FSWM and FSWOM separately

2.1 Test procedure

- i. The samples were oven dried at 105°C for 24hrs in the University laboratory.
- ii. The samples were weighed.
- iii. Following the intended proportions, the FSWOM and FSWM preservatives were individually combined with specific types of petroleum oil.
- iv. The insoluble oil layer present in the solution was effectively removed using an injection method.
- v. For the experimental procedure, the solutions were applied to the wood samples using a brush in a surface application manner. Initially, a layer of solution from the mixed layer was applied, followed by a second layer of the respective oil layer, ensuring proper and thorough application.
- vi. To facilitate the drying process of the treated wood samples, they were left to air dry for 7 days. The choice to utilize air drying instead of an oven drying procedure was made due to the presence of petroleum oils mixed with the solution.
- vii. Then the wood samples underwent a 24-hour submersion in water.
- viii. Following the submersion in water, the samples were carefully removed from the water and excess surface water was gently wiped using a cotton cloth or paper. The samples were then weighed and immediately immersed in water once again. This process was repeated iteratively until the weight of the samples reached a constant value, indicating saturation with water.
- ix. The water absorption was calculated by the following equation.

$$WA (\%) = \{(W_2 - W_1) / W_1\} \times 100$$

2.2 Equations

Typically, the calculation of water uptake follows a standardized equation provided by the testing standards (Devi & Maji, 2012)

$$\text{Water uptake (\%)} = \{(W_t - W_d) / W_d\} \times 100$$

W_t = Weight of the sample after immersion in distilled water after a certain time interval

W_d = Weight of the oven-dry sample

In order to determine the moisture content prior to water saturation and achieve a consistent weight by eliminating hygroscopicity, the wood samples were subjected to oven-drying at temperatures ranging from 103°C to 105°C. This process ensures an irreversible loss of moisture and provides a baseline weight for further analysis (Sargent, 2019)

3.0 Results and discussion conclusion

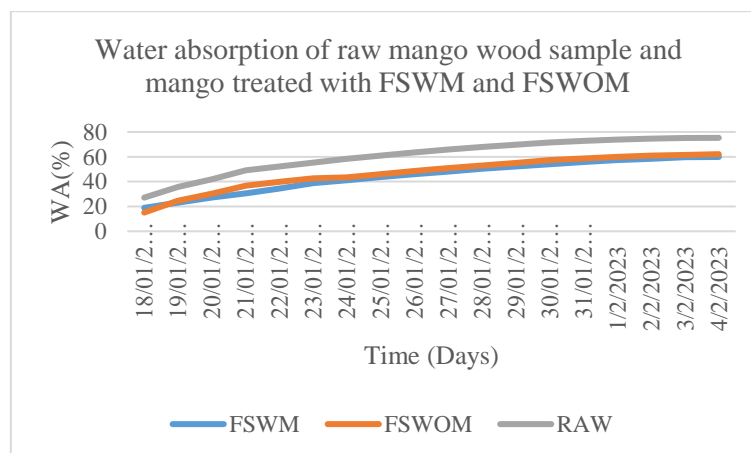


Figure 2: Water absorption of raw mango wood sample and mango treated with FSWM and FSWOM.

When mango was treated with FSWM, water absorption is reduced by 15.4% while it was reduced by 13.14% when it was treated with FSWOM.

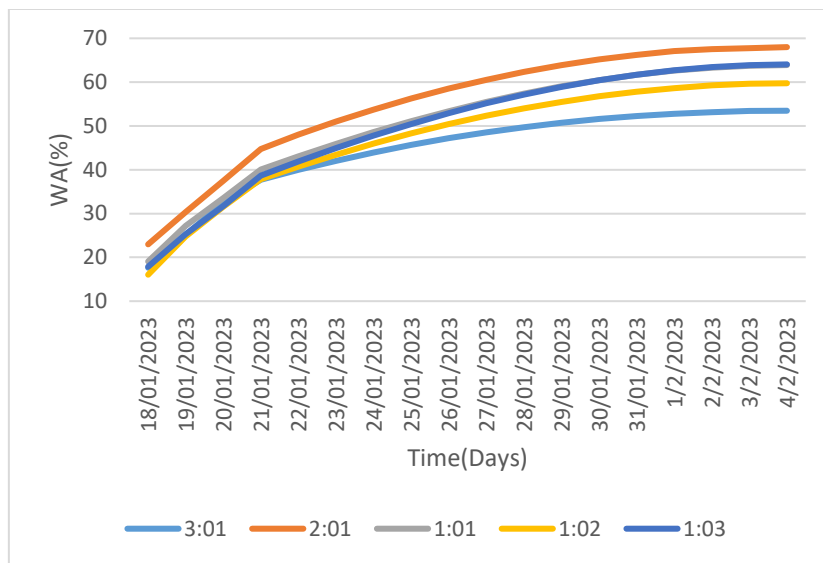


Figure 3: Water absorption of mango wood treated with FSWM coupling with petrol.

Minimum water absorption is given when FSWM coupling with petrol in a 3:1 ratio. It reduces the water absorption by 21.76 % compared to the raw sample.

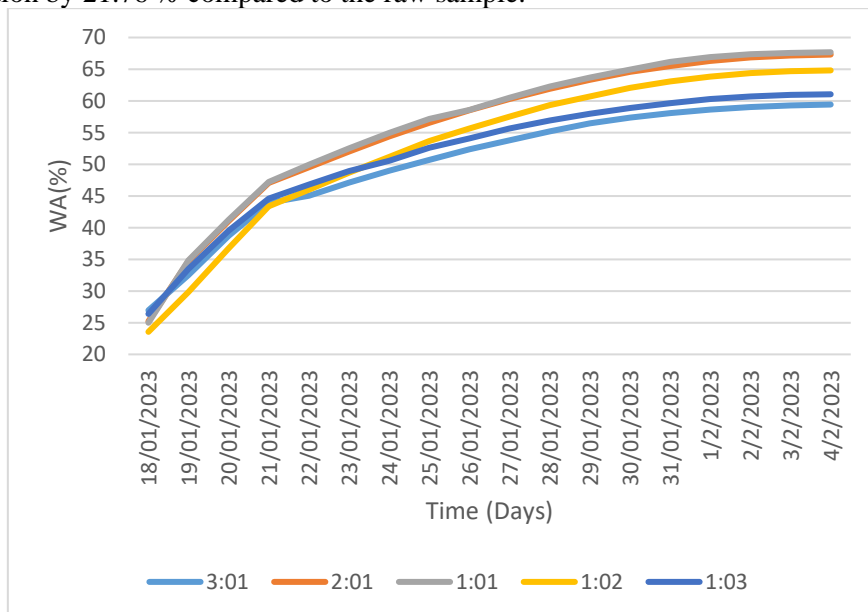


Figure 4: Water absorption of mango wood treated with FSWOM coupling with petrol.

Minimum water absorption is given when FSWOM coupling with petrol in a 3:1 ratio. It reduces the water absorption by 15.81% compared to the raw sample.

4.0 Conclusion

The best solution to minimize the water absorption is given by FSWM: Petrol, 3: 1 ratio solution.

Acknowledgment

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USE OF GRAPH DATA MODELING FOR UNVEILING INTERCONNECTED STRATEGIES OF CLIMATE ACTIONS

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Abstract: Climate change has emerged as a pivotal area of research and action for governments, academic institutions, and industries, driven by the need for effective policy-making, strategic planning, and thorough investigation of causes and mitigation strategies. The diverse involvement of these stakeholders underscores the complexity of creating a standardized approach to mapping climate actions. This paper argues that understanding the intricate relationships between various climate initiatives is crucial for unveiling effective paths towards sustainability. We explored the potential of graph-based modelling as a novel approach for analyzing unstructured data in climate change research. Unlike traditional relational and non-relational data models, graph-based modelling offered unique insights by contextualizing climate actions within social, ecological, and geological frameworks. Our analysis reveals that graph-based modelling not only facilitates a deeper understanding of the connections between different climate actions but also highlights the importance of considering multiple perspectives to identify viable solutions for climate change mitigation. This approach promises to enrich our understanding of climate dynamics and foster the development of more targeted and effective climate policies and actions. Data were collected through an extensive review of previous studies and expert analyses across various sectors, utilizing large language models to ensure a comprehensive and nuanced understanding of climate actions. These actions were precisely categorized according to their roles in policy development, strategic planning, and mitigation efforts. In this structure, nodes symbolize specific climate mitigation actions, while edges represent the intricate relationships and dependencies among these actions. The design meticulously incorporates attributes for both nodes and edges, detailing crucial information such as the actions' sectoral affiliations, their estimated impact magnitudes, and the dynamics over time. Therefore, climate actions and their mapping are readily visualized and extracted, offering tailored insights for specific localized contexts.

Keywords: Climate change; Climate action; Graph data modeling; Sustainability strategies

1. Introduction

The primary responsibility for achieving Sustainable Development Goal (SDG) 13, which focuses on Climate Action, rests with government bodies, alongside various associated organizations and ministries. The effectiveness of these entities in implementing measures against climate change is significantly hampered by the absence of robust communication mechanisms. This lack of communication becomes a critical barrier, even when a specialized steering body for Climate Action is established by the government. The challenge is compounded by the fact that diverse organizations require distinct action plans tailored to their specific mandates to effectively contribute to the overarching goal of climate action. Therefore, the development and enhancement of inter-organizational communication strategies are imperative to harmonize efforts, facilitate collaborative action, and ensure the successful realization of SDG 13.

In the United Nations, 2023, a variety of critical sectors were identified as pivotal to global climate action efforts. These sectors include health, food and water security, the livelihoods of people and communities, energy generation and access, transport, infrastructure and the built environment, ecosystems and ecosystem services, as well as buildings, cities, industries, appliances, forests, and land use. However, a significant challenge has emerged: many of these sectors do not align well with local governance structures or are incompatible with existing local administrative mechanisms.

In response to these challenges, and as a direct outcome of the Paris Agreement, nations participating in the convention have submitted their self-defined actions and targets, known as National Determined Contributions (NDCs), aimed at achieving NetZero emissions. Most importantly the NCD is not the commitment, it is the action that we need to meet the commitment. These NDCs reflect an acknowledgement of local governance structures and propose customized sectors that are better aligned with local administrative frameworks. Moreover, the convention has emphasized the importance of identifying climate-related issues on a subnational or regional basis. This approach has led to the introduction of Locally Determined Contributions (LDCs), which aim to foster tangible achievements at the local level by tailoring climate action initiatives to specific regional needs and capacities.

This evolution towards localized action plans represents a significant step forward in making climate action more effective and responsive to the unique conditions and capabilities of different regions and communities. Efforts to delineate climate actions and targets on national, subnational, and regional levels are being meticulously coordinated by expert individuals and dedicated bodies, all operating under the guidance of a national steering committee. In a bid to fully leverage the insights derived from these efforts, the application of advanced Artificial Intelligence (AI) techniques and data modelling methods is advocated. This approach is aimed at crafting a comprehensive perspective that encapsulates potential actions and their corresponding targets, thereby ensuring a strategic and informed response to climate change.

Given the complexity and multitude of sectors involved in mitigating the impacts of climate change across various geographic scales, it is imperative to develop a transformative action modelling framework. Such a framework should aim to reduce overlaps and inefficiencies while elucidating the interconnections between identified actions. To be effective, this model must embody flexibility, adaptability, and a data-intensive approach, enabling it to accommodate evolving insights and facilitate a dynamic response to the challenges posed by climate change. By adopting this sophisticated modelling approach, it is possible to streamline climate action efforts, ensuring that they are both efficient and tailored to the unique environmental, social, and economic contexts of each national or subnational region.

The objective of this research was to employ graph data modelling techniques to construct a comprehensive model of climate action, focusing on the interrelations between various sectors and their

corresponding targets. How can we utilize existing knowledge bases to answer the following two questions raised by commuters and policymakers within the transportation sector?

1. What are the most effective mitigation actions for reducing Greenhouse Gas emissions in city passenger transport?
2. Which policies and regulations are most needed to enable the widespread adoption of electric vehicles?

Therefore, we aim to create a graph database that encapsulates climate action initiatives across different sectors, highlighting the intricate network of relationships among them. In this study, we mainly focused on the transportation sector-related modelling for the model demonstration. This methodological approach allows for a nuanced understanding of how sector-specific actions contribute to overarching climate objectives, facilitating targeted and effective climate action strategies.

2. Literature Review

The primary responsibility of government bodies in implementing climate action measures is well-acknowledged (Smith and Johnson, 2021). However, Smith et al. (2022) highlight how the effectiveness of these measures is often compromised by inadequate communication mechanisms within and between these entities. Jones (2023) further emphasizes that the absence of robust communication channels not only hinders the implementation of climate measures but also poses a significant barrier to the establishment of a cohesive climate action strategy.

The 2023 United Nations Framework Convention on Climate Change identified multiple sectors crucial to climate action, underscoring the importance of their alignment with local governance structures (United Nations, 2023). Williams and Patel (2024) discuss the challenges that arise when global climate action efforts clash with local administrative mechanisms, suggesting that the lack of alignment can significantly impede the effectiveness of these initiatives.

Following the Paris Agreement, nations have submitted National Determined Contributions to signal their commitment to achieving NetZero emissions, reflecting an understanding of local governance structures (Doe and Clark, 2022). The introduction of Locally Determined Contributions marks a pivotal shift towards more localized and responsive climate action plans (Brown, 2023). This approach, according to Lee and Kim (2024), allows for the tailoring of climate action initiatives to the specific needs and capacities of regional communities, enhancing their effectiveness.

The application of Artificial Intelligence (AI) techniques and data modelling methods is advocated to overcome the complexity of planning and implementing climate action across diverse sectors and geographic scales (Zhang et al., 2023). Green and Harris (2023) propose a transformative action modelling framework that employs AI to reduce redundancies and elucidate the interconnections between actions, ensuring a strategic and informed approach to climate change mitigation.

3. Methodology

This study acknowledges the inherent diversity in climate action requirements across different geographical regions and subregions, driven by their unique environmental, social, and economic contexts. Despite this diversity, there exists a unified objective among all regions: the reduction of greenhouse gas emissions to mitigate climate change. To account for these variations while maintaining a coherent framework for analysis, our methodology employs a standardized representation structure, tailored to encapsulate the distinct elements pertinent to each region's specific climate action strategies.

To operationalize this approach, we adopt international sector categories mentioned in United Nations, 2023 as the basis for our analysis. This decision allows us to apply a consistent framework across different regions, facilitating comparative analysis while acknowledging the unique challenges and

opportunities present in each. For instance, the impact of sea-level rise is considered more significant in regions with oceanfronts, illustrating how geographical characteristics influence the prioritization of climate action efforts. Conversely, regions lacking oceanfronts may prioritize other climate-related concerns, such as desertification or forest degradation.

Our methodology is designed to be both inclusive and flexible, ensuring that the diverse range of climate actions, from mitigation to adaptation strategies, can be effectively categorized and analyzed within the international sector framework. This approach enables us to draw meaningful insights into the efficacy and scope of climate actions across different regions, providing a comprehensive overview of global efforts to achieve emission reduction goals.

By leveraging this structured yet adaptable methodology, the study aims to contribute to a deeper understanding of the global landscape of climate action, highlighting areas of progress and identifying gaps where further efforts are necessary. Through the consideration of international sector categories, we ensure that our analysis remains relevant and applicable across various geopolitical and environmental contexts, facilitating the development of targeted recommendations for enhancing the effectiveness of climate action initiatives worldwide.

In this study, we focus on showcasing data associated with transportation. To achieve this, we gathered extensive climate hazard elements and action association data from a variety of online sources relevant to the transportation sector. Our collection encompasses both national and international climate reports, databases maintained by governmental and non-governmental organizations, scholarly articles, and well-regarded climate action platforms. This comprehensive data compilation ensures a robust foundation for our analysis, drawing from a wide spectrum of authoritative resources to inform our exploration of transportation-related climate actions.

The graph data modelling approach involved constructing a comprehensive graph structure where nodes represent primary elements of the sector, and edges denote relationships and dependencies between these elements. Attributes associated with nodes and edges captured pertinent information such as sectoral affiliations, impact magnitudes, and temporal dynamics.

The second critical aspect of graph data modelling involves uncovering potential relationships among the identified nodes. To achieve this, Large Language Models (LLMs) were employed to discern these connections. As innovations and discoveries emerge globally, new nodes and relationships are incorporated, ensuring that the model remains dynamic and responsive to future developments.

The third fundamental characteristic of the graph database is its capability to store properties associated with nodes and relationships. Typically, these supplementary attributes are stored in the form of key-value pairs. Several crucial attributes were identified as necessary for generating insights. These values are both critical and subjective across different regions; therefore, localized values will be determined by experts and research findings to ensure regional relevance and accuracy.

The selection of a graph database was guided by criteria such as scalability, flexibility, query performance, and ease of integration. Given the dynamic nature of climate mitigation data, the chosen database must support efficient updates and accommodate evolving schema requirements. Christos Tjortjis (2023) evaluated popular graph databases, such as Neo4j, ArangoDB, and Amazon Neptune, was conducted based on established benchmarks and performance metrics. This comparative analysis guided the selection process, considering factors like data volume, transaction complexity, and the capacity to handle relationships within the context of climate mitigation actions. Neo4J technologies were selected to model nodes, relationships and attributes.

After identifying the nodes, relationships, and properties, we constructed the graph model, designed with the flexibility to adapt and evolve in response to emerging findings and innovations. Utilizing the Cypher query language, we facilitate the exploration and extraction of insights from the constructed graph, enabling the analysis of complex relationships and patterns within the climate action data. This adaptive approach ensures that our model remains relevant and capable of integrating new knowledge, thereby supporting ongoing research and decision-making processes in the field of climate change mitigation and adaptation.

4 Results and Discussion

In the results section, Table 1 presents the array of transportation elements that were gathered from global sources, highlighting the diversity of transportation-related elements encountered. These elements are organized into eight principal categories, with each category comprising various nodes. Furthermore, each node is detailed with its specific instances, as enumerated in Table 1. This organization facilitates a clear understanding of the breadth and depth of the elements impacting the transportation sector, showcasing the comprehensive nature of our data collection effort.

Table 1: Identified transportation elements using online resources

Node	Instances
Transportation Modes	Air, Rail, Road, Walking and Cycling, Water
Transportation Vehicles	Aeroplanes, Boat, Buses, Cars, Foot Bicycles, Mini Busses, Motor Bicycles, Ships, SUVs, Trucks, Trains
Fuel Technology	Biofuels, Diesel, Electric, Gasoline, Hydrogen, Natural gas
Infrastructure	Airports, Foot Bicycle lanes, Charging stations, High-speed rails, Mono rails, Public transport terminals, Ports
Policies and regulations	Carpool incentives, Emission standards, Fuel taxes
Locations	Cities, Countries, Subregions
Subsectors	Freight transport, Passenger transport, Tourism
Stakeholders	Governments, Individuals, Private organisations, Research institutions

The interconnectivity among nodes serves as the foundational mechanism for linking specific elements to corresponding actions within the transportation sector. Table 2 elucidates these relationships, showcasing the intricate network of interactions discovered through our analysis.

Table 2: Identified relationships using Large Language Models

Relationship	Explanation	Example
Generate emissions	Connects a mitigation action, measured in CO ₂ e grams per passenger per km	Electric vehicles have fewer emissions
Requires	Connects an action to its necessary prerequisites	Charging stations for electric vehicles
Enables	Connects an action to other actions it facilitates	Public transport reducing car usage
Impacted by	Connects an action to policies and regulations that affect it	Emissions standards for vehicles
Implemented by	Connects an action to the stakeholders responsible for its implementation	Government subsidies for charging stations

Located in	Connects an action to the geographic areas where it applies	City bike sharing program
Finance	Connects an action to its estimated implementation and maintenance costs	Investment opportunities
Impacts	Connects an action to its broader social, economic, and environmental impacts	Job creation, air quality improvement, waste generation

The construction of decision-making queries leverages the attributes associated with nodes and relationships, emphasizing the crucial impact of these attribute values on critical decisions bound by legal, environmental, and financial considerations. Table 3 outlines the attributes identified, capturing a wide array of factors. As local experts contribute new attributes, there is a continuous process of refining and optimizing existing parameters. This ensures that our decision-making framework is both comprehensive and adaptable, capable of incorporating fresh insights and adapting to changing circumstances.

Table 3: Identified relationship-attributes using Large Language Models

Attribute	Explanation	Example
Effectiveness	Quantifies the mitigation potential of each action	Percentage of greenhouse gas reduction
Feasibility	Assesses the technical, economic, and social feasibility of implementation	Infrastructure readiness, public acceptance
Scalability	Evaluate the potential for widespread adoption and impact	Reduce EV consumer/import taxes
Synergy	Indicates potential for combining actions for enhanced effectiveness	Electric car sharing with renewable energy charging

Figure 1 illustrates the dynamically expanding graph, which evolves in response to updates. Decision-makers and policymakers can readily identify the various branches and assess the impacts of each circuit based on specified query criteria. This adaptability underscores the graph's superiority as a flexible data structure, particularly suited for mapping climate-related data and analyses.

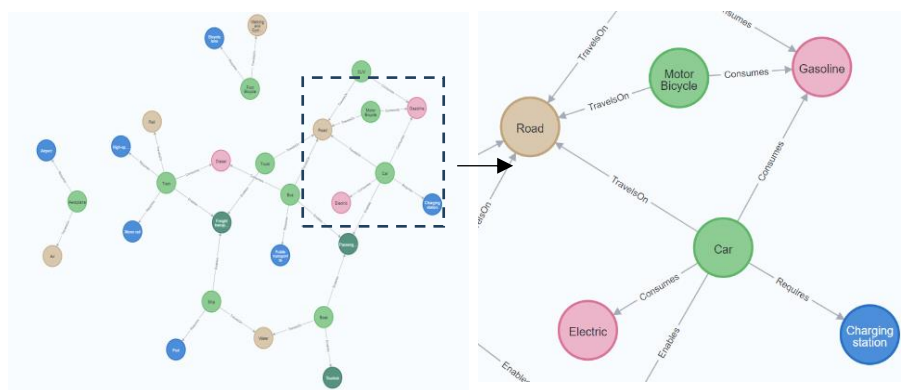


Figure 1: Graph structure for transport-related element relationships.

5 Conclusion

The literature underscores the critical role of effective governance, communication, and technological innovation in advancing climate action. Improved communication strategies within government bodies and between them and other organizations, alignment of climate action efforts with local governance

structures, and the adoption of advanced technological solutions are essential for the successful realization of SDG 13. The shift towards localized action plans, underpinned by NDCs and LDCs, and the application of AI and data modelling techniques, represent significant strides towards a more effective and responsive global climate action framework. Therefore, this study has developed a novel graph data structure aimed at effectively mapping climate actions, grounded in the elements and assets pivotal to understanding climate hazards. Leveraging insights from previous research and the innovative application of Large Language Models (LLMs), we have meticulously charted the properties of climate elements and delineated the requisite actions. This structured approach not only enhances our grasp of the intricate web of relationships inherent in climate data but also paves the way for informed decision-making in climate action initiatives.

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**STRENGTH ENHANCEMENT OF LIMESTONE AGGREGATE CONCRETE
PRODUCED WITH FLY ASH IN PARTIAL SUBSTITUTION OF CEMENT IN
NORTHERN PROVINCE CONSTRUCTION**

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Abstract: To produce good quality concrete, the materials used should meet standard specifications. Proper selection of aggregates in a concrete mix is critical to the long-term performance of concrete. To increase the properties of limestone aggregate concrete, INSEE Rapid Flow plus (R. F+); Portland Fly Ash Cement containing 15% Fly Ash, SLS 1247, Strength Class 42.5 N was used in the limestone aggregate concrete mix. There were three different concrete mixes cast in this research study such as INSEE Portland Limestone Cement (PLC) with granite and limestone aggregate concrete mixes and PFAC limestone aggregate concrete mix. Initially, Properties of aggregates such as Relative Density, Water Absorption, Particle Size distribution, and Aggregate Impact Value, Los Angeles Abrasion Value, and Soundness test were studied to find the suitability of limestone aggregate in concrete practices. After that, the impact of concrete properties such as Workability, Compressive Strength, Flexural Strength, Splitting Tensile Strength, and Depth of Penetration of water under pressure were investigated under laboratory conditions. The test results reveal that water absorption of limestone aggregate is higher than the granite aggregate, PFAC (15% Fly ash cement) Limestone aggregate mix was achieved good physical and mechanical properties of concrete compared to PLC limestone and granite aggregate mix, also, the maximum depth of penetration of water under pressure was 22.46mm only in PFAC mix. Further, the durability and thermal properties of limestone concrete needs to be investigated in future research studies to ensure the quality of limestone aggregate concrete.

Keywords: Limestone aggregate; Fly ash; Sustainable Concrete; Properties of Concrete

1. Introduction

Concrete is one of the most widely used building materials in the civil industry. Concrete is typically composed of cement, fine aggregate, coarse aggregate, and the amount of water required, depending on the concrete mix and the designed water/cement (W/C) ratio. Basically, in concrete, more than seventy percent of the concrete volume is occupied by aggregate, but the ideal quality of aggregate can adversely affect the properties, durability, and structural performance of concrete. Limestone aggregate is a coarse aggregate that has been used in concrete since wartime as an alternative to granite aggregate in the Northern Province. In Sri Lanka, limestone aggregate and granite metal are the two main aggregate types commonly used in Sri Lankan construction practices, especially in low-rise construction projects. Although in Sri Lanka, the application of limestone in some projects is limited due to environmental conditions.

2. Literature Review

Supplementary cementitious materials (SCMs), also known as supplementary cementing materials, are materials that contribute to concrete performance through hydraulic or pozzolanic activity, or both when used with Portland or blended cement. Fly ash and Silica fume can be used as cementitious materials to improve the strength and durability of concrete. These materials can be added as a part or substitution in cement production or when making concrete in common practices. The performance of fly ash in concrete is strongly influenced by its chemical composition, and fly ash from different sources can behave very differently. Class F fly ash is usually used in a dosage of 15% to 25% of the mass of the cementitious material, and class C fly ash is used in a dosage of 15% to 40% of the mass of the cementitious material (Gamage & Liyanage, 2011).

2.1 Cement

Ordinary Portland Cement (OPC) is the main component in concrete for common practices. The production of cement is mainly the burning of limestone (CaCO_3) and releases large amounts of carbon dioxide (CO_2). Although Portland Limestone Cement has a slightly lower heat of hydration than OPC, it is not a low-heat cement because the content of C3S and C3A is not much smaller than OPC (SLS 1253, 2015). Composition of PLC is detailed in Table 1.

Table 1: Composition of Portland Limestone Cement (SLS 1253, 2015)

Designation (1)	Equivalent cement type in BS EN 197-1 (2)	Composition % (m/m)		
		Main constituents		Minor additional constituents (5)
		Clinker (3)	Limestone (4)	
Portland Limestone Cement	CEM II/A-LL	80 to 94	6 to 20	0 to 5

2.2 Fly ash

Fly ash is commonly categorized into two classes in accordance with ASTM C618, the Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete; Class F and Class C. Class F fly ash, which provides a greater amount, is usually low in lime, less than 15%, and with more Silica, Alumina, and Iron (over 70%) compared to Class C fly ash. Class C fly ash is normal from coals that produce ash with higher lime content, typically in excess of 15%, usually up to 30%. In addition, high calcium oxide (CaO) provides the best unique self-hardening properties features in Class – C Fly ash. Class C is mainly used where higher early strength is important (Gamage & Liyanage, 2011).

2.3 Aggregate

Limestone aggregates have been used as a substitute coarse aggregate for concrete in certain areas of Sri Lanka. Mainly in northern areas such as Jaffna, usage of limestone as a coarse aggregate for concrete

is not a rare practice. There were two types of limestone samples, namely Red and White limestone. Red limestone was found from Walikamam west, Jaffna and White limestone was identified from Chavakachcheri (Hemadasa & Dilrukshi, 2014).

3. Methodology

There are several experimental studies conducted at laboratory to achieve the objectives. In this research study, properties of coarse aggregates were initially studied to use for concrete works after that properties of fresh and hardened concrete were investigated on limestone aggregate and granite aggregate concrete mixes. To study the properties of concrete, sample preparation was done at INSEE i2i laboratory after that the trial mixes were made based on the BRE mix design method as given in Table – 02.

Table 2: Trial mix detail of concrete per m³

Constituent Materials/ Raw materials of Concrete	Weight per m ³ (Kg)
Cement	386.79
Water	205
Fine Aggregate (River Sand)	679.52
Coarse Aggregate (20mm)	1108.69

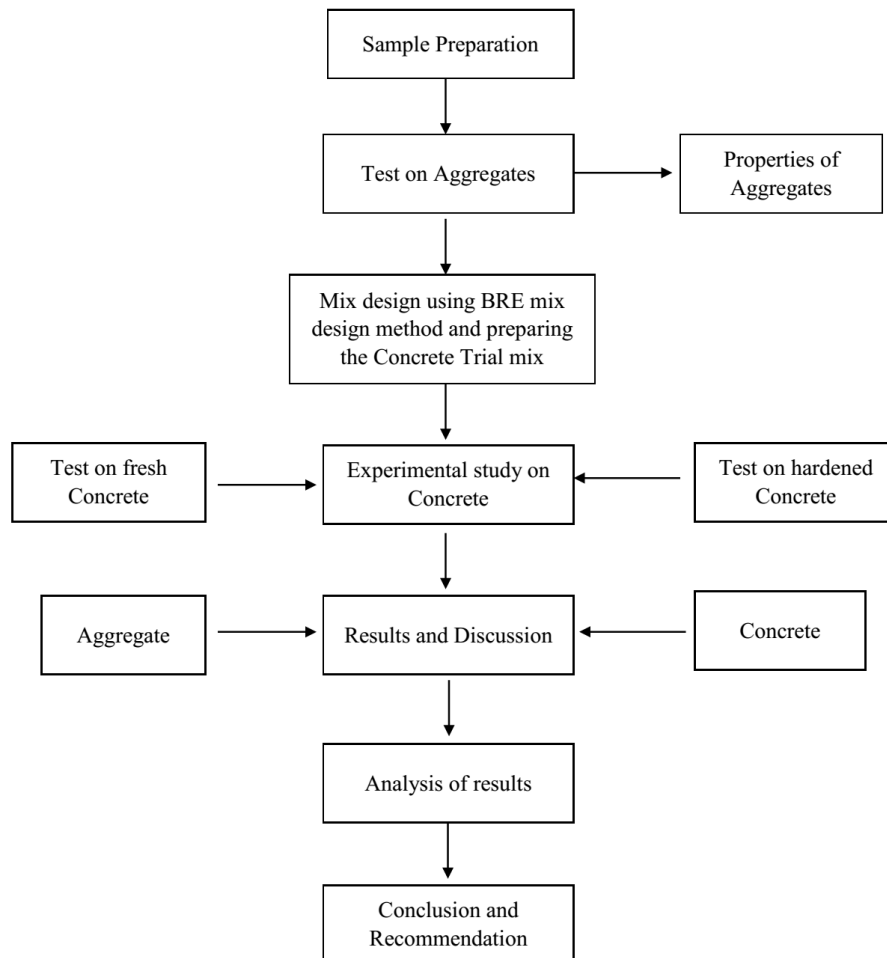


Figure 1: Flow Chart of the research study

3.1 Preparation of Concrete mixes

In this study, three different concrete trial mixes were prepared to achieve the aim and objectives. INSEE Portland Limestone Cement (PLC) and Portland Fly ash Cement (SLS 1247) were used in mixing of concrete samples as shown in Figure 2.



Figure 2: Mixing of concrete mix sample.

3.2 Test on Aggregates

To study the properties of aggregate, Relative density and water absorption test, Particle size distribution and, Aggregate Impact Value test was done at the laboratory. After that, Los Angeles Abrasion Value test was done as per the ASTM C131, and also Soundness test was performed based on ASTM C88 as shown in Figure 3.



Figure 3: Preparation of limestone aggregate sample.

3.3 Experimental studies on test on concrete

There were two different stages of mix obtained in this stage such as fresh concrete and hardened concrete. The properties of fresh and hardened concrete were investigated in accordance with BS 1881 – 102: 1983 used in slump test, BS 1881 – 103: 1993 referred for compacting factor test and BS EN 12390 – Part: 01 to 08:2000 for compressive strength, tensile splitting strength, Flexural strength and depth of penetration of water under pressure.

4. Results and Discussion

This chapter reveals the results of each experimental studies obtained from aggregate and concrete. Discussion of the result explains in details by comparing the limitations and specification mentioned in code of practices and Sri Lankan Standard apply in the civil engineering.

4.1 Results on Aggregate

Particle size distribution of aggregate sample was studied at laboratory to both limestone and crushed granite aggregate sample. The results of granite aggregate sample in the grading test are detailed in Table – 03.

Table 3: Results of sieve analysis test on granite aggregate

Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Percentage Passing (%)	Std. Lower	Std. Upper
37.5	0.0	0.00	100.00	100.00	100.00
20	325.0	5.84	94.16	90.00	100.00
14	2124.0	38.14	56.03	40.00	80.00
10	1456.0	26.14	29.88	30.00	60.00
5	1360.0	24.42	5.47	0.00	10.00
2.36	540.0	9.70	-4.23		
Pan	10.0	0.18			
Sample Weight	5815.0				

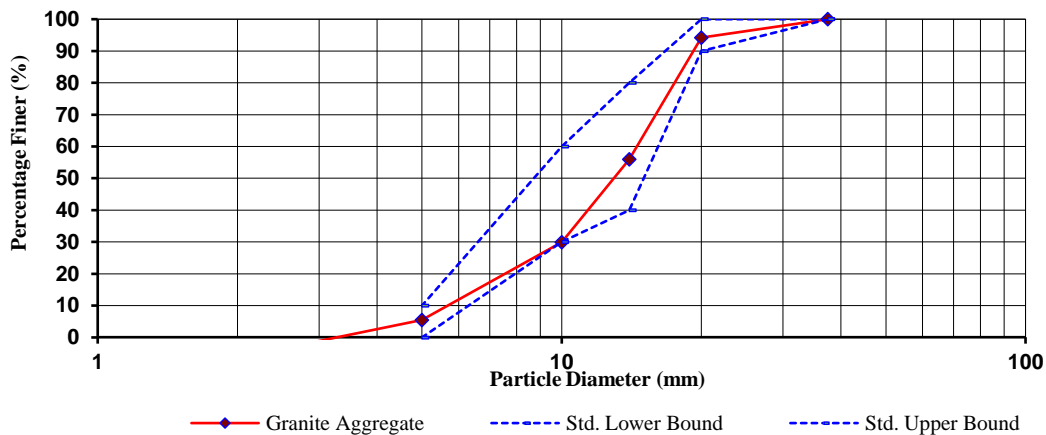


Figure 4: Grading Curve of Crushed granite aggregate sample.

The above grading curve was drawn in log scale and which shows that well graded fine aggregate grains were presented. The shape of grading curve covers more particle sizes within the fine aggregate specimen. Relative density and water absorption of limestone aggregate and granite aggregate were tested in laboratory and the results of water absorption and relative density are shown in Figure 5.

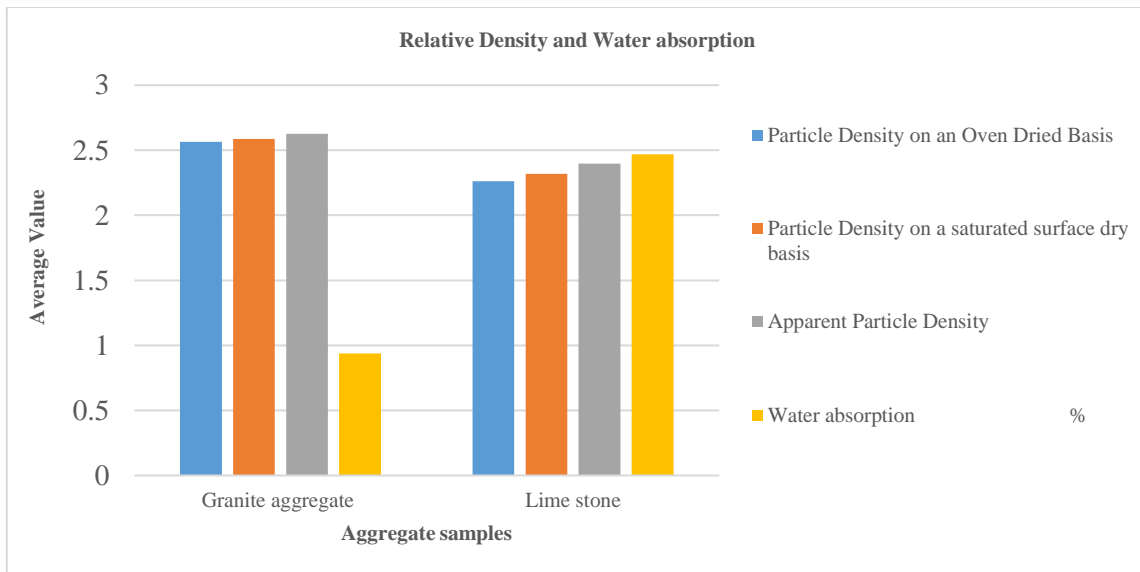


Figure 5: Results of Density and water absorption of aggregate samples.

4.2 Results on Concrete

Slump test and compaction factor test were done for fresh concrete and compressive strength, flexural strength, tensile splitting strength and Penetration of water under pressure were performed to hardened concrete. PFAC limestone aggregate mix slump height was increased due to present of fly ash content into the cement and which was improved the workability. This result is the evidence in affecting the aggregate water absorption. Fly ash content in cement has been highly improved the workability compare to PLC limestone aggregate concrete mix and slump height shows the best results as an outcome from the analysis. Concrete cubes were initially placed into the curing tank and which were tested in 7, 14, 28, 60 days. Average compressive strength in 7, 14, 28, and 60 days were determined to each trial mixes. The results of compressive strength are shown in Figure 6.

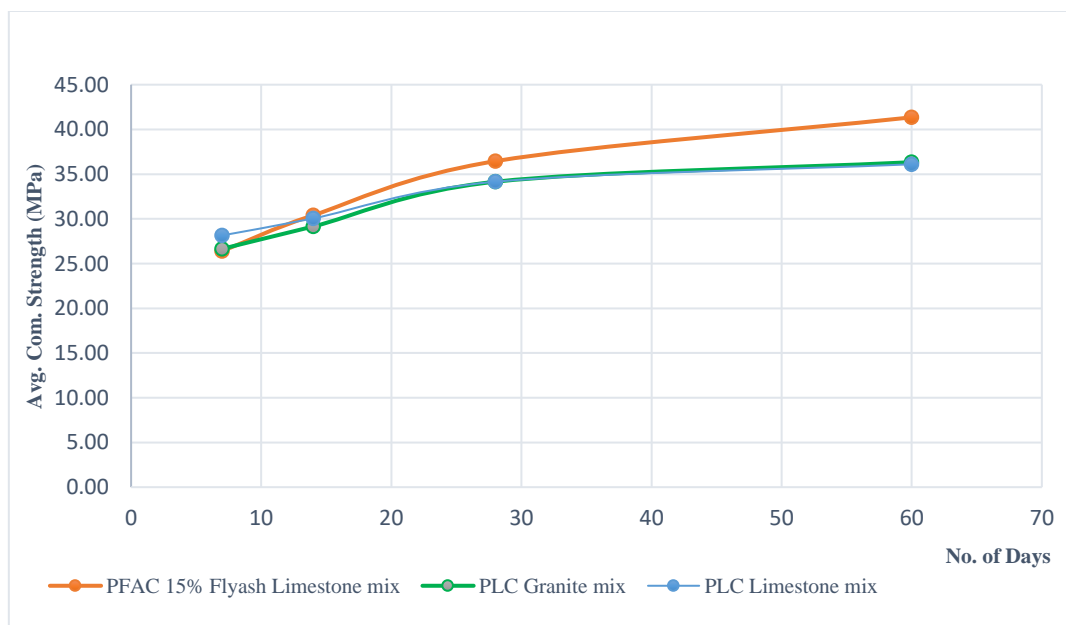


Figure 6: Compressive strength of concrete cube samples.

Flexural strength of concrete was studied by casting a beam in the cross section of 100mm × 100mm and length of 400mm. In each mix, two beams were cast and tested in 28 days at the laboratory.

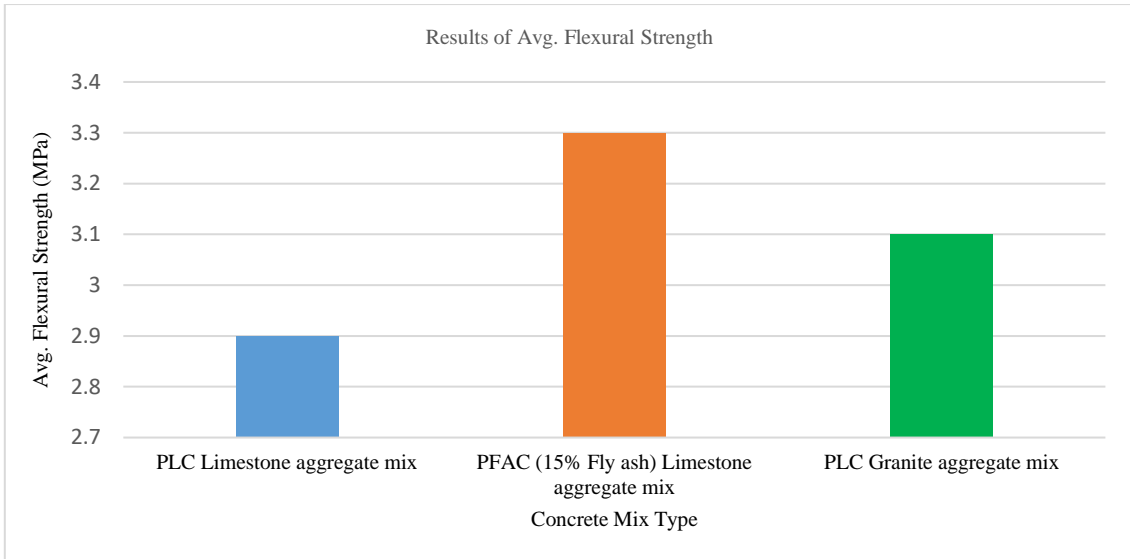


Figure 7: Results of Average Flexural strength of concrete beam samples.

According to BS EN 12390 – Part: 06: 2000, cylindrical samples were casted and it was tested at laboratory. The results of tensile splitting strength values are detailed in Table – 04.

Table 4: Tensile splitting strength of concrete cylinders

Type of concrete	Sample no	Failure load (kN)	Tensile splitting strength (MPa)	Average strength (MPa)
PLC Limestone aggregate mix	01	155.3	2.2	2.3
	02	158.1	2.4	
15% Fly ash (R.F+) Limestone aggregate mix	01	199.45	2.8	2.95
	02	214.32	3.1	
PLC Granite aggregate mix	01	239.2	3.4	3.3
	02	218.4	3.2	

According to BS EN 12390 – Part: 08: 2000, concrete cube samples are set up under water pressure condition for 72 hrs continuously after that cubes were crushed in the middle and observed the water penetration in the surface. Figure 8 shows the fly ash-based limestone aggregate concrete cube sample (PFAC) after the water penetration.



Figure 8: Measuring depth of water penetration in Fly ash-based limestone aggregate concrete cube sample.

PLC limestone and granite mixes were fully penetrated the water and PFAC limestone mix was greatly signed in water penetration within 72 hrs. The penetration depth of water into the concrete cube was recorded and the maximum depth of water penetration is 22.46 mm.

5. Conclusion

From this research study, it was found that limestone aggregate has higher water absorption capacity than normal granite aggregate. Hence, this has a major impact on the properties of concrete made with limestone concrete. Compared with ordinary granite aggregate concrete, the workability and compaction efficiency of limestone concrete are significantly reduced at a given water-cement ratio. From the analysis of properties of coarse aggregate, LAAV and AIV values are mostly satisfied for the pavement wearing coarse and also depth penetration of water in PFAC limestone mix was signed the good performance. 15% Fly ash (PFAC/ R.F+) limestone mix has shown the increment in compressive strength in long time period especially in 60 days strength, it was gone to more than 14% increment in the compressive strength results compare to granite concrete mix and it was nicely worked out in the strength development due to Fly ash content. There are more valuable properties needed to study by considering durability and resistance against harsh environment must be considered in low rise building projects in Northern Province.

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INVENTION AND INNOVATION – AGRICULTURE

ICSD 021

PROBIOTIC DRINKING YOGHURT PRODUCTION INCORPORATE WITH FERMENTED COCONUT WATER

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Abstract: Probiotics are living microorganisms that offer health benefits. When consumption of probiotic drinking yoghurt is one of the prime ways to improve human gut systems. The present study investigated the possibility of developing a novel Probiotic drinking yoghurt incorporated with fermented coconut water (*Cocos nucifera*) and evaluated the growth of probiotics (*Lactobacillus acidophilus*, *Lactobacillus casei*) and its sensory quality parameters. Coconut water was extracted manually and stored for 2 days for the fermentation at 37°C and determined the viable cell count of two probiotic cultures (*L. casei* showing higher growth at 3.02x10⁵ CFU/ml while *L. acidophilus* population 0.9x10⁵ CFU/ml) and the pH (4.45 ± 0.38) of fermented coconut water during the 2 days periods. Two probiotics grew well in fermented coconut water and showed similar growth pattern. Drinking yoghurt prepared by incorporating fermented coconut water with four levels 10%(T1),15%(T2),20%(T3) and 25%(T4) (W/V) and compared with the control (0%) (TC). The developed product was store at 4°C for 21 days. Nutritional and physicochemical properties of the developed products were analyzed. Sensory evaluation was done with 25 untrained panelists using nine-point hedonic scales. Titratable acidity and pH of the developed products were tested at 2, 6, 21 days and microbial counts (Total Plate count, Yeast & Mold, Coliform) were tested at 7, 14, 21 days of storage. Sensory data analyzed by ANOVA test in MINITAB. Results revealed that brix level (5.85±0.01) % were not significantly different but Protein (4.50±0.00) %, Ash (0.6±0.00) %, Fat (2.12±7.07) %, Moisture (81.0±0.02) %, SNF (5.23±0.00) % and Total Solids contents (7.37±0.00) % were significantly different (p<0.05) among treatments. Sensory analysis revealed that the drinking yoghurt incorporated with 10% fermented coconut water had the best sensory qualities. Titratable acidity and pH showed the significant difference among developed products. The significant interaction was observed between treatment and storage time on pH and acidity for the developed products. And it was accepted to 21 days of storage period at 4°C. In conclusion, 10%(T1) of fermented coconut water can be incorporated to produce drinking yoghurt with the best sensory attributes and can be stored 21 days at 4°C without any quality deterioration.

Keywords: Probiotic; Fermented coconut water; Drinking yoghurt; Storage

1. Introduction

The demand for the fermented dairy products such as curd, set and drinking yoghurts is growing up due to its numerous health benefits. These products provide and preserve nutrients, different flavor, aromas, and texture, enhance organoleptic properties and increase economic value. Now days gastrointestinal disorder is one of the major health problems among people. stress lifestyle, intake of fast food, improper diet pattern and consumption of alcohol cause gastrointestinal diseases and decrease the number of beneficial microorganisms in the stomach. As such, the survival probiotic in the gut systems is questionable. Therefore, probiotics are added to probiotic drinking yoghurt in order to enhance the survival of probiotics. Yoghurt is a coagulated milk product obtained by lactic acid fermentation through the action of *Lactobacillus bulgaricus* and *streptococcus thermophilus*. Yoghurt drinks are categories under stirred yoghurt which contain low viscosity due to high agitation after formation of fermented coagulum. The use of fermented coconut water has been providing mainly two probiotic sources such as *Lactobacillus acidophilus* and *Lactobacillus casei*. Today consumer demand is moved toward the probiotic health and nutrition. Therefore, fortifications of food products with various functional ingredients have been used to fulfil above requirements. There for the main objective of the study was to developing the growth of probiotic microorganisms *Lactobacillus acidophilus* and *Lactobacillus casei* in drinking yoghurt with nutritional analysis.

2. Material and methods

Manufacturing of fermented coconut water incorporated drinking yoghurt, sensory test, chemical analysis and microbial analysis were carried out at Food science and technology laboratory, Department of Biosystems Technology, Faculty of Technology, South Eastern University of Sri Lanka. Bacteria culture and chemicals were provided by Faculty of Technology, University of Jaffna. Fresh cow milk and coconut water (*Cocos nucifera*) were collected from Dairy farm from Oluvil. The experiment was with 5 treatments including T1, T2, T3, T4 and control (TC).

2.1 Extracted the coconut water

The King Coconut water was poured into glass jar and determined the initial Brix and pH value of coconut water. After the glass jar was covered with plastic lid or clothe cover. Then the coconut water was allowed to incubator for the fermentation processing carry out for 2 days at 37°C. After the fermentation processing the probiotic microbial counts were analyzed using CFU method.

2.2 Media Preparation

2g of Potato Dextrose Agar (PDA) was prepared and it was dissolved with 90ml of distilled water. The agar media was kept into the water bath to completely dissolve. After the agar media was removed from water bath and kept into Autoclave at 120°C for 15 minutes. Then agar media was removed from Autoclave and allowed to cool and prepare the agar media was poured into 3 petri dishes.

Preparation of serial dilution

The fermented coconut water was diluted by the serial dilution and counted the number of probiotic microorganisms. (*Lactobacillus acidophilus*, *Lactobacillus casei*)

Diluted factors: 10^{-3} , 10^{-4} , 10^{-5}

Lactobacillus acidophilus: 0.9×10^5 CFU/ml

Lactobacillus casei: 3.02×10^5 CFU/ml

2.3 Developing of drinking yoghurt

The Cow milk was through a clean strainer and measured the initial pH of the Cow milk. Filtered milk was added into a clean vessel and heated at 95°C for 10 minutes while stirring continuously. After heated of milk the reconstituted skim milk powder and already dissolved sugar were added and mixed while heating. Then milk was cooled to 42°C and added already dissolved gelatine and inoculated with 2 – 5 % of the starter culture. Finally, the fermented Coconut was added with specific percentage after inoculated (10%, 15%, 20%, 25%)

Different formula used for the development of fermented coconut water incorporated drinking yoghurt

T1 – Milk + fermented Coconut water (90:10)			
T2 – Milk + fermented (85:15)		Coconut	water
T3 – Milk + fermented (80:20)	$\frac{\text{Volume of NaOH} \times 0.1 \times 90 \times 100}{\text{Volume of milk} \times 1000}$	Coconut	water
T4 – Milk + fermented (75:25)	$\frac{X \text{ ml} - Y \text{ ml} \times 0.1 \times 90 \times 100}{10 \text{ ml} \times 1000}$	Coconut	water
TC – Milk (Control)		Sample - 100 %)	

After the inoculated it was allowed to incubated at 37⁰C – 42⁰C for 4 hours and beat the yoghurt mix thoroughly using the beater and filled into cups and stored at refrigeration condition 4⁰C.

2.4 Analysis of proximate composition of probiotic drinking yoghurt

Based on AOAC (2005), the moisture content, ash content was determined. Protein content, fat content, total soluble solid and solid non – fat was determined by the Lactoscan. Put the analyzer on the working place, providing good ventilation and not in the vicinity of heat providing devices or sources. The temperature in the premises has to be in the boundaries 10⁰C - 30⁰C

2.5 Analysis of physiochemical properties with storage

pH content

pH value in each developed fermented coconut water incorporated drinking yoghurts were significantly different (p<0.05) among treatments and also with the storage. Initial pH value of fermented coconut water incorporated drinking yoghurts were significantly lower than control drinking yoghurt. Drinking the storage period, pH of yoghurt gradually decreased in all treatment. According to the standard of SLSI normally pH value of drinking yoghurt ranged between 4.6 – 4.2. In this study pH value of developed drinking yoghurts were varied between SLSI standard up to 21th days of storage. The final pH value of developed treatment drinking yoghurts ranged between 4.7 – 4.5pH.

The pH and acidity of the samples were measured at 2 days intervals during storage period up to 21 days using a pH meter. Acidity was estimated by titration with 0.1% NaOH.

Acidity content

Titrateable acidity of developed fermented coconut water incorporated drinking yoghurts were significantly different (p<0.05) among the treatments and it was increased during the storage period. Initial pH value of fermented coconut water incorporated drinking yoghurts were significantly higher than control drinking yoghurt. Reported that the titrateable acidity was increased with the storage period. It happened due to the microbial activity during storage.

Initial reading of NaOH = X ml
 Final reading of NaOH = Y ml
 Used milk for titration = 10 ml

% of acidity = (1)

Acidity content % = (2)

Microbiological analysis

Yeast and mold counts were increased with the storage periods. According to the Sri Lanka Standard, yeast and mold counts in drinking yoghurts were in acceptable range within 21 days of storage. During first 7 days, the yeast and molds were not developed in the treatment drinking yoghurts. Yeast and molds were shown in samples up on 14th day of storage. The highest yeast and mold counts were observed in control drinking yoghurt up to 21th day of storage. From 21th days onward, yeast and mold counts were exceeded the acceptable limit in all treatment levels and highest count was reported in drinking yoghurt prepared with incorporating 10% of fermented Coconut water.

Increasing the yeast and mold count of drinking yoghurt samples due to increment of acidity and reduction of oxygen during fermentation process may offer proper conditions for growth of yeast and molds. Total Coliform counts were zero for all treatments during storage period for 21 days, probably due to good hygienic practices adapted during manufacturing process.

2.6 Sensory evaluation

Sensory evaluation was done with 25 untrained panelists along with ballot paper prepared as nine-point hedonic scale. Sensory qualities such as appearance, taste, flavor, smell, texture and overall acceptance were evaluated. The sample were given three-digit random numbers and placed in plastic carton. These were served in random order to panelists.

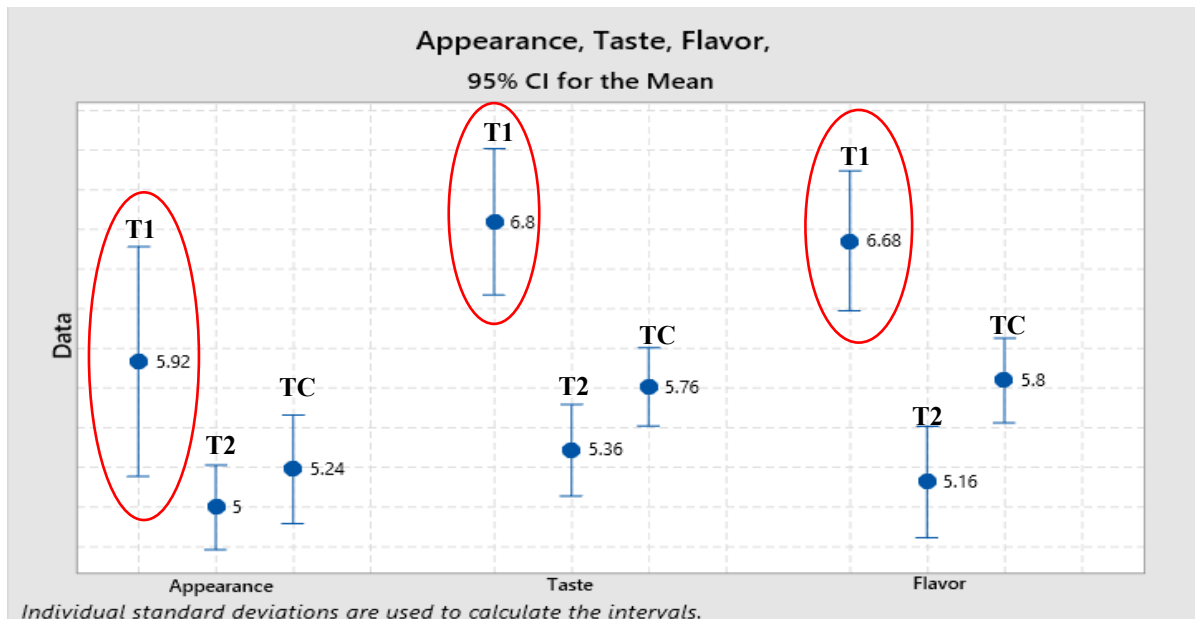


Figure -1 For the Sensory Test - T1- (90:10) %, T2 - (85:15) %, TC - (100) %

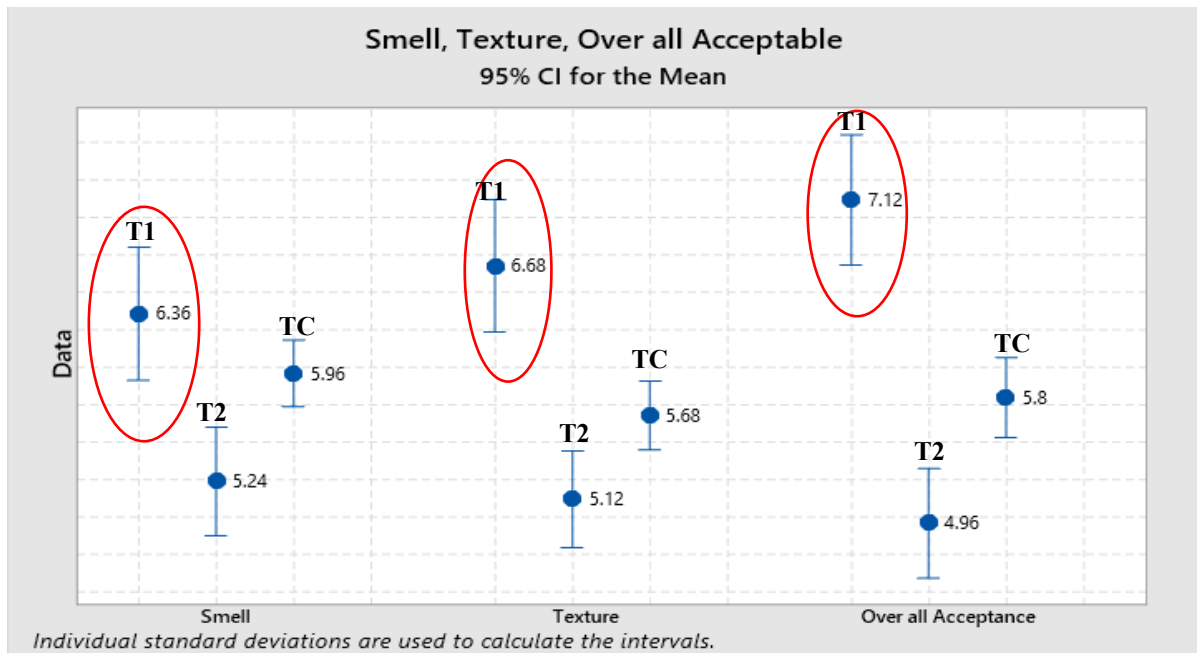


Figure -2 For the Sensory Test - T1- (90:10) %, T2 - (85:15) %, TC - (100) %

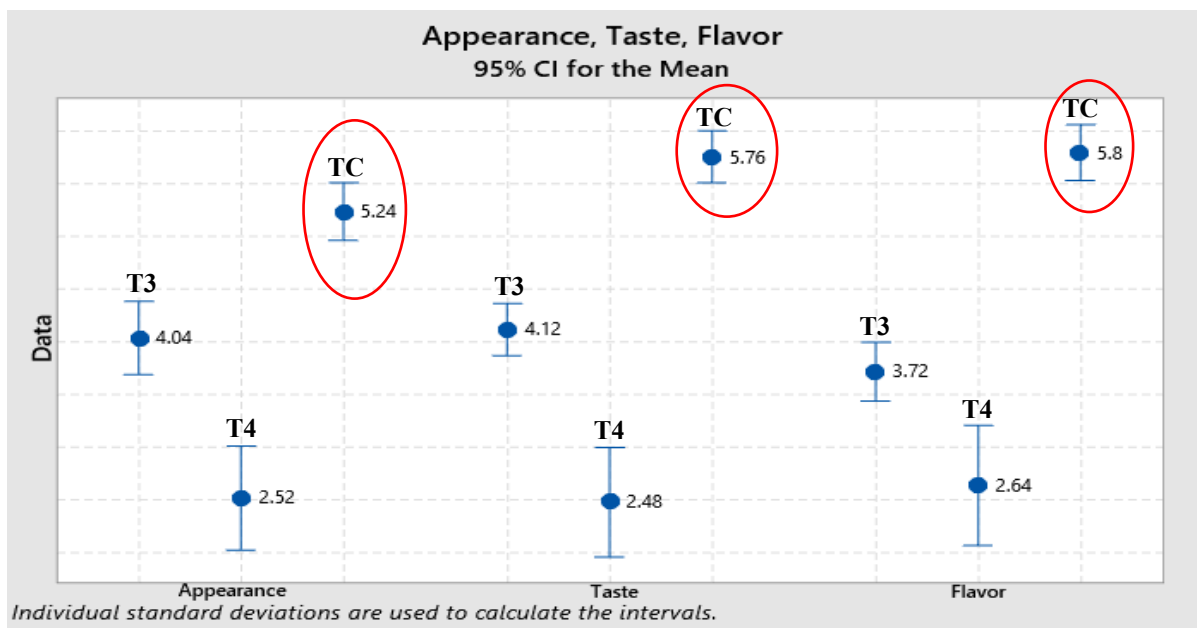


Figure -3 For the Sensory Test – T3- (80:20) %, T4 - (75:25) %, TC - (100) %

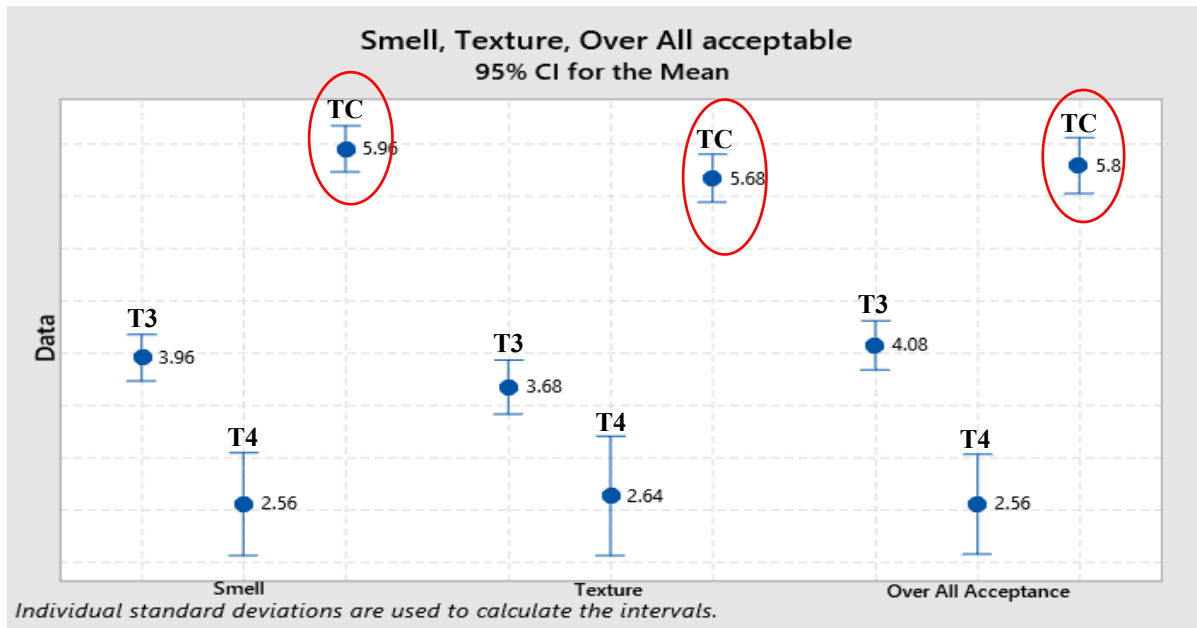


Figure -4 For the Sensory Test – T3- (80:20) %, T4 - (75:25) %, TC - (100) %

The results of sensory test for the appearance, taste, flavor, smell, texture and overall acceptability of developed drinking yoghurts are shown in above table. The panelists were able to differentiate a significant difference ($P < 0.05$) for appearance, taste, flavor, smell, texture and overall acceptability among different type of yoghurt. A higher mean value for appearance, taste, flavor, smell, texture and overall acceptability were observed in drinking yoghurt developed by incorporating 10%, 15% fermented Coconut water and control sample (TC). Drinking yoghurt developed from adding 10% fermented Coconut water showed the best sensory qualities when compare to other samples and showed the highest score for overall acceptability.

3. Results and discussion

3.1 Proximate composition of yoghurt

Moisture content

Moisture content was determined by the Oven drying method as described on AOAC (2000). The developed drinking yoghurt samples were taken from three samples (90:10 – T1, 85:15 – T2 and TC) into cleaned, dried and Pre weighed petri dishes and dried in an oven at 120°C for 30 minutes until constant weight was obtained. The percentage of moisture content in the developed drinking yoghurt samples were calculated from the weight loss

W1 = Weight of Petri dish

W2 = Weight of Perti dish + Sample weight

W3 = Weight of Petri dish + Dried Sample

$$\text{Moisture content (wet basis)} = \frac{W2 - W3}{W2 - W1} \times 100\% \quad (1)$$

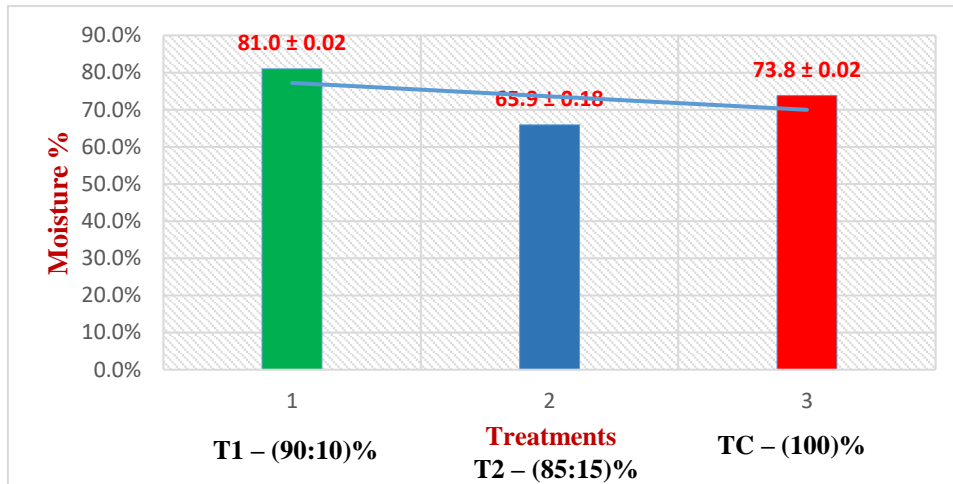


Figure -5 Moisture content.

Ash content

Ash content was determined by the method described in SLS 772:1987

Heated, Cooled and the pre – weighed crucible was taken. Then about 10g of the developed drinking yoghurt samples were taken. After the crucible with the samples were burned in the muffle furnace at 700°C till constant weight was obtained. Then samples were allowed to cool in the desiccator. Finally, the weights were taken.

W1 = Initial weight of Crucible

W2 = Weight of Crucible + Sample weight

W3 = Weight of Crucible + Dried Sample

$$\text{Ash content} = \frac{W3 - W1}{W2 - W1} \times 100\% \quad (1)$$

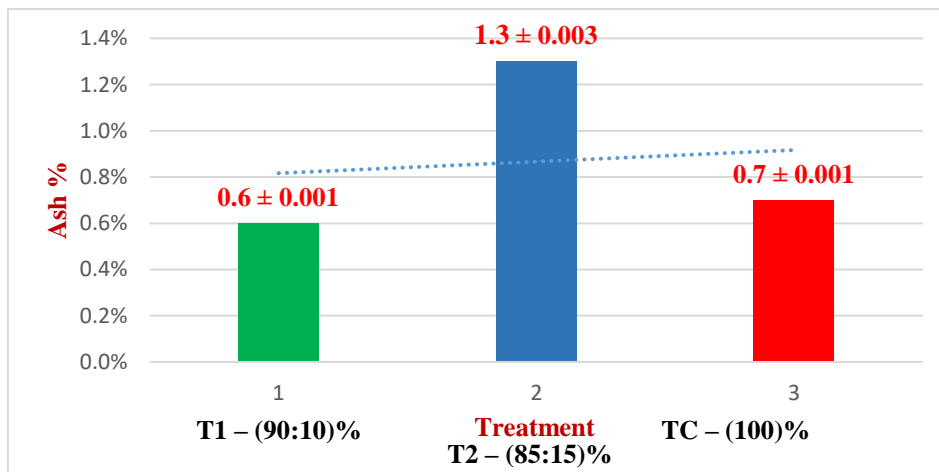


Figure -6 Ash content.

Determination of Protein, Fat, TSS and SNF content of drinking yoghurt

Taking samples and preparation for analysis,

In order to receive reliable results in qualification of milk, dairy products and derivatives are needed. Precise sample taking, correct sample storing, correct preparation before making measurement. The rules and requirements for this are described in details in sampling.

Preparing the **LACTOSCAN** analyzer for working mode, Put the analyzer on the working place, providing good ventilation and not in the vicinity of heat providing devices or sources. The temperature in the premises has to be in the boundaries 10⁰C -30⁰C

To start measurement

- Pour the preliminary prepared sample in the sample holder of the analyser
- Put the sample holder in the recess of the analyser
- Press the button enter

The analyzer sucks the sample, make the measurement and returns the sample in the waste liquid reservoir. During the measurement the temperature of the sample is shown on the display. Ignore the results received immediately after switching on the analyzer and after measuring distilled water. Make a second measurement with new portion of the same sample. Write down the results in the form. The results remain on the display till a new measurement is started. If the analyzer is connected to a computer or a printer, it sends the data to the computer or prints them.

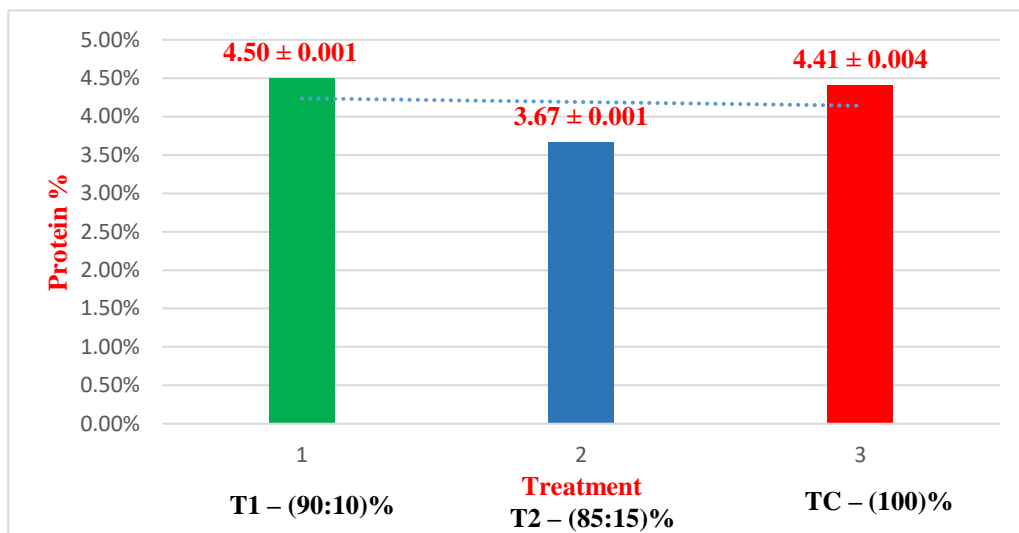


Figure -7 Protein variation in developed drinking yoghurts with storage period.

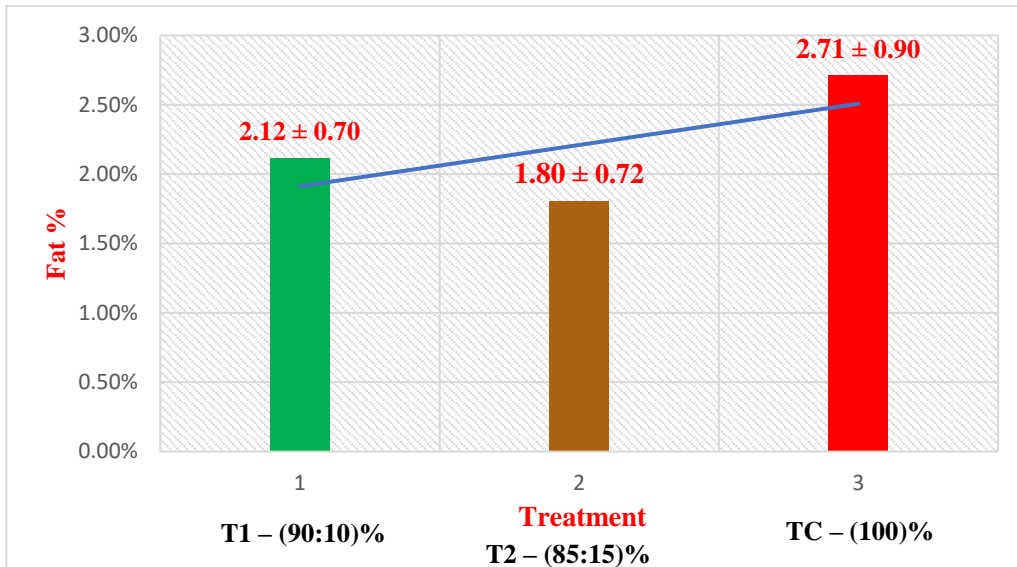


Figure -8 Fat variation in developed drinking yoghurts with storage period.

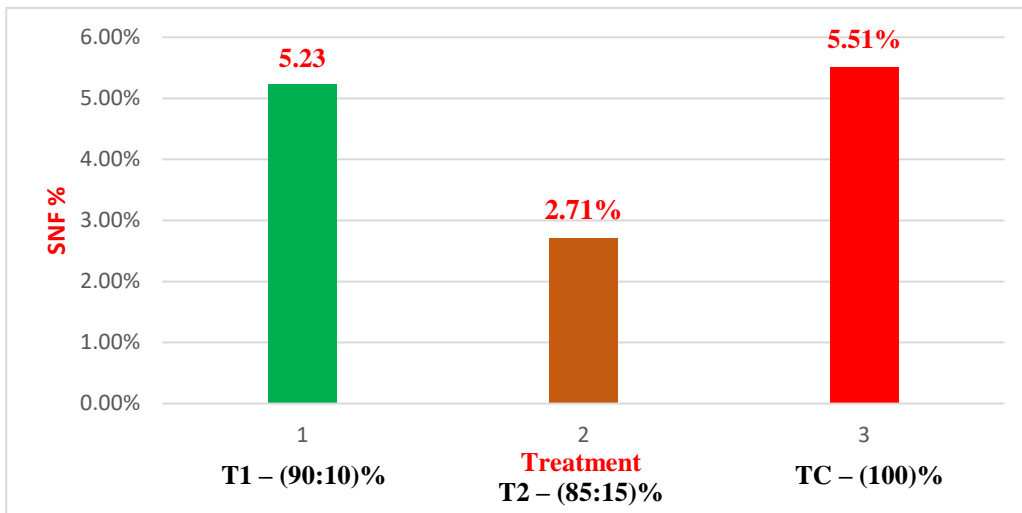


Figure -9 SNF variation in developed drinking yoghurts with storage period.

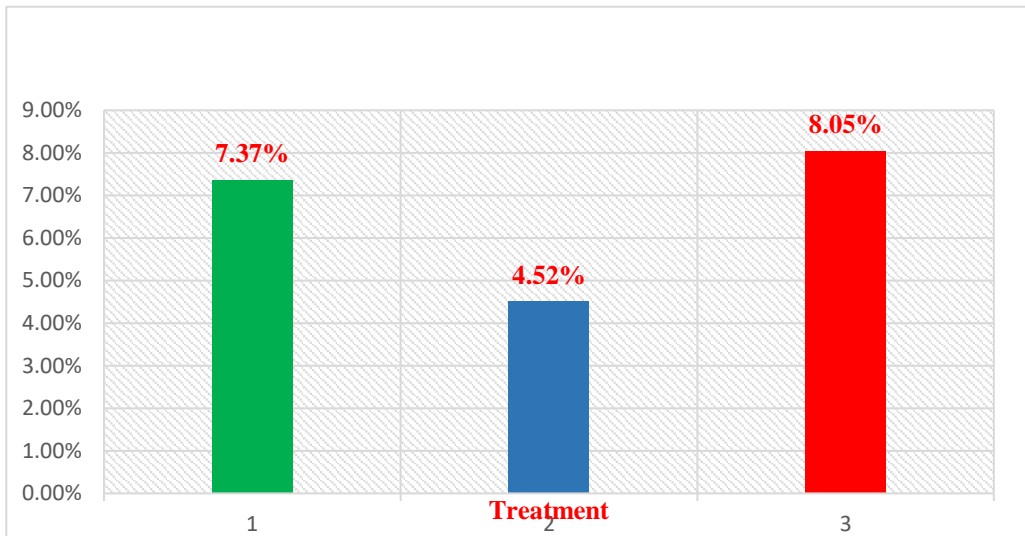


Figure – 10 TSS variation in developed drinking yoghurts with storage period.

3.2 Physiochemical properties with storage

pH content

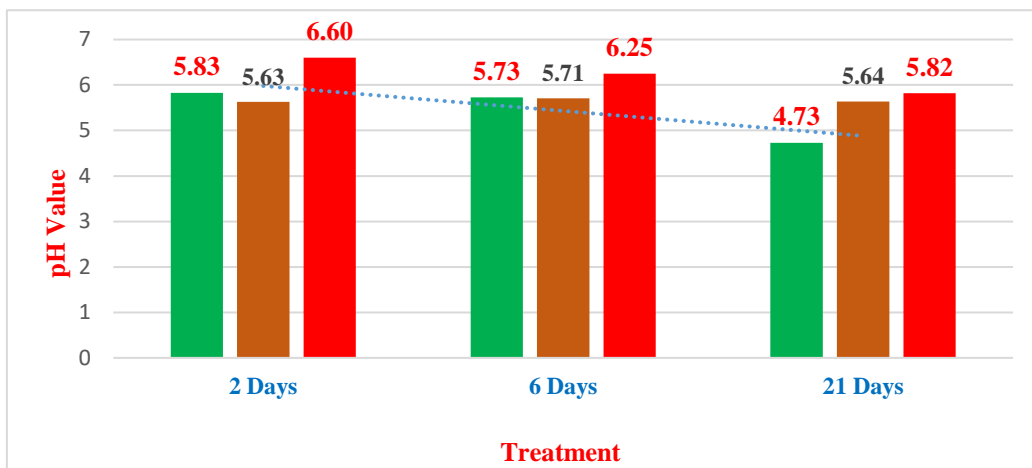


Figure – 11 pH variation in developed drinking yoghurts with storage period.

Acidity content

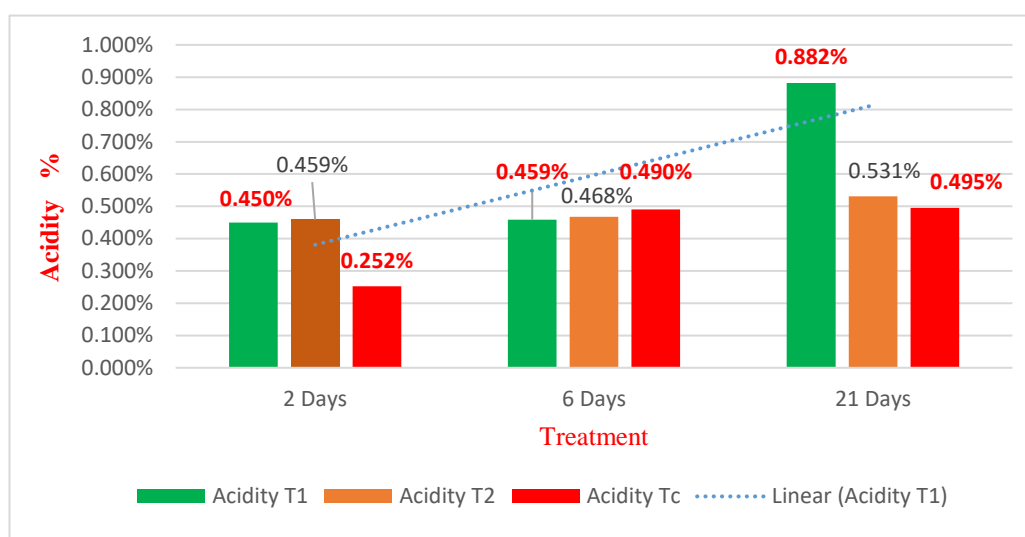


Figure – 12 Acidity variation in developed drinking yoghurts with storage period.

Microbial content

Table 1: Microbial content

Microbiological Quality	Days of storage	T1 – (90:10) %	T2 – (85:15) %	TC – (100) %
Total Plate Count	07	05	05	06
	14	08	09	06
	21	16	17	16
Yeast and Mold	07	02	09	05
	14	08	08	09
	21	15	16	18
Coliform bacteria	07	Nil	Nil	Nil
	14	Nil	Nil	Nil
	21	Nil	Nil	Nil

Shelf life of developed fermented coconut water incorporated drinking yoghurt

Shelf life of the developed drinking yoghurt was 21 days. According to the yoghurt standard SLS 824: part 2: 1989, pH value should not be more than 4.2 in yoghurt. pH value was not in acceptable range after 21 days of production and also titratable acidity was exceeded acceptable limit. According to the pH variation product could be stored up to 21 days

Conclusion

Probiotic drinking yoghurt can be developed by incorporated 10% of fermented coconut water to 90% of milk with acceptable probiotics development, nutritional and qualities. The developed probiotic drinking yoghurt can be stored 21 days in refrigerator at 4°C with acceptable limit of yeast and mold count and without any quality deterioration.

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ICSD 076

FORMULATING INNOVATIVE CINNAMON TEA PRODUCTS FOR ENHANCED VALUE OF CEYLON CINNAMON

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Abstract: Cinnamon stands as one of the top agricultural exports in Sri Lanka, exporting various cinnamon products such as quills, cut quills, bark pieces, and crushed cinnamon without incorporating value addition. Ceylon cinnamon (*Cinnamomum zeylanicum*), with its unique characteristics, is renowned for its distinct flavor and aromatic profile, qualities that can be safeguarded and promoted through geographical indications. In recent trends, there has been a notable surge in consumer interest in innovative tea blends, driven by their rich flavor profiles and potential health benefits. The study aims to examine consumer-led product development, focusing on the innovation of teas through the blending of Ceylon cinnamon with Ceylon spices, natural flavors, and underutilized fruits. The outcome is to enhance the functional properties and organoleptic qualities of typical tea formulations, moving beyond traditional thinking. The spices such as cardamom, ginger, turmeric, and pepper, natural flavors like vanilla, tamarind, and lemongrass, and the underutilized fruit *Aegle marmelos* (*beal*), are blended with Ceylon cinnamon to create exceptional value-added teas. After multiple rounds of selection, specific tea blends were carefully chosen for sensory evaluation, and optimal sensory excellence was attained through ingredient variations. Further, transforming cinnamon quills into novel tea blend and incorporating them into tea processing prolongs shelf life, maximizes storage efficiency, and generates additional income. By prioritizing differentiation and quality, innovative product blenders empower stakeholders to boost market competitiveness and counter climate-related issues. The study identified gaps, resulting in ready-to-consume prototypes that incorporate private labeling, functional advantages, and traceability. These efforts build resilience by accurately recognizing demand risks and fortifying businesses against challenges posed by competition. This study emphasizes the fusion of tradition and innovation, resulting in a product that not only captivates the sense but also adds significant value to the rich heritage of Ceylon Cinnamon.

Keywords: Ceylon cinnamon; Functional properties; Innovation; Sensory; Value added teas

1. Introduction

The Ceylon cinnamon value chain is organized as a set of traditional practices to obtain bulk cinnamon as a form of bale; however, this stagnates obviate potentials in the world market. The importance of developing new products with high commercial value is emphasized for the growth of the spice sector. The creation of high-value, innovative products is critical for spice sector growth, gain a larger share in the international spice trade, enhancing value has been recognized as the ideal strategy. The global demand for value-added cinnamon products has risen significantly (Jayathilaka & Dasanayaka, 2019). The time has arrived for Sri Lanka to diversify its production and export portfolio through the development of new products with high potential. Cinnamon is one of top agricultural exports in Sri Lanka, covering about 31,000 hectares of land and providing jobs for approximately 400,000 people, both directly and indirectly (EDB, 2020). Sri Lankan cinnamon has unique characteristics that can be protected and promoted through Geo-geographical Indications (GI) (Jeewanthi et al., 2020). This industry contributes significantly to Sri Lanka's economy, with an average export income of USD 191 million and an additional USD seven million from value-added products, making it a vital source of revenue and employment in the country (EDB, 2020).

Ceylon Tea is leading agricultural export in Sri Lanka, employing nearly 1 million people directly and indirectly. Approximately 4% of the land of country, covering about 203,000 hectares, is dedicated to tea plantations (EDB,2023). The revenue earned with tea in 2019 was 1.24 billion USD (EDB, 2020). Over the years, Ceylon tea has gained recognition globally and remains a favourite among tea enthusiasts. The tea sector is a vital component economy of Sri Lanka, providing employment opportunities for more than 1.5 million people, both directly and indirectly. Sri Lanka exports various Ceylon tea products, including black tea, green tea, white tea, herbal tea, organic tea, flavoured tea, tea in bulk (EDB, 2023).

Product innovation involves developing new or improved products that satisfy customer demands and provide value. It also serves as an effective approach to tackle significant global sustainability issues, including climate change, limited resources, social disparities, and health concerns. In the cinnamon industry, value creation is essential for making the value chain more sustainable. Value is created by enhancing the actual or perceived benefits for the end customer, resulting in a superior product. This can be achieved by introducing fresh ideas, new products, and offering unique customer experiences (Jeewanthi et al., 2020).

Ceylon cinnamon and Ceylon tea, two iconic exports in Sri Lanka, to safeguard the yields and generate additional income, it is crucial to focus on product innovation and value addition, rather than simply exporting raw materials. By embracing innovative processing and product development, Sri Lanka can enhance the resilience of these industries while simultaneously benefiting from higher value exports. Cinnamon production in Sri Lanka faces challenges related to management, pests, and diseases, leading to a significant yield gap. The unique quill processing method, involving hand-made peeling of stems, is exclusive to Sri Lanka, but limited to specific seasons. The lack of technology for diversification, value addition, and branding, coupled with lengthy value chains, heightens the risk of adulteration and contamination. Consequently, Sri Lankan farmers and processors fail to maximize revenue from their exports (Suriyagoda et al., 2021). Sri Lanka exports cinnamon in three primary forms: as whole sticks, crushed, and in powdered form (Sugathadasa et al., 2021). Sri Lanka sole global supplier true cinnamon, yet the local industry lacks substantial value-added products.

Further research is needed to explore unconventional applications of cinnamon, as there is currently a deficiency in studies focusing on value-added cinnamon products. An interesting avenue worth exploring is the introduction of cinnamon tea to both domestic and international markets by Sri Lanka. Given well established reputation in Sri Lanka for producing high-

quality tea, famously known as Ceylon tea, the introduction of products like Ceylon cinnamon tea holds the promise of being a pioneering concept. The brand name alone carries inherent marketing value. Furthermore, highlighting the ayurvedic and therapeutic advantages of Sri Lankan cinnamon adds an economical dimension to this proposition. The primary aim of this study is to examine the consumer-led product, innovative teas development by Ceylon cinnamon blended with Ceylon spices, natural flavours and underutilized fruits. The conceptual framework (Figure 1) for the study in the context of value-added. Through innovative approaches, such as value addition to tea/cinnamon, we can mitigate the seasonal fluctuations in yield, reduce postharvest losses, create higher value products, and generate employment opportunities.

Through blending Ceylon cinnamon with, Ceylon tea, local spices, natural flavors, and underutilized fruits, issues and challenges within the cinnamon and tea value chain can be minimized. Moreover, economic benefits for Sri Lanka will be provided through this approach.

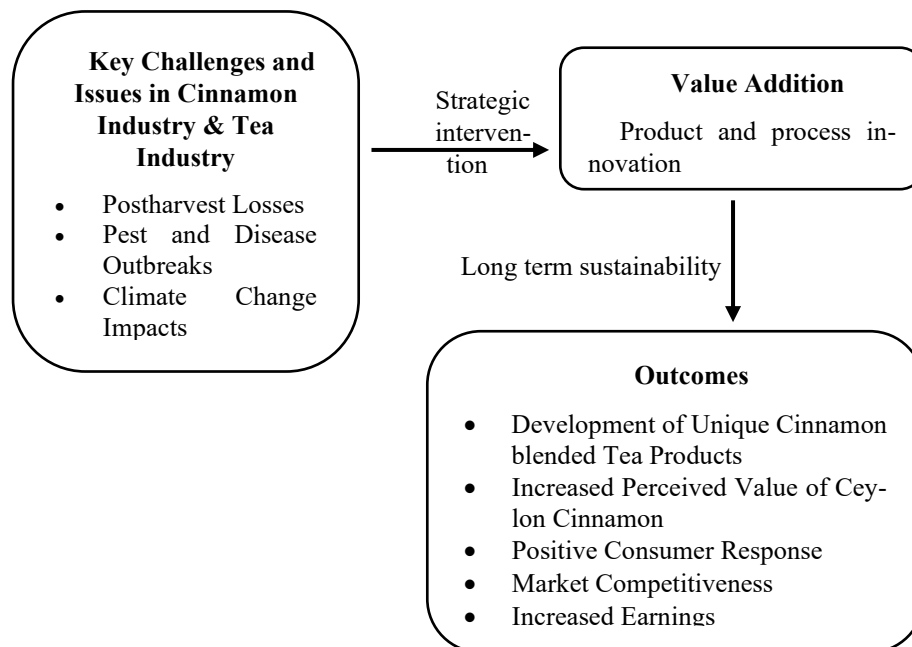


Figure 1: Conceptual framework.

2. Methodology

This experiment was undertaken at the Ceylon Cinnamon Beverage Development Laboratory, Department of Agribusiness Management, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka. Before starting the experiment, Ceylon cinnamon- (C4/C5 grades), Ceylon black tea, Ceylon green tea, cardamom, ginger, turmeric, pepper, vanilla, tamarind, lemongrass, and the underutilized fruit *Aegle marmelos* (beal) were bought from a local market in Sri Lanka.

2.1. Ingredient preparation

Ceylon cinnamon, Ceylon black tea, Ceylon green tea, cardamom, ginger, turmeric powder, pepper, vanilla, tamarind, beal fruit and lemongrass Ingredients were cleaned and vanilla, Ginger, tamarind, beal fruit, and lemongrass were oven dried at 45-50°C for 8-15 hours. Then the ingredients were ground, sieved, and stored in airtight containers until further use.

2.2. Product selection and Design of the formulation

All the products were selected through the market survey, and ingredients selection was done after a comprehensive literature review. A completely randomized design was used to find the optimum particle size and the main ingredient for the final product formulation. Then the ingredients were measured using a lab-scale analytical balance, and tea bags were prepared by mixing them according to the formulations.

2.3. Preparation of the infusion and Analysis of the physical and functional properties of the final product

150 ml of 90 °C water was used to brew each tea bag for 2 minutes. Following physico-chemical analysis was tested for infusions. The pH values of the tea brews were analysed using the calibrated pH meter. pH meter (Eutech pH 700, Eutech Instrument, Netherlands) was used. Readings were taken in triplicates. Colours of the tea brews were determined using the Chroma Meter (Konica Minolta, CR-400, Japan). Triplicate measurements were taken and L* values a* values and b* values were taken. The total soluble solid contents of the tea brews were measured using the brix meter.

2.3.1 Moisture Content

Using the oven drying technique (AOAC 990.19), the samples' moisture contents were examined. An empty petri dish (W1 weight) was filled with 2g of tea. Then the petri dish was weighed and weight (W2) was recorded. After that, the petri dish was put in an oven and dried at 102 °C until it reached a constant weight. The petri dish was moved to a desiccator and given time to cool. At room temperature, the dish was weighed, and the final weight (W3) was noted. The following equation was then used to determine the moisture content.

$$\% \text{Moisture content} = \frac{(W_2 - W_1) \text{ g} - (W_3 - W_1) \text{ g}}{(W_2 - W_1) \text{ g}} \times 100\%$$

2.3.2 Total phenolic content

The total phenolic content will be measured spectrophotometrically using the modified Folin-Ciocalteu colourimetric method (Lee et al., 2015). First, the standard curve for the Gallic acid was plotted using a series prepared from Gallic acid. A stock solution of 1 mg/ml was used to prepare the dilution series. 10, 5, 2.5, 1.25, 0.625, 0.312 GAE mg/l dilutions were taken as the dilution series. The absorbance of each dilution was measured using the spectrophotometer. 5 ml from one dilution was pipetted and mixed with 10.5 ml of Folin-Ciocalteu reagent (1:10 V/V with distilled water) and allowed for a 5-minute incubation period. Then the mixture was neutralized using 8 ml of 10% sodium carbonate and allowed for a 20 minute incubation period at room temperature. Then the absorbance values were measured at the 762 nm wavelength using the spectrophotometer. Then the absorbance values of the teas were measured using 5 ml of the sample instead of Gallic acid. The absorbance of the sample was compared with the prepared standard curve.

2.3.3 Antioxidant content

The antioxidant activity of the produced functional beverage was determined by the free radical scavenging method using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) mentioned in (Ahmad et al., 2016) and with slight modifications. 1000 ppm stock solution of DPPH was prepared by dissolving 20 mg of DPPH in 100 ml of methanol in a volumetric flask. Then the flask was covered with aluminium foil and stored in the dark overnight. Then the standard curve was plotted using a series prepared from the ascorbic acid. Prepared ascorbic acid series included 40 ppm, 20 ppm, 10 ppm, 5 ppm and 2.5 ppm dilutions. The Absorbance of each dilution was measured using the spectrophotometer. 2.5 ml from the one dilution, 4.5 ml methanol and 6.3 ml DPPH solution was added into a 10 ml volumetric flask. The flask were covered with an aluminium foil and kept in the dark for 10 minutes. The controller was prepared using distilled water instead of ascorbic acid. Then the absorbance value was measured at

the 517 nm wavelength using spectrophotometer. Readings were taken in triplicates. Then the inhibition values were calculated using the following equation.

DPPH scavenging activity (%) = [(A control – A sample)/ A control] x 100 Where,

Control – Absorbance of control solution containing ascorbic acid and DPPH.

Sample – Absorbance of the sample at 517 nm.

A standard curve was plotted using the inhibition against the concentration. The concentration of the sample for the 50% inhibition was taken as the IC₅₀ value. Then the curve for the milk sample was prepared according to the above method using milk instead of ascorbic acid and the IC₅₀ value for the milk samples was determined.

2.3.4 Statistical analysis

Statistical analysis was done using Minitab 21 software and Microsoft Excel 2010 software. One-way ANOVA was followed to analyze the reading taken in triplicates. Friedman test was done in sensory evaluation.

3. Results and discussion

Ceylon cinnamon (*Cinnamomum verum* or *Cinnamomum zeylanicum*) content antidiabetic, antioxidant, anti-inflammatory, lipid-lowering antimicrobial, anticancer, and cardiovascular-disease-lowering compounds (Ponnusamy et al., 2011 and Rao and Gan, 2014) and characteristic for its distinct aroma and flavour (Thomas and Kuruvilla, 2012). Cinnamon bark and leaves contain essential oil glands which responsible to its characteristics fragrance and flavour. These oil glands are highly sensitive to environmental factors, such as temperature, light and relative humidity (Pratiwi, Darmadji and Hastuti, 2016). If cinnamon bark is being transported, it's important to ensure that it is not exposed to hard environment during transit. High humidity can cause cinnamon bark to become damp, leading to mould growth and loss of essential oils (Thomas and Kuruvilla, 2012), (King, 2006). These cinnamon products incorporate other natural spices and flavouring agents to extend the life of raw cinnamon as an all-natural, high-quality, safe and preservative method.

The spices such as cardamom, ginger, turmeric, and pepper, natural flavours like vanilla, tamarind, and lemongrass, and the underutilized fruit *Aegle marmelos* (beal), are blended with Ceylon cinnamon to create exceptional value-added teas. Fruit juice and pulp powders are valuable materials in terms of transportation, packaging, storage and shelf life, compared with their raw and liquid counterparts (Muzaffar and Kumar, 2016). *Aegle marmelos* is a highly perishable fruit and it contains a high amount of moisture condition. Wijewardana et al., 2016 mentioned that Drying is a suitable alternative for postharvest management of beal, specifically in countries like Sri Lanka where exist poorly established low-temperature distribution and handling facilities. Other spices cardamom, ginger, turmeric, and pepper also preserve from reducing moisture in the raw material and proper packaging is cause to reduce external damages from handling and storage. To address this problem, innovative tea blends were prepared by prioritizing differentiation and quality to boost market competitiveness and counter post-harvest loss issues.

3.1. Sample preparation

Sensory evaluation for formulation selection the formulated final combinations are shown in Table 1 and sensory evaluation was conducted to obtain a basic idea about the formulation. Figure 2 represents the Basic procedure of the cinnamon tea sample preparation.

Table 1: Cinnamon tea products and the Cinnamon tea percentage of each formulation

Table 2: Cinnamon tea products and the Cinnamon tea percentage of each formulation

No	Code	Tea type	Cinnamon grade	Cinnamon percentage	Other ingredients percentage	Other Ingredients
1	CBL	Cinnamon Black tea	C4, C5	12.50%	87.50%	Ceylon Black tea (BOP)
2	CGR	Cinnamon Green tea	C4	12.00%	88.00%	Ceylon Green Tea
3	CGI	Cinnamon Ginger tea	C4	24.00%	76.00%	Ceylon Black tea (BOP), Cardamom powder
4	CCD	Cinnamon cardamom tea	C4	9.00%	91.00%	Ceylon Black tea (BOP), Ginger powder, Lemon grass
5	CVL	Cinnamon Vanilla tea	C4	33.30%	66.70%	Ceylon Black tea (BOP), Vanilla powder, Sugar
6	CLG	Cinnamon Lemon grass tea	C4	20.00%	80.00%	Ceylon Black tea (BOP), Lemon grass powder, cardamom powder
7	CTU	Cinnamon Turmeric tea	C4	7.14%	92.86%	Ceylon Black tea (BOP), Turmeric powder, cardamom powder, Black pepper powder
8	CTU	Cinnamon Turmeric tea	C4, C5	7.14%	92.86%	Ceylon Black tea (BOP), Turmeric powder, cardamom powder, Black pepper powder
9	CT-M	Cinnamon Tamarind tea- mild	C4	40.00%	60.00%	Ceylon Black tea (BOP), Tamarind powder
10	CT-S	Cinnamon Tamarind tea- strong	C4	35.00%	65.00%	Ceylon Black tea (BOP), Tamarind powder
11	CBE	Cinnamon Beal tea	C4	25.00%	75.00%	Bael flakes, Ceylon Black tea (BOP)
12	PC-M	Pure Cinnamon tea- mild	C4, C5	100.00%	-	-
13	PC-S	Pure Cinnamon tea- Strong	C4, C5	100.00%	-	-
14	CC	Cinnamon Coffee	C4	60.00%	40.00%	Coffee powder

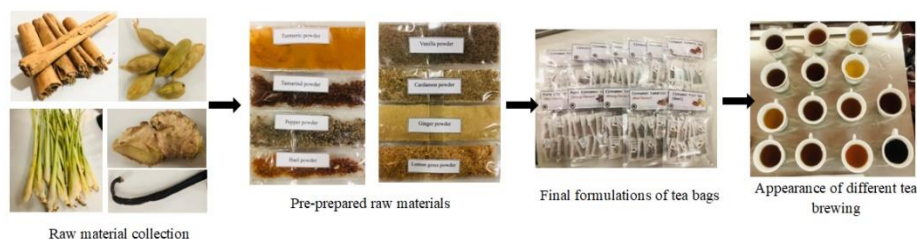


Figure 2: Basic procedure of the cinnamon tea sample preparation.

3.2. Moisture content, pH value and Brix value of the tea formulations

Tests were conducted to determine these values in different tea samples including a control sample (Black tea). The results obtained from the readings are given below (Table 2).

Table 3: Moisture content, pH value Brix value of the different formulations

No	Code	Moisture content%	pH value	Brix value %
1	CBL	5.97±0.02	6.97±0.02a	1.10±0.00ab
2	CGR	5.74±0.10	6.73±0.05b	1.16±0.05a
3	CGI	10.03±0.52	6.72±0.01b	1.06±0.05abc
4	CCD	5.76±0.93	6.67±0.02bc	1.10±0.00ab
5	CVL	5.35±0.33	6.71±0.00b	1.10±0.10ab
6	CLG	6.31±0.29	6.67±0.01bc	1.00±0.00abc
7	CTU	6.80±0.30	6.63±0.02c	0.96±0.05bc
8	CT-M	6.06±0.11	5.06±0.01e	1.13±0.05a
9	CT-S	5.91±0.76	4.65±0.04f	1.00±0.10abc
10	CBE	6.11±0.15	6.44±0.02d	1.13±0.05a
11	PC-M	9.06±0.74	7.03±0.03a	0.93±0.05bc
12	PC-S	9.57±0.09	7.01±0.01a	0.90±0.10c
13	CC	8.13±0.24	6.70±0.02bc	1.13±0.05a
Control	BT(Black tea)			

Data represented as mean ± SE. The Mean within each column followed by the same letter are not significantly different at p=0.05.

The pH value of tea can vary depending on several factors, including the type of tea, brewing time, water quality, and any additives used. For most teas, the pH value typically ranges from 4.00 to 6.50, making them slightly acidic. According to the data, pure cinnamon has a pH value higher than 7, which is higher than others, likely due to its cinnamon content without additional ingredients. The lowest pH values can be observed in Cinnamon tamarind tea, as tamarind is an acidic ingredient. Brix values of various teas are reported to be between 0.90 and 1.1. All tea samples have very low values, as tea brews are infusions without a solid part. Significant differences in moisture content, pH, and Brix values ($p < 0.05$) were observed among different infusions.

The moisture content of tea can fluctuate due to several factors, including the tea type, processing techniques, storage environment, and packaging methods. Generally, during processing, tea leaves undergo moisture reduction to prevent deterioration and uphold quality. Typically, the moisture content of tea leaves ranges from 2.50% to 6.50%. However, these blends incorporate diverse ingredients, leading to moisture levels surpassing the standard range, particularly attributed to cinnamon. Pure cinnamon tea exhibits the highest moisture content among various tea powders. Additionally, cinnamon coffee displays elevated moisture levels compared to others. The presence of supplementary in-

redients and preparation procedures might contribute to increased humidity in certain samples, along with alterations in packaging materials and conditions. Elevated moisture in tea can potentially foster microbial growth, particularly molds, thereby warranting attention. Proper drying of tea can keep moisture content at the desired level and proper packaging and containers prevent excessive moisture absorption (balasooriya et al., 2019). This kind of result was also found by Ahmad et al. (2016).

3.3. Colour values of different infusion

Considering about colour analysis, L*, a*, b* values represent that L* = 0 means black and L* = 100 means white, -a means greenness and +a* means redness, -b* mean blueness and +b* means yellowness. There were significant differences in L*, a* and b* values (p<0.05) of different infusion samples. The highest L* values were observed in pure cinnamon teas because tea brewing has light colours than others.

Table 3 indicates L*, a*, b* color values of different brews. The highest dark color was observed in Cinnamon turmeric tea. The dark colour mainly depends on black tea content. The Cinnamon turmeric content has the highest black tea percentage (92.86%) compared with other ingredients. Due to the values, cinnamon tamarind tea has a red colour than the others. Because of the characteristic color of tamarind powder. Pure cinnamon tea contains the highest b*/yellowish colour than the other tea formulations.

Table 4: L*, a*, b* color values of different brews

No	Code	L*	a*	b*
1	CBL	32.32±0.49 ^{cd}	5.73±0.66 ^{de}	3.93±0.64 ^c
2	CGR	37.15±0.10 ^b	6.38±0.60 ^{cd}	10.34±1.16 ^b
3	CGI	30.11±0.25 ^{ef}	6.46±0.33 ^{cd}	3.91±0.19 ^c
4	CCD	28.89±0.57 ^f	6.71±0.84 ^{cd}	3.23±1.41 ^c
5	CVL	29.53±0.23 ^f	6.85±0.24 ^{cd}	4.30±0.08 ^d
6	CLG	28.63±0.21 ^f	7.28±0.21 ^{bc}	4.15±0.09 ^d
7	CTU	28.46±1.69 ^f	5.92±1.05 ^{de}	2.39±0.36 ^{ef}
8	CT-M	31.63±0.01 ^{de}	10.29±0.00 ^a	9.45±0.00 ^{bc}
9	CT-S	33.91±0.50 ^c	10.13±0.82 ^a	12.50±1.26 ^b
10	CBE	29.35±0.32 ^f	8.93±0.27 ^{ab}	7.22±0.29 ^{cd}
11	PC-M	44.22±0.23 ^a	5.47±0.38 ^{de}	18.47±1.57 ^a
12	PC-S	43.67±0.58 ^a	4.64±0.53 ^c	16.70±2.40 ^a
13	CC	21.60±0.50 ^f	2.12±0.08 ^f	0.06±0.01 ^f
14	BT			

Data represented as mean ± SE. Mean within each column followed by the same letter are not significantly different at p=0.05.

3.4. Antioxidant Activity and Total phenolic content in different formulations

The method is based on the reduction of alcoholic DPPH solution in the presence of a hydrogen-donating antioxidant due to the formation of the non-radical form DPPH-H by the reaction. Ahmad et al. (2016) found the same kind of result in the case of cinnamon and different spices.

Table 4 displays the DPPH radical scavenging activity and Total phenolic content in different formulations. There were significant differences in IC50 and Total phenolic content values (p<0.05) of different infusion samples. Compared with the IC50 of ascorbic acid, Cinnamon turmeric tea contains the highest DPPH scavenging activity than other tea formulations. Cinnamon coffee, Cinnamon gin-

ger tea, Cinnamon black tea, Cinnamon tamarind tea with a mild flavour and Cinnamon ginger tea have the required amount of Antioxidant activity when compared with others. The lowest DPPH scavenging activity can be observed in pure cinnamon teas.

Table 5: DPPH radical scavenging activity and Total phenolic content in different formations

No	Code	IC50 ($\mu\text{g/mL}$)	Total phenolic content (mg GAE/g)
1	CBL	76.5 \pm 0.19 ^{fg}	3.88 \pm 0.00 ⁱ
2	CGR	138.63 \pm 0.12 ^{bc}	23.22 \pm 0.02 ^b
3	CGI	71.06 \pm 0.65 ^{fg}	8.50 \pm 0.02 ^g
4	CCD	118.6 \pm 0.19 ^{de}	14.17 \pm 0.01 ^d
5	CVL	104.01 \pm 0.58 ^e	5.49 \pm 0.03 ^h
6	CLG	109.88 \pm 2.17 ^e	8.94 \pm 0.01 ^g
7	CTU	46.23 \pm 0.57 ^h	12.78 \pm 0.00 ^e
8	CT-M	76.70 \pm 0.72 ^f	15.60 \pm 0.00 ^c
9	CT-S	132.03 \pm 2.66 ^{cd}	10.47 \pm 0.00 ^f
10	CBE	81.08 \pm 1.97 ^f	14.32 \pm 0.00 ^d
11	PC-M	156.36 \pm 0.28 ^{ab}	1.83 \pm 0.00 ^j
12	PC-S	168.56 \pm 0.23 ^a	0.26 \pm 0.00 ^k
13	CC	5670 \pm 1.69 ^{gh}	5.86 \pm 0.02 ^a
	Ascorbic acid	6.69 \pm 0.02 ⁱ	

Data represented as mean \pm SE. The Mean within each column followed by the same letter are not significantly different at $p=0.05$.

The highest total phenol content was recorded in Cinnamon green tea. Cinnamon tamarind tea mild flavour and cinnamon bael tea. Cinnamon cardamom tea contains the required amount of total phenolic content based on Gallic Acid Equivalents. The lowest total phenolic content was observed in pure cinnamon tea types than others. Figure 3 represents the calibration curve of standard Gallic acid over a range of concentrations.

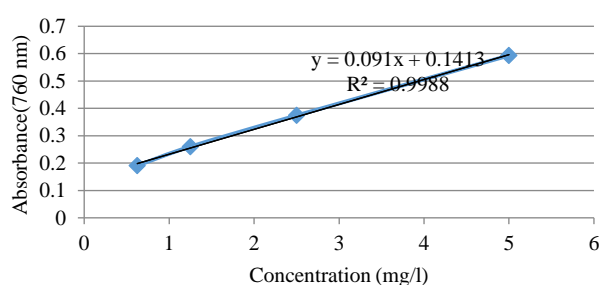


Figure 3: Calibration curve of standard Gallic acid over a range of concentrations.

4. Conclusions

Tea is known as one of the most popular beverages and plays a vital role as a medicinal agent. The addition of cinnamon, other spices, and underutilized fruits to black tea enhances its quality and imparts a superior taste compared to general black tea. Cinnamon-incorporated products serve as highly demanded herbal and medicinal drinks worldwide. The present study reveals that different types of cinnamon-based spice teas exhibit high antioxidant activity and total phenolic activity.

Conversely, value-added cinnamon experiences high demand in local and international markets compared to raw cinnamon. To address these challenges, introducing value-added Cinnamon tea emerges as the optimal solution. Teas are low-moisture products, ensuring the shelf life of cinnamon and other ingredients in comparison to their raw forms. These innovative products are stored in air-tight proper packages, thereby minimizing external environmental damage throughout the entire storage period while retaining their characteristic premium quality.

Acknowledgement

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REVIEWING IDEAL RICE TRAITS FOR CLIMATE CHANGE ADAPTATION IN SRI LANKA

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Abstract: Future food security faces challenges due to increasing food demand, changing in consumption patterns, and the effects of climate change. Crop ideotype is a model plant that is expected to yield with greater crop performance under specific environment whereas crop ideotype for climate change is the combination of traits that satisfying adaptation to climate change variabilities in specific environments. Rice is the staple food in Sri Lanka, and yet, Sri Lanka has not achieved self- sufficiency in rice production. In accordance, a holistic literature analysis was done to (a) disseminate knowledge on agricultural adaptation strategies to climate change that are suitable to Sri Lanka and (b) investigate ideal rice traits suitable for climate change scenarios in Sri Lanka. Ten scientific communications published between 2000 and 2021 were examined for this study and those were critically reviewed. These research articles suggest that a new rice ideotype with early growth vigour, low tillering capacity, few unproductive tillers, more filled grains per panicle, plant height (90-100 cm), thick and sturdy stems, leaves that are thick, dark green and erect, a vigorous root system, 100-135 days crop duration and increased harvest index under temperature and water stress condition. Research evidence justifies that climate change has a negative impact on yields of most crops in long-term. Thus, adaptation strategies such as developing ideotypes can help minimize negative impacts of adverse environmental conditions on crop production. In conclusion, it is mandatory to develop ideotypes which can withstand the changing climatic conditions and to implement agricultural adaptation strategies to ensure the sufficient food production for the increasing population.

Keywords: Ideotype; Rice plant; Adaptation; Climate change

1. Introduction

1.1 Climate Change

Average weather at a given point and time of year, over a long period (typically 30 years) is defined as climate change. It is a worldwide challenge that has started to affect several industries. In particular, the vulnerability of the agricultural sector is a worrying worldwide situation since irreversible weather changes pose a threat to global food security. Consequently, it is challenging the world's eating habits, especially in nations where agriculture plays a significant role in overall output and the economy (FAO, 2017). Due to changes in the ideal temperature ranges, climate change has also jeopardized the life and integrity of many species, hastening the loss of biodiversity by gradually altering the ecological architecture.

1.2 Global scenario

Undoubtedly, human activity has increased the temperature of the atmosphere, sea, and land. Numerous weather extremes and climate change induced by humans are already being sensed in every region of the world. This has resulted in several negative effects on the food security and water availability, human health, economies, and society, as well as associated losses and harm to both people and the nature. According to the IPCC's sixth assessment report, it is obvious that human activity—primarily the release of greenhouse gases—has contributed to global warming. Between 2011 and 2020, the average global surface temperature increased by 1.1°C over the period between 1850 and 1900, and by 2100, it is predicted to have increased by 2.8°C (IPCC,2007). Due to increasing land evapotranspiration, human-caused climate change has contributed to a rise in ecological and agricultural droughts in some areas. Due to warming, altered precipitation patterns, loss and reduction of cryospheric elements, increased frequency and intensity of climatic extremes, and altered precipitation patterns, climate change has impacted water security and decreased food production, making it more difficult to achieve the Sustainable Development Goals. Over the past 50 years, global agricultural productivity has increased overall, but this growth has been negatively affected by climate change. The associated negative crop yield impacts have mostly been observed in mid- and low-latitude regions, with some positive impacts also observed in some high-latitude regions. Unsustainable agricultural growth raises human and ecological vulnerability, intensifies competition for land and/or water resources, and is partly caused by imbalanced diets. The largest impacts have been seen in many locations and/or communities in Africa, Asia, Central and South America, LDCs, Small Islands, and the Arctic, as well as for small-scale food producers, low-income households, and Indigenous Peoples globally. Increasing weather and climate extreme events have exposed millions of people to suffer due to food insecurity and reduced water security (IPCC, 2022).

1.3 Sri Lankan Scenario

Being a tropical country, Sri Lanka is extremely susceptible to the effects of climate change. Sri Lanka is a small island in the Indian Ocean, hence sea level fluctuations might affect its coastal areas. Low-lying plains in the coastal zone will be susceptible to any future rise in sea level, as the 2004 tsunami has shown. Due to its small size and tropical climate, Sri Lanka experiences little annual temperature change. However, because of height, a notable regional difference in temperature could be seen. The average yearly temperature in lowland regions typically ranges from 26.5 to 28.5 °C, and it decreases swiftly with elevation (National adaptation plan for climate change impacts in Sri Lanka: 2016–2025).

This systematic review was conducted with the ultimate objective to investigate the impact of climate change on Sri Lankan rice production and to identify the most applicable adaptation strategies to optimize the local rice production surpassing the negative impacts of climate change. This review will assess and suggest the most suitable rice ideotype which consists of the traits to withstand the prevailing and possible climatic variations.

2. Methodology

A rigorous and comprehensive review approach was used to deeply review the most appropriate rice traits for climate change adaptation in Sri Lanka. The procedure began with a thorough search of several academic databases and this comprehensive search included the use of pertinent keywords including “ideotype”, “climate adaptation”, “rice cultivation in Sri Lanka”, “Climate change in Sri Lanka” etc. to find a variety of research, articles, and papers that provided insight into the topic. This study included reviewing scientific communications published 2000 to 2021. To determine its applicability to the subject, the calibre of the methodology used, and the veracity of the results reported, the chosen literature went through a thorough screening procedure. Only the most important, trustworthy, and relevant studies made it into the review process after this meticulous inspection. After that, data extraction was carried out in order to pinpoint and extract important findings that addressed the most important aspects of how climate change impact of rice production in Sri Lanka. Furthermore, the technique used in this study involved more than just data analysis; it also involved a critical assessment of the benefits and drawbacks of earlier research, guaranteeing a comprehensive and well-informed approach.

STEPS OF SYSTEMATIC REVIEW METHODOLOGY

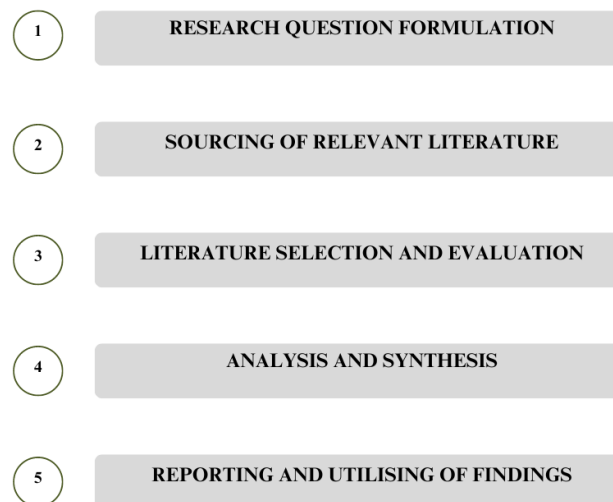


Figure 1. Systemic review process.

3. Results and Discussion

Based on the literature provided by the reviewed scientific researches and investigations it is evident that there has been a significant impact of the climate change on Sri Lanka particularly in reference to climate and food production.

3.1 Impact of Climate Change on Sri Lankan Climate

Temperature:

Historical data analysis states that the country's air temperature is progressively increasing practically everywhere (Chandrapala, 2007a; De Costa, 2008; Eriyagama *et al.*, 2010; Nissanka *et al.*, 2011; Sathischandra *et al.*, 2014). Different places have recorded varying rates of temperature increase, and in recent years, the warming trend has accelerated. Over the past few decades, all stations have reported notable increases in annual mean air temperature (Basnayake, 2007). It has also been noted that there has been an increment in mean daytime maximum and mean night time minimum air temperatures (Basnayake, 2007; Zubair *et al.*, 2005). According to data, a rise in the minimum air temperature

at night has a greater average annual temperature increase effect than an increase in the maximum air temperature during the day (National Adaptation Plan for Climate Change Impacts in Sri Lanka: 2016 – 2025).

Precipitation:

In contrast to temperature, precipitation has not shown any recognizable pattern or trend. Certain experts propose that there is a downward tendency in average rainfall when comparing the mean annual precipitation of previous and contemporary times (Basnayake, 2007; Chandrapala, 2007b; De Costa 2008; Jayatillake *et al.*, 2005). Researchers disagree on this point, and conflicting patterns can be seen in several places with observations that the frequency of heavy rainfall events in the central highlands has increased recently (Punyawardena *et al.*, 2013a). In addition, there are now more consecutive dry days than the number of consecutive wet periods. Research also suggests that the spatial distribution of rainfall is changing, even though no clear pattern has been identified yet (Basnayake, 2007; Marambe *et al.*, 2013; Nissanka *et al.*, 2011; Sathischandra *et al.*, 2014). Some studies even contend that these changes may cause the boundaries between agro-ecological zones to alter. Some studies have projected increased rainfall in wet zone, intermediate zones and north and south-western dry zones and decreased rainfall in other areas of dry zone by 2050 (Source: National Adaptation Plan for Climate Change Impacts in Sri Lanka: 2016 – 2025).

Extreme events:

Extreme weather disasters like droughts and floods have become more frequent and intense in recent years (Imbulana *et al.*, 2006; Ratnayake and Herath 2005; Premalal and Punyawardena, 2013; Punyawadana and Premalal, 2013). There is a substantial association between the locations of landslides and areas with high rainfall intensities. According to a different recent estimate, Sri Lanka's climate pattern will grow more polarized in the next years, with the dry zone being drier and the wet zone becoming wetter (Nissanka, 2009).

Sea level rise:

In the Asian region, sea levels are rising at a rate of 1-3 mm/year. This rate is slightly faster than the global average. Sea level rise in the Asian region has been seen to have increased (3.1 mm/year) between 1993 and 2001. The exact amounts of sea level rise in the region around Sri Lanka has not been evaluated yet. (National Adaptation Plan for Climate Change Impacts in Sri Lanka: 2016 – 2025).

3.2 Impact of climate change on Rice production in Sri Lanka

The sown extent under paddy cultivation during 2022 yala season was 481,669 hectares while the harvested extent during this season was estimated to be 480,289 hectares. The average yield of paddy estimated for 2022 yala season was 3,207 kg per net hectare. The estimated paddy production for 2022 yala season was 1,461,675 metric tons. The sown extent under paddy cultivation during 2021/2022 Maha season was 775,846 hectares while the harvested extent during this season was estimated to be 766,148 hectares. The average yield of paddy estimated for 2021/2022 Maha season was 2,853 kg per net hectare. The estimated paddy production for 2021/2022 haha season was 1,931,230 metric tons. (Source: Agriculture and Environment Statistics Division of the Department of Census and Statistics).

Almost 100 countries around the world utilize rice as their primary staple food, making it the most significant cereal crop and the reason it has been earned the reputation as the global grain (Khan *et al.*, 2015). Concerns about both the beneficial and negative effects of global climate change on Sri Lanka's agricultural products have grown recently. Studies conducted over an extended period of time have demonstrated variations in the amount of rainfall during extended dry spells, as well as higher minimum and maximum air temperatures and atmospheric CO₂ concentrations. The rising demand, saturation of cultivable field and climate change cause a shortage in the supply of rice in the future. By the near 2025, about 785 million tonnes of paddy which is 70% more than the current production is needed to meet the growing demand. To achieve the expected yield and hike the productivity of

rice, it becomes necessary to design new rice varieties with higher yield potential in order to enhance average farm yields. (Chaudhari *et al.*, 2014).

3.2.1 Impact of increased atmospheric CO₂ concentration

The benefits of elevated atmospheric [CO₂] is higher for C₃ plants like rice than C₄ plants. All rice cultivars' leaf photosynthesis increased in response to rising atmospheric [CO₂] (Lawlor & Mitchell, 1991; Kimbal *et al.*, 2002). Grain yield rose by at least 27% when atmospheric CO₂ content was raised to around 550 μmol mol⁻¹, albeit the response differed according to the examined variety. Elevated atmospheric CO₂ leads to enhanced tillering, by enhancing N intake and fertilizer N recovery (Weerakoon *et al.*, 2005). However, it decreases leaf partitioning. Finally, higher atmospheric [CO₂] led to an increase in the accumulation of dry matter and rice grain production (Makino *et al.*, 1997; Weerakoon *et al.*, 1999).

3.2.2 Impact of increased temperature

The maximum and minimum air temperature growth rates in Sri Lanka have differed depending on the season and location. There has been nearly constant warming in several areas that correspond to Sri Lanka's main agroecological zones between the 1930s and 2007. The rate of increase in air temperature in Anuradhapura, the main rice-growing region in Sri Lanka's Dry Zone, has been roughly 0.0078 °C year.

According to Weerakoon and Costa (2007), in all major rice growing ecosystems in Sri Lanka, both maximum and minimum air temperatures have increased over the years. In certain ecosystems, during certain periods of the year, air temperatures have reached to its maximum threshold levels for rice. This would have a profound negative impact on the productivity of the rice crop in Sri Lanka. Increasing temperature hasten development resulting in the reduction in absorption of solar radiation by the canopy. Further, it increases respiration and may affect C assimilation depending on the level of air temperature.

Out-crossing percentage is highly dependent on the season indicating that air temperature has a significant impact on out-crossing in the field. Increased incidence of "weedy rice" in farmers' fields is clear evidence of increased cross-pollination in rice. Mild high temperature stress experienced at present would affect the quality of the seed paddy produced as well as the consumption paddy. On the other hand, if temperature increases by another 1-20 C during the flowering stage of a rice crop in the future, the production will also decrease (Weerakoon and Costa, 2007).

A rise in temperature will also alter partitioning, which will alter the harvest index. Nonetheless, the reproductive phase, which is particularly susceptible at heading, is the most significant period in which elevated air temperature affects rice plants, particularly during anthesis. The yield of Sri Lanka's rice crop is significantly impacted by higher maximum air temperatures, particularly with regard to spikelet sterility. On the other hand, future rice crop productivity will likewise decline if temperatures rise by an additional 1–20 C during the flowering period. The average spikelet fertility decreased from approximately 95% to 25% with increased relative humidity and a temperature increase from 30/24°C to 36/30°C (Anuruddhika, 2008). Many of the island's rice-growing districts have seen a notable rise in the population of weedy rice recently, perhaps due to air temperatures that were higher than ideal during blooming. The season has a major influence on the out-crossing %, suggesting that air temperature affects out-crossing in the field. A prominent sign of increased cross-pollination in rice is the increased occurrence of "weedy rice" in farmers' fields. The evaporative demand for water from crop surfaces and from standing water in rice fields will increase due to rising air temperatures. Consequently, less water will need to be diverted for hydropower generation in order to maintain a steady supply of water to fulfil the increased water demand from agricultural crops (U.R. Sangakkara, 2009).

3.2.3 Deteriorating quality and quantity of irrigation water

Weerakoon and Costa (2007) suggest that the amount of water diverted remained essentially the same, but the increased demand for domestic and industrial water in the dry zone brought about by population growth—which in the districts of Anuradhapura and Polonnaruwa increased by approximately 29% between 1981 and 2001—has effectively reduced the amount of water available for agriculture, particularly rice cultivation. Additionally, there is a rise in the amount of dirty water that is discharged into rivers, which eventually finds up in the dry zone and builds up salt. As a result, the decline in irrigation water quantity and quality will exaggerate the negative impacts of climate change on rice production.

3.2.4 Impact of sea level rise

The rice land extent under inland flood plain and coastal saline flood plain ecosystems in Sri Lanka are approximately 16,000 ha and 6000 ha respectively. There could be a direct impact of sea level rise through submergence and increased salinity levels to a certain percentage of these coastal saline rice lands but in general it would be very low. Therefore, there is a need for an urgent attention to develop varieties and associated technologies to overcome negative impacts of increased air temperature, reduced availability of water quality and quantity and deteriorating soil environment with increased inland and coastal salinity. Therefore, a research and development programme must be implemented to overcome the negative impacts and fully utilize the positive impacts of climate change to increase rice production in Sri Lanka and ensure its future food security. However, at present, increasing productivity to meet the future demand is met with many abiotic and biotic constraints such as inadequate water, nutrient deficiencies, soil toxicities, higher day and night temperatures and change in weeds, insects and disease composition and pressure (Weerakoon and Costa, 2007).

3.2.5 Concept of Ideotype

Professor Colin Malcolm Donald originally created the term "ideotype" when working with wheat in 1968. He proposed the idea of an ideotype of wheat, which was initially presented in 1968 at the Third International Wheat Genetics Symposium in Canberra. Based on morphological and physiological characteristics, he stressed this idea. Later, biochemical, anatomical, and phenological features were included to this concept. According to Yuan, L. (2001) it illustrated how creating new ideotypes can lead to an improved understanding of crop ecology and physiology and eventually provide ideotypes that are increasingly more successful.

An ideotype is one that's assumed to operate or act in a foreordained way in a particular setting. It comprises of an assortment of morphological, phenological, and physiological qualities that, when created as a cultivar in comparison to already existing assortments within the field, contribute to surrender, greater amount of grains, fiber, oil, or other item. More particularly, this ideotype optimizes trim performance to a certain biophysical environment, edit administration, and end-use. It may be a blend of morphological and/or physiological highlights, or their hereditary underpinnings (Yuan, L., 2001).

There are several types of ideotypes. The isolation ideotype performs well under spaced plantings but not under crop densities, while the competition ideotype performs well in genetically heterogeneous, competitive environments. The crop ideotype performs best at commercial crop densities (surrounded by plants of the same form) because individual plants in this ideotype are poor competitors (Swetha Sree & Hima Sree, 2021). Market demands dictate the market ideotype's traits, developed particularly for market value and customer demand. Edaphic ideotypes adapt to unique soil characteristics rather than climatic factors, while stress ideotypes can survive against biotic and abiotic threats. Finally, climatic ideotype is the combination of traits (genes) that confers on the crop a satisfying adaptation to climate variability and extreme climate events in specific environments and under specific cropping systems. (Razzaq et al., 2018).

3.2.5 Adaptation Strategies

Food security is one of the most critical areas that need special attention in climate adaptation in Sri Lanka. To ensure the long-term sustainability of Sri Lanka's rice production in the face of climate change, several crucial adaptation strategies must be implemented. Climate-resilient rice production in Sri Lanka demands multifaceted adaptation strategies. Cultivating short-duration cultivars, adhering to optimal planting times, and maintaining saturated field conditions optimize water use and minimize heat stress. Precise nutrient application, irrigation system upgrades, and development of tolerant varieties further enhance resilience (Weerakoon, W.M.W. and De Costa, W.A.J.M., 2009). On-farm water management through rainwater harvesting, wastewater reuse, and improved nursery protection is crucial. Additionally, promoting micro-irrigation, diversifying crops, and increasing organic matter in soil contribute to sustainability. Finally, research capacity on tolerant varieties and climate-resilient methods is indispensable (National adaptation plan for climate change impacts in Sri Lanka: 2016–2025).

A new plant type was conceptualized in 1988 to increase the yield potential of rice further and this proposed ideotype became the “New Plant Type” (NPT) highlighted in IRRI’s strategic plan. These research articles suggest that a new rice ideotype with favourable traits including early growth vigour, low tillering capacity, few unproductive tillers, more filled grains per panicle, plant height (90-100 cm), thick and sturdy stems, leaves that are thick, dark green and erect, a vigorous root system, 100-130 days crop duration and increased harvest index under temperature and water stress condition (Table 1).

Table 1: Proposed attributes of a rice ideotype

Ideal Traits	Description	References
Tillers	Lower tillering capacity (9-10 tillers per plant and 270–300 panicles m ⁻²)	Swetha Sree & Hima Sree, 2021
Panicle	Heavy panicles (5 g panicle) and drooping panicles at maturity	Swetha Sree & Hima Sree, 2021
Grains per panicle	200-250 grains per panicle	Swetha Sree & Hima Sree, 2021
Yield	yield-13 t/ha	Razzaq et al., 2018
Plant biomass	22 t/h	Razzaq et al., 2018
Harvest Index (HI)	Around 0.6	Swetha Sree & Hima Sree, 2021
Plant height	At least 100 cm (from soil surface to unbent plant tip) and panicle height at 60 cm (from soil surface to the top of panicles with panicles in natural position) at maturity	Razzaq et al., 2018
Planting duration	100-130 days	Razzaq et al., 2018
Root system	Should be vigorous	Razzaq et al., 2018

Leaf characteristics	<ul style="list-style-type: none"> a) Leaves should be thick, dark green and erect b) Attributes of the top three leaves: c) Flag-leaf length of 50 cm and 55 cm for the 2nd and 3rd leaves d) All three leaves are above panicle height e) Should remain erect until maturity f) Leaf angles of the flag, 2nd, and 3rd leaves are around 58, 108, and 208°, respectively 	Swetha Sree & Hima Sree, 2021
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4. Conclusion

According to the results of this study it is evident that climate change has a significant impact on global crop production. Climate change influences crop yield, quality and fertility status of soils and may pose a serious threat to food and nutritional security. This climate change variability could cause significant fluctuations in production in terms of yields of most crops in both long-term and short term. Adaptation strategies can help minimize negative impacts, but these need greater research, policy and financial support. Developing ideotypes suitable for adverse environmental conditions is a better choice as adaptation practices take time to become effective. Nevertheless, the ideotype breeding approach is not an alternative but a supplement to traditional breeding approaches because selection for yield is still needed in ideotype breeding. A new rice ideotype may require concurrent modification of crop management such as seedling age, planting geometry, fertilization, irrigation regime, and weed control to fully express its yield potential. And many plant traits are under control of multiple genes, some of which may be unknown. However, since its proposal, the ideotype concept has been applied to a variety of different crop species, expanded to specific environments and alternative cropping systems, and applied to varying end uses. In addition to traditional breeding approaches, biotechnological approaches, especially tissue culture and protoplast technology, must be utilized in future for designing new plant types. To ensure sustained food security in Sri Lanka where rice is the staple food, research efforts must prioritize developing climate-resilient rice ideotypes while simultaneously developing targeted management practices.

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**DESIGN AND DEVELOPMENT OF AN AUTOMATED REGULAR TIME
WATERING SYSTEM AND FEASIBILITY ASSESSMENT FOR OUTDOOR
APPLICATIONS**

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Abstract: In Sri Lanka, 45% of agriculture related issues are related with watering. Precision water usage is important for crop production, yet a lack of understanding among farmers leads to a substantial loss in harvest. Emphasizing the importance of controlling water, and addressing the key challenges in various watering methods, this research aimed to address the pressing challenges faced by household and small-scale farmers in Sri Lanka, specifically focusing on the impact of drought and irregular rainfall on agriculture. This research proposes a regular time-based systematic and scheduled approach watering method for outdoor applications using an automated regular watering system to ensure a consistent and reliable moisture supply to plants, preventing under-watering or over-watering. The suggested watering method was tested in an open field in Hanwella, Western province in Sri Lanka and checked the feasibility and acceptability in real-world outdoor applications. The results show that there is a significant difference in plants growing rates in the traditional and the automated systems with a fast-growing rate in the automated regular watering method. There is a 36.6% of water saving in the automated regular watering method. Moreover, the automated system shows 20.43% of increase in the harvest. Further, the results describes that the effect of rainfall is an uncontrollable factor in outdoor farming.

Keywords: Outdoor farming; Automated; Scheduled; Watering; Harvesting

1. Introduction

Watering is a crucial factor in crop production, and it has to be done at the right time in the correct amount. Figure 1 shows the percentages of reported agriculture-based issues in two different seasons in Sri Lanka. Accordingly, 45% of issues are related to watering (Agricultural survey 2016/17). However, many farmers in Sri Lanka are lack of proper understanding of precision water usage.

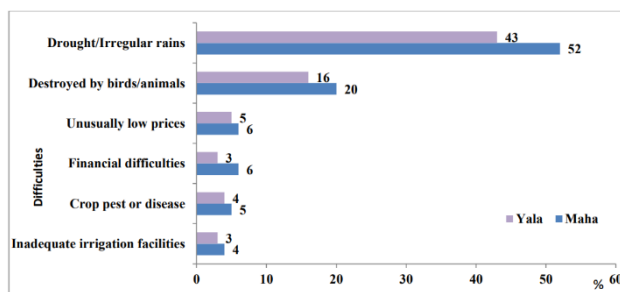


Figure 1: Percentages of agricultural household reported difficulties in Sri Lanka.

1.1 Importance of Watering Control

Proper watering control is crucial for successful outdoor cultivation, preventing issues like overwatering or underwatering and promoting resource efficiency. This practice aids in conserving water, reducing irrigation costs, and contributing to sustainability. It also allows adaptability to changing weather conditions. Sri Lanka's agriculture sector faces challenges in water usage, with over 50% of freshwater dedicated to agriculture (Mastiaanssen, Chandrapala, 2003). Water scarcity and outdated irrigation practices present significant challenges, emphasizing the need for sustainable water management in the country's agriculture (Udara, Somabandu, 2022).

1.2 Aim of the Research

Considering the all the key challenges and the advantages and disadvantages of different watering methods, here propose a regular time-based watering method suitable for outdoor applications. "Regular time watering" refers to a systematic and scheduled approach to watering plants or crops. In this method, water is supplied to plants at specific time intervals, typically on a regular basis, regardless of the other conditions.

The goal of regular time watering is to provide consistent and reliable moisture to plants, promoting healthy growth and ensuring they receive an adequate water supply, especially in areas with irregular rainfall patterns or during dry seasons. It helps prevent under-watering and over-watering by adhering to a predetermined schedule based on the specific water needs of the plants being cultivated.

This system is fully automated and designed for outdoor use. It will assess the feasibility and acceptability of this system in real-world outdoor applications. The research methodology, results, discussions, and the final conclusion will be presented in the following chapters.

2 Methodology

2.1 Watering

In this experiment, two plant beds were set up, one with a traditional manual watering system and the other with an automated regular watering system. Chili (*Capsicum annuum*) was chosen for short-term crop assessment, with 28 of M.I.2 chili plants in each bed. This variety is known for outdoor resilience and quick yields. To maintain consistency, similar fertilizers were used in both beds under the same environmental conditions.

2.1.1 Bed 01 - Traditional Manual Watering System

An 8-letter flower basket was used to a watering and that volume was measured in each watering time. The water volume was adjusted based on the plant's growth stage and the amount of rainfall. The data sourced for this study is derived from the Agriculture Department's records (*Chilly cultivation*).

2.1.2 Bed 02 - Automated Regular Watering Method

In this test case, an Arduino-based timer circuit facilitates an automated regular watering system. The circuit stores preset time intervals, activating a relay to control a solenoid valve for water distribution. The schedule starts at 07.30 am and next operate in 3 hours of time intervals (07.30H, 10.30H, 13.30H, 16.30H) and that run consistently throughout the research. This approach minimizes water consumption and addresses issues linked to excessive watering. Figure 2(a) shows the manual watered bed and figure 2(b) shows the automated watering bed with supporting pipelines.

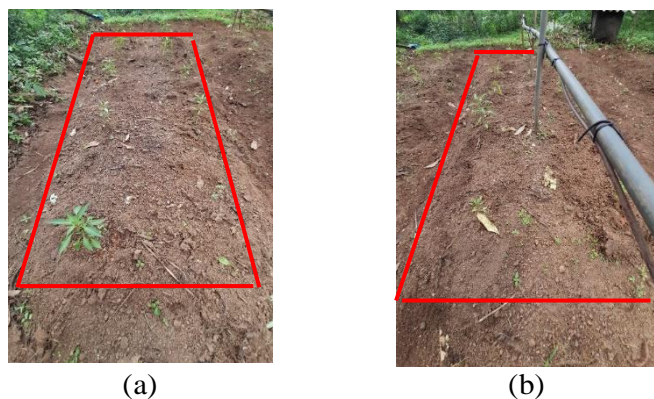


Figure 2 (a): Traditional manual watered bed. 2 (b): automated watering with pipe lines.

2.2 Automated Regular Time Watering Circuit

Figure 3 shows the circuit diagram and components of automated regular time watering circuit. Using the LCD display and control buttons, the user can configure the time values. The relay, activate according to the given schedule and it controls the solenoid valve, enabling precise and timely watering. Figure 4(a) shows the solenoid valve use for open/close the valve. A flow controller is coupled to valve to further adjust the water flow. Figure 4(b) shows how this time inputs are given to systems using the LCD display and control buttons. (Divani, Punjabi, 2016). This circuit is specially designed with a focus on outdoor usage. To make this circuit accessible in remote areas, especially those far from grid connections, it has been equipped with a 12V solar power supply, which is elaborated upon in the following subchapter.

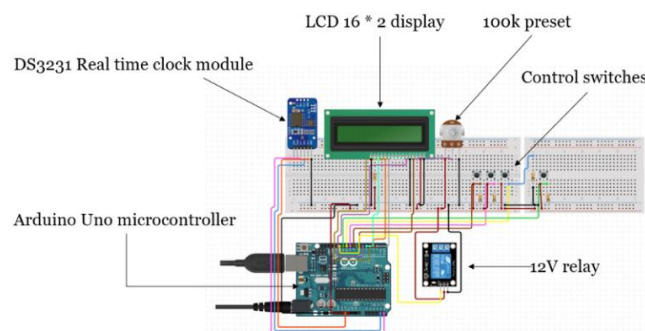


Figure 3: Automated regular time watering circuit.

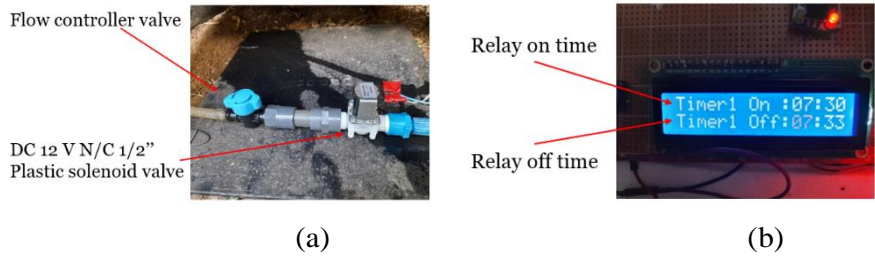


Figure 4 (a): Solenoid valve and flow controller. 4 (b): User inputs to the systems.

2.3 Solar Power Supply

This circuit has been purposefully designed with a primary focus on outdoor applications. This solar-powered system offers several advantages, making it suitable for use in rural or remote areas where direct grid power supply is unavailable. It eliminates issues related to power cuts and features low power consumption. This system incorporates a 0.5 kW solar panel for charging a 20Ah battery, providing a stable 12V power source to energize the Arduino circuit and the solenoid valve. A visual representation of this solar power supply arrangement is presented in figure 5.

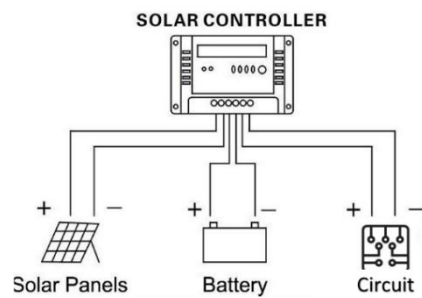


Figure 5: Solar power supply arrangement.

2.4 Water Distribution System

An automated bed contain a spray nozzle pipe network, with five nozzles covering 1-square meter each. Figure 6 depicts the water distribution pipe network layout, targeting plant root areas to minimize water loss.



Figure 6: Water distribution pipe network & spray nozzle.

3 Measurements

A number of factors, including both manual measurements and sensor data, were measured in order to evaluate the viability of the suggested method (Gunawardena, De Silva 2014).

3.1 Manual Measurements

3.1.1 Average Height Variation

The height of the plants was measured with a ruler to track their growth in every two weeks. Out of the 28 plants on a single bed, the 25 healthiest plants were used for this measurement.

3.1.2 Average Leaf Area Variation:

Plant area was determined by measuring it with a ruler in every two weeks. The measurement process involved selecting the 25 healthiest plants out of the 28 in one bed. For symmetrically growing plants, the maximum length between leaves was recorded. In the case of asymmetric growth, both the maximum and minimum lengths were measured, and the average was calculated.

3.1.3 Yield Variation

To take the productivity of the plants, yield measurements were taken once every two weeks. Harvested fresh chili fruits were weighed to determine the yield.

3.1.4. First Harvest Duration

The time taken for the plants to yield their first harvest in the field was recorded. This parameter provides insights into the system's impact on the timing of crop production.

3.2 Circuit Measurements

To acquire sensor data, a second circuit was developed and programmed using the Arduino microcontroller.

3.1.3 Environmental Parameter Monitoring Circuit

Figure 7 shows the circuit diagram and components of environmental parameter monitoring circuit. It enables the activation of on-field sensors, facilitating the collection of data at predefined intervals. Soil moisture content in each bed was measured using Arduino soil moisture sensors. One sensor was placed in each bed, with hourly readings taken. To measure the impact of air temperature and humidity on plant transpiration, Arduino DHT 11 sensors were used. Placed in the open field, hourly measurements were recorded and stored on an SD card module for subsequent analysis. Figure 8(a) shows the on-field attachment of Arduino DHT 11 sensor and the figure 8(b) shows the soil moisture level sensor

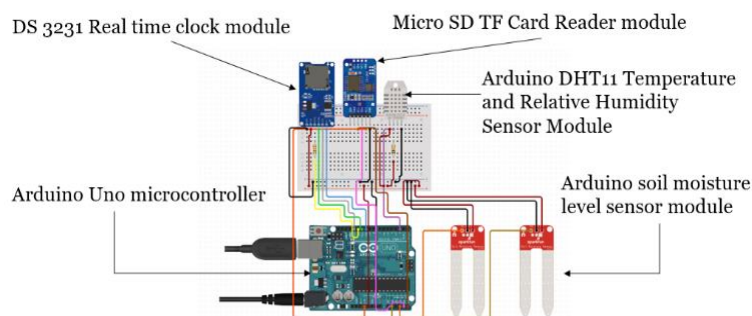


Figure 7: Environmental parameter monitoring circuit.



Figure 8 (a): On field attachment of Arduino DHT 11 sensor, 8 (b) soil moisture level sensor.

4.0 Results

The outcomes of the data collection are shown in this part for additional study and analysis.

4.1 Plant Growing Variation

To assess the impact of the suggested system on plant growth, two primary plant growth parameters were measured. The first parameter examined was plant height variation, which involved measuring the height from the soil layer to the topmost leaf. Measurements were taken once every two weeks, and Figure 9 depicts the height variation of the two beds. Notably, the data illustrates that the automated bed exhibited faster growth compared to the manual bed.

The second parameter, illustrated in the second graph figure 10, focused on the variation in plant leaf area for both beds. Leaf area serves as an indicator of branch spread within the environment. Measurements were taken once every two weeks. The data clearly demonstrates that the plants in the automated bed exhibited greater branch growth and coverage, while the manual watering bed occupied less space and had a limited number of branches. Additionally, a visual observation revealed that the plants in the automated bed exhibited more symmetrical growth compared to the manual counterpart.

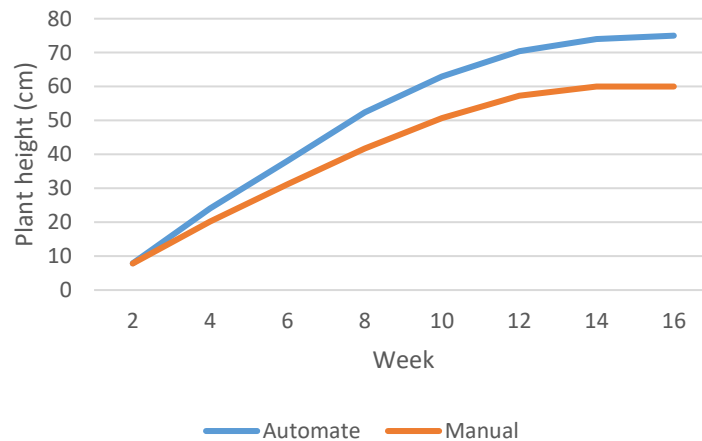


Figure 9: Mean height variation.

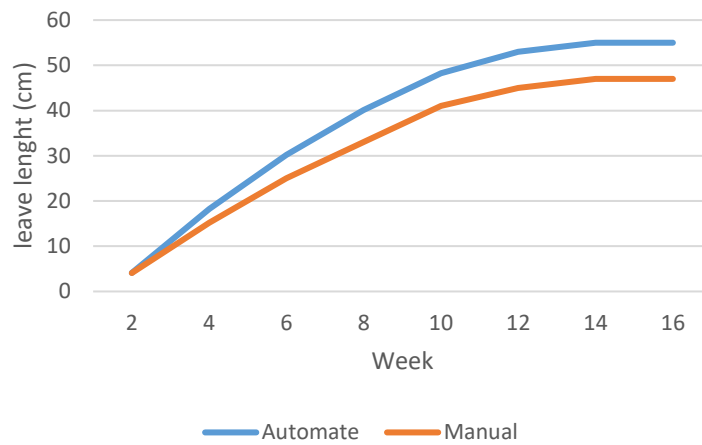


Figure 10: Mean leave area variation.

4.2 Water Consumption Variation

One of the primary objectives of this research was to assess the water-saving capabilities of the proposed regular timing watering system. Figure 11 illustrates the weekly variation in water consumption for both plant beds. Given that this experiment was conducted in an open environment, it is essential to account for rainfall as a critical factor. To address this, the total rainfall received was divided and considered as the table 1.

Table 1: Total rainfall variation

Category	Conditions
Dry	No raining. Full day sun light
Medium	Rain below 2 hours. More than 6 hours of sun light
Heavy	More than 3 hours of rain. Limited sun light.

The automated bed consumed 135 liters of water, whereas the manual bed used 213 liters, resulting in a water saving of 78 liters with the automated system. This represents a significant 36.6% reduction in water usage.

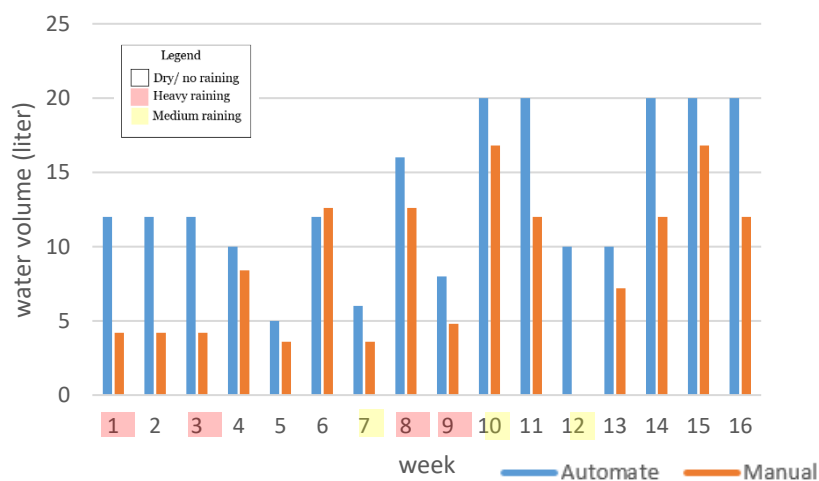


Figure 11: Weekly variation in water consumption.

4.3 Soil Moisture Content Variation

In this experiment, efforts were made to maintain uniform conditions across both cases, with the primary differentiation being the water supply system. To measure the effectiveness of the proposed watering system, the variation in soil moisture content was monitored in both cases. Soil moisture content serves as a direct indicator of the water available in the soil and any additional water requirements. In this context, soil moisture content readings were collected from each bed on an hourly basis. The figure 12 presented herein is generated from the mean soil moisture data recorded between 7:00 am and 5:00 pm.

Existing researches suggests that a range of 60-80% for soil moisture content is conducive to optimal plant growth and productivity during cultivation. Analysis of the figure reveals that the soil moisture content in the automated bed consistently falls within this favourable range, while the manual bed exhibits variations consistently below 60%.

It is important to note that rainfall directly impacts soil moisture levels, a correlation that is clearly evident in the graph. On days with significant rainfall, the soil moisture content approaches nearly 100%, whereas on days with moderate rainfall, it exceeds the 80% threshold. These observations emphasize the crucial role of rainfall in soil wetness management

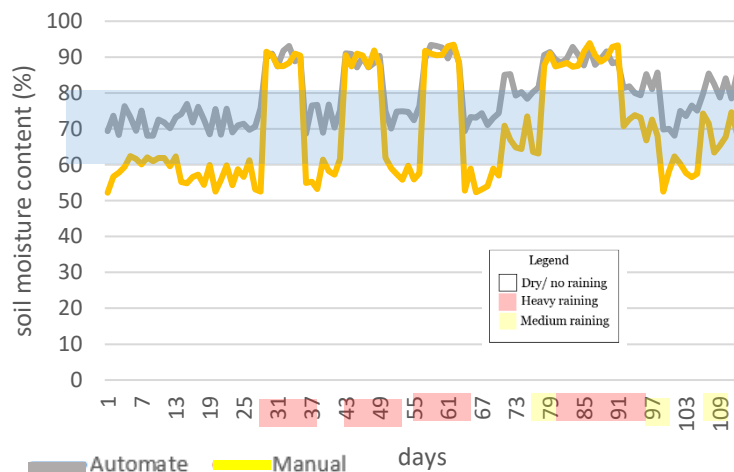


Figure 12: Mean soil moisture content variation

4.4 Temperature and Humidity Variation The open field temperature and humidity readings were collected from each bed on an hourly basis. The figure 13 presented herein is generated from the mean temperature and humidity data recorded between 7:00 am and 5:00 pm. According to this figure, it can be observed that there is a humidity variation ranging from 75% to 85% on normal days. This range is sufficient for short-term crops during their growing period. However, on rainy days, it shows a higher humidity variation, exceeding 85%, which is unsuitable for cultivations. It difficult to see a significant variation in temperature so there is a less effect on that.

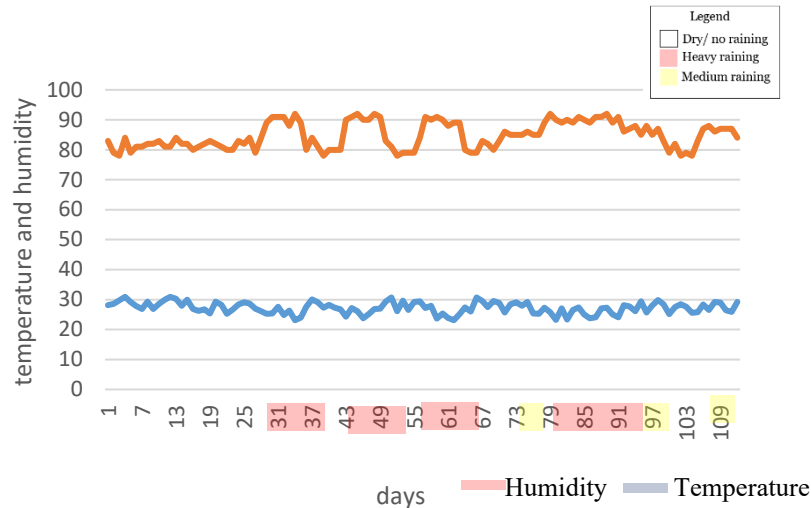


Figure 13: Mean temperature and humidity variation.

4.5 Harvest Variation

The harvest data was collected 14 weeks after the cultivation commenced, and both systems yielded their first harvest in the same week. Figure 14 illustrates the harvest variation in both testing beds, revealing an increase in yield in the automated watering bed. During this harvesting period, the impact of rainfall was significant, leading to a reduction in the overall harvest.

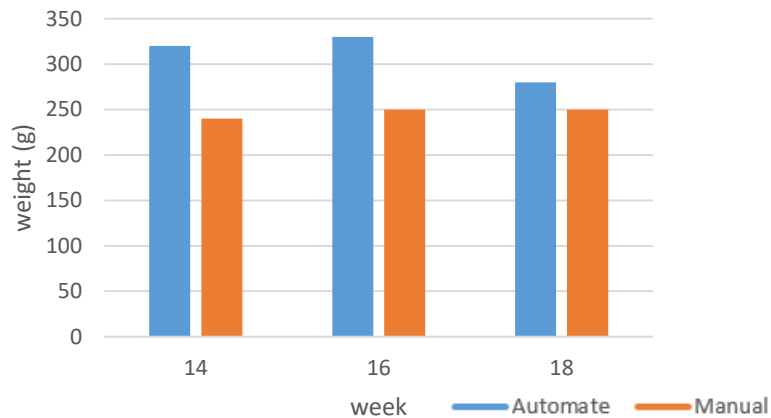


Figure 14: Harvest variation.

5.0 Discussion

In this experiment, several key observations were derived from the experimental data and general insights. The following are noteworthy indicators, especially those that significantly impact open-field cultivations.

5.1 Effect of Rainfall

Rainfall is a crucial yet uncontrollable element in open-space agriculture. Due to the absence of effective rain protection methods in open-field farming, plantations are highly susceptible to the impact of rainfall. This issue is particularly pronounced in tropical regions, where rainfall patterns are notoriously unpredictable, making it challenging for farmers to plan their cultivations systematically. The experimental results presented here illuminate the profound influence of rainfall on soil moisture. These findings reveal that even moderate rainfall events can elevate

soil moisture content to levels inadequate for plant growth, and this elevated moisture level can persist for more than a day.

5.2 Feasibly on Remote Applications

The experimental results clearly demonstrate that the suggested regular time watering system performs exceptionally well under dry or low moisture conditions. The integrated solar power system, well-suited for such environments, can effectively power the system without relying on an AC power supply. Furthermore, this solar power infrastructure allows farmers to integrate a solar water pump and water storage, enabling fully autonomous agricultural operations even in the absence of a direct power supply.

6. Conclusion

This research aims to design and develop an automated regular time watering method for short-term crops and assess its feasibility in open-field cultivations. The results demonstrate the practical usage of the suggested system in open-field settings. In automated plant beds, plants exhibit fast growth and appear healthier compared to their manual counterparts. Soil moisture variation analysis reveals that the automated plant beds maintain soil moisture content within the optimal 60-80% range during dry periods. The study indicates that air humidity and temperature variations have minimal impact on plant growth, but humidity values exceeding acceptable limits of 85% during rainy periods are noted. Additionally, the automated plant beds yield higher harvests.

The water consumption in the automated beds consistently remains lower than that in the manual beds, with a notable 36.6% reduction in water usage. This reduction is particularly pronounced during periods of rainfall, influencing both cases. The suggested system demonstrates significant water-saving capabilities.

Given the uncontrollable nature of weather conditions in open-field settings, the impact of rainfall is substantial. Therefore, the watering efficiency during wet seasons may not be conducive to plant growth. In open-field farming, regular time watering is well-suited, especially during dry or low rainy seasons. The effectiveness of regular time watering in a controlled environment is yet to be tested, which could prove even more efficient due to minimal rainfall effects.

Acknowledgment

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CHARACTERIZATION OF PHYSICOCHEMICAL PARAMETERS AND ORGANOLEPTIC ASSESSMENT FOR THE AUTHENTICATION OF SRI LANKAN BEE HONEY AND OPTIMIZATION OF A METHODOLOGY FOR POLLEN DNA EXTRACTION

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Abstract: Bee honey, crafted from floral nectar by bees, has its botanical origins historically determined by methods like palynology and chromatography, albeit time-consuming. DNA-based techniques now offer faster, more reliable identification, crucial for combating mislabeling and adulteration, enhancing efficiency in identifying honey's floral source. This study set out to delve into the microscopic world of bee honey, unravel its physicochemical intricacies, and refine protocols for pollen DNA extraction. The pollen density, pH, conductivity, reducing sugar, sucrose, glucose to fructose ratio, moisture, solid content, acidity, Fiehe's test and colour intensity underwent thorough evaluation according to Codex and SLS standards. The organoleptic assessment was conducted based on colour, aroma, texture, taste and overall preference. Statistical analysis was employed to discern any significant differences among these parameters. For DNA extraction from bee honey, a DNeasy® plant mini kit, three CTAB methods with and without optimizations were used. All these seven different DNA extraction protocols were compared in terms of DNA integrity and purity. A detailed card including all physicochemical parameters, the colour, geographical location, and the harvesting season, was developed that is commercially applicable. Geographical differences were found to significantly influence the physicochemical parameters of bee honey, with samples clustering together based on their floral origins and distinct compositions. Interestingly, organoleptic assessments revealed notable variations among honey from different locations. Despite these findings, an optimized CTAB protocol (125 mM Tris.HCl, 50 mM EDTA, 50 mM NaCl, 3.5% CTAB, pH 7.8, 4% β-mercaptoethanol) with an overnight incubation at 65°C yielded the highest DNA purity for all samples. Moving forward, optimizing DNA extraction protocols through pre-treatment methods and alternative kit protocols is imperative. These study outcomes hold promise in combating honey adulteration by pinpointing the floral sources of multifloral bee honey.

Keywords: Bee honey adulteration; Multifloral bee honey; Palynology; PCR amplification; Resistant layer of sporopollenin

1. Introduction

The honeybee, scientifically known as *Apis mellifera*, orchestrates the creation of honey, a luscious and viscous elixir (Majewska *et al.* 2019). This complex concoction, derived from flower nectar and honeydew secretion sourced from live plants or the excretions of insects feeding on them (Silva *et al.* 2018) not only tantalizes the taste buds but also boasts significant nutritional and therapeutic benefits. Across diverse medical traditions, from ancient practices to modern medicine, honey has been lauded as a remedy for ailments ranging from the common cold to cancer (Beretta *et al.* 2005). In Sri Lanka, bee honey holds a revered status, revered both for its culinary versatility and medicinal prowess. It finds applications across a spectrum of food systems, from fruit and vegetable products to fermented goods, serving as both a staple in the diet and a preservative for meats and fruits (Adebiyi *et al.* 2004). Despite its esteemed reputation, the purity and authenticity of bee honey are not always guaranteed. Variations in geographical and botanical origin, coupled with environmental factors during production, such as weather conditions and humidity within the hive, bestow honey with diverse characteristics and compositions (Braga *et al.* 2019). Regrettably, unscrupulous practices, including adulteration by dilution with water, sugar syrup, or highly concentrated corn syrup, threaten to compromise its integrity. To safeguard consumers and uphold fair competition among producers, stringent testing protocols are essential. These include assessments of sugar content, sucrose levels, and the fructose-to-glucose ratio, crucial steps in qualitative tests aimed at detecting adulteration (Jayasinghe *et al.* 2012). Notably, Sri Lankans, valuing flavour and authenticity, favour lighter-hued honey variants. Amidst the pursuit of authenticity, the development of robust methodologies for verifying the botanical origins of honey is imperative. Traditional approaches, such as melissopalynology, which relies on the microscopic examination of pollen grains, are laborious and demand specialized expertise (Lalmangaihi *et al.* 2014). A promising alternative lies in DNA-based techniques, offering rapidity, sensitivity, and specificity in identifying floral sources. However, the effectiveness of DNA extraction methodologies is paramount to the success of these techniques, especially when dealing with complex matrices like honey. Despite honey's cultural significance in Sri Lankan Ayurvedic treatments, research in this domain has been scarce.

Thus, this study endeavours to characterize physicochemical parameters and conduct organoleptic assessments to authenticate Sri Lankan bee honey. Furthermore, by optimizing methodologies for pollen DNA extraction, this research aims to pave the way for a DNA barcoding approach that can reliably identify the floral sources of multifloral bee honey. In doing so, it not only safeguards against adulteration but also opens avenues for applications in the realms of food, medicine, and cosmetics, enriching lives and ensuring the purity of this cherished natural treasure.

2. Materials and Methods

2.1 Sample Collection and Study Sites

Bee honey samples, along with their respective pollen layers, were sourced from Ceylon Bee Honey Pvt. Ltd., Kandy, Sri Lanka, and Gobnait Bee's Honey, Nugegoda, Sri Lanka, ensuring authenticity. Samples were collected during the August-November seasons in 2022 and the February-June seasons in 2023 (Figure 1a). Properly labelled, the bee honey samples were stored in sterile airtight glass containers under refrigerated conditions (4°C) until analysis. Raw pollen layers from samples (A, B & C) were provided (Figure 1b), and stored in a freezer for 24 hours before collection, while frozen pollen from hives was retrieved using sterilized tweezers.

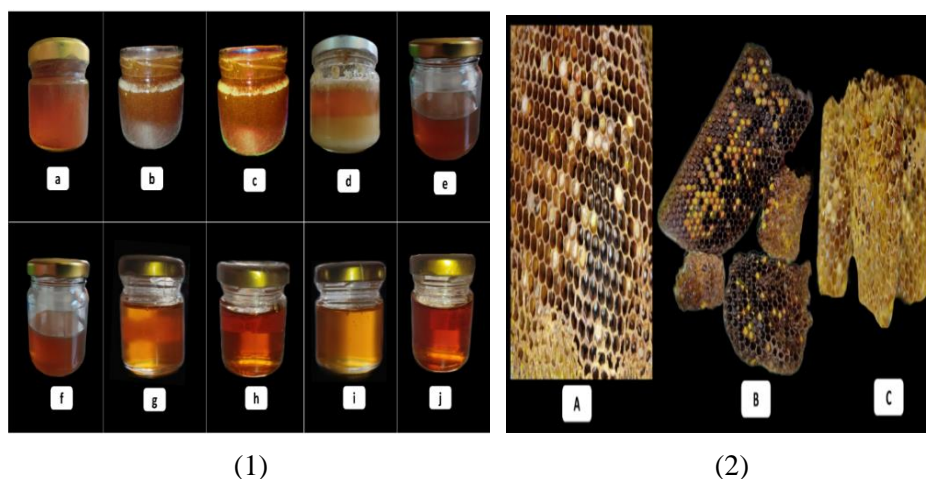


Figure 1: (1) Collection of 10 bee honey samples from different geographical locations in Sri Lanka (a) Nuwara Eliya, (b) Gannoruwa, (c) Bowalawatta, (d) Awissawella, (e) Ogastawatta, (f) Pilimathalawa, (g) Welimada, (h) Badulla, (i) Uva-Paranagama and (j) Buttala. (2): Collection of 03 raw pollen samples from 3 different geographical locations in Sri Lanka (A) Nuwara Eliya, (B) Gannoruwa and (C) Bowalawatta.

2.2 Microstructure Analysis

Evenly distributed one or two drops of bee honey were observed by an inverted phase contrast microscope (Nikon ECLIPSE TE300, Japan) under 400 magnifications. The pollen structures were then compared to the examples given by Silva *et al.* (2018).

2.3 Absolute Pollen Count Analysis

Pollen extraction from bee honey followed a method with minor adjustments (Waiblinger *et al.* 2012). After dissolution in sterile distilled water and incubation, centrifugation and air-drying were conducted. Absolute pollen count (APC) was determined using a method outlined by Jayasinghe *et al.* (2012), considering sediment weight and slide count. An APC <1,000 grains/10 g indicated syrup adulteration. Samples were categorized based on APC as per Shukla *et al.* (2021), from extremely poor to extremely rich pollen content.

2.4 Physicochemical Analysis

The physicochemical analysis of honey encompassed various parameters as follows: pH determination, conducted using a digital pH meter (Eutech pH 700, India) as outlined in Kebede and Adgaba (2011). Electrical conductivity measurement involved dissolving 20 g of honey in 100 ml of distilled water, followed by calibration of the conductivity meter (Eutech con 700, India) with potassium chloride solution, following AOAC (2005) guidelines. Reducing sugar and apparent sucrose content determination followed the procedures specified in SLS 464:1979-Bee honey. The fructose to glucose ratio was determined by preparing honey solution, diluting it to a known volume, and titrating it against iodine solution as per the method described for reducing sugar content (SLS 464:1979-Bee honey). Fiehe's test was employed to detect HMF presence in honey (Bogdanov, 2009). Acidity was determined by titration against carbonate-free 0.1 N sodium hydroxide solution with a phenolphthalein indicator (Majewska *et al.* 2019). Moisture content assessment adhered to SLS 464:1979-Bee honey method. Soluble solids content was directly measured using a refractometer (ATAGO PAL-3, Japan) at 20 °C. Colour intensity was determined by diluting honey, filtering, and measuring the absorbance at 450 nm and 720 nm using a UV/VIS spectrophotometer (Microdigital, South Korea), following Beretta *et al.* (2005).

2.5 Data analysis

The quantitative data collected for the characterization of physicochemical parameters were subjected to normality testing, and LS-means separation under General Linear Model (GLM) procedure in the statistical package SAS 9.4 (SAS Institute, NC, Cary, USA).

2.6 Organoleptic assessment

30 different tasters (untrained taste panel) were selected to evaluate the consumer preference for each bee honey sample. The samples for five parameters: colour, aroma, texture, taste and overall preference were ranked using a three-tier scoring system (the highest, medium and lowest levels of choice will be indicated by a score of three, two and one, respectively for each parameter). The generated data were analyzed using Cross tabulation and chi-square in Minitab 19 (Minitab Inc., USA) to decipher the associations with varietal preferences.

2.7 Pollen DNA extraction

The study aimed to identify the most efficient methodology for pollen DNA extraction by employing seven different DNA extraction methods on concentrated pollen pellets from eight bee honey samples and three raw pollen samples. In the first method, DNA was isolated using DNeasy® plant mini kit as per the manufacturer's protocol (DNeasy® 1). In the second method, 400 µl of API Buffer and 25 µl of Proteinase K (20 mg/ml; NEB) were added to the pollen pellet after lysis. The pellet was incubated for 10 minutes at 56°C and then 4 µl of RNase A (100 mg/ml) was added. The remaining steps for extracting plant gDNA were carried out as per the manufacturer's instructions (DNeasy® 2). In the third method, DNA isolation was carried out as mentioned in Manivanan *et al.* 2018) (CTAB method 1 (a)). As the fourth method, the protocol was optimized by adding an overnight incubation at 65°C (CTAB method 1 (b)). In the fifth method, incubation at 60°C for 30 min was done after adding the buffer mentioned in CTAB method 1. Chloroform:isoamylalcohol and ice-cold isopropanol extraction steps were done after that step (CTAB method 2). In the sixth method (CTAB method 3 (a)), DNA isolation was carried out as described by Lalmangaihi *et al.* 2014). In the seventh method, the method was modified by discarding the supernatant after adding buffer 1 (CTAB method 3 (b)). The quality and purity of the isolated genomic DNA were assessed through agarose gel electrophoresis and UV/Vis spectrophotometry (Microdigital, South Korea), respectively. The correlation between pollen density and DNA purity was analyzed, and the seven extraction methods were statistically compared using the Turkey method in Minitab. This comprehensive approach aimed to identify the most effective method for pollen DNA extraction, which is crucial for further genetic analysis and identification of floral origin in bee honey samples.

2.8 Development of a Detailed Card to Inspect for Adulterations

The direct adulteration of honey poses a significant concern, often involving the addition of sucrose syrup obtained from various sources such as sugar beets, High Fructose Corn Syrup (HFCS), or maltose syrup. Highly adulterated honey mixtures may pose health risks, necessitating measures to ensure authenticity and safety for consumers. To address this issue, a comprehensive card has been developed, showcasing the authentic colour and characteristics of honey samples based on their geographical origins and harvesting seasons. This card provides valuable information to consumers, including pollen density, pH, conductivity, total reducing sugar content, sucrose content, fructose-glucose ratio, acidity, colour intensity, moisture content, solid content, and the presence or absence of 5-hydroxymethylfurfural (HMF). By aligning with the flowering seasons of each bee honey sample, this card serves as a practical tool for consumers to verify the authenticity and quality of honey products. Its commercial applicability offers a promising solution to mitigate the risks associated with honey adulteration, ensuring consumer confidence and safety in honey consumption.

3. Results and Discussion

3.1 Microscopic analysis of bee honey samples

Microscopic analysis of bee honey samples revealed distinct pollen structures (Figure 2). Pollen was evident in samples A-F, showcasing varied floral sources despite the predominant source in Nuwara Eliya being Tuna flower. Crystalline structures in Nuwara Eliya and Awissawella samples indicated differing glucose-fructose ratios affecting crystallization rates. Gannoruwa's primary sources were *Cassia zeylanica* and *Cocos nucifera*, while Bowalawatta's was *Cassia zeylanica*. Awissawella's was *Hevea brasiliensis*. Samples G-J were filtered, lacking pollen due to automated processing, a common consumer complaint addressed by removing pollen to prevent crystallization. Pollen species variation reflects geographical floral density and diversity (Burlasons Honey, 2022).

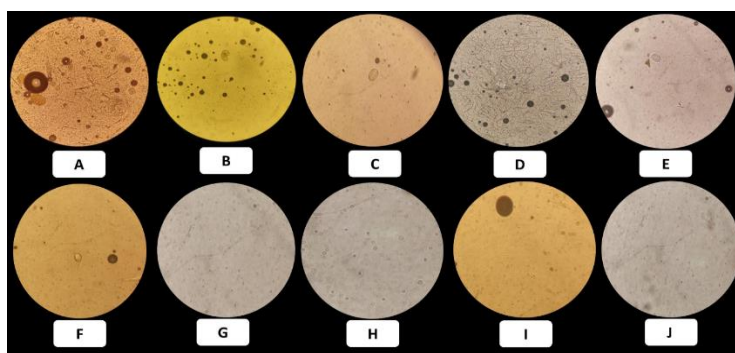


Figure 2: Microscopic view of bee honey (400×). Each English capital letter corresponds to a microscopic view of honey samples:(A) Nuwara Eliya, (B) Gannoruwa,(C) Bowalawatta,(D)Awissawella,(E) Ogastawatta,(F) Pilimathalawa, (G) Welimada,(H)Badulla, (I) Uva-Paranagama, (J) Buttala.

3.2 Microscopic view of pollen

The microscopic examination of extracted pollen (Figure 3) revealed diverse pollen units and grains with varying morphologies. Notably, Awissawella and Badulla bee honey samples lacked observable pollen pellets, likely due to Awissawella's collection from rubber nectar sources and Badulla's filtering process. Despite the potential presence of minute pollen in Badulla, the filtration process may have removed larger grains. Rubber nectar collection methods contribute to the absence of rubber pollen in Awissawella samples (Bradley, 1999). This underscores the impact of collection methods on pollen observation and highlights the multifloral nature of the samples.

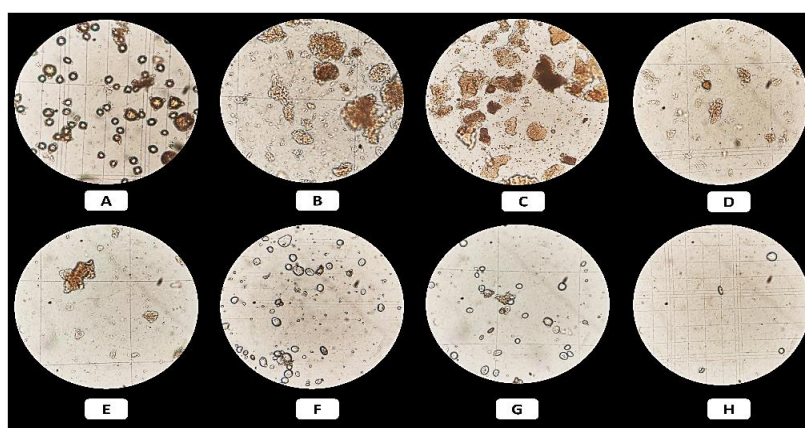


Figure 3: Extracted pollen pellets (400X) (A) Nuwara Eliya, (B) Gannoruwa, (C) Bowalawatta, (D) Ogastawatta, (E) Pilimathalawa, (F) Welimada, (G) Uva-Paranagama, (H) Buttala.

3.3 Quantitative analysis of pollen

Table 1 presents the pollen density classification of bee honey samples. Nuwara Eliya falls into group 3, while Gannoruwa, Bowalawatta, and Ogastawatta are in group 2. Pilimathalawa, Welimada, Uva-Paranagama, and Buttala are classified in group 1. Low density may result from adulteration or bee-feeding practices (Silva *et al.* 2018).

Table 1. Pollen density of bee honey samples

Location	Pollen density (pollen grains/10g)
Nuwara Eliya	290950
Gannoruwa	26086
Bowalawatta	39060
Awissawella	-
Ogastawatta	35055
Pilimathalawa	15400
Welimada	7395
Badulla	-
Uva-Paranagama	1960
Buttala	425

3.4 Physicochemical analysis of bee honey

Table 2 displays the physicochemical data of bee honey samples. Electrical conductivity ranged from 0.15 to 1.17 mS/cm, crucial for detecting adulteration (Santos *et al.* 2018).

Table 2. Physicochemical analysis of different bee honey samples

Location	pH	Electrical conductivity (mS/cm)	Reducing sugar	Apparent sucrose	Fructose/Glucose	Acidity	Colour intensity/mAU	Moisture content (%)	Refractive index	TSS (%)	Positive/Negative (Fiehe's test)	Colour and the time taken to appear a colour change in Fiehe's test
Nuwara Eliya	4.34±0.01) ^g	(1.15±0.00) ^g	(55.56±0.00) ^g	(0.69±0.17) ^g *	(0.50±0.01) ^g	(0.03±0.00) ^g *	(711.03±0.06) ^g	(31.60±0.82) ^g	1.4575	(68.40±0.82) ^g	-	Pink- after 2 minutes
Gannoruwa	2.72±0.01) ^g	(0.97±0.00) ^g	(58.03±0.10) ^g	(9.90±0.44) ^g	(0.23±0.00) ^g	(0.04±0.00) ^g *	(801.47±0.06) ^g	(26.47±0.85) ^g	1.4700	(73.53±0.85) ^g	-	Pink- after 4 minutes
Bovalavatta	4.08±0.01) ^g	(0.98±0.00) ^g	(51.81±0.00) ^g	(13.23±0.09) ^g	(0.14±0.00) ^g	(0.03±0.00) ^g *	(931.90±0.00) ^g	(25.10±0.53) ^g	1.4740	(74.90±0.53) ^g	-	Pink- after 1 minute
Amissavella	4.23±0.01) ^g	(0.70±0.00) ^g *	(65.50±0.06) ^g * *#	(4.43±0.08) ^g *	(0.28±0.00) ^g	(0.02±0.00) ^g *	(280.37±0.06) ^g	(32.20±0.95) ^g	1.4560	(67.80±0.95) ^g	-	Salmon pink-after 3 minutes
Ogastavatta	4.07±0.02) ^g	(1.17±0.00) ^g	(47.17±0.00) ^g	(3.90±0.01) ^g *	(0.12±0.00) ^g	(0.04±0.00) ^g *	(1080.10±0.00) ^g	(26.63±0.51) ^g	1.4700	(73.37±0.51) ^g	-	Reddish pink-after 1 minute
Plimathalawa	3.81±0.01) ^g	(0.66±0.00) ^g *	(58.14±0.10) ^g	(1.44±0.16) ^g *	(0.03±0.01) ^g	(0.02±0.00) ^g *	(1314.37±0.06) ^g	(28.77±0.87) ^g	1.4645	(71.23±0.87) ^g	-	Reddish pink-after 2 minutes
Welimada	2.81±0.00) ^g	(0.15±0.00) ^g *	(54.05±0.00) ^g	(15.86±0.98) ^g	(0.03±0.01) ^g	(0.01±0.00) ^g *	(342.13±0.15) ^g	(24.67±0.76) ^g	1.4745	(75.33±0.76) ^g	+	Cherry red- after 2 sec
Baandula	2.55±0.01) ^g	(0.30±0.00) ^g *	(53.38±0.06) ^g	(11.95±0.39) ^g	(0.26±0.00) ^g	(0.02±0.00) ^g *	(599.80±0.17) ^g	(24.57±0.55) ^g	1.4750	(75.43±0.55) ^g	+	Cherry red- after 1 sec
Uva-Parangama	2.82±0.01) ^g	(0.20±0.00) ^g *	(58.14±0.10) ^g	(18.88±0.92) ^g	(0.34±0.00) ^g	(0.02±0.00) ^g *	(312.10±0.10) ^g	(24.90±0.98) ^g	1.4740	(75.10±0.98) ^g	+	Cherry red- after 2 sec
Buttala	4.32±0.01) ^g	(0.35±0.00) ^g *	(51.99±0.06) ^g	(0.43±0.16) ^g *	(0.05±0.00) ^g	(0.01±0.00) ^g *	(746.00±0.17) ^g	(27.20±0.98) ^g	1.4685	(72.80±0.98) ^g	+	Cherry red- after 6 sec

All values are represented as the mean of triplicates±standard deviation. Means denoted by different letters are significantly different among samples at p<0.05. Samples which met Codex standards and

SLS standards are given in * and # respectively. Codex and SLS standards for some parameters are not given.

pH values varied significantly, with Nuwara Eliya at 4.34 ± 0.01 and Badulla at 2.55 ± 0.01 ($p < 0.05$). Ogastawatta showed the highest conductivity (1.17 ± 0.00) mS/cm, while Welimada had the lowest (0.15 ± 0.00) mS/cm ($p < 0.05$). Samples not meeting Codex and SLS standards aren't necessarily adulterated, as these are mean values for specific groups (Jayasinghe *et al.* 2012). Regional floral sources influence pH and conductivity, emphasizing the need for broader analysis (Sereia *et al.* 2017). The sugar profile of bee honey exhibits significant variations influenced by geographical location, botanical origin, climate, processing, and storage conditions. In a study comparing honey samples from different regions, Awissawella showed the highest reducing sugar content (65.50 ± 0.06), while Ogastawatta had the lowest (47.17 ± 0.00). Apparent sucrose content ranged from 18.88 ± 0.92 in Uva-Paranagama to 0.43 ± 0.16 in Buttala samples. Nuwara Eliya had the highest fructose-to-glucose (F/G) ratio (0.50 ± 0.01), while Pilimathalawa and Welimada had the lowest (0.03 ± 0.01). These variations are attributed to factors such as agroecological zones and floral sources. Despite not meeting Codex and SLS criteria, the samples were not considered adulterated. Crystallization propensity is influenced by factors including the F/G ratio, sugar content, temperature, and storage conditions. Lower storage temperatures discourage crystallization, with the Nuwara Eliya sample exhibiting a crystalline structure possibly due to water-insoluble substances. Microscopic examination confirmed crystalline structures in Nuwara Eliya and Awissawella samples. Understanding these variations is crucial for assessing honey quality and authenticity. As depicted in Table 2, Gannoruwa and Ogastawatta samples exhibited the highest mean acidity (0.04 ± 0.00), while Welimada and Buttala samples showed the lowest (0.01 ± 0.00), all meeting Codex and SLS standards. The acidity of honey is influenced by its floral sources and organic acid composition. Colour intensity ranged from 280.37 mAU to 1314.37 mAU, with Pilimathalawa showing the highest intensity, indicating significant antioxidant capacity. These variations in colour can be attributed to honey composition, heat treatments, mineral content, and storage time. Notably, all samples fell within the range reported by Kek *et al.* (2014), demonstrating consistency in colour intensity across different honey types. The refractive index, total soluble solids (TSS %), and moisture content (%) of Sri Lankan bee honey varied significantly by geographical origin, as detailed in Table 6. Refractive index values ranged from 1.4560 to 1.4750, with nearly all samples meeting the SLS standard maximum limit of 1.4740. TSS (%) ranged from 67.80 ± 0.95 to 75.43 ± 0.55 , with a maximum specified limit of 75% according to SLS standards. Moisture content ranged from 24.57% to 32.20%, with geographical and environmental factors contributing to variation. Improper storage conditions can lead to increased moisture content, affecting honey quality (Beeculture, 2002). Floral sources and climatic conditions influence solid content variations, correlating with sugar composition (Krishnasree & Ukkuru, 2017). Variations in these parameters across different agroecological zones highlight the importance of considering geographical factors in honey quality assessment. The Fiehe's test is employed to detect adulterations, sugar additions, or improper storage in honey. In Braga's (2019) study, four out of ten honey samples tested positive for this test (Table 2), potentially indicating tampering, especially in warmer climates. However, elevated levels of hydroxymethylfurfural (HMF) can occur naturally in honey due to extended storage or overheating. The differential reactivity of glucose and fructose influences HMF formation, with fructose reacting more rapidly due to its higher enolization rate. Additionally, fructose's equilibrium formation of difructose and dianhydride mixtures may inhibit certain reactive groups, leading to the production of specific byproducts. Glucose's generation of oligosaccharides with reactive reducing groups also increases the likelihood of cross-polymerization with HMF intermediates (Kuster, 1990). Understanding these chemical dynamics is crucial for interpreting Fiehe's test results accurately and discerning potential adulterations in honey samples.

3.5 Evaluation of consumer preference

Consumer preference for bee honey is significantly influenced by its geographical origin, with colour, aroma, texture, taste, and overall preference showing significant associations ($p < 0.05$, $\chi^2 = 128.930$ -

183.423) (Figure 4). Light, amber-coloured honey, such as the Awissawella sample, is highly preferred, while darker varieties, like Nuwara Eliya, are less favoured. Preferences for aroma, texture, and taste vary among samples, with factors such as fermentation affecting aroma perception and floral nectar sources influencing taste. Overall, Awissawella honey is the most preferred, while Buttala is the least favoured.

3.6 DNA extraction

The quality of DNA extracted from eight bee honey samples was assessed (Table 3), although none of the DNA extraction methods were able to show proper DNA bands in agarose gel electrophoresis. Positive correlations were found between pollen density and DNA purity for various extraction methods, including Dneasy® and CTAB (Table 4). Higher pollen density corresponded to increased DNA purity, indicating method effectiveness. Notably, CTAB method 1(b) consistently yielded the highest DNA purity across all samples, significantly differing from other methods. These findings highlight the importance of extraction methodology in obtaining high-quality DNA from bee honey samples.

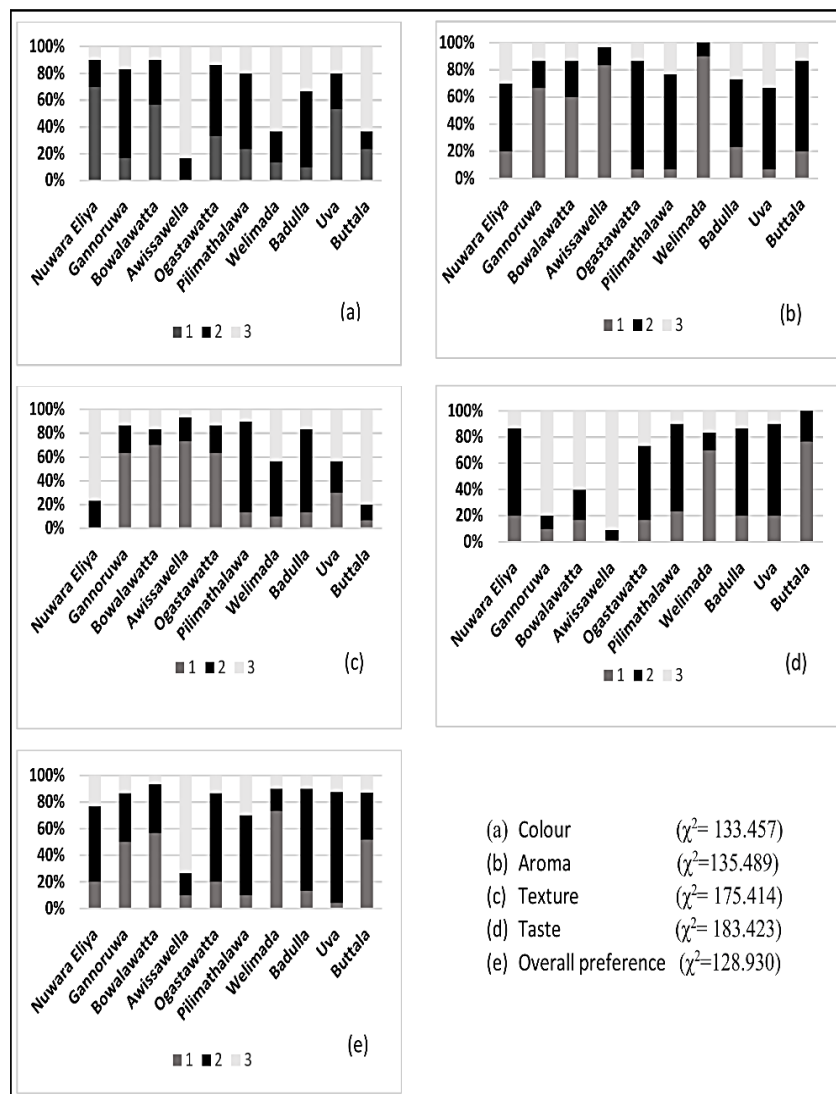


Figure 4. The association between the organoleptic parameters (a-e). The chi-square value is given for each association and all five parameters were significantly associated with the geographical origin ($p = 0.00$). The x-axis represents the geographical origin and the y-axis represents the % of respondents.

Table 3. Quality (260/280 absorbance ratio) of the DNA extracted from bee honey samples and raw pollen samples.

Sample	DNeasy® Plant Kit		CTAB method 1		CTAB method 2	CTAB method 3	
	Manufacturer's protocol	Optimized protocol	Without optimization	With optimization		Without optimization	With optimization
Extracted pollen							
Nuwara Eliya	(0.85 ±0.01)	(1.00±0.01)	(0.88±0.01)	(1.06±0.01)	(0.76±0.01)	(0.60±0.01)	(0.50±0.01)
Gannoruwa	(0.68±0.00)	(0.80±0.01)	(0.79±0.01)	(0.88±0.00)	(0.66±0.01)	(0.59±0.01)	(0.48±0.01)
Bowalawatta	(0.84±0.00)	(0.92±0.00)	(0.79±0.01)	(0.91±0.00)	(0.72±0.02)	(0.55±0.00)	(0.51±0.00)
Ogastawatta	(0.77±0.00)	(0.88±0.01)	(0.84±0.00)	(0.90±0.01)	(0.70±0.01)	(0.51±0.02)	(0.43±0.01)
Pilimath-alawa	(0.79±0.00)	(0.89±0.01)	(0.80±0.00)	(0.95±0.01)	(0.69±0.02)	(0.48±0.02)	(0.41±0.02)
Welimada	(0.52±0.01)	(0.69±0.00)	(0.67±0.01)	(0.78±0.01)	(0.58±0.01)	(0.33±0.01)	(0.24±0.03)
Uva-Paranagama	(0.49±0.01)	(0.60±0.00)	(0.60±0.01)	(0.79±0.02)	(0.51±0.01)	(0.30±0.02)	(0.21±0.01)
Buttala	(0.34±0.01)	(0.51±0.01)	(0.48±0.00)	(0.58±0.01)	(0.48±0.01)	(0.26±0.01)	(0.19±0.00)
Raw pollen							
Nuwaraeliya	(0.88±0.01)	(0.99±0.01)	(0.93±0.02)	(1.25±0.02)	(0.99±0.00)	(0.88±0.01)	(0.78±0.00)
Gannoruwa	(0.87±0.02)	(0.98±0.00)	(0.88±0.01)	(1.22±0.01)	(0.95±0.01)	(0.86±0.01)	(0.70±0.01)
Bowalawatta	(0.85±0.00)	(0.94±0.02)	(0.91±0.01)	(1.23±0.01)	(0.96±0.00)	(0.87±0.02)	(0.80±0.00)

Values are presented as mean ± standard deviation calculated for each extraction protocol in triplicate assays.

Table 4. Correlation among different DNA extraction methodologies with the pollen density.

	Pollen density	Dneasy®1	Dneasy®2	CTAB 1 (a)	CTAB 1 (b)	CTAB 2	CTAB 3(a)
Dneasy®1	0.521						
Dneasy®2	0.646	0.974					
CTAB 1 (a)	0.550	0.959	0.974				
CTAB 1 (b)	0.659	0.937	0.960	0.949			
CTAB 2	0.596	0.980	0.988	0.970	0.920		
CTAB 3 (a)	0.554	0.907	0.908	0.924	0.857	0.934	
CTAB 3 (b)	0.507	0.933	0.909	0.909	0.837	0.947	0.987

3.7 A detailed card to inspect for adulterations

A specially designed card for honey inspection features the true colour of each sample based on its geographic origin and harvest season. This card aids in detecting adulterations, such as the addition of sucrose syrup, by providing consumers with information on physicochemical parameters. Various sources, including maltose syrup and industrial sugar syrups, can adulterate honey, posing health risks. By visually displaying key information, this card serves as a practical tool for consumers to make informed choices and has potential commercial applications (Figure 5).











Geographical location	Colour	Harvesting season	Pollen density (Pollen grains/10g)	pH	Conductivity (mS/cm)	RS	Sucrose	F/G ratio	Acidity	Colour Intensity (mAU)	MC	SC	Fiehe's test (+/-)
Nuwara Eliya		May-June	290950	4.34	1.15	55.56	0.69	0.50	0.03	711.03	31.60	68.40	-
Gannoruwa		June-July	26086	2.72	0.97	58.03	9.90	0.23	0.04	801.47	26.47	73.53	-
Bowalawatta		June-July	39060	4.08	0.98	51.81	13.23	0.14	0.03	931.90	25.10	74.90	-
Awissawella		February-March	-	4.23	0.70	65.50	4.43	0.28	0.02	280.37	32.20	67.80	-
Ogastawatta		June-July	35055	4.07	1.17	47.17	3.90	0.12	0.04	1080.10	26.63	73.37	-
Pilimathalawa		June-July	15400	3.81	0.68	58.14	1.44	0.03	0.02	1314.37	28.77	71.23	-
Welfimada		August-October	7395	2.81	0.15	54.05	15.86	0.03	0.01	342.13	24.67	75.33	+
Badulla		September-November	-	2.55	0.30	53.38	11.93	0.26	0.02	599.80	24.57	75.43	+
Uva-Paranagama		August-October	1960	2.82	0.20	58.14	18.88	0.34	0.02	312.10	24.90	75.10	+
Buttala		August-September	425	4.32	0.35	51.99	0.43	0.05	0.01	746.00	27.20	72.80	+

Figure 5. Development of a commercially applicable card for human benefit.

4. Conclusion and Future Remarks

The analysis of bee honey samples revealed diverse floral sources, crystalline structures, and pollen variations, influenced by geographical origin and collection methods. While some samples lacked observable pollen due to filtration, microscopic examination highlighted distinct pollen structures and grains, emphasizing the multifloral nature of honey. Classification based on pollen density, physicochemical properties, and consumer preferences elucidated significant variations among samples from different regions. Physicochemical analyses including pH, conductivity, reducing sugar content, and colour intensity demonstrated variability influenced by floral sources, climate, and processing methods. Despite variations, most samples met Codex and SLS standards, with differences attributable to regional factors rather than adulteration. DNA extraction and PCR analysis revealed challenges in detecting DNA due to PCR inhibition from honey constituents and insufficient DNA quantity. Future research should focus on optimizing extraction methods and overcoming PCR inhibition to enhance DNA detection and authentication of honey samples. The development of a specialized inspection card provides consumers with valuable information on honey authenticity, aiding in detecting adulterations and making informed purchasing decisions. This tool has potential commercial applications in ensuring honey quality and consumer satisfaction. Future studies should focus on improving DNA extraction

methods and PCR protocols to enhance the detection of DNA from honey samples. Optimizing extraction techniques to increase DNA yield and developing PCR strategies to overcome inhibition from honey constituents are essential for accurate authentication.

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ICSD 225

IMPACT OF TREE TO TRE YIELD VARIATION OF *Hevea brasiliensis* RUBBER CLONE RRI SL 203: A CASE STUDY IN MAPALANA (WL 2) – SRI LANKA

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Abstract: Rubber (*Hevea brasiliensis*) is an Industrial Crop grown in Wet and Intermediate zone of Sri Lanka, where 64% of the total Rubber extent is with small holders. The low productivity is experienced in many farmer fields though the recommended clones have high yield potential. The main objective of this study is to evaluate the impact of different shading conditions on growth and yield within the field. The study was carried out at 11 years old RRI SL 203 field (1 ha) established at Faculty of Agriculture, University of Ruhuna with different shade levels (high, mid, low). The variation of growth & yield during the cropping season and wintering season was monitored by applying S 2 D 3 tapping system. With respect to shade levels, the immature growth and height to the first branches are significantly higher in trees where under low shade levels compare under high and medium shade levels. However, bark thickness was not significantly different among shade level. The yield is significantly high in low shade levels. However, during the wintering months (December, January) yields was no significantly different with shade levels. The volume of latex is also significantly high under low shade condition compared to medium and high shade conditions. Therefore, it is recommended to establish commercial scale rubber plantations under low shade conditions to get higher income for RRI SL 203 clone in Low Country Wet Zone (WL 2) in Sri Lanka.

Keywords: Growth; *Hevea*; Recommendations; Shade; Variation yield

1. Introduction

Rubber (*Hevea brasiliensis*) is a deciduous perennial tree belongs to the family Euphorbiaceae, a major latex-producing crop in the world (Jain and Priyadarshan, 2009). Rubber cultivation was introduced to Sri Lanka in 1876 and now it was ranked as the third-largest plantation crop according to the land extent in Sri Lanka (Ranasinghe *et al*, 2019). A main economically important part of the rubber tree is latex while timber and biomass are having equal economic importance for its 30 years economic lifecycle. The traditional rubber growing areas are located mainly in the wet zone in Sri Lanka including Kaluthara, Kandy, Mathale, Galle, Matara, Rathnapura and, Kegalle. Rubber cultivation has attracted vast attention as a result of expanding economies in the global market for natural rubber (Lekshmi and George, 2003). In 2020, Sri Lanka earned more than US\$ 3 billion by exporting rubber products around the world. The rubber industry creates direct and indirect employment opportunities, especially for rural people. Rubber smallholders and contributes 85442 hectares (64%) out of the total rubber extend in Sri Lanka (Rodrigo *et al*, 2011). A major problem in the rubber industry was that the commercial yield is lower than the potential yield (Rodrigo *et al.*, 2011). High-quality latex and optimum growth in rubber cultivations were highly dependent on environmental factors, soil, and good management practices especially in the immature phase of rubber around 5 to 9 years Identifying and recommending appropriate agronomic measures are necessary for maintaining sustainable and economically viable rubber cultivation is a timely need (Orimoloye *et al*, 2010). A proper understanding of the physical and chemical barriers for the optimum rubber growth and yield by providing necessary amendments in the early stages ensures a good return on investment at later productive stages of rubber.

Rubber is currently planted in the form of grafted trees, at a density of about 512 - 520 trees per hectare (Kalpani *et al*, 2020). Height and girth are directly related to crop growth and yield quantity of rubber as they are the main indices considered in evaluating vegetative growth and uniformity of rubber plantations (Withanage *et al*, 2017). In plantations, climate plays a dominant position and directly impacts production. Climatic factors such as rainfall, temperature, relative humidity, radiation, and altitude highly affect the success of the final harvest. The ideal annual rainfall for rubber should be in the range of 1650 – 3000 mm/year and be reasonably uniformly distributed. The annual average temperature of 23- 28 °C, 80% relative humidity and 200 m altitude are considered as the optimum climatic requirements for rubber. 2000hr/year sunshine hours without lengthy dry spells during wintering period further enhance the rubber productivity (Kudaligama *et al*, 2010).

The study was carried out to assess growth parameters, the volume of latex, and yield performances with respect to changing of the light intensity received or the levels of shade to address the problems of deviation from the expected yield, mainly due to tree to tree variation within the field.

2. Materials and Methods

The research was carried out at an RRISL 203 clearing maintained at the faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya in (WL2) agro-ecological zone from December 2020 to February 2021. There were 271 plants from RRISL 203 planted in 2011 with 4.3 m × 4.5 m spacing. The trial was managed according to the recommendation of the Rubber Research Institute of Sri Lanka. But some of the instructions given by the RRISL were not able to adhere and the surrounding wild trees of the clearing were not removed and the field was subjected to the different shade levels. Accordingly the field was divided into three blocks according to the light intensity as high shade, medium, and low shade. The rubber field was opened for tapping in 2017 and was not tapped during for last 2 years due to the skilled tapper shortage.

Table 1: Treatments used in the experiment

Treatments and light intensity	
Treatment 1	low shade (less than 1 $\mu\text{mol}/\text{m}^2/\text{s}$)
Treatment 2	medium shade (in-between 1-3 $\mu\text{mol}/\text{m}^2/\text{s}$)
Treatment 3	high shade (higher than 3.0 $\mu\text{mol}/\text{m}^2/\text{s}$)

Fifty-three rubber trees were identified under the low shade, 80 trees were under the medium shade, and 34 trees were under the high shade. Girth and bark thickness were measured at 120 cm height from the bud union using a measuring tape and bark gauge respectively. Height to first branching point was measured using a clinometer and a measuring tape. In general, the clinometer was used to measure the angle from the eye to the first branching point and then the horizontal distance from the measuring point to the tree was measured using a measuring tape. Then, the height to the first branching point was calculated by using the Pythagoras equation. Light intensity measurements were made 60 cm away from the trunk using a light meter (SKS 1100/1110). By placing the light meter near the tapping panel and the sensor of the light meter was turned towards the canopy and reading was recorded. Data were collected once per month. Even after wintering period measurements were taken to determine the effect of penetrated light during the shade condition due to wild trees.

Tapping was carried out on virgin bark (1st year tapping panel A) in similar aged trees. A half spiral, continuous excision tapping cut was marked from high left to low right at an angle of 30 ° to the horizontal. In each tapping, approximately 0.125 cm (0.049") bark was shaved off along the tapping cut. S2d2 tapping system was practiced without applying yield stimulant. It has shaved a thin layer of the bark along the downward half spiral on the tree trunk. Tapping was started early in the morning (at 6 a.m.) when the temperature and evaporation were low while the turgor pressure was highest in the latex vessels. During rain or if the panel is wet tapping was not done and therefore the number of tapping days was 20 (2020 December to 2021 February). Latex was collected as soon as possible after stopped the latex flow, 3 hours after the first tree was tapped. Latex was collected into collecting buckets separately according to the shade conditions. Estimation of Dry Rubber Content (DRC) was measured using the standard Metrolac method. Metrolac was allowed to freely move in latex and the reading was recorded and the weight of dry rubber content of latex was calculated using a Metrolac chart. Slandered laboratory method was to get actual DRC by using a portion of a 20ml representative sample of latex. Under the laboratory method, empty weights were measured in Petri dishes. 20ml rubber latex was transferred to the Petri dish and the latex was coagulated using a sufficient quantity of acid, well mixed using a glass rod. It was allowed to coagulate for 24 hours. After 24hr, the coagulum was washed with running water and it was pressed with a glass roller to get a uniform thickness without exceeding 2 mm. The coagulum was thoroughly washed and placed in a thermostatically controlled oven at about 60°C. After drying, the rubber was allowed to cool in a desiccator and weighed using an analytical balance. Drying and weighing procedures were continued until the coagulum is dried to a constant weight and the dry rubber content was calculated from the weights of the dry coagulum and the latex sample.

All the statistical analyses were carried out using SAS version 9.1. Data were subjected to analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (D'MRT) for mean separation.

3. Results and Discussion

Latex volume, yield gram per tree per tapping (g/t/t), and the mean value of growth parameters (girth, bark thickness, and height up to 1st branch) of different shade levels and latex volume and yield between peak months and wintering period were tested and the significance of differences in means (ANOVA) and means as was separated in Duncan's Multiple Range Test (D'MRT)

Table 2: Mean volume of rubber latex (ml) and their D'MRT group of three shade levels in three months

Shade level	Mean volume (ml) in December and D'MRT group	Mean volume (ml) in January and D'MRT group	Mean volume (ml) in February and D'MRT group	Total volume (ml)
Low	44.715 ^{ab}	31.15 ^a	52.00 ^a	40.43 ^a
Medium	48.553 ^a	32.87 ^a	43.33 ^{ab}	40.19 ^a
High	41.490 ^b	32.38 ^a	35.29 ^b	37.31 ^a
CV%	9.18 %	18.15 %	16.35 %	19.31%

*means with the same letters are not significant.

Mean latex volumes were significantly affected by different shade levels ($P \leq 0.05$) in December, January, and February. DMRT values for mean latex volumes in three months were given in Table 2.

Latex volume in the medium shade level was recorded the highest value in December and it was significantly different from latex volume from high shade level. In January, there was no significant difference in latex volumes among low, medium, and high shade levels. In February, the highest mean latex volume was observed in low shade level and it was significantly different from high shade level. But total latex volumes in all three months were not significantly different from each other among the three-shade levels. Shade was a long-term impact on the trees grown in different shade levels. Sunlight strength can have a direct impact on latex levels and reduced daylight during the taping period can lower latex output (Yogarathnam, 2000). Similarly, Rodrigo *et al.*, 1995 proved that the latex yield in individual trees tends to decrease with increased planting shade.

Table 3: Mean DRC (gram/tree/tapping) and their D'MRT group of three shade levels in different months

Shade level	Mean yield (GTT) in December and D'MRT group	Mean yield (GTT) in January and D'MRT group	Mean yield (GTT) in February and D'MRT group	Total yield (GTT)
Low	16.48 ^a	10.88 ^a	20.12 ^a	13.80 ^a
Medium	16.94 ^a	11.72 ^a	14.60 ^b	14.00 ^a
High	14.09 ^a	10.91 ^a	13.88 ^b	12.60 ^a
CV%	18.19 %	26.18 %	14.63%	22.51%

*means with the same letters are not significant.

Mean yield (g/tree/tapping) in December, January and February were significantly affected ($P \leq 0.05$) by the shade levels, and DMRT values of mean yield (g/tree/tapping) in each month were given in Table 3. Here mean yield (g/tree/tapping) in December and January were not significantly different among the three-shade levels. But in February, the highest mean yield (g/tree/tapping) was recorded from low shade levels and it was significantly different from medium and high shade levels. Total yield (g/tree/tapping) in all three months was also not significantly different in the three-shade levels considered. According to Ranasinghe *et al.*, (2019) the physiological capability, the number of tapping days, and the precipitation pattern were identified as the major influencing factors on the monthly yield of BPM 24 and RRIC 121 rubber clones. Moreover, a severe reduction in radiation interception can cause a reduction of photosynthetic productivity and growth. It has been found that the photosynthetic rate of rubber leaves developed in 25% full sunlight was reduced by one-third that of plants grown in full sunlight, proving that leaves developed in the deep shade have considerably reduced in assimilatory capability (Nugawela *et al.* 1995). Hence, high shade can impart to reduce mean yield of rubber latex and shade management is an important agronomic practice.

Table 4: Mean girth and their D'MRT groups of three shade levels

Shade level	Mean girth (cm) and D'MRT group	Mean bark thickness (mm) and D'MRT group	Mean height of first branch (ft) and D'MRT group
Low shade	70.27 ^a	9.07 ^a	9.73 ^a
Medium shade	65.85 ^b	8.61 ^a	9.65 ^a
High shade	67.06 ^b	8.82 ^a	8.30 ^b
CV%	10.24%	12.86%	20.53%

* Means with the same letters are not significantly different

Mean girth, mean bark thickness, and mean height of the first branch were significantly affected ($P \leq 0.05$) by the different shade levels, and DMRT values of each parameter in three shade levels were given in Table 3. The low shade level showed the highest mean girth while it was significantly different from the medium and high shade. Mean bark thickness in three shade conditions was not significantly different from each other. The mean height of the first branch was high in low and medium shade levels and they have significantly differed from the high shade level. The level of shade was highly impacting during the immature period for the girth and impact was reflected through the differences in growth performances. Supporting our results, Ranasinghe *et al*, 2019 found that stem diameter and plant height of 15-months old rubber plants showed the greatest values in plants grown in full sunlight, and both Stem diameter and plant height were reduced with increasing shade level in the field. But in contrast, Xianhai *et al*, 2012 found that the mean rate of girth increment during 8 years tapping period was slightly better in the medium shade double row system than the traditional single-row system. The mean rate of bark thickness increment was also slightly higher in the double row system than the single-row system with very low shade. But in general, growth parameters have a direct correlation for their yield in any plant species. Mainly stem girth of rubber has a high interrelation with latex yield (Thattil *et al*, 1991). According to Senevirathna *et al*, 2003, with increasing shade, specific leaf area increased, leaf weight ratio and relative growth rate also were reduced. They found that Chlorophyll a/b ratio decreased in high shades, compared to the unshaded plants. The bark thickness and the amount of latex vessel rings in the bark were decreased as growth rates were reduced in rubber. Shorter tapping cuts are often used in smaller tree trunks and this will cause lower per-crop yield (Xianhai *et al*, 2012).

Table 5: Mean yield (gram/tree/tapping) and their D'MRT group of three shade levels between wintering and peak period

Period	Mean latex volume and their D'MRT group	Mean yield (g/tree/tapping) and D'MRT group
Wintering	50.26 ^a	15.22 ^a
Peak (cropping)	37.24 ^a	12.49 ^a
CV%	26.9%	17.26%

*means with the same letters are not significantly different

Mean latex volume and mean yield (gram/tree/tapping) were significantly influenced by the wintering and cropping months (December and January) and the DMRT values of mean latex volume and mean yield (gram/tree/tapping) in three shade levels were given in Table 5. Both mean latex volume and mean yield (gram/tree/tapping) were not significantly different with the periods. Monthly yield variation in rubber is a common phenomenon and it affects the livelihood of rubber smallholders and also the cash flows. The effect is more pronounced in income levels and monthly financial performance of the cultivation (Ranasinghe *et al*, 2019). More than the seasonal variation, components such as water balance factor, rainfall factor, topographic factor, tapping frequency, and planting density showed a significant positive correlation with average rubber yield per plant and that above- and below-ground

carbon stocks (Yang *et al.*, 2017). Moreover, the climate is an important ecological factor that greatly influenced rubber yield, and Wijesuriya *et al.*, 2010 highlighted the importance of well-distributed rainfall with short dry spell rubber growing areas. Under harsh dry environments tend to reduce plant growth and result in delayed maturity. Shade adaptation of rubber latex volume and yield (DRC) has not been reported in previous studies and present literature lacks information on shade adaptation of rubber trees.

In this clearing, the leaf fall has started in the low shade level trees hence, reduced their photosynthetic rate, the basic requirement for the vegetative growth of the plant and this may alter the volume of rubber latex and yield in January. Generally, rubber yields drop below average during February to July each year, followed by the 'Peak Yielding' period extending from November to the end of January (Wijesooriya *et. al.*, 1997). But in this study, there was no significant difference between latex yields between the two periods because this rubber field was yet to be stabilized. Therefore, there was a decrease in the amount of latex volume in the early tapping period. The rapid coagulation process of rubber latex within a short period (2hr) and time delays in collecting latex also affected the accuracy of the latex volume. Expected rubber yield cannot be taken immediately after tapping although the clone has a higher potential of yield. Data collection during the rainy season was carried out without rain guards to the panel and this will also cause to alter the results of the present study.

Similarly, the total yield was directly associated with the number of tapping days. A considerable time was required for the drying of the tapping panel after rain. High shade areas required more time for the drying process of tapping panels than low and medium shade areas. According to the observations on growth parameters, low shade area (high light intensity) showed the highest girth and height of fist but bark thickness was not significantly different with shade levels. During the immature stage of rubber plants, the shade was directly affected for the girth and with the tapping they reflect in the yield variations. There was a positive relationship of girth with latex volume and mean yield (gram/tree/tapping) in the clone used in the experiment. This showed that one unit of girth increment resulted in the increase in volume and mean yield (gram/tree/tapping) of latex. Further girth can be used as a covariate in future experiments of rubber in tested clones. The regression coefficients in three clones can be used as a factor for the adjustment of the treatment effect. (Wijerathna and Arunakumara, 2006)

The duration and intensity of sunlight have a significant effect on rubber latex levels while the increase in sunlight until the end of the rainy season is highly influencing. Low rubber latex production during the rainy season was mainly due to the lack of sunlight. But in contrast, high radiation and prolonged sunshine hours from December to April cause the bark burning in immature rubber plants (Yogaratnam, 2000). It can be suggested that young plants may benefit from shade rather than high radiation. Tapping panel dryness is another major problem in the rubber plantation leading to low productivity. It was believed to be a physiological disorder resulting from excessive tapping (RRISL). Optimal sunlight of 6 hours a day each month with rainfall of 2000–2500 mm per year and the average temperature of 26–28 °C were identified as the best combinations for rubber growth and yield (Hazir *et al.*, 2020).

Plants with proper radiation have a better photosynthetic performance and they obtained saturating irradiance and absolute carbon dioxide fixation values were higher in unshaded plants than in shaded plants (Senevirathna *et al.*, 2003). Higher tree densities and higher shades were not recommended in horticulture as maximum yields were achieved at lower densities than can generate maximum dry rubber yields in plants. Generally, overlapping distribution of leaf area in the crown will minimize the crown size, negatively influencing light interception and can have a significant decrease in girth and gram/tree/tapping yield growth (Xianhai *et al.*, 2012).

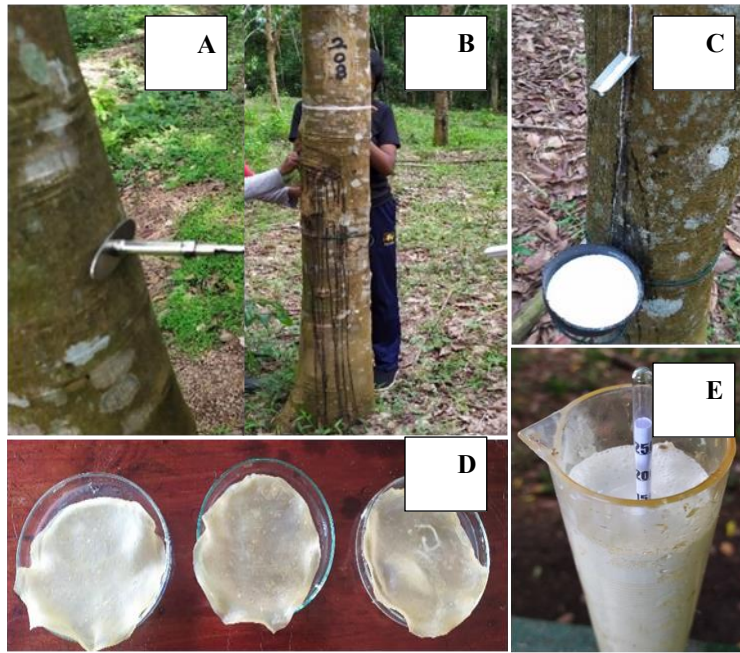


Figure 1: A- Measuring bark thickness, B- Measuring girth, C- Collecting latex, D- Measuring the dry rubber content using metrolac, E- Measuring dry rubber content using the laboratory method.

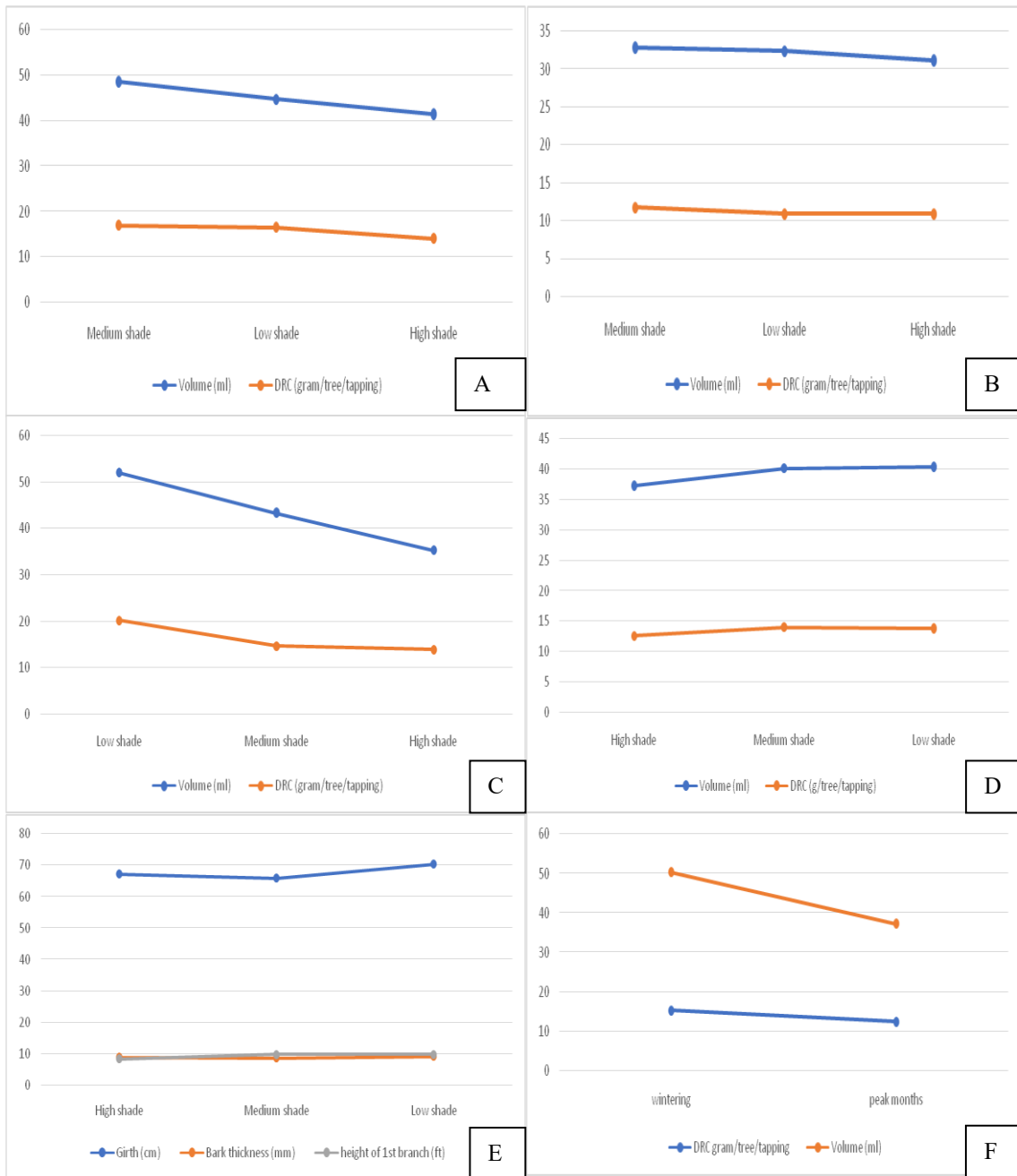


Figure 1: A- Summary of the mean values of latex volume and DRC among shade levels in December, B- Summary of the mean values of latex volume and DRC among shade levels in January, C- Summary of the mean values of latex volume and DRC among shade levels in February, D- Summary the total values of latex volume and DRC among shade level in three months, E- Summary of the mean values of the girth, bark thickness and height of the first branch among shade levels, F- Summary of the mean values of latex volume and DRC in wintering and peak months.

4. Conclusion

The girth and height to the first branch were significantly high in trees under low shade level. Bark thickness was not showed a significant difference concerning the shade levels. Present study showed a tree-to-tree growth variation within the yield (GTT) was significantly high under low shade during February (wintering period). But in December and January (cropping months) the difference was not significant concerning the shade levels. The volume of latex was also significantly high under the low shade level and yield (gram/tree/tapping) was not significantly different between cropping months and

wintering period. Immediately after the tapping started the total amount of yield might be low, until adjusting the trees and therefore the difference might be low to see the significant difference among the shade levels. Further few more months should be tapped to normalize the expected yield according to the clone. Therefore, this has been shown that the shade has a negative impact on yield and to get the expected yield and need to follow the RRISL recommendations accordingly. Shade levels were affected for the yield, and latex volume and growth parameters of the rubber. Therefore, tree to tree yield variation studied need to be carried out further with respect to the field.

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Author Contribution

Data collecting; K.M.A. Gunawardena, I.R. Palihakkara

Conceptualizing , drafting and manuscript writing; IR Palihakkara, S.P. Withanage, K.M.A. Gunawardena

Data analysing; K.M.A. Gunawardena, S.P. Withanage

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DURABILITY ASSESSMENT OF PLANT HOUSES CONSTRUCTED WITH TWO DIFFERENT BAMBOO SPECIES

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Abstract: Bamboo has become increasingly popular as a versatile building material due to its high mechanical properties. Bamboo is a strong, lightweight and fast growing material. Different bamboo species are used for various constructions in Sri Lanka. This research aimed to identify the most suitable bamboo species and culm part for constructing plant houses from two most commercially important bamboos in Sri Lanka namely *Bambusa vulgaris* and *Dendrocalamus hookeri*. The study was conducted at Faculty of Agriculture, University of Ruhuna, Mapalana, Sri Lanka in year 2023. Upper, middle and lower culm parts of bamboos were used with and without boron treatment. Thirty six structures of plant houses were prepared for data collection of insect damages, fungal infect and physical damages from visual observations. The experimental design was a three factorial Completely Randomized Design. The durability of bamboo depends on its boron treatment, therefore, needs to be treated to ensure its long-term usage. Untreated bamboo has a lower lifetime, in contact with the atmosphere and soil. Durability properties depends on the density and moisture content of the material used. The density and moisture content varied along the culm from lower to upper sections. The results showed that for both species wood density and moisture content decreasing along the culm with no significant differences among the two species. Boron treatment is affected to durability of bamboo. According to the results, *Dendrocalamus hookeri* is more durable than *Bambusa vulgaris* for commercial scale plant house construction during the research period.

Keywords: Bamboo, Boron treatment; Moisture content; Culm parts

1. Introduction

Bamboo is a type of woody grass that grows perennially and is a member of the Bambusoideae sub-family of the Poaceae family. This plant is extensively distributed throughout the world's mildly temperate, tropical, and subtropical regions. Bamboo have more specific characteristics like very rapid growth, renewable, easy-to-grow, high biomass and yield in a short time period (yield can be harvested in 3-5 years while other woods need approximately 20 years to reach the maturity). (Anokye et al., 2014) In Sri Lanka, bamboo has long been cultivated and is valued as a resource for a number of uses.

Bamboo culm is a well-recognized sustainable and environmentally friendly building material that can be used in place of more traditional materials like steel, concrete, brick, and wood. (Chaowana et al., 2021) In Sri Lanka, 10,000 hectares of seventeen different types of bamboo are grown. (Allalagoda et al., 2022) Worldwide, there are more than 1300 species of bamboo. (Samarawickrama et al., 2020) Six of the more than 14 well-known bamboo species found in Sri Lanka are indigenous.

Compared to timber, bamboo often has thinner walls and is less vulnerable to natural toxins; even a small amount of degradation can cause a significant percentage change in durability. Bamboo wood degrades because of termite, insect, and fungal attacks. (Kaminski et al., 2016) Bamboo's limited applicability due to its durability need treatment to ensure long-term use. When bamboo is exposed to the soil and atmosphere, its lifespan is reduced. (Javadian et al., 2019) Preservatives are essential to protect the bamboo from fungal and insect damages and to help to increase the durability. Boron treatment is the most popular and environmentally friendly preservation method. (Vipushnan et al., 2021)

2. Methodology

The study was conducted in Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka. There are two types of bamboo species were used in this study as *Bambusa vulgaris* and *Dendrocalarmus hookeri*. The bamboo species used in this study were collected from the faculty bamboo research field managed by Faculty of Agriculture, University of Ruhuna. The selected species for this study were matured culms, having the age of 5 years old. The culm was cut 30 cm above the ground level using chain saw. Upper, middle and lower culm parts were cut separately according to needed size. A 9m height of the felled bamboo culm were measured from the basal cut to the upwards. Thereafter each 9m culms were cut and divided into three equal sections as upper, middle, and lower sections, having 3m each. All of upper, middle and lower culm parts were cut according to suitable size for construct plant houses. Firstly, 100 l of water was filled in the barrel and heat. Then, 5kg of borax and 5kg of Boric acid was added and mixed properly. After 100 l of water was filled again and mixed properly. Bamboo culm parts were put into barrel at about one hour. (Upper, middle, lower parts were put separately into gunny bags.) After, water was transferred to other two barrel equally. Thereafter bamboo culm parts were kept in the barrel for 7 days. Thirty six small plant houses were made using upper, middle, lower parts separately from two bamboo species as Boron treated and untreated. The experimental design was three factor factorial Completely Randomized Design. Three replicates were taken from one treatment.

MC of the samples was first determined to ascertain any influence it might have on the density of both species. A 20 mm x 10 mm x thickness MC samples were taking from internodes parts. As many as three replicates were cut from each section of two bamboo species. Moisture content was determined culms cut after one week (moisture content 1) and after six weeks (moisture content 2). Firstly, initial weight was taken before drying. The Samples were then oven dried at a temperature of 105 °C until constant weight is reached. The moisture content of the samples was calculated using below equation.

$$\text{Moisture Content (\%)} = \frac{W_i - W_o}{W_o} \times 100\%$$

Where,

W_i: initial weight before drying (g)

W_o: oven dried weight (g)

The samples used for the determination of density were the same as used for MC determination. The volume of the sample was determined by water displacement method. A measuring cylinder filled to three-quarter level of water. The samples were dipped into water before to prevent the water from being absorbed by the samples. The electronic weighing balance was used to record the mass of each sample before it was dipped into the measuring cylinder containing the water. The volume was then determined by the amount of water displaced by the sample. The density of the samples was calculated using below equation. Density was determined culm cut after one week (Density 1) and after six weeks (Density 2).

$$\text{Density (g/cm}^3\text{)} = \frac{\text{mass (g)}}{\text{Volume (cm}^2\text{)}}$$

Where,

$$1 \text{ ml} = 1 \text{ cm}^3$$

$$\text{Volume of sample (cm}^3\text{)} = (\text{Vf} - \text{Vi}) \text{ ml}$$

Vi: weight before the sample dip into the water

Vf: weight after the sample dip into the water

Mass: final weight of sample after oven-drying

Insect damages, fungal infestations and physical damages (cracks) were determined by visual observation. Four treatments were used for collect data and data analysis.

Treatment 1- variety 1+ Boron treated

Treatment 2- variety 1+ non-treated

Treatment 3- variety 2 + Boron treated

Treatment 4- variety 2 + non- treated

3. Results and Discussion

The moisture content 1 and moisture content 2 results for *Bambusa vulgaris* and *Dendrocalamus hookeri* for treated and non-treated at three section of upper, middle and lower of the culm are shown in table 1. From the statistical analysis, there is significant difference between moisture content and culm parts of bamboo. There is no significant difference along the moisture content and two varieties of bamboo. Also, there is no significant difference between moisture content and treatments. The moisture content at the lower part of the culm was higher as compared to the middle and the upper part of the bamboo culm. The lowest moisture content recorded was at the top section of *Dendrocalamus hookeri* species. The moisture content decreased along the culm from basal section to the top section. Among the two species, moisture content 2 was lower as compare to the moisture content 1.

Table 1: Data of MC 1 and MC 2 for *Dendrocalamus hookeri* and *Bambusa vulgaris*

Species	Culm part	Treatment	Moisture content 1 (%)	Moisture content 2 (%)
<i>Bambusa vulgaris</i>	Upper	NT	23.03	19.25
<i>Bambusa vulgaris</i>	Middle	NT	32.18	30.04
<i>Bambusa vulgaris</i>	Lower	NT	36.99	36.31
<i>Bambusa vulgaris</i>	Upper	T	23.42	21.31
<i>Bambusa vulgaris</i>	Middle	T	32.83	30.79
<i>Bambusa vulgaris</i>	Lower	T	38.28	37
<i>Dendrocalamus hookeri</i>	Upper	NT	21.8	19.87
<i>Dendrocalamus hookeri</i>	Middle	NT	31.29	28.31
<i>Dendrocalamus hookeri</i>	Lower	NT	36.29	34.62
<i>Dendrocalamus hookeri</i>	Upper	T	22.83	22.18

<i>Dendrocalamus hookeri</i>	Middle	T	32.11	29.6
<i>Dendrocalamus hookeri</i>	Lower	T	36.6	35

The result for density 1 and density 2 for *Bambusa vulgaris* and *Dendrocalamus hookeri* are shown in the table.2. From the statistical analysis, the density varies along the culm from lower to upper sections were significant for both bamboo species. Results of *Dendrocalamus hookeri* showed the density of lower part was the highest compared to the middle and upper parts. The upper part revealed the lowest density among the three sections along the culm. The density decreased along the culm from lower to the upper sections.

For both species the densities shows significant different along the culm from upper, middle and lower parts. From the statistical analysis, there is no significant difference between density and treatment. It means treatments were not affected for density.

Table 2: Data of density 1 and density 2 for *Bambusa vulgaris* and *Dendrocalamus hookeri*

Species	Culm part	Treatment	Density 1 (Kgm ³)	Density 2 (Kgm ³)
<i>Bambusa vulgaris</i>	Upper	NT	817.62	783.58
<i>Bambusa vulgaris</i>	Middle	NT	860.85	839.3
<i>Bambusa vulgaris</i>	Lower	NT	1015.56	993.79
<i>Bambusa vulgaris</i>	Upper	T	838.28	808.59
<i>Bambusa vulgaris</i>	Middle	T	873.26	873.03
<i>Bambusa vulgaris</i>	Lower	T	1035.38	1021.1
<i>Dendrocalamus hookeri</i>	Upper	NT	873.2	842.73
<i>Dendrocalamus hookeri</i>	Middle	NT	990.54	967.37
<i>Dendrocalamus hookeri</i>	Lower	NT	1047.27	1020.78
<i>Dendrocalamus hookeri</i>	Upper	T	896	884.9
<i>Dendrocalamus hookeri</i>	Middle	T	1000.53	992.6
<i>Dendrocalamus hookeri</i>	Lower	T	1051.82	1038.38

From the statistical analysis, percentage of insect damage of *Bambusa vulgaris* was highest compared to *Dendrocalamus hookeri*. Boron treated *Dendrocalamus hookeri* samples was not appeared insect damages. Also, there is a significant difference between treated and non-treated samples. For both species the percentage of insect damages shows significant difference at ($\alpha - 0.05$) levels.

For the fungal infect of *Bambusa vulgaris* was highest compared to *Dendrocalamus hookeri*. There is a significant difference between treated and non-treated samples. For both species the percentage of fungal infects shows significant difference ($\alpha - 0.05$). Physical damages were not appeared.

4. Conclusion

Based on the results obtained, the densities for the two bamboo species decreases along the culm from lower to upper sections. Lower culm parts have higher densities and higher moisture content as compared to upper and middle culm parts. *Bambusa vulgaris* have lower densities as compared to *Dendrocalamus hookeri*. Boron treatment is not significantly affected for density and moisture content of

culm parts. The moisture content of both bamboo species varies along the culm from upper to the lower sections. Insect damages were not appeared in *Dendrocalamus hookeri* with Boron treated samples. Boron treated samples have lower fungal infects as compared to non-treated samples. Therefore, Boron treatment is affected to increase the durability of plant houses during the research period. Also, Lower culm part is most suitable for construct plant houses. The most suitable bamboo variety is *Dendrocalamus hookeri* for construct plant houses when compared with *Bambusa vulgaris*.

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Author Contribution

Data collecting; Hasanthi H.A.M, Palihakkara I.R

Conceptualizing, drafting and manuscript writing; Palihakkara I.R, Hasanthi H.A.M

Data analyzing; Hasanthi H.A.M ,Palihakkara I.R

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ASSESSING THE VIABILITY AND ADOPTION BARRIERS OF ECO-FRIENDLY PRODUCTION METHODS IN AGROINDUSTRY: A SYSTEMATIC REVIEW

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Abstract: It is important to scrutinize whether it is worthwhile introducing eco-friendly production processes into the world agro-industry because this imperatively implies sustainability. Systematic review Following the PRISMA method, we reviewed 21 science papers from the years between 2000 and 2022. We were found through the Google Scholar search engine using ‘Adoption barriers’; ‘Agroindustry sustainability’; ‘Eco-friendly production methods’; ‘Global perspective’; and ‘Viability assessment’ as keywords. The main purpose is to review literature in this domain to uncover the existing trends and patterns in adoption, outlining major determiners of feasibility for these environmentally friendly approaches and listing the most common barriers against global adaption in this area for agriculture. A systematic approach for data extraction and synthesis and a critical appraisal of the quality of included studies. This review will diminish bias and generate findings supported by sound evidence. Initial indications highlight a wide range of research focusing on different regions and utilizing different research designs. Economic considerations and policy frameworks influence the diffusion of green practices across regions. The systematic review shows the gaps that exist in research and thus calls for more empirical evidence to enrich understanding of the complex nature related to sustainability in agribusiness. Finally, this systematic review provides a synthesis of the literature on environmentally friendly production techniques associated with the agro-food sector globally, considering opportunities, viability challenges, and constraints for implementation. The pointed-out lacunas in the literature stress the need for future studies aimed at a more comprehensive analysis of the processes involved. These results inform policymakers, industry stakeholders, and researchers who collaborate in designing future sustainable and resistant Agro-industrial systems.

Keywords: Adoption barriers; Agroindustry sustainability; Eco-friendly production methods; Global perspective; Viability assessment

1. Introduction

The global agroindustry stands at a critical juncture, facing the pressing need for sustainable transformation to mitigate environmental degradation and ensure long-term viability. With agriculture being a significant contributor to greenhouse gas emissions, soil degradation, and biodiversity loss, the imperative for eco-friendly production methods has never been more apparent (Teo et al.,2020). As such, understanding the viability and adoption barriers of these methods becomes paramount in navigating towards a more sustainable agroindustry landscape. This introduction seeks to provide a comprehensive background, delving into the necessity of eco-friendly practices, the global context, and specifically examining the scenario in Sri Lanka (Astudillo et al.,2023).

1.1. The Urgency of Sustainable Agriculture

The imperative for sustainable agriculture arises from the recognition of its pivotal role in addressing global challenges such as climate change, food security, and biodiversity conservation. Unsustainable agricultural practices, characterized by intensive chemical inputs, monocropping, and deforestation, have resulted in soil erosion, water pollution, and loss of biodiversity (Rehman et al.,2022). These practices not only compromise the resilience of agroecosystems but also contribute significantly to greenhouse gas emissions, exacerbating climate change. Therefore, transitioning towards sustainable agriculture is imperative to mitigate environmental impacts, ensure food security, and foster rural livelihoods (Wijerathna-Yapa & Pathirana.,2022).

1.2.Global Context

Across the globe, there is a growing momentum towards adopting eco-friendly production methods in the agroindustry. Governments, international organizations, and civil society are increasingly recognizing the importance of sustainable agriculture and promoting policies and initiatives to support its adoption (Araujo et al.,2022). From precision agriculture and organic farming to agroforestry and integrated pest management, various eco-friendly approaches are being explored and implemented. However, the adoption of these methods varies widely across regions, influenced by factors such as socio-economic conditions, technological readiness, and policy support.

1.3. Sri Lankan Scenario

In the context of Sri Lanka, agriculture plays a crucial role in the economy, livelihoods, and food security of the population. The agricultural sector contributes significantly to the country's GDP and provides employment for a large portion of the rural population. However, unsustainable agricultural practices, including the overuse of chemical fertilizers and pesticides, have led to soil degradation, water pollution, and loss of biodiversity. Furthermore, the sector is vulnerable to the impacts of climate change, including erratic weather patterns and extreme events (Dissanayake et al.,2021). In response to these challenges, there is a growing recognition of the need to transition towards sustainable agriculture in Sri Lanka.

The Sri Lankan government has introduced various initiatives to promote eco-friendly practices in the agroindustry. For instance, the "Govi Jana Seva" program aims to support smallholder farmers in adopting organic farming methods and reducing chemical inputs. Similarly, the "Wana Ropa" program encourages tree planting and agroforestry to enhance soil fertility and mitigate climate change impacts. Despite these efforts, several barriers hinder the widespread adoption of eco-friendly practices in Sri Lanka (Jayasinghe et al.,2021). These include limited access to technical know-how and resources, inadequate infrastructure, and socio-economic constraints faced by smallholder farmers.

The transition towards eco-friendly production methods in the agroindustry is imperative for ensuring environmental sustainability, food security, and rural livelihoods. While there is a growing recognition of the importance of sustainable agriculture globally, significant challenges

remain, particularly in developing countries like Sri Lanka (Malkanathi., 2021). Addressing these challenges requires concerted efforts from governments, civil society, and the private sector to provide the necessary support, incentives, and infrastructure for farmers to adopt eco-friendly practices. Only through collective action can we build a more resilient and sustainable agroindustry that meets the needs of present and future generations.

2. Methodology

The systematic review conducted to investigate the viability and adoption barriers of eco-friendly production methods in the agroindustry adhered to the established guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A comprehensive search strategy was devised, leveraging key terms such as "Adoption barriers," "Agroindustry sustainability," "Eco-friendly production methods," "Global perspective," and "Viability assessment." The search was conducted across reputable academic databases, with a focus on peer-reviewed literature published between 2000 and 2022 (Da-Silveira et al.,2021).

The inclusion criteria encompassed studies (Table 1) that examined eco-friendly production methods within the agroindustry context, elucidating factors influencing their adoption and assessing their feasibility (Dadhaneeya et al.,2023). A meticulous screening process was employed to identify relevant studies, followed by data extraction and synthesis using a systematic approach. Critical appraisal of the included studies was performed to ensure methodological rigor and minimize bias, thereby enhancing the robustness of the review findings.

Table 1: Outlining the inclusion and exclusion criteria for selecting studies in the systematic review

Criteria	Inclusion	Exclusion
Publication Type	Peer-reviewed journal articles, conference papers, and academic dissertations	Non-peer-reviewed sources such as blog posts, newspaper articles, and opinion pieces
Time Period	Studies published between 2000 and 2022	Studies published before 2000 or after 2022
Language	Studies available in English	Studies published in languages other than English
Topic Relevance	Studies focusing on eco-friendly production methods in the agroindustry, adoption barriers, and sustainability	Studies unrelated to eco-friendly production methods, agroindustry, adoption barriers, or sustainability
Geographic Coverage	Global studies examining various regions, with a specific focus on Sri Lanka if available	Studies focused solely on a single region or country, excluding Sri Lanka if no relevant studies are found
Methodological Rigor	Studies employing robust research methodologies, including quantitative, qualitative, and mixed-method approaches	Studies with methodological flaws, insufficient data, or lacking clear research methodologies

This table provides a clear overview of the criteria used to include or exclude studies in the systematic review, ensuring a systematic and rigorous selection process.

3. Results and Discussion

The systematic review identified a total of 21 studies that met the inclusion criteria, providing valuable insights into the viability and adoption barriers of eco-friendly production methods in the agroindustry. The results and discussion are presented below (Figure 1), focusing on key themes and findings derived from the reviewed literature (Kee et al., 2021; Nazam et al., 2020).

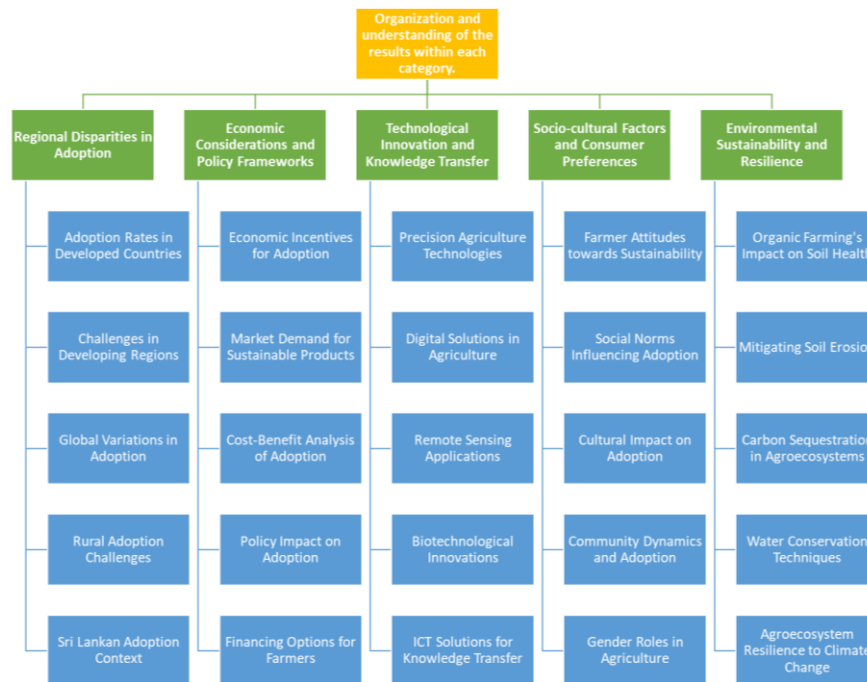


Figure 1: Organization and understanding of the results within each category.

3.1. Regional Disparities in Adoption

The studies reviewed revealed significant regional disparities in the adoption of eco-friendly production methods within the agroindustry. While some regions, particularly in developed countries, have made substantial progress in implementing sustainable practices such as organic farming and agroforestry, others lag behind due to limited resources, infrastructure, and technical expertise (Table 2). This disparity underscores the importance of tailored interventions and support mechanisms to facilitate the adoption of eco-friendly practices in regions with limited resources, such as rural areas in developing countries like Sri Lanka.

Table 2: Regional Disparities in Adoption

Study Title	Region/Country	Main Findings	References
Regional Differences in Adoption Rates	Developed Countries	High adoption rates due to robust infrastructure and institutional support.	Rumlet et al.,2022
Challenges in Developing Regions	Developing Countries	Limited adoption attributed to resource constraints and lack of technical expertise.	Zghurska et al.,2022
Global Disparities in Adoption	Global	Varied adoption rates across regions, with developed countries leading in implementation efforts.	Curry et al.,2021
Rural Challenges	Rural Areas	Challenges include limited access to markets, extension services, and financing.	Hiloidhari et al.,2020
Sri Lankan Context	Sri Lanka	Specific challenges identified, such as the need for targeted interventions to support adoption.	Herath et al.,2021; Zghurska et al.,2022

3.2. Economic Considerations and Policy Frameworks

Economic factors emerged as crucial determinants influencing the adoption of eco-friendly production methods. Studies highlighted the role of economic incentives, subsidies, and market demand in promoting sustainable agriculture practices. Additionally, supportive policy frameworks, including regulations, certification schemes, and extension services, were found to facilitate the adoption of eco-friendly practices (Table 3). However, challenges persist, particularly

in developing countries like Sri Lanka, where limited access to financial resources and institutional support hinders widespread adoption.

Table 3: Economic Considerations and Policy Frameworks in Agri Industry Collaboration

Study Title	Economic Factors	Policy Interventions	References
Economic Incentives	Role of economic incentives	Government subsidies and financial incentives	Faqih et al.,2020
Market Demand	Consumer demand for sustainable products	Certification schemes and labeling regulations	Oliveira et al.,2021
Cost-Benefit Analysis	Economic analysis of adoption	Extension services and farmer training programs	Curry et al.,2021; Faqih et al.,2020
Policy Impact	Influence of agricultural policies	Integration of sustainability goals in policies	Hiloidhari et al.,2020; Herath et al.,2021
Financing Options	Funding options for farmers	Incentives for sustainable agriculture practices	Faqih et al.,2020; Zghurska et al.,2022

3.3. Technological Innovation and Knowledge Transfer

Technological innovation and knowledge transfer emerged as critical drivers of adoption in the reviewed literature. Studies highlighted the importance of research and development in advancing eco-friendly production methods, including the development of new technologies, practices, and tools (Table 4). Additionally, knowledge dissemination and capacity-building initiatives were found to be instrumental in promoting the uptake of sustainable agriculture practices among farmers. However, challenges related to technology access, literacy, and infrastructure remain barriers, particularly in rural and marginalized communities.

Table 4: Technological Enhancement Vs Agro-industry

Study Title	Technological Advancements	Knowledge Dissemination	References
Precision Agriculture	Adoption of precision farming technologies	Farmer field schools and demonstration plots	Almadani & Mostafa et al.,2021; Siddegowda & Devi.,2021
Digital Farming	Use of digital tools in agriculture	Training programs and capacity-building workshops	Mukhamedova et al.,2022
Remote Sensing	Application of remote sensing technologies	Extension services and knowledge exchange platforms	Almadani & Mostafa et al.,2021
Biotechnological Innovations	Innovations in biotechnology	Collaborative research projects and partnerships	Mukhamedova et al., 2022
ICT Solutions	Information and communication technology (ICT)	Farmer-to-farmer knowledge sharing networks	Mukhamedova et al.,2022; Siddegowda & Devi.,2021

3.4. Socio-cultural Factors and Consumer Preferences

Socio-cultural factors and consumer preferences were identified as influential factors shaping the adoption of eco-friendly production methods. Studies underscored the importance of farmer attitudes, beliefs, and social norms in influencing adoption decisions. Furthermore, changing consumer preferences towards sustainably produced food products have incentivized farmers to adopt eco-friendly practices to meet market demands (Table 5). However, challenges related to cultural traditions, social dynamics, and consumer awareness persist, necessitating targeted interventions to promote behavioral change and consumer education.

Table 5: Consumer Preferences Vs Socio-cultural factors on Agro-industry

Study Title	Farmer Attitudes	Consumer Behavior	References
Perceptions of Eco-Friendly Practices	Attitudes towards sustainable agriculture	Preferences for sustainable food products	Siddegowda & Devi.,2021
Social Norms	Influence of social norms on adoption	Awareness of environmental and ethical issues	Herath et al.,2021; Zghurska et al.,2022
Cultural Traditions	Impact of cultural practices on adoption	Demand for organic and fair-trade certifications	Zghurska et al.,2022
Community Dynamics	Influence of community dynamics on adoption	Impact of media and advertising on consumer choices	Rumlet al.,2022
Gender Roles	Gender dynamics in agricultural decision-making	Trends in consumer purchasing behavior	Hiloidhari et al.,2020

3.5. Environmental Sustainability and Resilience

Environmental sustainability and resilience emerged as central themes in the reviewed literature, highlighting the importance of eco-friendly production methods in mitigating environmental degradation and enhancing agroecosystem resilience. Studies emphasized the role of practices such as organic farming, agroforestry, and integrated pest management in promoting soil health, biodiversity conservation, and climate resilience (Table 6). Furthermore, sustainable agriculture practices were found to contribute to water conservation, carbon sequestration, and ecosystem services, thereby enhancing the long-term sustainability of agro-industrial systems.

Table 6: Sustainability vs Resilience in Agro-industry

Study Title	Soil Health	Biodiversity Conservation	References
Organic Farming Practices	Effects of organic farming on soil health	Role of agroforestry in enhancing biodiversity	Curry et al.,2021
Soil Erosion Mitigation	Techniques to mitigate soil erosion	Conservation agriculture practices	Almadani & Mostafa et al.,2021; Siddegowda & Devi.,2021
Carbon Sequestration	Carbon sequestration in agroecosystems	Importance of habitat restoration	Mukhamedova et al.,2022
Water Conservation	Methods for conserving water in agriculture	Ecosystem-based approaches to pest management	Almadani & Mostafa et al.,2021
Climate Resilience	Resilience of agroecosystems to climate change	Linkages between sustainable agriculture and ecosystem services	Zghurska et al.,2022

Overall, the results and discussion underscore the multifaceted nature of the challenges and opportunities associated with the adoption of eco-friendly production methods in the agroindustry. While progress has been made in certain regions and sectors, significant barriers remain, particularly in developing countries like Sri Lanka. Addressing these barriers requires a holistic approach that integrates economic, technological, socio-cultural, and environmental dimensions to promote sustainable agriculture practices and build resilient agro-industrial systems for the future.

4. Conclusion

In conclusion, the systematic review sheds light on the multifaceted landscape of eco-friendly production methods in the agroindustry, uncovering both opportunities and challenges inherent in their adoption. The findings underscore the pivotal role of economic considerations and policy frameworks in shaping the diffusion of green practices across different regions. Despite the wealth of research addressing various aspects of sustainability in agribusiness, notable gaps persist, highlighting the need for further empirical studies to deepen our understanding of the complexities involved. Moreover, the review underscores the imperative for collaborative efforts among policymakers, industry stakeholders, and researchers to design and implement sustaina-

ble agro-industrial systems. By addressing the identified barriers and leveraging emerging opportunities, stakeholders can foster a transition towards more resilient and environmentally responsible agricultural practices. Ultimately, the synthesis of literature presented in this review serves as a valuable resource for informing strategic decision-making and guiding future research endeavors aimed at advancing sustainability goals within the agroindustry.

5. Recommendations

Building upon the insights gleaned from the systematic review, several recommendations emerge to facilitate the uptake of eco-friendly production methods in the agroindustry. Firstly, policymakers are encouraged to enact supportive regulatory frameworks and incentives that incentivize sustainable practices while fostering innovation and investment in green technologies. Additionally, greater emphasis should be placed on fostering collaboration and knowledge exchange among stakeholders, including farmers, researchers, and industry actors, to facilitate the co-creation of sustainable solutions tailored to local contexts.

Furthermore, investment in research and development initiatives aimed at overcoming technological barriers and scaling up proven eco-friendly practices is paramount. By prioritizing interdisciplinary research and leveraging emerging technologies such as precision agriculture and agro-ecology, stakeholders can unlock new opportunities for enhancing sustainability and resilience within the agroindustry. Lastly, efforts to enhance public awareness and consumer education regarding the environmental and social benefits of eco-friendly agricultural practices are essential to drive demand and catalyze widespread adoption. Through concerted action guided by these recommendations, the agroindustry can chart a course toward a more sustainable and equitable future.

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VALUE ADDITION OF SEAWEED (*Kappaphycus alvarezii*) AS A HIGH NUTRITIONAL COOKIE FOR ASTRONAUTS

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Abstract: Space foods are food products designed and processed for the consumption of astronauts during missions in the outer space. Space missions may take a few months to several years and the astronauts will not be able to consume all types of meals to fulfill their nutritional needs as in land. Therefore, it is critical that the designed space food will have higher nutritional content, easy digestibility, and longer shelf life. This research is aimed to develop a protein-rich, low-fiber cookie as an astronaut's food which may have a longer expected shelf life. Seaweed cultivation is well practiced in the coastal areas of Sri Lanka. Despite the fact they are exported to several countries there is no guarantee of a local market. As a result, this research aims to give value addition to the seaweeds as well. Cassava and *Kappaphycus alvarezii* seaweed will be combined with local spices and by-products of tuna filleting to give the cookie a distinct Sri Lankan flavor. Because of the combination of byproducts of tuna filleting and seaweed, the proposed cookie is projected to have a higher protein content than traditional cookies, as well as less fiber. After the production of the cookie, an analysis will be conducted to evaluate the biological, physical, and chemical characteristics of the cookie. The proposed cookie is intended to provide high nutrition to the consumers as well as to value addition to the seaweed. Furthermore, the incorporation of seaweed and tuna filleting by-products will be a novel approach to cookie production as well as to the food production of astronauts.

Keywords: Cookie; Seaweed; Space food; Value addition

1. Introduction

1.1 Introduction

Space foods are especially focusing on fulfilling the nutrient requirements of the astronauts, which need to be well-balanced, compact, high-dense of nutrients, and convenient to consumption during outer-space missions. Also, should be shown a much longer shelf-life than normally processed food products and preferably consist of less fiber content to reduce the excretory requirement during the mission. Most importantly these food items should be formed to be consumed in a zero-gravity environment.

Astronauts usually consume three main meals, which are tailor-made according to the specific formula and need to be further certified according to the specifications given by nutritionists, generally should have high nutrients and minerals content recommended for the astronaut's diet. The calorie requirement can be varied according to different factors such as gender, Body Mass Index, and also their duty (NASA, 2021).

The astronaut may have a chance to choose different types of foods during their journey ranging from fruits, nuts, chicken, beef, seafood, candy, and brownies. Also, there is an option for different drinks and beverages including coffee, tea, orange juice, fruit punches, and lemonade (NASA, 2021).

China, Indonesia, the Republic of Korea, Malaysia, the Philippines, Singapore, and Thailand is the global leading seaweed producer in the Asia region (Ferdouse et al., 2018). In Sri Lanka, North, North-West and North-East coastal areas including Jaffna, Mannar, and Mullaitivu districts are popular for seaweed culture. However, it is not very popular in Sri Lankan cuisine yet (Ginigaddara et al., 2018). Seaweeds are photosynthetic, macroscopic, eukaryotes that are visible to the naked eye (Coppejans and Clerck, 2009). There are about 900 green seaweed varieties, about 4000 species of red seaweed, and 1500 species of brown seaweeds around the world where 221 species of seaweeds are commercially utilized (Kariyawasam, 2016). It is significantly important for the extraction of phycocolloids like agar, alginate, carrageenan, and agarose; which are potential substrates for many food processing applications, significant for pharmaceutical and cosmetic manufacturing (Smit, 2004). At present, Sri Lanka exports seaweeds to various countries, especially to Japan, and receives higher demand due to the cleanliness of the sea area (Kariyawasam, 2016; Jayasuriya, 1990).

This reason has led to major attention towards the usage of seaweeds in food processing as value addition. Space food is not a popular term among Sri Lankans. However, Sri Lanka is popular as a high-quality seafood exporter in the world. The wealth of its name has opened a new window to the manufacturing of seaweed-based value-added processed food products for astronaut or other export purposes.

1.2 Background and Justification

Space foods have a wide range of fast foods, daily meals, and traditional foods such as burgers, salads, sausage patties, brownies, mashed potatoes, pike pork, broccoli and cheese, dried beef, sushi, ramen, and fruit, curry steak, fish, and pork soup. However, the baseline space shuttle food and beverage list has mainly tuna as seafood and the international space station daily menu food list has fish, baked fish, grilled fish, sauteed lobster, broiled tails scallops, baked seafood, gumbo with rice shrimp, cocktail tuna, noodle casserole as seafood (NASA, 2021). High nutrition, easy digestibility, palatability, lightweight, quick to serve, compactness, well packed, and high acceptability with minimum preparation are the usual characteristics of space foods.

Sri Lanka also known as the pearl of the Indian Ocean has one of the most unpolluted sea areas around the country. Sri Lankan EEZ (Exclusive Economic Zone) is rich in marine resources. The location of the island in the Indian Ocean will help to enhance the country's marine industry development programs. Sri Lanka owns an EEZ which is 8 times bigger than the land area. EEZ area is extent around 517,00 km². The highly diversified EEZ can provide the optimum tropical conditions for seaweed culture. Therefore, the occurrence of residual hazards is much lower in the Indian Sea than in the seafood taken from other ocean areas. This is a promising factor that Sri Lankan seaweeds have a very low risk of poisons and are safe to consume. The organoleptic properties of the seaweed are not much appreciated by Sri Lankans especially due to its fishy odor as well as its preparation methods. Thus, this would be a major reason for reporting fewer research activities than that of other marine species.

Seaweed-based processed foods are the one of popular space food items among astronauts. The Miyeok-Guk is a popular traditional Korean seaweed soup made by using brown seaweed (*Undaria pinnatifida*) (Song et al., 2012). Hijiki (*Sargassum fusiforme*) seaweed salad is a seaweed-based space food that is certificated by the Japan Aerospace Exploration Agency. Indian food tech company 'Naka Foods has developed an energy bar using Spirulina, cyanobacteria as space food.

Kappaphycus alvarezii which is also known as Doty – Doty is an edible red alga cultured in Sri Lanka by NARA (National Aquatic resource Research and Development Agency). As a thickening agent, *Kappaphycus alvarezii* has been used in more than 250 food applications (Shanmugam et al., 2017). The Processed *Kappaphycus alvarezii* has reported less moisture content, carbohydrates, proteins, fats, and ash as 0.89%, 65.20%, 3.40%, 1.10%, and 11.57% respectively (Abdul Khalil et al, 2018). According to Abirami and Kowsalya (2011), 100 (g) of *Kappaphycus alvarezii* contains calcium, phosphorous, iron, magnesium, and niacin as 1068, 124, 0.93, 152, and 2.2 (mg) respectively.

Cassava (*Manihot esculanta*) is a well-known tuber that belongs to the *Euphorbiaceae* family and has reported a high carbohydrate yield. Cassava starch has been used in numerous numbers of processed food preparations also used as a good binding agent. In Indonesia, cassava starch is used in the bakery industry to produce sweetened and unsweetened biscuits formulas, thus, cassava can be considered as a better replacer for wheat starch (FAO,2020). Cassava starch is obtained by steeping and wet milling of the cassava root tubers (Niba et al., 2002). Cassava tubers are a good source of energy due to their high percentage of carbohydrates and reported a considerably higher percentage of proteins (1-3%) and dietary fiber (4%).

Tuna backbone and tail fins removed in the tuna fish processing industry in Sri Lanka are a good source of protein and calcium (Gamarro et al., 2013). Spices are significant in culinary science as flavoring agents which give enhance spicy taste and gain many other health benefits. Cardoman (*Elettaria cardamomum*), cinnamon (*Cinnamomum verum*), pepper (*Piper nigrum*), and demon chili (*Capsicum frutescens*) will be used in the proposed cookie as flavoring agents (Kurian, 2012). The general composition of a cookie includes higher ash, fiber, and carbohydrates (Ho and Latif, 2016). However, the composition can be varied with carb and protein content. Enhanced protein content in the cookie will be an advantage for the astronaut's food formulation and fortification. Protein takes a long time for the digestion process in the stomach will delay the occurrence of hunger and the production of excretory materials. Also, cookies formulated with low fiber content than the usual recipes may result in lesser fecal materials than normal. In one of the features published on NASA's website, Vickie Kloeris, sub-system manager for the international space station food aptly noted that astronauts are now staying in space for longer and need tasty nutritious meals, something which is now close to achieving a level of perfection (WION, 2021). However, the space station pizza party may still be a dream yet to come true.

Therefore, this study is aimed to develop a cassava starch-based protein-rich cookie made by incorporating *Kappaphycus alvarezii* seaweed, as an astronaut's food which may have a longer expected shelf life.

2. Methodology

2.1 Raw material collection

Fresh seaweed will be collected from a private seaweed farm in Mannar (Latitude in degrees 80 52' 0" North, Longitude in degree 80 5' 60"). Collected seaweed packed in polyethylene bags and will be transported by using a Styrofoam box filled with jell-ice. Cassava tubers (CARI-555 variety) will be collected from the Piliyandala area (Latitude in degrees-60 47' 0.978" North, Longitude in degree-790 55' 49.668"). The diameter of cassava tubers around in 5 to 8 cm and 20 to 25 cm long. All the time unwounded tubers will be collected and transported to the research station in ambient condition at Styrofoam boxes. All the other biscuit ingredients will be purchased from the supermarket in Colombo. Seaweed will be stored at cold room in zip lock bags until further use. Cassava will be stored at ambient temperature in cool dark and dry place until further process.

2.2 Sample preparation

Collected seaweed will be crushed after thawing in ambient temperature for few hours and subjected to drying by using conventional oven at 60°C (± 5 °C) degree. Then will be stored in air tight container until further use. After peeling, cassava tubers will be wash and cutting manually into 4 x 4 cm² squares pieces. Then cassava need to be boiled 3 hours in open container at 100 °C(± 5 °C), and pulp will be prepared by using dough mixture. The prepared cassava pulp will be stored in cold room after putting to the airtight container. The cookie dough will be prepared according to the three formula while only changing the percentage of seaweed, cassava and wheat crenel flour. The prepared cookie dough will be smashed down with hand to flatten it and further rolled by using rolling pin until thickness become to ¼ inches. Then dough will be cut manually with round shape cutter and baked at conventional oven at 180 °C (± 5 °C), for 15-20 minutes. The baked cookies will be cool under air condition and coated with a spice incorporated caramel. Cookies will be stored in thermos stable vacuum package until transport to astronaut programming area.

2.3 Analysis of the samples

2.3.1. Proximate Analysis

The moisture (oven drying method, AOAC 990.19), ash (AOAC, 900.02), crude protein (AOAC 955.04), crude fat (Soxhlet method AOAC 920.39), and crude fiber (AOAC 978.10) will be determined with AOAC standard methods (AOAC, 2005).

2.3.2. Total energy

Energy content of the cookie will be calculated by using bomb calorie meter.

2.3.3. Determination of pH

The pH variation of the samples will be determined with digital calibrated pH meter.

2.3.3.4. Determination of cookie thickness

The thickness of the cookie will be measured with the use of micrometer screw gauge with a sensitivity of 0.001 mm. Measurements from 5 random points including the center point of the cookie will be taken.

2.3.5. Determination of surface morphology

The surface morphology and compactness will be determined through Scanning electron microscopy (SEM) technique which will be obtaining from university of Peradeniya.

2.3.6. Determination of oxygen permeability

An oxygen transmission rate tester (OTR machine) will be used to determine the rate of oxygen transmission through the packaging material.

2.3.7. Determination of cookie tensile properties

A tensile tester will be used to determine the tensile strength.

2.3.8. Determination of the cookie strength

The CT-3 Brookfield texture analyzer will be used to determine the film strength and the friction properties.

2.3.9. Color Analysis

The L*, a* and b* values will be determined as a chromameter reading (CR-400, Konica Minolta Inc., Tokyo, Japan). values of L*, a*, and b* indicated the darkness or lightness (dark color to white), redness to greenness color (+ to -), and yellowness to blueness (+ to -) respectively. The results will be obtained by spotting the chromameter on the outer surface of the cookie.

2.3.10. Biological properties

Total plate count, coliform count, zero tolerance (*Salmonella* and *Shigella* identification) test will be performed.

2.4. Sensory Evaluation

Seven scale hedonic test will be performed using 30 semi-trained panelists to identify the most consumer-accepted formula.

2.5. Statistical Data Analysis

All the time five replicates will be used and results expressed as mean \pm standard deviation (SD). The analysis of variance (ANOVA) need to be done with SPSS computerized statistical software package (SPSS 21.0, IBM SPSS Inc., Chicago, USA), and Duncan's multiple range tests will be performed to define the significant difference ($p < 0.05$) among the treatments.

2.6. Cost Analysis of the product

The cost per one unit will be calculated.

3. Discussion

3.1 Raw material collection

The raw material collection for product development should be done carefully since the quality of the product can directly be affected by the quality of the raw materials used. Therefore, good quality raw materials from reliable sources will be used for the production of the cookie. The use of quality raw materials is crucial for several reasons. Good quality raw materials will ensure the consistency of the final product. This will help reduce the inconsistency of taste, texture, and appearance of cookies. The use of fresh seaweed and cassava would ensure the development of a unique taste and texture to the cookie enhancing its taste and mouthfeel. Good-quality raw materials are less likely to be contaminated by harmful substances like heavy metals, pesticides, and pathogens. Thereby this will help ensure the safety of the product and reduce the risk of health hazards. Most importantly good quality raw materials will provide better nutrient content.

Seaweeds can contribute with essential vitamins and minerals as well as proteins (Table 01) to the cookie and high-quality cassava would ensure that the product contains an adequate amount of carbohydrates and other nutrients in the cookies.

Table 01: Nutrient content of seaweed (Source: Hardjani, 2017)

Nutrition profile	Seaweed
Energy (calorie)	2882.8
Crude protein (%)	3.26
Fat (%)	0.22
Moisture (%)	8.9
Total Ash (%)	18.68
Crude fibre content (%)	4.6
Carrageenan (%)	63.2

The use of good quality raw materials is further important as the production of a cookie for astronauts requires additional considerations. The product should have a long shelf life since space missions may take several months to several years period of time to finish. Using high-quality ingredients and employing suitable preservative techniques can help extend the shelf life of the cookie with compromising taste and nutritional value. The nutritional density of the food taken on space missions is also important. Therefore, the use of seaweed, cassava, and tuna filleting by-products will ensure that the cookie will consist of high nutrient content, especially with protein, vitamins, and minerals.

Tuna filleting by-product incorporation into the cookie formulations has not been investigated before. This will be a novel approach for cookie production and will be important in reducing waste in the food industry while contributing to environmental sustainability. Furthermore, this will be a valuable source of proteins and the addition of other ingredients for nutrient development will not be required. The use of by-products will also have economic benefits for the seafood industry by creating an additional revenue stream. This can improve the overall profitability and sustainability within the industry.

3.2. Sample preparation

Sample preparation will play a crucial role in ensuring the quality, safety, and nutritional value of the final product. Preprocessing of the raw materials before cookie production is also important to get a quality final product. Seaweeds will be thawed and crushed before drying them. Slow thawing to ambient temperature will soften the material and help preserve nutrients than the rapid thawing method. Crushing will break the structure making it easier to incorporate into cookie dough. Conducting the process in ambient conditions will preserve the nutrient conditions. Drying the seaweeds will remove excess moisture while extending the shelf life and preventing the growth of microbes. Conventional drying will ensure gentle drying, minimizing the loss of heat-sensitive nutrients while preserving the unique taste and texture of the seaweed. Uniform cutting of cassava will facilitate even cooking and will ensure the consistency of the texture of the final product. The boiling process will break the carbohydrate complexes improving the digestibility and texture of the cookies. The pulp formation will also facilitate easier processing.

Cookie dough formulation will play a major role in the process. The ingredients should be mixed with correct proportions and the smashing and rolling process will ensure uniformity of the product. Further baking with a specific temperature, and time combination will result in providing the desired taste, colour, and texture of the final product. Spice-incorporated caramel coating

will provide the cookie with a unique Sri Lankan spice flavor and also will act as a protective barrier to the cookie, preserving the freshness and extending the shelf life of the cookie.

Thermostable vacuum packages will facilitate preserving nutritional content and ensure safe consumption since it will help preserve a stable environment protecting from environmental factors like moisture, oxygen, and light.

3.3. Analysis of the samples

Evaluation of the proximate composition of the cookie will provide an idea about the nutrient content of the product. It is expected that the product will contain higher protein content and low fibre content than the market-available cookies since the product consists of protein-rich raw materials such as seaweed and tuna filleting by-products. Surface morphology and texture analysis provide insights into the cookie's sensory attributes, ensuring it meets astronauts' expectations for taste and texture.

Analysis of the pH variation of the cookie will ensure the product remains palatable and safe for consumption. Evaluation of the color variations over time would provide the details on the palatability of the product as well as the shelf life of the product. Further the determination of the oxygen permeability, biological properties such as total plate count, coliform count and zero tolerance test will provide the details on shelf life of the product. Additionally, oxygen permeability testing ensures the cookie's packaging maintains freshness and shelf life during space missions. Microbiological analysis ensures the cookie is free from harmful pathogens, safeguarding astronauts' health in the isolated environment of space.

The expected shelf life of the product is 1 year and 6 months by considering the conditions of the raw materials used, processing conditions, packaging conditions and storage conditions. This will also provide the details on the safety of the food product.

3.4. Sensory evaluation

Sensory evaluation of the developed formulas will be used to identify the most consumer accepted formula. It is important to produce a consumer accepted product when launching a novel product to the market. Hedonic scale has been identified as a popular test used to identify consumer acceptability of food products by evaluating the overall characteristics of the food products such as taste, color, texture, odor, etc. A semi-trained panel will be used as the product should be evaluated by the general consumers as well. This will help in obtaining a better result in identifying the best formulation of a food product.

3.5. Speciality of the product

There are special conditions that should be fulfilled by the products that are taken as space food. When considering cookies like bakery items, the crumble formation has been a huge problem for using them as space food. To overcome this problem this product will be coated with a spice flavor incorporated sugar coating so that the crumbles will not be formed. Furthermore, the product will be smaller, so that the number of bites that should be used when eating the cookie will be less. This will also reduce the crumble formation while eating.

When considering the shelf life of the product, due to the quality of the raw materials, processing conditions, packaging conditions and storage conditions the product will have a longer shelf life than the cookies currently available in the market.

The product will contain higher nutrient content as well as lower fibre content than the market-available cookie products. Therefore, it will be easier for the consumer to digest. This will

produce less excreta but provide with high nutrient content and it will be a great advantage for the astronauts.

This cookie formulation has been developed to contain high protein content, therefore this can be used not only as a product suitable for astronauts but also as a product suitable to be used as a good source of nutrition when main meals have to be skipped. Furthermore, this will be a product that can be used as a low-cost nutrition source in poor countries.

4. Conclusion

The integration of seaweed, tuna filleting by-products, and cassava into a high-protein, low-fiber cookie presents a promising solution for addressing the nutritional needs of astronauts during space missions. Beyond its utility in space exploration, this innovative cookie formulation will offer a viable source of essential nutrients for individuals facing mealtime constraints. This cookie can also serve as a convenient and nourishing option for anyone on the go. Ongoing research and development in this area showcase how combining new cooking ideas with nutritional knowledge can improve how we eat, both in space and here on Earth

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MAPPING AGROINDUSTRY DYNAMICS: TRENDS, PATTERNS, AND DEVELOPMENTAL IMPACTS IN DEVELOPING COUNTRIES

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Abstract: The UN clearly reflects the complex relationship between the SDGs and agricultural growth. On the other hand, poverty and starvation in developing countries have a damaging effect. Ultimately, the agriculture sector can overcome this while providing food security for a growing global population. Hunger is an inevitable consequence of food price hikes during economic crises. In Sri Lanka, 17% of people are in moderate acute food insecurity which can be seen to be in the Northern, Eastern and Central Provinces. Agro-industry is highlighted in this study as a way of increasing food and nutrition security, achieving climate goals, overcoming economic crisis, and reducing environmental stress through relevant literature about trends, patterns and developments. The agro-processing sector contributes greatly to manufacturing of value-added products and economic growth. It is 50% for poor countries and 32% for upper-middle-income countries. The agro-industry is moving towards green production, technology integration, and global market expansion while creating income and employment opportunities by extending postharvest activities and agribusiness opportunities. Sustainable approaches such as precision farming and organic farming are gaining more acceptance over environmental consciousness and market demand. The use of advanced technologies like IoT and artificial intelligence become customizable to traditional farming methods, optimizing resource use and improving productivity. This reveals a growing role of value addition, diversification, and supply chain resilience. The supply processes become more complicated with agribusinesses integrating the activities of processing, packaging, and distribution in order to meet the needs of the global markets. Strategies like vertical integration and niche market development are becoming the core trends of diversification. The agro-industry development has numerous facets that affect not only economic, but social and environmental domains as well. Economically it contributes a lot to employment, income generation and income generation. In the social view, the development of the agriculture sector is of paramount importance for rural development. As it promotes shared growth, improves the quality of life and advances the community in general.

Keywords: Agro-industry; Trends; patterns; Economic development; Social development; Environmental development

1.Introduction

The world faces off with an alarming paradox increasing urbanization, which is expected to decrease land used for agriculture, and a population that is predicted to reach 9.7 billion by 2050. The Food and Agriculture Organization of the United Nations (FAO) has noted that the shortage of land places significant strain on agricultural productivity. Regions with low incomes are more susceptible to food insecurity, which is characterized as limited or unpredictable access to sufficient food, as a result of demand exceeding accessibility (World Bank, 2024).

By increasing productivity and efficiency, the agro-industry which encompasses large-scale farms and food processing companies offers viable alternatives. Regardless, concerns about its effects on resource and labor exploitation, environmental pollution, and land degradation persist (Holt-Giménez, 2020). The trick is to maximize the potential of the agro-industry while minimizing its drawbacks.

A diverse strategy is required to achieve sustainable food security for all. Increasing productivity and preparing for climate change require funding for agricultural research and development, especially in low-income nations (Global Panel on Agriculture and Food Systems for Nutrition, 2020). By assisting small-scale farmers, who frequently grow a variety of resilient crops, we may empower marginalized communities and promote community-based food systems (ETC Group, 2017). Furthermore, encouraging sustainable agricultural methods like integrated pest management and crop rotation preserves soil health and biodiversity, guaranteeing long-term productivity (FAO, 2023).

Finally, addressing food insecurity demands tackling its root causes, including poverty, inequality, and lack of access to education and healthcare. Investing in social safety nets, fostering economic opportunities in rural areas, and empowering women farmers are crucial steps toward building a more equitable and food-secure world (World Food Programme, 2023).

By embracing innovation, fostering collaboration, and prioritizing responsible resource management, we can navigate the complex challenges of feeding a growing population while ensuring a just and sustainable future for all.

2.Literature review

2.1 Global market expansion

The agro-industry, encompassing agriculture, food processing, and related sectors, plays a complex and multifaceted role in global market expansion. Its impact can be analyzed through several key lenses:

2.1.1 Economic Expansion:

Increased trade in agricultural products is propelled by the growing global population and escalating living standards, which escalate the demand for diverse and high-quality food items (FAO, 2021). This surge in trade is pivotal for numerous developing countries, as it significantly boosts their export earnings (World Bank, 2020). Moreover, the agro-industry presents lucrative investment prospects due to continuous innovations in agricultural technology and value chains, which attract investments and facilitate the development of essential infrastructure, logistics, and processing facilities (OECD, 2019). Furthermore, the agro-industry serves as a vital source of employment, directly and indirectly engaging millions of individuals worldwide, thereby fostering rural development and contributing to poverty reduction. (World Bank, 2020)

2.1.2 Technological Advancement:

The imperative for heightened productivity and sustainability within the agricultural sector propels advancements in various fields such as biotechnology, genetic engineering, precision agriculture, and digital technologies (FAO, 2021). These innovations not only address immediate challenges but also have a broader impact, spilling over into other sectors and catalyzing global market expansion. Additionally, the substantial investments made by large agribusinesses in research and development have the potential to consolidate markets and influence trade dynamics significantly (UNCTAD, 2019).

2.1.3 Environmental Impact:

The expansion of agricultural land poses critical challenges to sustainable market growth, including deforestation, biodiversity loss, and water resource depletion (World Bank, 2020). Furthermore, agriculture's substantial contribution to greenhouse gas emissions and its susceptibility to the adverse impacts of climate change underscore the urgency for adopting sustainable practices and market-driven solutions (FAO, 2021). These factors emphasize the necessity for strategic interventions to mitigate environmental degradation and ensure the resilience of agricultural systems in the face of climate variability.

2.1.4 Social and Political Implications:

Ensuring access to diverse and affordable food is paramount for global stability, with unequal market access and distribution exacerbating poverty and food insecurity (FAO, 2021). Moreover, the policies governing agricultural trade wield significant influence over market access, prices, and the livelihoods of farmers and consumers worldwide (UNCTAD, 2019). The agro-industry's impact on global market expansion resonates across economic, technological, environmental, and social dimensions. Recognizing the multifaceted nature and potential challenges is essential for fostering sustainable and inclusive growth within a globalized market landscape.

2.2 Precision farming

Precision farming revolutionizes agriculture by applying data-driven decision-making. Sensors, Remote sensing, Geographic Information Systems (GIS), Variable rate applicators and Data analytics and software to gain deep insights into individual fields. This allows for targeted interventions, optimized resource use, and variable-rate application of water, fertilizer, and pesticides, maximizing yield and profitability while minimizing waste and environmental impact (Azad et al., 2020; Liakos et al., 2018). With reduced costs, improved crop quality, and data-backed decisions, precision farming empowers farmers to be more competitive and sustainable (Gebbers & Adamchuk, 2010). However, initial investment costs, the need for technical expertise, and the digital divide pose challenges requiring innovative solutions for inclusive and equitable growth in this exciting field (OECD, 2019).

2.3 Supply Chain Management:

Agriculture is crucial for many countries' livelihoods and economies with a strong agricultural base have a comparative advantage in industrializing through agriculture. However, challenges persist due to systemic issues within the agriculture sector, such as the predominance of small and marginal farmers, fragmented supply chains, lack of economies of scale, limited processing and value addition and deficient marketing infrastructure. Agriculture production is vulnerable to external factors like weather fluctuations, seed quality, and cultivation practices, which are beyond the control of supply chain stakeholders (Rahman, n.d.). Globalization and demographic shifts have heightened the demand for agricultural and food products, but adapting to climatic variations, product perishability and shifting consumer preferences poses challenges for developing an efficient supply chain system (Balaska et al., 2023).

The agro-industry's evolving demands place additional pressure on the farming sector to produce specific agricultural outputs suitable for processing. Effective management across all aspects of agriculture is essential as demand for agricultural products rises.

Supply chain success is determined by the seamless coordination of activities across various links, generating value for consumers and enhancing profitability. This involves farmers, collectors, SMEs and consumers, with collectors often experiencing the lowest profit margins (Indah et al., n.d.).

Supply chain management focuses on trust, market information exchange, innovation, and streamlining supplier relationships to create long-term partnerships with original equipment manufacturers. It includes managing materials and supplies, recycling, and re-use processes.

Logistics management focuses on delivering the right product to the right consumer in optimal condition, at the right time, and at the right cost, aiming to maximize farm revenue while minimizing losses(Bhatia and Bhat, 2020).

It invests heavily in the transportation sector, particularly in agri-logistics, where perishability and product quality are paramount concerns.

Time is a critical factor in the supply chain, especially for perishable crops, where timely delivery, continuous product flow, and efficient routes are crucial for success. Effective product packaging plays a pivotal role in the supply chain, facilitating transportation to local markets and mandis for easy consumer access. Perishable crops, such as fruits and spices, require specialized packaging to maintain freshness and quality during transit(Chen et al., 2020).

The supply chain analysis involves evaluating factors like labor availability, resource availability, demand, productivity and crop prices. Skilled labor is a major challenge. Farm planning decisions involve operational, tactical, and strategic levels. Operational decisions involve production management, inventory storage and distribution logistics. Tactical decisions involve land allocation, crop variety selection and irrigation planning. Strategic planning optimizes the supply chain by ensuring consumer accessibility. A model is being developed to analyze crop allocation, operational tasks, labor requirements, harvesting methods and distribution planning. This initiative aims to expand market access, provide technology and financing information, maintain product quality, mitigate risks, reduce lead times, foster economies of scale, and enhance employment opportunities(Bhatia and Bhat, 2020).

2.4 Internet of Things (IoT) and AI Technology

The Internet of Things (IoT) is a growing network of smart devices that integrate sensors and actuators with smart energy. AI in agriculture was first applied in 1985 by McKinion and Lemmon to optimize cotton production (Zha, 2020).

IoT is built on existing technology like wireless sensor networks, cloud computing and RF identification. It can be applied in fields like monitoring, precision agriculture, tracking, greenhouse production and agricultural machinery. IoT uses data analysis in various forms, including sensor data, audio, image and video, for prediction, storage management, decision-making, farm management, precise application and insurance. Digital technologies like big data, AI, robotics, IoT and virtual and augmented reality are being developed to improve smart agriculture, focusing on resource efficiency and environmental sustainability (Balaska et al., 2023).

IoT technology involves the transition from manual methods to smart, automatically controlled systems, facilitated by internet connectivity for cloud-based data assessment (Mirani et al., 2019).

2.4.1 Soil management

Soil is crucial for successful agriculture, storing essential nutrients like water, nitrogen, phosphorus, potassium, and proteins. It improves soil porosity and aggregation, inhibits physical degradation, and minimizes negative factors like soil-borne pathogens and pollutants. AI can create soil maps, showing soil landscape relationships and underground layers, while monitoring critical parameters like temperature, humidity and theft using sensors connected to smart microcontrollers (Zha, 2020).

2.4.2 Weed management

A robotic platform has been developed for weed management, mapping weed populations and locating precise herbicide spots. The system uses image recognition to interpret plant types, reducing excess herbicide pollution in water by proposed commercial technologies for precision weed control include sensors for weed/crop detection, decision algorithms for efficient herbicide types and precise sprayers.

These technologies aim to minimize runoff contaminants and improve water quality (Balaska et al., 2023).

Artificial intelligence weed detection systems have been tested in laboratories to calculate the precise amount of spray and spray on target locations, lowering costs and reducing the risk of damaging crops (Zha, 2020).

2.4.3 Crop protection.

Weed resistance, disease resistance and pest resistance can all rise with the ongoing application of a small number of active substances. Crop production requires creativity and astute solutions to overcome these obstacles. Although biopesticides are less harmful to the environment and human health, their effectiveness is dependent on a number of variables. To enhance food quality and lessen environmental effect, synthetic pesticides, chemical fertilizers and selective breeding are employed. Pesticides, fertilizers and the development of resistance are the main targets of farm-to-fork, soil and biodiversity programs. Agricultural crop disease diagnosis is now more accurate thanks to the combination of sensors, microcontrollers, actuators and the Internet of Things. Crop protection has undergone a revolution because to artificial intelligence (AI) and robotic technologies, which offer enhanced capacities and accuracy in handling agricultural problems. These technologies make it possible to provide tailored treatments, identify diseases and pests early, monitor automatically and manage resources effectively. Plant protection systems with intelligent robots increase productivity, decrease labor needs and boost crop output. Cost, scalability and compatibility with current agricultural practices are obstacles, though.

Farmers are able to make educated decisions on crop selection, water usage and planting dates thanks to the use of sophisticated algorithms and environmental sensors. These solutions enable timely modifications and minimize crop losses using AI-driven climate modelling by providing real-time data on weather, soil moisture levels and pest outbreaks.

By administering fertilizers, automating chores like weeding and sowing and monitoring deficiencies, intelligent systems and robotics can optimize nutrition while reducing waste and improving resource efficiency (Balaska et al., 2023).

Information on the life cycle of the product and its transportation is input, stored and processed as part of the tracking and tracing of the agricultural supply chain. For business purposes, this procedure is advantageous, especially when it comes to fostering confidence between buyers and sellers. Agricultural enterprises may identify smart business partners, make informed decisions and save time and money by knowing the complete history of their product (Zha, 2020).

2.5 Value addition in the agroindustry

Value addition in the agroindustry refers to processing raw agricultural products into higher-value goods, such as packaged foods, biofuels, or textiles. This process can generate significant positive impacts on the economy, both at the individual and broader levels.

2.5.1 Increased profitability and incomes:

Value addition allows farmers to capture a larger share of the final consumer price, leading to increased profit margins and improved livelihoods (Aregbesola & Ogunwuyi, 2011; World Bank, 2013). Processing adds value and creates new products, expanding markets and revenue streams for agribusinesses (Regmi & Bhadra, 2011).

2.5.2 Job creation and economic growth:

New jobs are created throughout the value chain, from processing and packaging to marketing and distribution (World Bank, 2013). Increased economic activity in rural areas, leading to regional development and poverty reduction (Regmi & Bhadra, 2011; IFPRI, 2018). Empowering women and youth by creating new opportunities in the value chain.

2.5.3 Enhanced competitiveness and innovation:

Value addition incentivizes research and development, leading to new products, improved efficiency, and increased competitiveness in global markets (FAO, 2012). Diversification of agricultural production, reducing dependence on single commodities and mitigating risks (World Bank, 2013).

2.5.4 Improved food security and nutrition:

Processing can extend shelf life, reduce spoilage, and increase access to safe and nutritious food (FAO, 2012). Development of value-added products like fortified staples can address micronutrient deficiencies (IFPRI, 2018).

3. SWOT analysis of the Agroindustry



Figure 1: SWOT analysis.

3. Conclusion

Food insecurity, climate change and economic crises pose serious obstacles for developing nations such as Sri Lanka, with the agriculture sector being particularly hard hit. Addressing issues in the agriculture sector is essential because of its critical position in the nation's economy. This calls for the agro-industry to take use of contemporary trends, patterns, and technologies. Expansion of the worldwide market, precision farming methods, effective supply chain management, AI technology integration and value-adding tactics are important areas for implementation. Developing nations may effectively negotiate the intricacies of the agricultural sector, address obstacles and promote sustainable growth by prioritizing these elements. Trends in the Agro-industry are moving towards sustainability, technology integration and expanding the global market while creating postharvest activities and agribusiness options that lead to revenue and employment prospects. Due to consumer demand and environmental awareness, sustainable farming methods like organic farming and precision agriculture are becoming more and

more common. To optimize resource utilization and boost output, classic farming techniques are adapted to leverage cutting-edge technology like artificial intelligence and the Internet of Things. The trends point to a growing emphasis on supply chain resilience, diversification and value addition. Agribusinesses incorporate processing, packaging and distribution activities into their value chains to fulfil the demands of the global market, which leads to an increase in complexity. Strategies for diversification, like specialized market development and vertical integration, are becoming increasingly important. The Agro-industry has a wide range of development implications that affect the social, environmental and economic spheres. Economically, it makes a major contribution to the creation of jobs, income and export earnings. Development in the agriculture sector is essential for rural development from a social point of view. because it promotes equitable development, improves livelihoods and increases the community's well-being.

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INVENTION AND INNOVATION – ENGINEERING TECHNOLOGY

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IMPROVEMENT OF THE PROPERTIES OF MYCELIUM-BASED BIO LEATHER WHICH GROWS ON THE RUBBER SAWDUST SUBSTRATE

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Abstract: The leather industry is a major contributor to environmental issues, largely due to the disposal of toxic chemicals and high-water usage in the tanning and production processes, as well as the negative impact of animal slaughtering. To address these challenges, fungal mycelium has emerged as a promising alternative material. Mycelium-based composites exhibit diverse morphology, mechanical, and thermomechanical properties that can be modified by changing the substrate. The tensile strength of the leather, water absorption, and morphological structure analysis were used to characterize the properties of mycelium-based leather. The FTIR analysis was used to study the chemical structure of the material and the TGA study gave the temperature characteristics of the material. One fungal strain, *Pleurotus ostreatus*, has been shown to produce sheets with a tensile strength of 0.43 MPa and a water absorption capacity of 300%. Mycelium is composed of lipids, chitin, protein, and polysaccharides, and chitin decomposition can yield chitosan that can be used for cross-linking to alter the properties of the mycelium-based films. The citric acid cross-linking process was found to improve the properties of these films, with cross-linked films exhibiting a tensile strength of 0.83 MPa. Additionally, the water absorption properties of mycelium-based films can be reduced by using a beeswax coating, which has been shown to decrease water absorption by 30%. Based on the results, it was discovered that, aside from tensile strength, the other properties of mycelium-based leather relied on the properties of animal leather. The use of bio leather can effectively mitigate the environmental issues associated with animal leather production.

Keywords: Mycelium; Bio leather; Animal leather; Cross-linked; Chitin

1. Introduction

Mycelium is a fungal strain matrix that consists of protein, lipids, chitin, and polysaccharides (Antinori et al., 2020). This can be categorized as natural polymeric composite fibrous material. This unique structure of the mycelium creates a way to produce many mycelium-based materials. Styrofoam-like packaging, leather, handbags, flooring, and sound-proofing acoustic panels, building material with fire-resistance are made from mycelium. The mycelium network properties can be adjusted after changing substrate, temperature, pH, and moisture content. These property changes create a way to produce various plastics. The utilization of mycelium-based products has several benefits, including low cost, low density, high compressive strength, tensile strength, and impact strength, as well as reduced energy consumption, the potential to sequester CO₂, and maybe most importantly, biodegradability. The mycelium-based products are sustainable compared to plastics and animal lather. The mycelium-based plastics are naturally safe, and the substance remains stable at temperatures as high as 200 °C (Jiang et al., 2016).

Typically, the growth time of the mycelium colony is around 5 to 7 days. After the growth of the network, heating can be used to interrupt the growth of spores. The main advantage is the shape and size of the material depend on the mold used to place the substrate. Another benefit is that mycelium growing does not consume valuable natural resources as it grows on agricultural waste. Also, unlike petroleum-based plastics, it doesn't release harmful fumes when burned and maintains clean, fresh air. The mycelium-based plastic has various applications. This can be used as a substitute for animal lather (Jiang et al., 2016). Under the trade name Resihi Mycelium, this is created from a woven cellular microstructure obtained from fungi (Lab, 2022). Reishi's fine mycelium is more sustainable and adaptable than leather made from an animal's skin. The mycelium-based plastic is also used in European high end footwear brands. Mycelium structures can be produced using various fungal species like *Ganoderma applanatum*, *Laetiporus sulphureus*, *Pleurotus ostreatus*, *Pleurotus cystidiosus*, *C. militaris*, *Pleurotus eryngii*, *Volvariella volvacea*, *Lentinus edodes*, etc (Haneef et al., 2017). The main problem is these various species needed various nutrients and growth conditions. Substrate and its quality also affected to the mycelium growth. The oyster (*Pleurotus ostreatus*) needs room conditions to grow. It is the most popular mycelium species in the world and It may be cultivated on a variety of substrates with acceptable food quality and quantity (Katel and Mandal, 2022). Rubber sawdust, rice bran, carboards and cassava bagasse are used as the substrate for the growth of *Pleurotus ostreatus* species. To choose the ideal substrate for mycelium growth, the first experiment was run. This mycelium growth is not stopped until the fungal species' demise. The films needed a heat treatment to destabilize the fungal species. The raw film of *Pleurotus ostreatus* mycelium matrix doesn't have good mechanical properties and water absorption quality. Thus, it requires some adjustment for further use. Mycelium contains chitin and this chitin can be transformed as chitosan using a process called deacetylation. After the deacetylation, chitosan can be cross-linked using various chemicals like acetic acid, genipin, aldehyde, or tannin (Bringham & Houston, 2012). That crosslinking process is shown in figure 1. The strengthening of leather during the tanning process is a well-known phenomenon. Cross-linking is a technique that involves the formation of molecular bonds between long-chain fibers, resulting in a material that is stronger and sometimes more flexible than the original (Houston, 2012). In leather production, the long-chain fibers are made of collagen and are cross-linked using chromium (III) compounds or aldehydes.

This study approach for improving the strength of the *Pleurotus ostreatus*-based material involves cross-linking the chitosan fibers using citric acid. That cross link may have resulted in the improvement of the mechanical properties of the mycelium film. Water absorption of the

raw mycelium film is also not in an acceptable region. That water absorption can be improved using the water-resistant coating throughout the film.

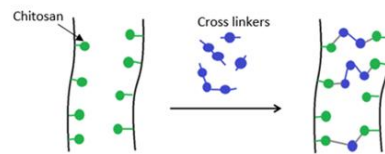


Figure 1: Illustration of cross-linking components for Chitosan (Bringham &Houston, 2012).

Beeswax is one of the major water-resistant coatings (Karunanayake et al., 2020). That can be applied to mycelium films. These two-adjustment done by this research study and compare the mechanical and water absorption properties using the FTIR, TGA SEM, and tensile strength analysis of the thin films.

2. Material and Methods

The experiment was carried out to obtain mechanical properties and water absorption of the mycelium-based films and compare the improvement of the properties after crosslinking and coating. Before the adjustment mycelium growth is the key component in this research. Sawdust substrate was selected after doing some experiments on cardboard, rice bran, and cassava bagasse. The amount of chemical addition was decided using the previous experiments.

2.1 Materials

Sodium hydroxide (NaOH) and citric acid ($C_6H_8O_7$) were purchased from Organic chemicals Pvt Ltd. Bees wax, Calcium carbonate ($CaCO_3$), Magnesium, Rice bran, and gypsum were purchased from the mushroom store. All the reagents were analytical reagent grade and used without any further purification.

2.2 Prepare the growth media of mycelium.

Rubber sawdust 400 (± 1) g was poured into heat-resistant polythene bags. The substrate was supplemented with 2% (w/w) calcium carbonate ($CaCO_3$), 0.25% (w/w) of Magnesium, 0.25% (w/w) of gypsum, and 10% (w/w) rice bran, which was based on the dry weight basis and was thoroughly mixed. The substrate mixture was autoclaved at 121 °C for 45 minutes to sterilize. After cooling, each substrate-prepared inoculum was poured into the three polythene bags and sealed. Figure 2 shows the pre-pared bag with the mycelium spores growing after 5 days. Then the mycelium was allowed to grow in dark conditions at room temperature. After 45 days mycelium structure was removed from the bags. Figure 2 b shows the fully growing mycelium after the bag was removed. Then the degraded substrate was re-moved and extract the mycelium film from the substrate.

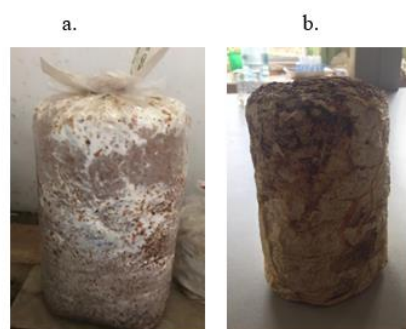


Figure 2. a.Mycelium growth after 5 days b. Mycelium composite with the substrate.

2.3 Heat treatment

The mycelium films were removed from the substrate and dry 8 hours in an oven at 70°C (Siwulski et al., 2011).

2.4 Deacetylation of chitin

Heat-treated mycelium film was poured into 50 ml of NaOH solution (50% in W/W). Afterward, the solution and film were heated up to 70 °C for 2 hours (Okoya et al., 2018).

2.5 Cross-linking

Deacetylated mycelium film was poured 50 ml citric acid sample (15% W/W). Afterward, the sample was heated up to 110 °C for 1 hour (Wu et al., 2019).

2.6 Water-resistant coating

Purchased beeswax 6g (± 1) mixed with 5 ml of turpentine and stirred for 2 hours until beeswax dissolved in turpentine. The mixer was applied on the mycelium film surface using a small paintbrush.

2.7 Fourier Transforms Infrared Spectroscopy (FTIR)

The functional groups in the mycelium were identified using an FTIR (PerkinElmer, USA) equipped with an ATR reflectance cell spectrometer. All spectra were recorded in the range from 4000 to 400 cm^{-1} , with an 8 cm^{-1} resolution. Raw mycelium film after heat treatment spectra and cross-linked film spectra were obtained and analysis was performed with Origin pro-2021 software.

2.8 Thermogravimetric analysis

Thermogravimetric analysis of the sample was performed using a thermogravimetric analyser (STA 6000 / STA 8000) in a nitrogen atmosphere. The heating rate was 10 °C per minute and the determination range was 40-600 °C. This analysis was carried out for the two samples after heat treatment and the cross-linked film. The weight loss and the first derivative of TGA were obtained and interpret the results using origin pro max 2021 software.

2.9 Scanning Electron Microscopy (SEM)

A scanning electron microscope (SEM) (CARL ZEISS EVO IS 15) was used to analyse the morphology of the mycelium film after and before heat treatment. The cross-link was also checked using the SEM image. The SEM micrographs were obtained from the surface of 5 mm \times 5 mm size samples.

2.10 Mechanical test

A tensile strength test was performed using the Instron 3365 Universal Testing Machine (Instron Ltd, Buckinghamshire) with crosshead speed fixed at 25 mm/min. The samples were prepared according to the dimensions provided by the standard. Specimens were cut from the films (five different samples from one film) with a sample width and length of 30 mm and 110 mm, respectively. For each test, five samples were analysed. The average of five samples of stress Vs strain was plotted.

2.11 Water absorption analysis

To study the behaviour of water absorption of the mycelium-based composite three samples of the mycelium-based composite were prepared after heat treatment. Three samples are mycelium films after heat treatment, mycelium films after crosslinking, and mycelium films after beeswax coating. The water absorption was measured according to the ASTM D570-98 standard. All the samples were conditioned at 50 °C for 24 h and weighted (W_0) before testing. After that, the samples were immersed in distilled water. After 15 min, 1h, 2h,3h, 4h, 5h, and 24 h all the specimens were removed from the water and wiped moisture with a tissue paper, and immediately weighted (W_t) after each time. The water absorption capacities of the thin films were calculated using the following equation.

(Husan and Haq, 2019). The percentage water gain of the sample vs time curve was plotted using Microsoft Excel.

$$M_w = (W_t - W_0) / W_0 \times 100 \quad (1)$$

M_w = Percentage of water gain weight gain of the sample

W_0 = Oven dry weight

W_t = weight after time t

3. RESULTS AND DISCUSSION

3.1 Fourier Transform Infrared Spectroscopy (FTIR) Analysis

The spectra were evaluated by using, table 1 illustrates the wavelength of peaks and corresponding functional groups. Figure 3 shows the FTIR spectroscopy of the raw mycelium (*Pleurotus ostreatus*) film, mycelium film after heat treatment, and crosslinked mycelium film grown on the rubber sawdust. According to figure 3, all sample show peaks at 3280, 2916, 2815, 1639, 1545, and 1376 per cm. The band of 3280 cm⁻¹ should be present in O-H stretching or N-H stretching. That peak is wide, but it is not strong. The OH peak should be wide and strong (Wahab et al., 2017). According to the peak 3280, cm-1 the mycelium network may have consisted of O-H bonds. The absorption at 2910cm⁻¹ and 2850cm⁻¹ are attributed to the symmetrical and asymmetrical stretching vibration of the C-H groups. It is located under 3000 cm⁻¹, therefore it is SP3 hybridized carbon. The 1639 cm⁻¹ peak and 1545 cm⁻¹ peak correspond to the amide I and amide II respectively (Naumann, 2009). The sharp peak in 1376 cm⁻¹ C-H bending in the film. According to Antinori et al., 2020, mycelium consists of proteins, lipids chitin, and polysaccharides. Identified C-H bending, and O-H stretching should be present in the polysaccharides. The C-H bending also presents lipids and chitin in the network. Amides I and II are present in the 1639 cm-1 peak and 1545 cm-1 peak present proteins in the network.

Table 1: Wavelength of peaks used for FTIR analysis and corresponding functional groups (Wahab et al., 2017)

Wave number (cm ⁻¹)	Phenomenon	Functional group
1670-1070	CC stretch	Alkenes
1800-1486	CO stretch	Amide I + II
1465-1440	CH ₃	Methyl groups
1475-1400	CH ₂	Methylene groups
3000-2850	CH stretch	Alkyl groups
3550-3000	NH stretch	Primary amines
3600-3200	OH Stretch	Alcohols, water

The heat treatment process did not affect any functional group of the film. All the peaks present in the raw mycelium film were presented in the heat-treated film. The main difference can be seen in the crosslinked film. The main advantage of this FTIR analysis is that graph gave the evidence for the crosslinking of the film. The crosslinked reaction happens between two citric acid and three carbonyl groups. That combination ejects water molecules and transforms citric acid into cyclic anhydride. That anhydride reacts with the polysaccharide's function in the mycelium film. That cyclic anhydride also reacts with the second functional group chitosan and creates the cross-link bridge (Wu et al.,

2019). That absorption band present in the 1720 cm^{-1} proved the crosslink of the mycelium film. According to the study of Wu et al., 2019 the absorption band can't reveal information about whether this is cross-linked or grafted.

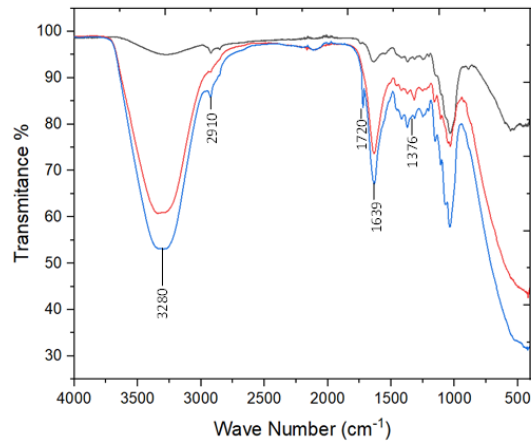


Figure 3: FTIR spectrum of Mycelium based film growth on rubber sawdust.

According to the FTIR analysis of the raw mycelium film, the mycelium film consists of chitin. The cross-linking process was done to the Chitosan. Then the chitin should convert to chitosan using NaOH. Figure 4 a show the deacetylation process of chitin. The chitosan crosslinking happened in citric acid treatment. A basic presentation of the crosslinking is shown in figure 4 b. The reactive groups of chitosan are $-\text{NH}_2$, and $-\text{OH}$ (Khouri, 2019). The crosslinking process of the chitosan was carried out with the esterification of citric acid. The reaction initiates when two of the three carboxylic groups of citric acid react, resulting in the release of a water molecule and the formation of a cyclic anhydride. The cyclic anhydride then reacts with a functional group of the polysaccharide, either an amine or a hydroxyl group, leading to the formation of an amide or an ester bond respectively. Loss of another water molecule, leading to the formation of a second cyclic anhydride from the citric acid derivative. This second cyclic anhydride then reacts with a second functional group from an adjacent residue, completing the formation of the crosslink bridge. At this stage, the bridge no longer has two available carboxylic groups to form a third cyclic anhydride. That crosslinking mechanism happens in this

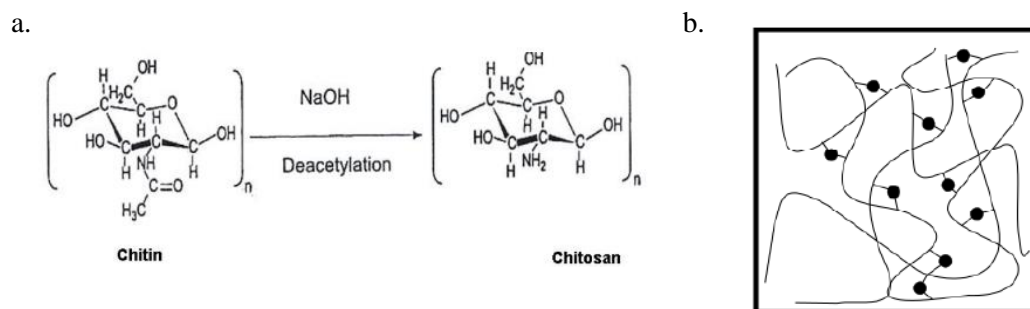


Figure 4 a. Conversion of chitin to chitosan by deacetylation (Okoya *et al.*, 2018). b. Basic representation of crosslink (Khouri, 2019)

3.2 Morphological analysis

The SEM images of the mycelium-based samples were analysed on the raw film, after heat treatment and the crosslinked film. All three sample has complex structures, and they can be used to prove the results obtain tensile and water absorption testing. As evidenced by the presence of a mycelium hy-

pha, the substrate particles are seen to be completely obscured by the mycelium. The substrate particles either loosen due to degradation or are physically twisted with the mycelium. The fungal species grew throughout the whole substrate and created a bonding between the hyphae and the substrate (de Lima et al., 2020). Those bonds have responsible for the mechanical properties of the film. Figure 5a shows the raw mycelium film surface SEM structure. That morphological structure was shown some voids and defects on the surface. That proved the poor mechanical properties of the raw mycelium film (Shakir et al., 2020). Figure 5b shows the structure of mycelium film after heat treatment. According to that structure, the void volume was decreased, and it was filled with material. The heat will be resulted in to increase in the size of cross bonds in these mycelium films. The cross-linkage mycelium film surface structure is shown in figure 5c. That surface structure deviates from the above two structures. According to the image, the cross-linkage between the chitosan can be identified. That linkage was given additional strength to the film.

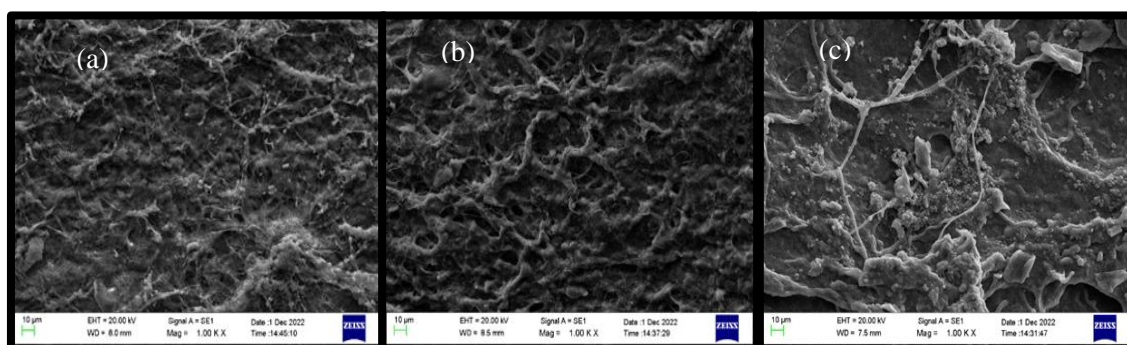


Figure 5: a. SEM image of raw mycelium film b. SEM image of mycelium film after heat treatment c. SEM image of mycelium film after cross-linked.

3.3 Hydrodynamic characterization

Water absorption is an inherent characteristic of materials and influences their other properties. water absorption may affect the use of materials such as leather applications. The heat-treated mycelium film water absorption increases up to 4 hours then after it did not change much. The high-water absorption rate was shown in the first 4 hours and after that, the mycelium film was saturated. That heat-treated mycelium film had a 350% of water uptake rate according to figure 6. That high water absorption can describe using the FTIR analysis of the film. The strong presence of polysaccharides content concerning proteins and chitin may have increased the water absorption ability (Antinori et al., 2020). Hydrophobicity depends on surface roughness and the air gaps on the surface (Antinori et al., 2020). According to the SEM analysis, this film shows the presence of air gaps. That could prove this high-water absorption of the mycelium film. The crosslinked film shows completely different results than the normal mycelium-based film. According to figure 6 the absorption increases up to 7.8 hours and after that small absorption rate is shows. After 24 hours that crosslinked film only absorbs 60% of water. The results proved the effectiveness of the adjustment. The crosslinking using acetic acid creates a difference in the structure of the film. The difference is the presence of acetate ions in the film. The acetate ions influence the hydrogen bonding network in such a capacity as to restrict the diffusion of water molecules through the film (Khouri, 2019). The surface roughness is also adjusted in this cross-linked and it changes the contact angle of the water to the surface. The raw film has high roughness, and the contact angle of water is high, it is also another factor in the difference of this water absorption property. According to the FTIR analysis, the presence of the carbonyl group also can be the reason for this lower contact angle (Khouri, 2019).

The beeswax coating film shows low water absorption than the other two films. It only uptake 28% of water after 24 hours. According to the study of (Naderizadeh et al., 2019) beeswax contains 30% wt. of silica nanoparticles. That particle act as the moisture barrier of the mycelium film. The coating cre-

ates the rollaway motion to the water droplet and increases the hydrophobicity of the film (Naderizadeh et al., 2019). That proved the improvement of the beeswax coating sample. According to the three samples, beeswax coating could use as the adjustment for the decrease in the water absorption property. That is important for leather films.

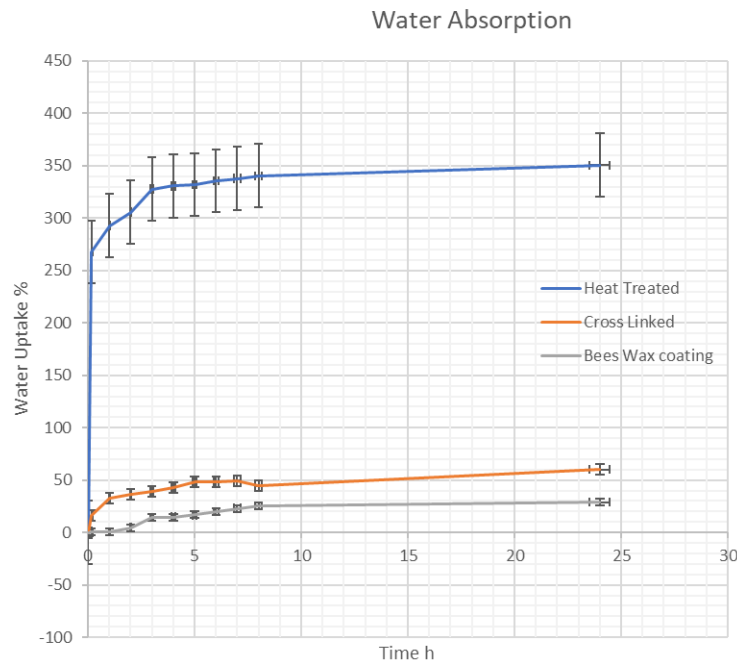


Figure 6: Water absorption results of mycelium-based films.

3.4 Thermogravimetric analysis

The results of the thermogravimetric analysis (TGA) of the samples are presented in Figure 7 a. The heat-treated mycelium film exhibited two significant weight losses. The sample started to lose weight at the outset of the analysis, which commenced at 400°C. An initial weight loss of 4% was observed, which may have been attributed to moisture evaporation from the sample surface (Abdelrazek et al., 2016). The first major weight loss, constituting 10% of the total weight, occurred in the temperature range of 40-100°C, and was attributed to moisture evaporation from the sample (Abdelrazek et al., 2016). The second significant weight loss, comprising 55% of the total weight, was observed in the temperature range of 220-360°C, and was attributed to the structural decomposition of chitin and polysaccharides present in the composite (Kim et al., 1994); (Dang, Wang and Lay, 2018). The bio-composite typically decomposed in the temperature range of 376-498°C (Suryanto et al., 2019) while animal leather typically decomposes at 323°C (Półka, 2019). In contrast, the TGA analysis of the cross-linked film exhibited distinct differences compared to the raw mycelium film. After cross-linking, the chitin was converted to chitosan and bonds were formed, resulting in altered behaviour in the TGA analysis. The cross-linked film also exhibited two distinct weight loss regions, like the heat-treated mycelium film, but with differences in the weight losses and temperature ranges. The first weight loss occurred in the temperature range of 50-100°C and constituted a 50% loss in weight, which was attributed to moisture decomposition (Abdelrazek et al., 2016). The cross-linked film contained 40% more moisture than the heat-treated film. The second weight loss, constituting 14% of the total weight, was observed in the temperature range of 240-310°C and was attributed to the decomposition of chitosan derivatives (Kumar and Koh, 2012). The TGA analysis of the heat-treated film provided evidence of the presence of chitin, while the TGA analysis of the cross-linked film provided evidence of the presence of chitosan, indicating that the deacetylation and cross-linking processes were

successful. However, the mycelium film did not exhibit improved resistance to high temperatures, as the heat-treated film demonstrated better performance with a maximum temperature resistance of 220°C.

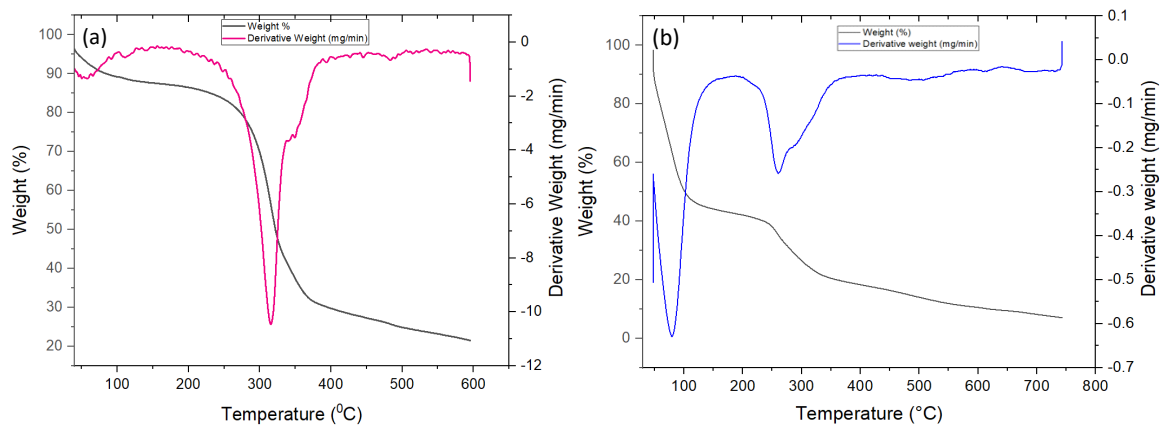


Figure 7: a. TGA analysis of the raw mycelium film b. TGA analysis of the crosslinked mycelium film.

3.5 Tensile strength

The tensile test is an important measure of the mechanical properties of leather production (Meyer et al., 2021). Normal animal leather typically exhibits high tensile strengths ranging from 8-25 MPa (Mutlu et al., 2014). Following ISO 20924 standards, the tensile strength of leather used for shoe manufacturing must exceed 15 MPa (Meyer et al., 2021). Figure 8 presents the stress-strain curve of mycelium films after heat treatment and cross-linking. The tensile strength of the two mycelium films exhibits significant differences. The heat-treated mycelium film exhibited a tensile strength of 0.42 MPa, while the cross-linked film showed a tensile strength of 0.83 MPa. The heat-treated film did not achieve the appropriate tensile strength of animal leather, as the strength of the material depends on the properties of the fibers and the bonding between them (Meyer et al., 2021). SEM analysis of the samples shown in Figure 5 provided evidence for the low tensile strength of the material. Figure 5b shows the weak bonding of the mycelium film, which contributed to its low tensile strength. The citric acid cross-linking process increased the tensile strength of the mycelium film. As indicated by Figure 11, there was a significant difference between the cross-linked and non-cross-linked films. Figure 5c shows the morphology of the cross-linked film, which indicates that the strong bonding contributed to the increase in tensile strength. However, the tensile strength of the *Pleurotus ostreatus* films was not within the appropriate range for use as an animal leather alternative, as indicated by the stress-strain curve. Further improvement of the tensile strength of these films is required before they can be considered as a viable alternative to animal leather.

3.6 Comparison Study

The results gained from the various test can be compared with the existing animal leather. According to previous studies like (Zhang et al., 2021) shown hydrophobicity is a more important parameter in leather. The tanned leather water absorption varied between 150%-250%. (Zhang et al., 2021) according to the water, absorption test the mycelium-based films showed better results than the animal leather. The heat-treated film showed 55% of water absorption and the bees wax-coated film was shown 45% of water absorption. The results gained from the TGA analysis proved another fact about mycelium-based films. The heat-treated mycelium film decomposes between 300-360 °C. the animal leather decomposes around 323 °C (Półka, 2019). According to that comparison, heat-treated mycelium film gave a better decomposition temperature than the animal leather but after crosslinking the decomposition region decrees to 240-310 0C. Tensile strength is the next result going to compare. The

animal leather normally gave 8-25 MPa tensile strength (Mutlu et al., 2014). According to the experiment results the mycelium-based film after crosslinking gave 0.85 MPa tensile strength. The tensile strength comparison proved the mycelium-based films not achieved animal leather tensile properties

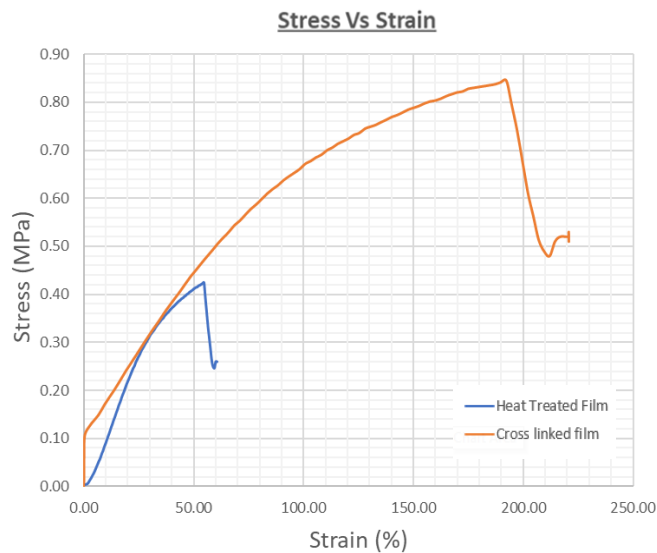


Figure 8: Stress-strain relationship of mycelium-based films.

4. Conclusion

The study aimed to evaluate the thermomechanical properties of mycelium-based films to find a potential alternative to animal leather. The mycelium strain used in the study was *Pleurotus ostreatus*, which can be easily grown under room conditions using sawdust as a substrate. The results showed that the heat-treated mycelium-based film had a water absorption capacity of 350% and a tensile strength of 0.43 MPa. However, these properties were not sufficient to make it a suitable alternative to animal leather. To improve the properties of the film citric acid crosslinking was used. FTIR analysis confirmed the crosslinking process which resulted in improved tensile strength and water absorption. A beeswax coating was then added to the mycelium film to protect it from water and reduce its water absorption even further. However, the tensile strength of the adjusted film was still not within the range of real animal leather. Further improvements are necessary before using the *Pleurotus ostreatus* mycelium-based film as a viable alternative to animal leather. It was found that crosslinking harmed the temperature stability of the film. Despite these limitations, mycelium-based films have the advantage of being completely biodegradable and having no negative impact on the environment, making them suitable for use as packaging material.

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ICSD 029

SELF-NAVIGATION INTERFACE SYSTEM IN COMPLEX BUILDINGS USING MICROCONTROLLER

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Abstract: Self-navigation technology proves to be among the most advanced methods for locating specific positions. However, it remains challenging to accurately determine desired locations within intricate building structures using self-navigation. This research introduces a cutting-edge Self-Navigation and Interface System designed to address the complexities of indoor navigation in diverse environments such as universities, banks, shopping centres, and restaurants. The system leverages microcontroller technology as its control system, featuring a bespoke app interface integrated with microcontroller and Bluetooth modules. The app, accessible via system-installed touchscreens or mobile phones, empowers users to effortlessly select specific location points, streamlining navigation within intricate indoor spaces. A key highlight of the system is its utilization of LED lights; each assigned a unique color, to guide users along the optimal path leading to different destinations. This innovative approach provides clear visual cues enhancing user orientation. Moreover, when transitioning to different indoor locations, the system seamlessly incorporates a map display feature through the app, offering users a comprehensive view of their surroundings. The microcontroller-based control system ensures the synchronization of LED lights and map displays, offering users a user-friendly and efficient means of navigating complex environments. Bluetooth modules facilitate real-time communication between the app and the system, ensuring timely updates and responsive interaction. This research contributes to the advancement of self-navigation systems, particularly in multi-story buildings where traditional navigation solutions may fall short. The seamless integration of microcontroller technology, LED lights, and Bluetooth modules establishes a robust platform for creating an intelligent and accessible self-navigation experience. The proposed system not only streamlines navigation within diverse indoor environments but also enhances user interaction through an intuitive app interface, thus addressing the evolving needs of modern navigational systems.

Keywords: Self-navigation; Micro controller; Bluetooth module; Special application

1. Introduction

A system that can be used to access internal locations inside a building, without the help of others is discussed in this paper. In simple words, like Google map applications used to travel to different places, this system helps to move inside a building or office. The prime objective of this research work is to design a system, which can be used to access any place inside a building, without the help of others and to save time on a job. On the other hand, it can be used to collect the data of the people who entered that particular office as well as the specific services they were expecting. There are several systems available to travel to a particular place such as Global Positioning System, Geographical Information System, Geospatial technology, Global Navigation Satellite System, Satellite-based radio navigation, etc. Even though all these technologies can help in accessing a place, they can't be used inside the building once we enter. Say for example, in a District secretariat office, there can be a lot of services rendered regarding the entire district. But none of the above-mentioned systems can be used to get our desired service from the particular person, but can only be used to access the district secretariat office. The path inside the building, the offices of various officers, the cabins of different services, cash payment counters, etc cannot be identified through the above-mentioned technologies. To address this issue, the system proposed here is developed. Through this system, one can move to the desired place in an office building, without depending on others. With the help of any Android device or a touch screen, the system can be accessed efficiently.

The proposed self-navigation system contains two parts - the application and hardware system. The user can access only the application and it is visible since it is the user interface device. This application can be installed on any Android device.

2. Literature Review

In a recent study, Zhuang, Y et al. (2016) discussed about smartphone-based identification system with Bluetooth low energy. A special algorithm with the combination of channel-separate polynomial regression model, channel-separate fingerprinting, and extended Kalman filtering was used there. This algorithm uses fingerprinting and a polynomial regression model to identify the desired location and the distance between the target point and Bluetooth Low Energy beacons respectively. However, this model is too complicated to fulfill the purpose. Su et al. (2015) developed an indoor positioning system based on the fingerprint method and Kalman filter on Android mobile devices. They created a positioning algorithm, discussed the practical challenges in antenna orientation and signal fluctuation, and eliminated the drawbacks to give a better performance than the work of Zhuang, Y et al (2016). They achieved 90% accuracy in indoor position systems up to 1.2 meters. R. Abhilash et al. (2015) prepared an indoor navigation system to identify the chosen location inside a campus. The task was performed with the help of 2-D (Two-dimensional) and 3-D (Three-dimensional) navigations. Two-dimensional navigation was used for the floor map and Three-dimensional navigation was used for the street view of the campus. But for indoor navigation, the accuracy of this proposed system wasn't enough. Shreyas J Jagtap et al. (2018) developed a technology with the help of smartphones and Wi-Fi. The objective of their work was to buy the product with the quick payment method. On a screen on the shopping mall, a person can select the items he wanted and immediately he can pay as well. But he needs to go to that particular shop and collect the items he ordered. Even though it is expected to reduce the rush and save time, the lack of clarity in the delivery mechanism seems to be the drawback of this model. Berkovich (2014) used different technologies, such as PDR, Wi-Fi fingerprinting, geomagnetic fingerprinting, and map matching for indoor positioning in an industry. To get different measurements, they used a 3D accelerometer, gyroscope, and magnetometer. When a user switches on their smartphone, the navigation engine starts automatically and identifies the starting position by GPS/GNSS receiver. Then the navigation engine operates in tracking mode and the accuracy of the system was mentioned as about 1-2m.

Jung et al. mentioned a global indoor positioning system (GIPS) that gives positioning services in buildings. WLAN-based location fingerprinting is one of the indoor positioning techniques. The im-

portance of WLAN is its wide availability and high resolution of fingerprint-based positioning techniques. Karimul Hoq et al. (2017) developed a mobile tracking system. The main purpose of this system was to track the movement of children by their parents. Parents and children need to install the software on their phones and they need to have the phone with them for this system to function effectively. Willemsen et al. (2014) developed an indoor navigation system based on less-cost smartphone sensors. The Micro Electro Mechanical System sensors such as accelerometer, gyroscope, magnetic field sensor, and barometer are installed in current smartphones. Data obtained from these sensors can be recorded on the smartphone. For example, the air pressure of the barometer gives height details, and due to this, the change in the height of floors can be found during navigation. The algorithms are created afterward with the help of Mat lab software. After testing the post-processing successfully, the algorithms were inserted into the application on the smartphone to test realistic as well as real-time applications. A mixture of sensors with the help of map information in vector format developed autonomous position determination. In every case, an approach with a Kalman filter and particle filter was presented. It displays the position estimate with both methods. Razak et al. (2015) developed an Android-based application for a navigation system for parking in shopping malls. They develop this technology with the help of motion sensors, barcode scanners, cameras, and smartphones. But this will indicate only if there is a vacant parking slot. It will not show how to reach that place. Singhal and Shukla (2012) introduced location-based services with the help of Google web services and Walk Score Transit APIs on Android Phones. This is an application that can be downloaded from the Google Play Store. Up until now, there hasn't been a straightforward way for users to discern complex building layouts. If individuals need to find a path within such structures, they typically have to seek assistance from others. However, this app is highly user-friendly, enabling users to easily navigate complex buildings and reach their destinations without relying on support from others.

3. Methodology

3.1 Hardware Implementation

This section describes the design and implementation method of the self-navigation system. The development process of a self-navigation system is split into two parts namely application development and hardware implementation. These are two discrete phases in developing mobile controlled application system and hardware control structure, combined with a component-based software implementation approach. Automated functions can adjoin the hardware and application with the help of a Bluetooth module. The requirement of the user i.e. the particular place the person needs to go can be found according to the signal sent by the Bluetooth module to the Arduino UNO device (Kunraj et al., 2021). Based on the received signal, the Arduino UNO discovers the path and it will be indicated with the help of a single-colored LED main area path. Different places would be indicated by different colored LED bulbs. According to these particular colors on the path, the user can reach the desired place. Figure 1 briefly shows a sample system - which is a university. Assume that block "A" is the Engineering Technology Department, block "B" is the Bio-system Department, block "C" is the IDS Department, block "D" is for the Auditorium, and block "E" is for the library. At the entrance, an LCD screen would be fixed. It shows all the blocks inside the university. If a person enters the university and decides to go to the engineering technology department, he has to select a particular button. According to his selection, the signal is sent from the screen to the Bluetooth module. The Bluetooth module gets the signal from the user and sends it to Arduino UNO. According to the programming, the controlling device shows the path the user has selected by LED lights. From where he was staying up to the main path. The colored LED lights show the path as shown in Figure 2, along with the time details of how far the place is located and how much time is required to walk accordingly. In the mobile application, there are two buttons; upon clicking the initial button, which displays the pathway to the primary zones such as Engineering Technology, Bio System Technology, or Interdisciplinary Studies, subsequent to that, when the second button is pressed, it reveals the map of the main area.

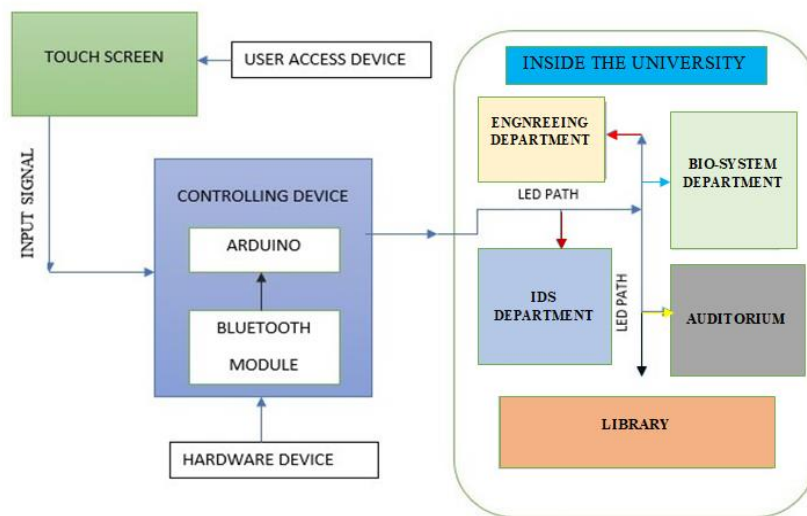


Figure 1: Block diagram of the system.

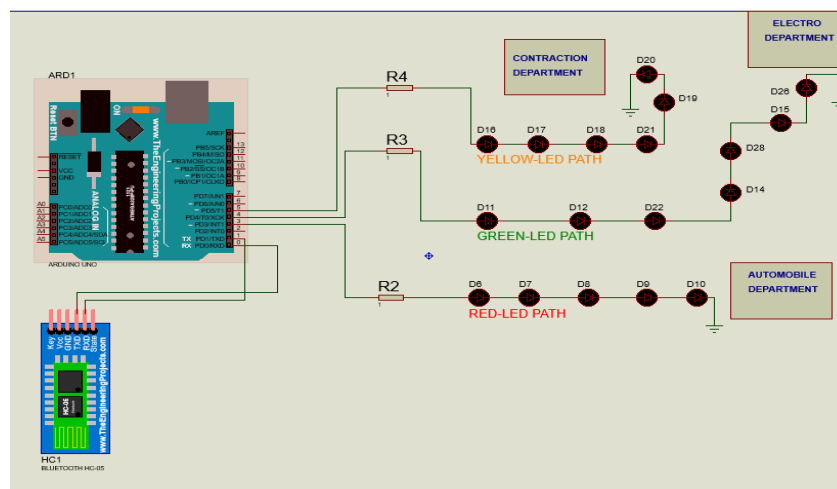


Figure 2: Circuit Diagram.

There are no switches provided to off-the-path indicator LED bulbs. If the time to reach the location is finished, then the LED bulbs will automatically be switched off. In this sense, users need not worry about energy wastage and switching off the LED lights. If the user can not able to reach the required place within the given time there is another option. He can install that application on his smartphone. Based on it, he can activate the LED bulbs again with the help of his smartphone Bluetooth activation method. This method will be useful when he comes again in the future. All the other places can be accessed in the same manner. Other places such as Bio-system Technology and Inter-Disciplinary Studies will also be indicated with LED lights, but an identical color for each location is used.

3.2 Development of the application

Figure 3 shows the application part of the self-navigation system. It was designed using the MIT online app inventor website. The design of the application contains the name of the application, Bluetooth connection, instructions to select the floor and room, the path button, and the map button of the indication path of the particular floor & room, and also the comment to follow the path. There are three floors mentioned as examples in this research work to go to different Departments such as Engineering Technology, Bio-system Technology, and Inter-Disciplinary Studies.



Figure 3: Floor selection in the self-navigation application.

4. Results and Discussion

The results of this application are showcased in detail in this section. When the “1st FLOOR” button is selected to go to the Engineering Technology, it shows the details of the Engineering Technology. The exact place one needs to go can be selected through this application as shown in Figure 4. The rooms or cabins available in the department are shown in the window which opens after the selection of floor-1 where the department is located, and it will indicate the path through which the particular place can be reached.



Figure 4: Department selection in self-navigation application.

According to the design, the Red “**Show the path**” button will show the path for the Construction department, the “**Show the Map**” button will show a map of the Construction Department, the Green “**Show the path**” button will show the path of the Electro department, and the “**Show the Map**” button will show a map of the Electro department, the Blue “**Show the path**” button shows the path of the Automobile department, the “**Show the Map**” button will show a map of the Automobile department

Three sample cases are shown here.

Case -1 When the Red “**Show the path**” button is pressed, the path of the Construction department is indicated in Red LED as shown in Figure 5. If the “**Show the Map**” button is pressed show a map of the Construction Department as shown in Figure 6.

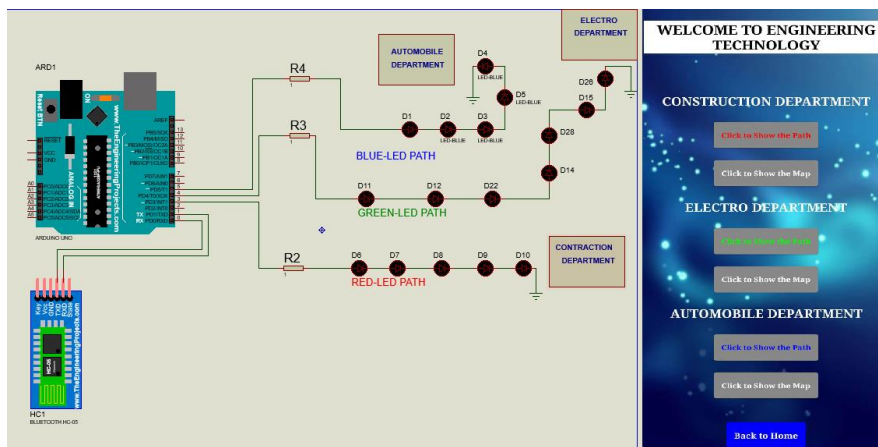


Figure 5: Path shown when the Construction department is selected.

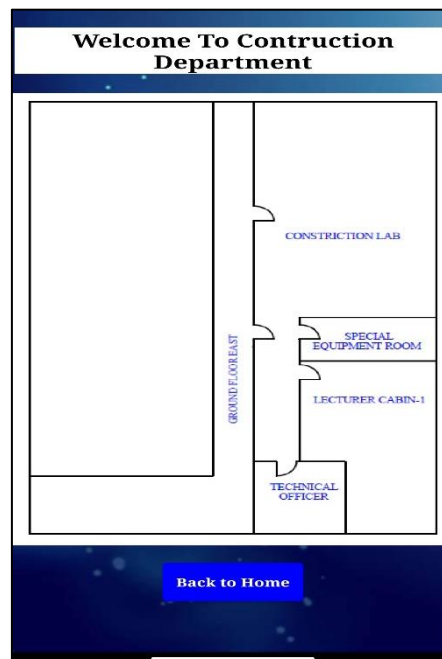


Figure 6: Map shown when the Construction department is selected.

Case - 2 When the Green “**Show the path**” button is pressed, the path of the Electro department is indicated in Green LED as shown in Figure 7. If the “**Show the Map**” button is pressed show a map of the Electro department as shown in Figure 8.

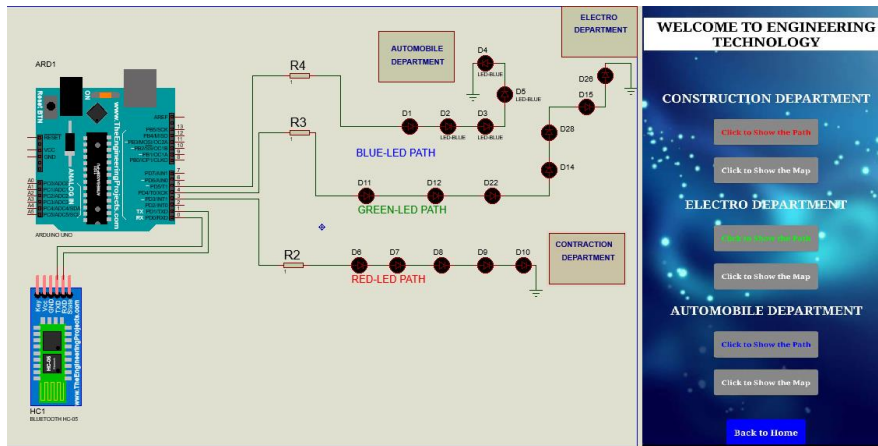


Figure 7: Path shown when the Electro Department is selected.

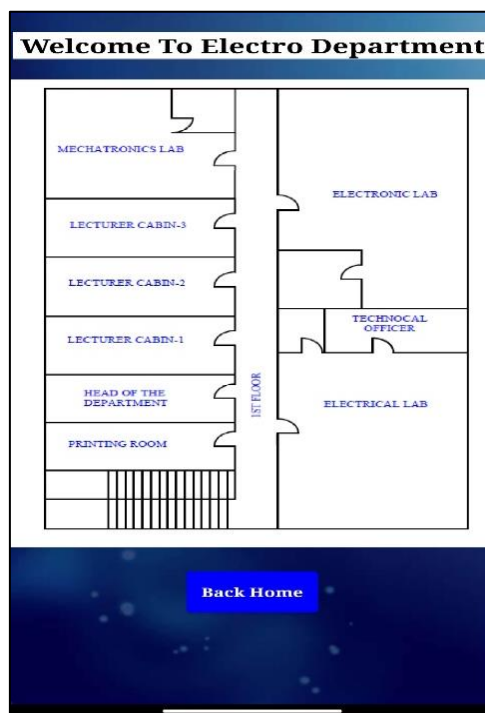


Figure 8: Map shown when the Electro department is selected.

Case - 3 When the Blue **“Show the path”** button is pressed, the path of the Automobile Department is indicated in Blue LED as shown in Figure 9. If the **“Show the Map”** button is pressed show a map of the Automobile Department as shown in Figure 10

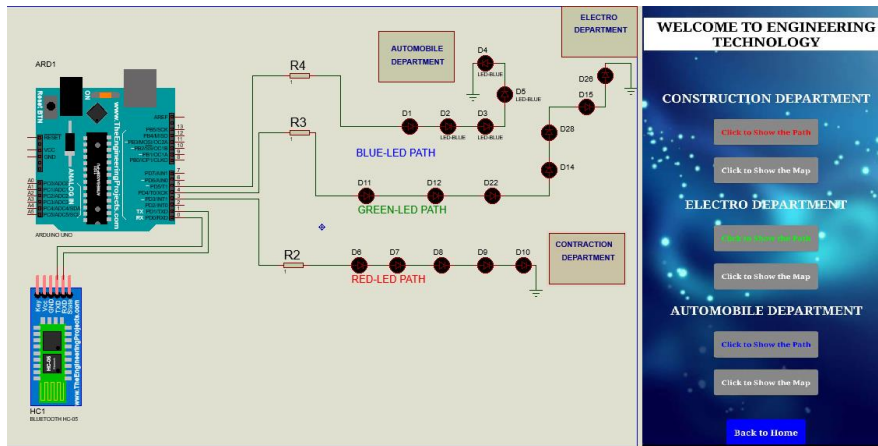


Figure 9: Path shown when the Automobile Department is selected.

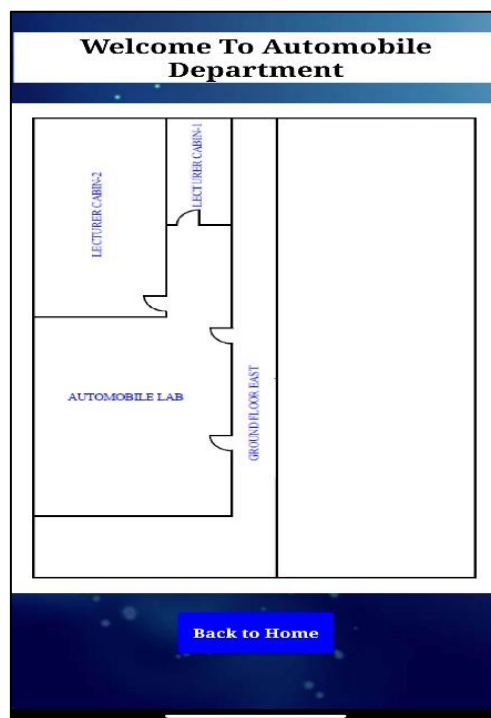


Figure 10: Map shown when the Automobile department is selected.

Similarly, if the 2nd floor button is selected, it would be directed to the Bio-System Technology according to the provided instructions. When the “**2nd FLOOR**” button is pressed, it will directly go to the second page of the application and on that page, the inside sections of the Bio-System Technology can be identified as shown in Figure 11. According to it, one can select the region where he wants to go. Pressing the “**Back to home**” button simply shows the main window page of the system and any other floor can be selected if it is required



Figure 11: Path shown when the Bio-System Technology is selected.

In the same manner, when the 3rd floor button is selected, according to the given instructions, the page shows the Inter-Disciplinary Studies. When the “**3rd FLOOR**” button is pressed, it would direct to different departments on that floor accordingly as shown in Figure 12.

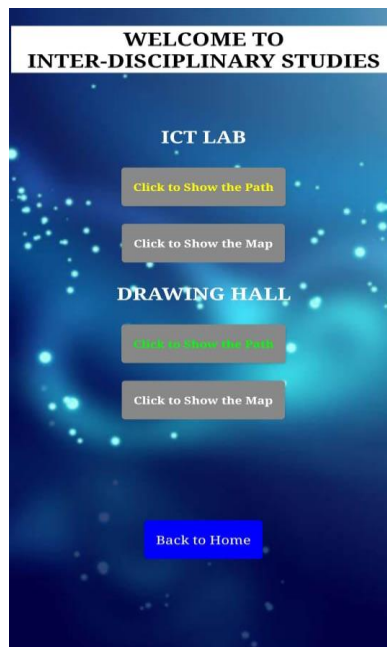


Figure 12: Path shown when the Inter-Disciplinary Studies is selected.

5. Results and Discussion

The implemented method has yielded favorable outcomes by indicating the direction for various location points through the use of distinct LED light colors. This research particularly aids in identifying the location points of both regular buildings and multi-story structures. The system is designed to be user-friendly, allowing anyone to use it without requiring technical expertise. Before selecting an option on the screen, customers have to provide their phone number to the system. Subsequently, when customers choose an option on the screen, they automatically receive a confirmation of their selection on their phone. This feature ensures that customers can verify their selection and provides them with the opportunity to rectify any erroneous choices they may have made.

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ICSD 102

EXPLORING A GENERATIVE AI PARADIGM TO REVOLUTIONIZE DESIGN AND PRODUCTION IN THE BATIK FASHION INDUSTRY

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Abstract: The Sri Lankan batik fashion industry is witnessing a surge in global demand, particularly from foreign tourists seeking traditional batik dresses during their visits. This research addresses the escalating demand and seeks to diminish reliance on human designers through an innovative application of Generative Artificial Intelligence (Generative AI), specifically leveraging Generative Adversarial Network (GAN) technology. At the core of this methodology is the training of a Deep Convolutional Generative Adversarial Network (DCGAN) model. The model is fed a diverse array of new and appealing batik images, devoid of explicit input from fashion designers. Impressively, the DCGAN proves adept at generating novel batik designs, showcasing high-performance outcome. Implemented in Python, the research employs TensorFlow, Keras, and other relevant libraries. The DCGAN model undergoes training on the Google Colab platform, chosen for its compatibility with Graphics Processing Units (GPU), essential for efficient deep learning model training. Evaluation metrics, including accuracy, generator loss, discriminator loss, and overall performance, are visualized using the matplotlib plotting library, offering a comprehensive assessment. The paper delves into encountered limitations and challenges, providing valuable insights. It also offers practical suggestions, guidelines, and future directions to enhance and refine this pioneering automated batik design generation approach. In conclusion, this research presents a promising solution to meet the demands of the growing Sri Lankan batik fashion industry. By harnessing cutting-edge technology, the approach creates captivating designs autonomously, eliminating the need for direct human intervention. This transformative method not only responds to market demands but also opens avenues for further innovation and advancement in the realm of automated fashion design, showcasing the industry's adaptability to technological trends.

Keywords: Batik; Generative adversarial network (GAN); Model; Python

1. Introduction

The allure of Batik arts has transcended borders, attracting a substantial demand from foreign enthusiasts. This vibrant facet of Sri Lanka's culture not only captivates art lovers but also holds the potential to contribute significantly to the country's economic wealth through foreign exchange. The resonance of this demand prompts Batik sellers to embark on a continual journey of artistic innovation, introducing fresh and captivating designs to satiate the preferences of their diverse clientele.

In an earnest endeavour to elevate the quality of their offerings, these sellers are on the lookout for a pool of highly qualified fashion designers and exceptionally talented artists. Their mission is clear: to infuse novelty into Batik arts by sketching and conceptualizing brand-new designs that not only resonate with cultural authenticity but also meet the evolving tastes of a global audience.

Recognizing the need for efficiency and originality, a pioneering research initiative has emerged, proposing the integration of Generative Adversarial Networks (GAN) into the creative realm of Batik design. GAN stands as an exciting innovation in the realm of Deep Learning, having been conceptualized by Ian Goodfellow and his colleagues in June 2014 (Goodfellow et.al., 2014). This transformative technology is poised to breathe new life into Batik art, with an elaborate process involving the utilization of numerous existing Batik images to train the GAN model. Through meticulous optimization and training, the model evolves into a digital artisan, capable of autonomously generating unique and captivating Batik designs. Subsequently, this model seamlessly takes on the role of an artist, automatically crafting fresh Batik images.

The significance of this research study lies in its potential to revolutionize the creative landscape by generating distinctive and appealing Batik styles without the need for manual intervention. This breakthrough spares fashion designers the expenditure of time, intellectual effort, and financial resources typically associated with the generation of new Batik styles. Consequently, this research emerges as the most fitting and innovative approach to foster the growth of today's Batik fashion industry, presenting a vision of efficiency and ingenuity that aligns seamlessly with the demands of a dynamic and globalized marketplace.

2. Literature

2.1 Generative Adversarial Nets

This is the very first paper related to the Generative Adversarial Networks by Ian J. Goodfellow and his colleagues in year 2014. This paper is made the huge influence in the field of deep learning with the exciting recent innovation named Generative Adversarial Network (GAN). They proposed a new deep learning framework for estimating generative models via an adversarial process. They simultaneously trained two models named a generative model G and discriminative model D. The generative model can captures the data distribution, and also discriminative model that estimates the probability that the sample came from the training data rather than the generator G. The training process for generator is to maximize the probability of discriminator making a mistake. Actually this framework is corresponds to a minimax two player game (Goodfellow et.al., 2014. In this scenario G and D are defined by multilayer perceptrons. The whole system can be trained with back propagation. In this research paper demonstrates the potential of the framework through quantitative and qualitative evaluation of the generated outputs.

Deep generative models have less of impact, due to the difficulty of approximating many of probabilistic computations that arise with the maximum likelihood estimation and related strategies, and due to the leveraging the benefits of piecewise linier units in this generative model context. Because of that Ian Goodfellow and his team proposed a new generative model to resolve these difficulties. In this proposed adversarial nets framework, the generative model G pitted against an adversary. A discriminative model that learns to determine whether a sample is from model distribution or data distri-

bution. The generative model can be thought of the analogous to a team of counterfeiters. And the generative model is trying to produce fake currency and use it without detection, while the discriminative model is analogous to the police, trying to detect the counterfeit currency. In this competition both models improve themselves until the counterfeits are indistinguishable.

According to this paper these researchers explore some special case when the generative model generates samples by passing random noises through the multilayer perceptron. They only used back propagation and dropout algorithms to train these both models and sample from the generative model using only forward propagation. According to the paper approximate inference or Markov chain are not necessary for the training purposes.

They trained adversarial nets using the MNIST handwritten digits dataset, the Toronto Face Database (TFD), and the CIFAR-10 dataset (Goodfellow et.al., 2014). According to the paper, the generator used a mixture of ReLU and Sigmoid activations. The discriminator network used maxout activation. Dropout was applied to train the discriminator. The theoretical explanation of the architecture, GAN training algorithm, and the challenges of various approaches to generative modeling were explained in this paper.

2.2 Unsupervised Representation Learning With Deep Convolutional Generative Adversarial Networks

Alec Radford, Luke Metz and Soumith Chintala are the researchers who tried to bridge the gap between the success of Convolutional Neural Networks for supervised learning and unsupervised learning in year 2015 (Radford et.al., 2015). They introduced the class of CNNs and named it as Deep Convolutional Generative Adversarial Network (DCGAN) architecture to success their hope. They used different kinds of image datasets and trained their DCGAN model.

These researchers provide some architecture guidelines to build stable Deep Convolutional Neural Networks. As the first guideline according to the paper is that, replace any pooling layers with strided convolutions (discriminator) and fractional-strided convolutions (generator). Next one is that use batch normalization in the both generator and the discriminator. Next guideline is that remove fully connected hidden layers for deeper architectures. Other guidelines are related to activation functions of the generator and discriminator models. Next guideline is that should use ReLU activation function in generator for all layers expect for the output, which used Tanh. Other thing is that should use Leaky ReLU activation function in the discriminator for all layers.

According to the paper they trained the DCGAN model using three datasets named Large-scale Scene Understanding (LSUN), Imagenet-1k and a newly assembled Faces dataset. Other important fact is that they did not apply any kind of pre-processing to the training images besides scaling to the range of the tanh activation function. All models were trained with mini-batch stochastic gradient descent (SGD) with mini-batch size of 128. All the weights were initialized from a zero centered normal distribution with standard deviation 0.002. In the Leaky ReLU, the slope of the leak was set to 0.2 in all the models. And also they used Adam optimizer in this as well (Radford et.al., 2015).

In this paper they proposed more stable architecture for training Generative Adversarial Networks. These networks learn about the best representation of images for generative modelling. According to the paper, researchers identified some little forms of instabilities were still remaining in this model. As the future work they hope to extend or explore this framework to tackle this form of instability. Other than that they hope to explore it to some other interesting domains like video frame prediction and audio speech synthesis (Radford et.al., 2015).

2.3 Image Generation for Real-Time Application using DCGAN

Dataset gathering for the machine learning is more time consuming activity, because of that new technique called Generative Adversarial Network (GAN) was introduced to do this operation easily. Actually this new technology can predict whether that image was real or not. Actually it can make the huge influence in the field of machine learning. Dr. V. Vijeya Kaveri, V. Meenakshi, Deepan. T, Dharnish. C.M, Haarish. S.L are the researchers and their aim is to generate different type of images which will be useful in some fields like animation and designing. According to this paper was published in year 2021, they used DCGAN architecture to generate new images that are not visible in real dataset. They used MNIST hand written digits dataset with 60,000 images and Anime dataset with 92,300 Anime face images for this research work. According to them DCGAN is the best solution for this case, because of that this architecture previously performed well with unlabelled data samples (Vijeya Kaveri et.al., 2021).

In this model these researchers used both MNIS and Anime dataset as well. They calculated the generator and discriminator loss for every ten batches. Each learning rate is mentioned as the 0.001 and batch size is 128 for both datasets. According to this research paper, they trained the GAN model for less number of epochs, because of that they only reached to the above efficiency. For get some more efficient and best results, they mentioned that size of the epochs should be rise. In other words GAN model should be train to large number of epochs. And also should improve the neural layers and learning rate as well. And also as the future works of this research they hope to develop user interface to be able to provide sample class of images for the discriminator, and then user will be able to generate similar images as the datasets.

3. Methodology

DCGAN was selected as the suitable GAN type for this research work. Because DCGANs are more powerful and give the best results according to the literature. First of all, some batik images were collected. After that these collected images were pre-processed (images were resized to the same size, and BGR images were converted to RGB images) using Python modules.

After these main tasks, there are some main steps followed. The first step is to implement the discriminator model. It has one input layer and 4 hidden layers. It consists of Convolutional 2D layers, Flatten layer, Dropout layer, Dense layer and Leaky ReLU activation ($\alpha=0.2$). The second step is to implement the generator model. It consists of Convolutional 2D Transpose layers, Dense layer (input layer), Convolutional 2D layer, and Leaky ReLU activation ($\alpha=0.2$). The last layer of the generator used Tanh activation. The third step is to implement the DCGAN model using both of the previous models. The optimizer was set as the Adam optimizer ($lr=0.0002$, $\beta_1=0.5$) and the loss function was set as the Binary Cross Entropy. The next step is to train the DCGAN model for the relevant number of epochs.

The next step is testing the DCGAN and analyzing the output results. The next step is to summarize the performance using the accuracy of both models, generative loss and discriminative loss. The final step is to visualize the output results of the trained DCGAN model using the Batik Fashion Generator user interface.

3.1 Software Platforms and Libraries

Google Colab was used as the GAN model training environment. It supports most of the machine learning libraries. The key feature of this environment is free cloud service with free GPU. And also some open-source machine learning-related libraries (TensorFlow, Keras) were used. Python language and its libraries (Matplotlib, Numpy, OpenCV, Tkinter) were used throughout this research. Batik Fashion Generator's graphical user interface was created using the Python Tkinter module. It was implemented in the Python IDE environment. Using this interface, new batik images can be generated according to the relevant batik style. These new styles were selected with some different mod-

els that were saved in each and every 10 epochs in the DCGAN training process. Here testing for each saved model and the most suitable models were selected for the user interface generation purpose.

4 DATA COLLECTION & ANALYSIS

There are 999 batik image dataset used to train the GAN model in this research. The main resource can be mentioned as the Indonesian Batik Motifs Kaggle dataset. This dataset contains 983 (.jpg) images of twenty designs of Indonesia's Signature Crafts. Some suitable images were selected from this Kaggle dataset and the other remaining images were selected from the internet. This Kaggle dataset contains lots of batik design categories. Those are batik-bali, batik-betawi, batik-celup, batik-cendrawaish, batik-ceplok, batik-ciamis, batik-garutan, batik-gentongan, batik-kawung, batik-keraton, batik-lasem, batik-megamendung, batik-parang, batik-pekalongan, batik-priangan, batik-sekar, batik-sidoluhur, batik-sidomukti, batik-sogan and batik-tambal.

<https://www.kaggle.com/dionisiusdh/indonesian-batik-motifs>

The following figure is represented the sample batik images that were used in the research.



Figure 1: Sample Batik Images.

5. RESULTS AND DISCUSSION

This GAN model training takes more hours to train the number of epochs. First of all this model was trained for the 100 epochs using Google Colab GPU. Around 30 minutes were taken to the training process. After that, the model was set to train for the 1000 epochs. However, in this scenario, the model was trained only up to 859 epochs. It took around 4 hours to train. The following figure shows the GAN images in some intermediate epochs related to that training process.

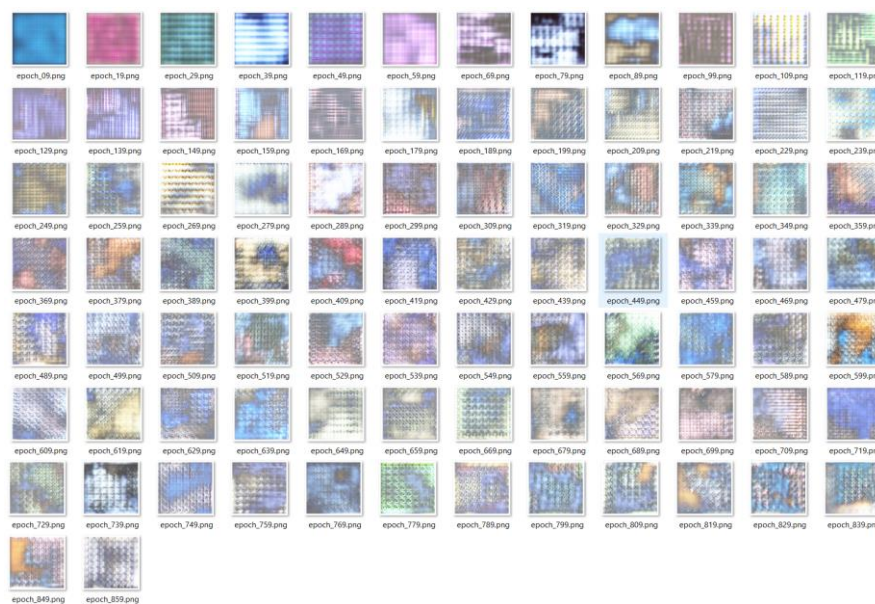


Figure 2: GAN Images in Some Intermediate Epochs Related to First Training Process.

Finally, the model was set to train for the 2000 epochs. At this stage, the model was trained to the 1449 epochs. It is the best effort of the training process. Around 6 hours were taken to the training process. The following figure represents some resultant GAN images in some random intermediate epochs related to that training process.

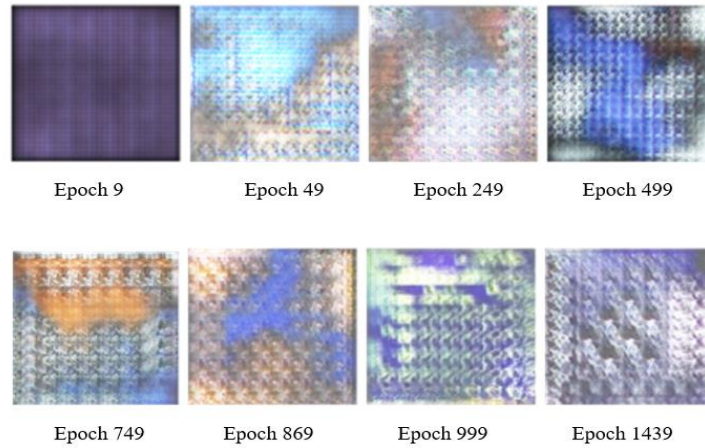


Figure 3: GAN Images in Some Intermediate Epochs Related to Second Training Process.

This DCGAN model was given better results than the original Vanilla GAN (Bermano et.al., 2022). Because the DCGAN used a convolutional layer with stride instead of an upsampling layer. And also another convolution layer instead of a fully connected layer. The following figure shows some best resultant images to prove the best performance of the DCGAN model.

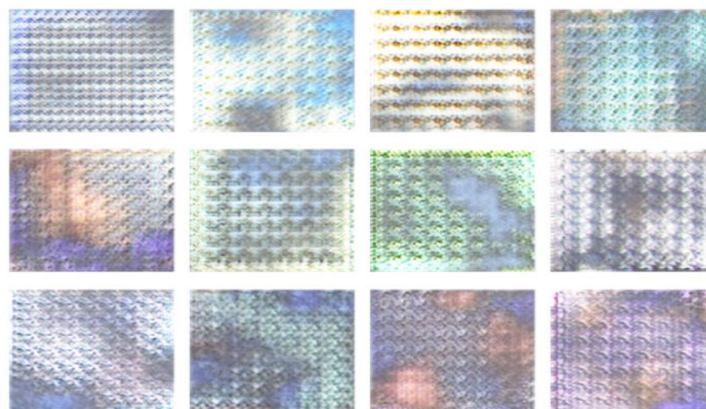


Figure 4: Best Batik GAN Images.

The Batik Fashion Generator user interface can be used to demonstrate the above results. Using the Batik Fashion Generator, the user can select a relevant batik style by clicking on the relevant button, and then the new batik image is visualized. And also the generated batik image can be saved or downloaded to the local computer. The following figures shows the functional results of the Batik Fashion Generator user interface and example of the downloaded batik style.

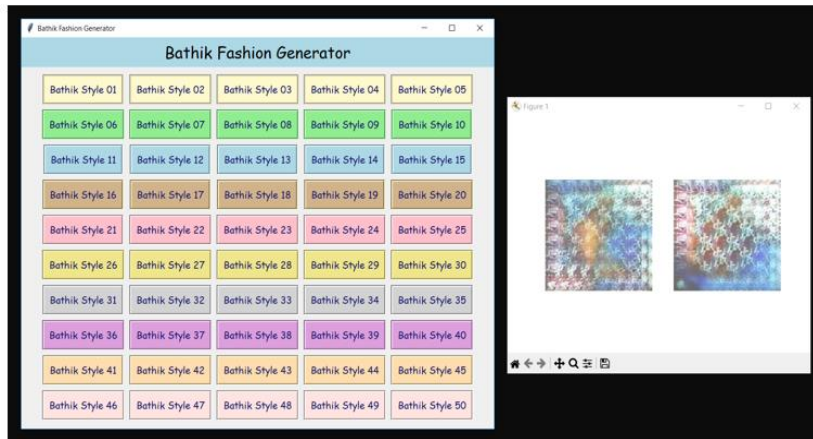


Figure 5: Functional Results of the Batik Fashion Generator UI.

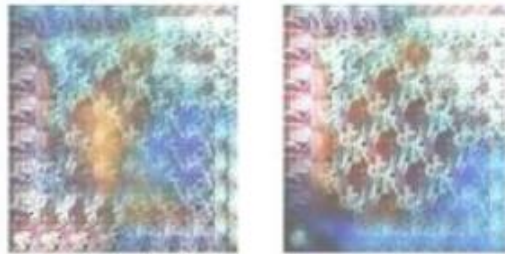


Figure 6: Example of the Downloaded Batik Style.

5.1 GAN Performance Summarization

In this research, GAN performance evaluation is the main part. Because the generator is learning unsupervised learning algorithms, because of that cannot calculate these objective errors go for generated images. Instead of that quality of the GAN should be manually evaluate. That means anyone don't know when to stop training the model without looking at the examples of generated images. For that classification accuracy of the discriminator real and the fake images were periodically evaluated. And the generator models were periodically saved for the each and every 10 epochs. And also while training the GAN model for each and every epoch, it will print the number of epochs count, generator loss, discriminator loss as well.

5.2 Loss and Accuracy Curves

In this research loss curves and accuracy curves were drawn using the matplotlib plotting library during the training epochs. The following figure represents the variations of both generative loss and discriminative loss according to each training epoch.

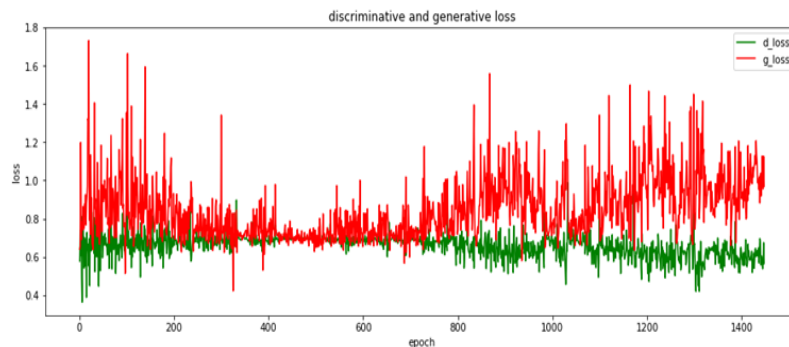


Figure 7: Generative and Discriminative Loss Curves.

The performance of the GAN model was manually evaluated. For that classification accuracy of the discriminator real and the fake images were periodically evaluated while training the GAN model. The following accuracy curves were plotted, according to the above periodic evaluation details. The following figure represents the accuracy curves on real and fake images according to each epoch.

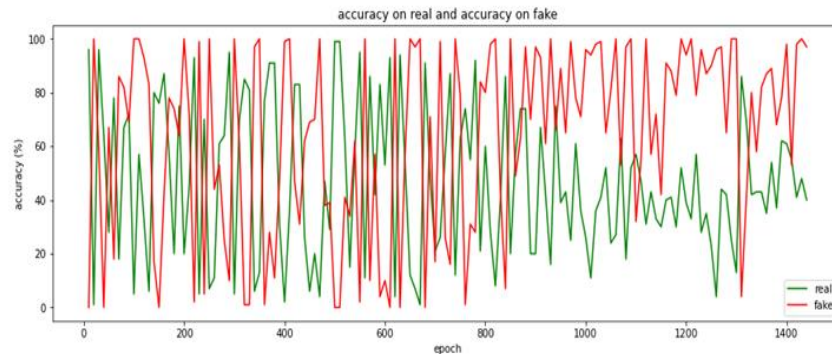


Figure 8: Accuracy Curves on Real and Fake Images.

6 Conclusion

There are some limitations were identified throughout this research. Training process was suddenly stopped because of the GPU usage limits. Then training processes could not continue from relevant stopped point. In these limitations, around 24 hours of time was passed to continue the work. In Google Colab free trial version I felt the above problems. Other thing is that training process was stopped in considerable number of epochs due to the power cuts. And also internet was disconnected during the power cut periods. These are the major difficulties I found in the research. However GAN model was trained for the 1449 number of epochs successfully.

As the future works I can suggest to train the model with huge number of epochs like 10,000 or above. Because of some limitations in free trial version, I suggest Google Colab Pro or Google Colab Pro+ versions to do training process for the huge number of epochs. Other suggestion is that other GAN types (like StyleGAN) (Hitawala, 2018) can be used for the batik dataset and check about the results. Then anyone can do the comparison about the results from each type of GANs.

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ICSD 214

CYLINDRICAL ROBOTIC STICKER PLACEMENT DESIGN AS A SMART SOLUTION FOR APPAREL BRANDING

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Abstract: In the contemporary landscape, the apparel industry stands out as a pivotal contributor to both industrial employment and foreign exchange earnings, playing a significant role in Gross Domestic Production (GDP). With the increasing competition and soaring demand for diverse products, this industry aims to deliver top-notch products to customers on time, creating a seamless experience that captivates and satisfies every fashion enthusiast. This research addresses a critical challenge prevalent in Sri Lanka's apparel industries, where the manual placement of stickers has impeded production efficiency. This study introduces a prototype module featuring a three-axis pick and place mechanism, leveraging a Raspberry Pi-based system. The mechanism, driven by linear actuators, incorporates image processing algorithms to enhance object recognition, resulting in significantly reduced response times. As a key component of the mechanism, a vacuum-driven suction cup is equipped with an 18 mm diameter silicone cup, which facilitates the precise placement of stickers on t-shirts. This innovation represents a novel and programmable solution aimed at automating the sticker placement process within the apparel industry. The significance of this approach lies in its potential to address challenges associated with manual processes, improve recognition efficiency, and ultimately contribute to heightened productivity and uniform quality in the apparel sector. The integration of the Raspberry Pi-based system and the vacuum-driven suction cup showcases a versatile and programmable solution with broad applicability in the field of industrial automation. This design not only automates repetitive tasks but also ensures consistent quality, with the flexibility to adapt to various sticker types. In essence, this automated system accelerates production, minimizes errors, and allows workers to focus on more critical tasks, resulting in a smoother and more effective overall process without damaging the stickers that happened in the manual sticker placing process.

Keywords: Image processing; Linear actuators; Object recognition; Programmable

1. Introduction

In the contemporary landscape, the apparel industry stands out as a pivotal contributor to both industrial employment and foreign exchange earnings, playing a significant role in Gross Domestic Production (GDP) (*Sri Lanka GDP - 2023 Data - 2024 Forecast - 1960-2022 Historical - Chart - News*, no date). Amidst heightened competition and increased demand for product diversification, the apparel industry shoulders the crucial responsibility of consistently delivering high-quality products to end-users within specified timelines. With industries evolving rapidly, the adoption of automation has become a strategic move to curtail labor costs and minimize non-value-added activities (Akram, 2017). Viewed not merely as machines, robots emerge as a paramount means to optimize industrial productivity (Annapureddy, Reddy and Reddy, 2015). Among their diverse applications, the picking and placing of objects stand out as one of the most prevalent tasks. Particularly, pick-and-place robots prove instrumental in mitigating human errors and find extensive utility across various sectors globally, including manufacturing and packaging (Mohanavelan *et al.*, 2019). Typically, cylindrical pick and place robot coordinates and often actuated by linear actuators. Despite these technological advancements, Sri Lankan apparel industries presently rely on manual operations for the majority of sticker placement tasks. This existing method is plagued by challenges such as time inefficiency, labor intensiveness, suboptimal operational accuracy and efficiency, and a high production cost.

2. Problem Identification and Research Gap

Presently, the APPAREL industry has witnessed substantial automation, yet a limited portion involves the use of robots dedicated to the pick-and-place task for stickers on t-shirts. Notably, existing pick-and-place robots in use have been reported to face various issues (kumar, Varman and murugan, 2016). The manual methods employed in this operation may lead to discrepancies in dimensional accuracy, posing operation may lead to discrepancies in dimensional accuracy, posing challenges in delivering products that meet the specified customer requirements. Ensuring the production of high-quality products without defects is a paramount responsibility for the industry. Despite some automated processes, the pick-and-place operation for stickers remains a manual endeavor, resulting in a notable drawback—prolonged processing time. Additionally, research is scarce on pick-and-place robots in the apparel industry, particularly in the Sri Lankan context. While existing scholarly articles provide insights from foreign contexts, their applicability to Sri Lanka may be limited. To bridge this empirical and knowledge gap, this study is undertaken with the primary objective of designing an automated, highly efficient, and accurate mechanism tailored for the pick-and-place process of stickers on t-shirts within the apparel industry.

3. Literature Review

Kato *et al.* (Kato, Onchi and Abarca, 2013) introduced an economical flexible robot arm for pick-and-place tasks, utilizing two DC motors and a single-step motor controlled by an Arduino Uno. The system incorporates polycarbonate and 3D-printed components to attach silicon bars to actuators, employing a wire mechanism for flexible connector control. Despite its capacity to handle objects more than twice its weight, its drawback lies in limited weight-bearing capability.

In another design, Kumar *et al.* (Kumar, 2015) presented a microcontroller-based mechatronic pick-and-place robot, integrating infrared sensors for object detection and employing mechanical and vacuum grippers for handling small and large objects, respectively. Harada *et al.* (Harada *et al.*, 2014) proposed an object placement planner for robotic pick-and-place tasks, involving offline clustering and online orientation planning. The system addresses environmental, object model, stability, extension, and robustness issues.

Pukkella *et al.* (Pukkella, Babu and Abubacker, 2020) introduced a versatile pick-and-place system using multi-affordance grasping and cross-domain image matching. It employs an agnostic object-grasping framework and recognizes objects based on affordance, offering advantages such as model-free operation and generalized functionality.

Dewi et al. (Dewi *et al.*, 2020) presented a 4 DOF pick-and-place arm robot manipulator with inverse kinematics and fuzzy logic controller. The robot demonstrates precise motion for harvesting tomatoes, addressing challenges related to grip, trajectory, and sensor-based control. This robotic manipulator, comprising four flexible links along the x, y, and z axes, employs inverse kinematics and a fuzzy logic controller (FLC) for precise and smooth motion (Teodorescu *et al.*, 2016). Specifically designed for picking and placing harvested tomatoes into a packing system, the robot follows a generated trajectory using inverse kinematics to achieve the desired motion. The gripper's smooth movement relies on FLC, integrating input from proximity sensors at the target's starting position and the robot's end-effector. These sensors detect tomato availability and measure the distance between the gripper and the tomato. Gripper parameters, determined through inverse kinematics, ensure optimal positioning for holding the tomato. Data collection involves recording arm robot motion and gripper data. Limitations include errors in position and orientation due to imprecise servo gears and rounding calculation constraints in the microprocessor memory.

3. Materials and methodology

3.1 Materials

The proposed sticker pick-and-place mechanism incorporates a robust array of key components to ensure its effective functionality. At the core of the control system is the STM32 series microcontroller, providing a balance of cost-effectiveness and performance for seamless coordination of the mechanism's operations. The camera module serves as the visual sensor, employing advanced image processing techniques for accurate sticker recognition and placement. NEMA 17 stepper motors drive the precision movement of the mechanism, ensuring controlled and repeatable actions. The pneumatic gripper enhances the efficiency of sticker retrieval, and the power supply unit, along with jumper wires, facilitates reliable power distribution throughout the system. To support smooth movement and durability, ball bearings and threaded bars with T8 screws are integrated. The structural integrity of the mechanism is reinforced through the use of carbon fiber for its exceptional strength-to-weight ratio, while steel box bars contribute to the overall robustness of the frame. This comprehensive selection of components ensures a cohesive and effective sticker pick-and-place system capable of reliable and precise operation.

3.2 Methodology

The improvement process for the sticker pick-and-place method begins with a systematic approach to recognize its existing shortcomings, as illustrated in the flowchart below. Once identified, a viable solution is carefully chosen and outlined. This leads to the development of a conceptual design, providing an initial framework for the proposed enhancements. Subsequently, the conceptual design evolves into a detailed version, incorporating all intricate aspects of the modification. The machine construction phase follows, integrating the established control programming. Wiring and programming are meticulously executed in the subsequent phase to ensure seamless operation. A comprehensive test run is conducted to assess the machine's performance, allowing for any necessary adjustments to be implemented. Rigorous testing ensues to validate the overall performance and output quality of the improved pick-and-place mechanism, completing the refinement process. This systematic progression ensures a methodical and effective enhancement of the existing pick-and-place system.

3.3 Automated system

Operation Steps of Cylindrical Pick-and-Place Mechanism for Sticker Placement on T-shirts:

Initial State: The T-shirts are conveyed along a belt conveyor, entering the work area of the mechanism.

Sticker Picking: Stepper motors controlling the rotation axis (X-axis) and vertical axis (Z-axis) prepare for sticker pick-up and the suction cup, controlled by a servo motor, moves into position above the sticker.

Approach to T-shirt: The rotating axis of the mechanism coordinates to move towards the T-shirt on the conveyor and the vision system, facilitated by a camera module, captures real-time images of the approaching T-shirt.

T-shirt Recognition: Image processing algorithms analyze the captured images to identify the relevant place on the T-shirt for sticker placement.

Sticker Placement: Upon identification of the target location, the mechanism carefully places the sticker on the T-shirt surface.

Return to Initial Position: After successful sticker placement, the mechanism smoothly returns to its initial position for the next cycle.

Continuation of the Process: The system awaits the arrival of the next T-shirt on the conveyor.

3.4 Image Processing Technique

In this project, the design is intricately woven around the practical implementation of image processing concepts, specifically aimed at recognizing and detecting the precise locations for the placement of stickers (Petrovic *et al.*, 2022). The mechanism unfolds in a series of three critical steps: firstly, the acquisition and enhancement of the image of the t-shirt, followed by the recognition of stickers, and finally, the precise control of axes through signal processing.

3.5 Design Mechanism

There were some steps involved in the design of the proposed mechanism such as material selection, specifications of mechanism, conceptual design, and experimental design.

3.5.1 Material Selection

Task 01 is the implementation of parallel manipulators which consists of one arm connected to a common base. This project a rotating axis and a vertical axis were used and each arm was actuated by its own motor due to its cost effectiveness and comfort to installation.

Task 02 involves selecting a gripper for the pick-and-place mechanism. While traditional pick-and-place robots commonly employ pneumatic, vacuum, 2DOF, complex grippers, etc. This project is specifically tailored for the apparel industry's sticker placing activity., a vacuum unit with a silicone suction cup was used for the proposed system due to some major characteristics (Diameter-18mm, working temperature range—100C to 800C).

Task 03 is the selection of a motor. We have opted for the utilization of two stepper motors, specifically the NEMA 17 HS4401 model, distinguished by, a holding torque of 0.1Nm. The decision to employ stepper motors was driven by their inherent simplicity and ease of use.

The task 4 involves choosing a mechanism to control the position of the pick-and-place system. In this context, opting for IR sensors proves to be a judicious choice due to their inherent accuracy in discerning the presence or absence of objects.

Task 05 focuses on choosing a methodology for object detection. The decision to employ a camera module for this purpose is rooted in several compelling factors.

Task 06 is the selection of a controller for the proposed pick-and-place mechanism. Utilizing the Raspberry Pi, a mini-computer with the Raspberry Pi OS, serves as the ideal processor for proposed pick and place mechanism. Its capability to run multiple programs concurrently aligns seamlessly with the demands of our industrial application.

In the context of constructing the body structure for the pick-and-place mechanism, the selection of materials plays a pivotal role. While the prevalent choice for existing Cylindrical pick and place robot-type robots is Aluminum Alloy, with its lightweight and corrosion-resistant properties, this project has opted for a different approach. The use of steel box bars and wood in fabricating the structure is a noteworthy alternative. An additional option to consider is carbon fiber composite material. Carbon fiber is renowned for its exceptional strength-to-weight ratio, corrosion resistance, and durability. Its use in the pick-and-place mechanism's structure would not only contribute to reduced weight but also enhance structural integrity. The importance of such a material lies in its ability to provide a robust yet lightweight framework, promoting efficiency, agility, and precision in the pick-and-place operation. Moreover, carbon fiber's resistance to environmental factors makes it a suitable choice for applications where longevity and resilience are paramount.

3.5.2 Conceptual designIn this project, an automated pick and place mechanism was designed based on an image processing technique, and the design used three coordinates. The used components were stepper motors, thread bars, connecting bars, baller bearings, and so on. In the first case, developed the following design by Solid Works. After all of the parts were modelled, they were assembled using the necessary constraints and relationships. The components list was completed at the end and the following are the primary components of this system. However, due to the high cost of the entry form and some efficiency issues, the following design was modified.

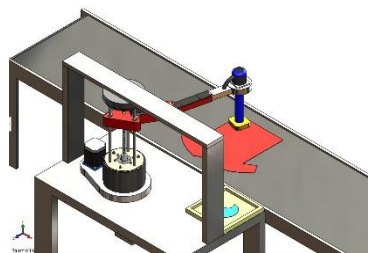


Figure 1: Conceptual Design.

3.5.3 Experimental design

Some modifications were made by considering the previously mentioned shortcomings. In the previous design Z axis was rigid so the camera module was not able to detect the t-shirt due to this rigid structure. Therefore, it was changed by design it simple. Five stepper motors were used in the previous design and it was changed to three stepper motors and a servo motor due to the complexity.

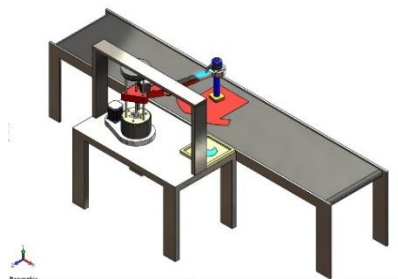


Figure 2: Experimental Design.

The suction cup was one of the special parts of this mechanism and was used as a sticker pick-up device in the vacuum gripper. Suction cups come in a variety of sizes and materials, but most are con-

structured of polyurethane or rubber and can be utilized at temperatures ranging from -500°C to 200°C . In our mechanism, a 50mm diameter, rubber suction cup was used and it was operated by a vacuum. The vacuum was generated through a vacuum pump. This type of suction cup was able to pick up stickers safely and quickly.

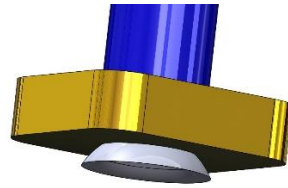


Figure 3: Suction Cup.

4. Results and Discussion

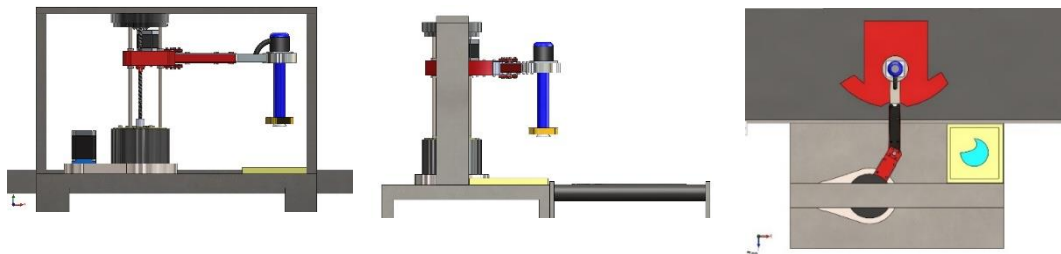


Figure 4: Front View, Side View, and Top View.

Considering the calculations, the motor speed was taken as 800 rpm which is one of the available rated motor speeds.

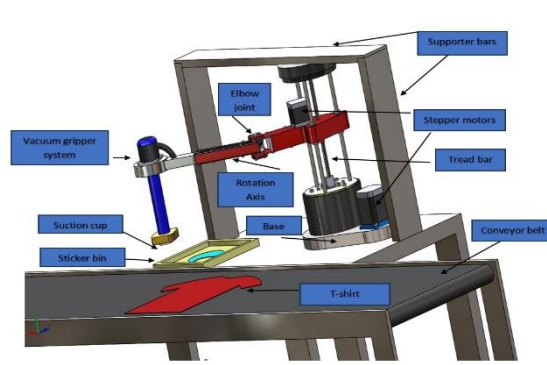


Figure 6: Main Parts of the Proposed System.

The performed calculations for the proposed sticker pick-and-place mechanism are as follows. These calculations helped in designing a robust and efficient sticker pick-and-place mechanism. Depending on the specific details of our design and requirements, some specific calculations were performed.

4.1 Motor Torque Calculation for the rotation and vertical axes

To perform motor torque calculations for two axes, specific values for the load inertia, angular acceleration, and friction torque were considered as follows;

- Load Inertia (I_{load}),
- Angular Acceleration (α),
- Friction Torque (T_f).

$$I_{load,X}=0.001\text{kg}\cdot\text{m}^2, I_{load,Z}=0.0012\text{kg}\cdot\text{m}^2$$

$$\alpha_X=10\text{rad/s}^2, \alpha_Z=12\text{rad/s}^2$$

$$T_{f,X}=0.05\text{Nm}, T_{f,Z}=0.03\text{Nm}$$

For the Rotation Axis (X-axis):

$$T_X=I_{load,X}\cdot\alpha_X+T_{f,X} \quad (1)$$

$$T_X=(0.001\text{kg}\cdot\text{m}^2)\cdot(10\text{rad/s}^2)+0.05\text{Nm}$$

$$T_X=0.01\text{Nm}+0.05\text{Nm}=0.06\text{Nm}$$

For the Vertical Axis (Z-axis):

$$T_Z=I_{load,Z}\cdot\alpha_Z+T_{f,Z} \quad (2)$$

$$T_Z=(0.0012\text{kg}\cdot\text{m}^2)\cdot(12\text{rad/s}^2)+0.03\text{Nm}$$

$$T_Z=0.0144\text{Nm}+0.03\text{Nm}=0.0444\text{Nm}$$

Certainly, selecting stepper motors involves considering torque requirements, step resolution, and other factors. Here are suitable specifications for two stepper motors connected to each axis based on the provided calculations:

Stepper Motor for Rotating Axis (X-axis)

Torque (holding torque): 0.1 Nm

Step Resolution: 1.8 degrees/step (200 steps/revolution)

Voltage: 12 V

Current: 1 A

Motor Size: NEMA 17

Driver Type: Bipolar

Maximum Speed: 300 RPM

Connection: 4-wire configuration

Stepper Motor for Vertical Axis (Z-axis):

Torque (holding torque): 0.05 Nm (Considering lower torque requirement)

Step Resolution: 1.8 degrees/step (200 steps/revolution)

Voltage: 12 V

Current: 0.5 A (Considering lower torque requirement)

Motor Size: NEMA 17

Driver Type: Bipolar

Maximum Speed: 400 RPM

Connection: 4-wire configuration

4.2 Linear Motion Calculation for Rotation Axis (X-axis):

Stepper Motor Step Resolution: 1.8 degrees/step

Lead of the Thread Bar (assuming a lead screw): 4 mm

The linear distance moved per step (D_{step}) is given by the formula as follows;

$$D_{step} = \frac{Lead}{Step\ Resolution} \quad (3)$$

$$D_{step} = \frac{4\text{mm}}{1.8\text{degrees/step}} = 2.22\text{mm/step}$$

For Vertical Axis (Z-axis):

Stepper Motor Step Resolution: 1.8 degrees/step

Lead of the Thread Bar (assuming a lead screw): 2 mm

$$Dstep = \frac{2\text{mm}}{1.8 \text{ degrees/step}} = 1.11\text{mm/step}$$

4.3 Suction Cup Force Calculation

The force required for the suction cup to pick up and hold the stickers depends on several factors, including the weight of the sticker, the friction between the sticker and the surface, and the vacuum pressure generated by the vacuum unit.

Sticker Weight (W_{sticker}) in Newtons.

Coefficient of Friction (μ) between the sticker and the surface.

Vacuum Pressure (P_{vacuum}) in Pascals.

Suction Cup Diameter (D_{cup}) in meters

$W_{\text{sticker}}=0.1\text{N}$ (assuming a small sticker).

$\mu=0.5$ (typical value for smooth surfaces).

$P_{\text{vacuum}}=50,000 \text{ Pa}$ (a common value for vacuum systems).

$D_{\text{cup}}=0.02 \text{ m}$ (20 mm, a typical suction cup diameter).

Then, the force required to pick up and hold the sticker was calculated:

$$\text{Force to Lift} = W_{\text{sticker}} + \mu \cdot P_{\text{vacuum}} \cdot \pi \cdot \left(\frac{D_{\text{cup}}}{2}\right)^2 \cdot g \quad (4)$$

Where:

g is the acceleration due to gravity (9.8 m/s^2).

$$\text{Force to Lift} = 0.1 \text{ N} + 0.5 \cdot 50,000 \text{ Pa} \cdot \pi \cdot \left(\frac{0.02 \text{ m}}{2}\right)^2 \cdot 9.8 \text{ ms}^{-2}$$

Force to Lift $\approx 0.9 \text{ N}$

Therefore, the calculated force required to pick up and hold the sticker is approximately 0.9 N.

4.4 Cycle Time Calculation

For X-axis:

Stepper Motor Speed: 100 steps/second

Total Rotation: 360 degrees

Step Resolution: 1.8 degrees/step

$$N_x = \frac{360}{1.8} = 200 \quad (5)$$

For Z-axis:

Stepper Motor Speed: 100 steps/second

Total Vertical Distance (if the vertical movement is 50 mm)

Linear Distance per Step (from previous calculations): $D_{\text{step}} \approx 1.11 \text{ mm/step}$

$$N_z = \frac{50}{1.11} = 45$$

Then, the total number of steps were calculated for both axes:

$$N = N_x + N_z = 200 + 45 = 245$$

$$T_{\text{step}} = \frac{1}{\text{Stepper Motor Speed}} = \frac{1}{100} \text{ seconds/step} \quad (6)$$

$$T_{\text{cycle}} = N \times T_{\text{step}} = 245 \times \frac{1}{100} = 2.45 \text{ seconds}$$

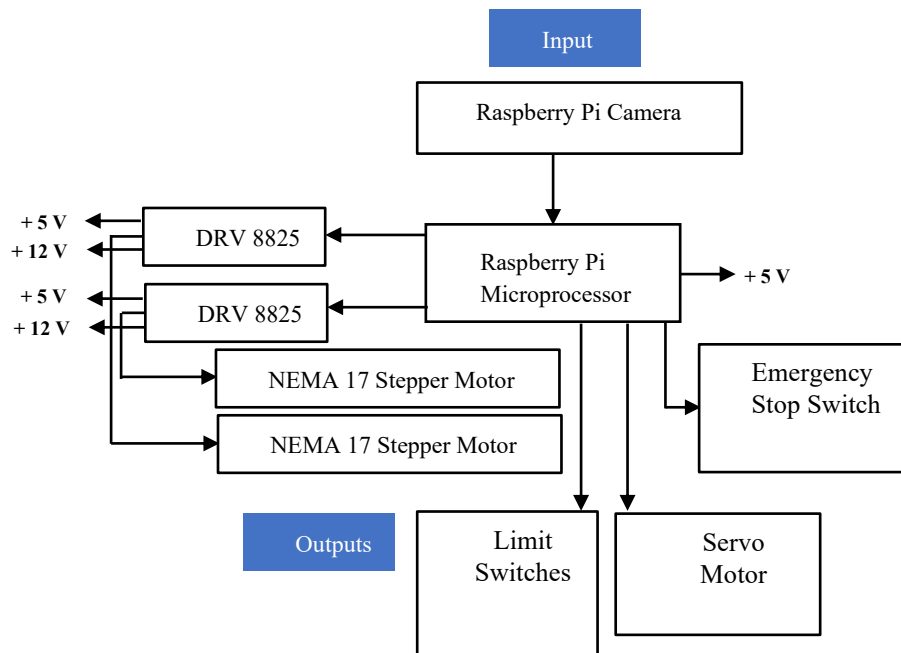


Figure 7: Programming Structure of the Proposed System.

Figure 7 presents the programming structure of the proposed mechanism which represents how the input and output are connected. The central processing unit, often referred to as the "brain" of the system, is embodied by the Raspberry Pi 4 Model B+. This latest iteration features an upgraded 64-bit quad-core processor running at 1.4GHz, complete with a built-in metal heatsink, and dual-band 2.4GHz and 5GHz wireless LAN capabilities. With a generous 40 GPIO pins, the Raspberry Pi interacts with connected devices, and specifically, GPIO pins configured as inputs receive signals from external devices. In this configuration, numerous digital pins facilitated communication between components and the Raspberry Pi board. The control of two stepper motors was managed through the DRV 8825 motor driver, streamlining operation with only two control pins for step and direction. The DRV8825 driver also provides various step resolutions, from full-step to thirty-second-step. Both stepper motors were intricately linked to the A1, A2, B1, B2 pins of the DRV 8825 motor driver board, while the STEP and DIRECTION pins were connected to GPIO pins on the Raspberry Pi board. The programming structure incorporates safety features such as an emergency stop switch, utilizing a normally closed contact connected to an input port on the microprocessor, along with a pre-connected limit switch.

5. Conclusion and Recommendations

Deep learning algorithms can be integrated for better T-shirt recognition, making the system more versatile and reducing manual adjustments. The mechanism can be enabled to pick and place multiple stickers at once for increased efficiency, especially when applying multiple stickers to a single T-shirt. An adaptive gripping mechanism can be developed to handle diverse sticker materials and shapes, ensuring reliability and reducing maintenance needs. IoT capabilities can be incorporated for remote monitoring and control, empowering operators with real-time updates and the ability to make adjustments from a distance. This modification improves system management, maintenance, and responsiveness to evolving production demands

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DESIGN AND MODIFY A MOTOR DRIVEN COCONUT DE-HUSKING MACHINE

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Abstract: The coconut industry is highly contributing to Sri Lankan economy. De-husking of coconut is the process of removing the husk from the coconut. The requirement for skilled labours, time-consuming, and the possibility of accidents are the major challenges faced in the manual de-husking process. Higher nut breakage percentage, improper de-husking, limitations of the crown removal, and non-adjustability to the size of different nuts are the major problems faced by available de-husking machines. To avoid those limitations, the proposed coconut de-husking machine was designed. The objective of the project is to design a coconut de-husking machine to enhance the efficiency of the de-husking process. An electric motor was used as the energy source of the coconut de-husker. The machine consists of two horizontal rollers with a set of sharp teeth. After the coconuts are placed on those two rollers, rubber pills are used to apply force on the coconut for pressing spikes into the husk. When rollers roll, the spikes grip the husk that is tearing from the coconut. The amount of shear force needed for mature green coconut is higher than the dry coconut. The rollers have the optimal number of spikes to de-husk the coconut with the least amount of force. The designed and modified coconut de-husking machine is efficient, productive, user-friendly, ergonomic, environmentally friendly, easy to transport, and more importantly cost-effective in terms of production, maintenance, and repairs. The machine has the facility to count the coconuts by a sensor system. A new design of the de-husking machine is implemented and manufactured to solve those shortcomings, increase automation, and provide operator safety. This modified machine will facilitate to use of renewable power sources in the future to reduce power consumption.

Keywords: De-husking; User-friendly; Productive; Ergonomic; Cost-effective; Environmental friendly

1. Introduction

The coconut industry is one of the main export-oriented food processing industries in Sri Lanka and coconut has been the third most important commercial crop in Sri Lanka. The average annual coconut crop production is around 3000 million nuts, of which around 65% is directly used for domestic consumption (for cooking purposes) and the rest is mainly used by two industries, namely desiccated coconut (DC) (18%) and the rest for producing coconut oil (L.E. Jackson, 2007). The former is export-oriented, and the latter caters mainly to the domestic market.

DC is a dried white, particulate, or shredded product manufactured from the peeled kernel of seasoned coconut under hygienic processing conditions. It is used in the bakery and confectionery industry for fillings for nut bars, cookies, biscuits, sanding of cakes, pies, etc. It is estimated that to produce 1 ton of DC, 8000 nuts are required. The DC industry in Sri Lanka consists of around 66 factories, which are mostly located in the coconut triangle. The capacity of an average factory varies from 30,000 to 40,000 nuts/day. Industry output is around 60,000 tons per annum (Krishnan.R1, 2018). Sri Lanka is the world's second-largest DC producer after the Philippines, sharing about 25% of the global annual DC production (S. Shamsudin, 2018).

2. Problem Identification

Coconut de-husking is the removal of the husk from the coconut. It is one of the hardest and most time-consuming post-harvesting operations because it is done by hand using sharp-edge steel tools either a crowbar or a machete (Č. Mizera, 2017). It is also risky and gives the workers serious health problems such as back pains. During the coconut de-husking process, a high number of workers are used (Anon., 2014). Before extracting oil from the coconut, the coconuts undergo de-husking and cutting processes. There are many traditional methods used to remove the husk from the coconuts. But it makes many problems.

To overcome these problems there is a need to design and creation of the mechanical de-husking device. It is very useful for solving such problems. Presently used techniques require skilled workers and are inefficient in their application. Attempts made so far in the production of de-husking tools were only moderately efficient in replacing manual methods, and not reliable.

The presently used coconut de-husking machine is at an advanced level. It increases the de-husking rate while reducing the de-husking time. Labors are required to put the coconuts into the de-husking machine and it doesn't need a high amount of human energy and increases the economy through de-husking the counts. This machine also reduces and rejects human injuries. More than 75% of the advantages can be gained from this available machine (Anon., 2017). But still, it has some problems, such as sometimes restricting coconuts inside the machine, always breaking a small amount of the coconuts inside the machine, and the machine is not working properly without an electric current. Here a three-phase motor was used to power this machine so only use in special places such as industries and workshops. This machine requires a uniform rpm to its proper working, otherwise increasing and decreasing the rpm creates increased damage. Machine design is also complex as many shafts are used to construct this machine and the cost is higher. The damage to shafts makes it difficult to find and buy those to replace. Therefore, our project is designing an effective and efficient de-husking machine, it reduces these problems through some modifications.

3. Literature Review

The coconut de-husker is most suited in the agriculture field for removing the outer husk of the coconut (Krishnan.R1, 2018). The removal of the husk/ the fiber also used to be involved

in many processes like fiber production in the country (3.75 tons) both white and brown (P.A.Wadile, 2017). The de-husking machine is capable of removing husk from the coconut in an easy way and also time taken for the process is very less when compared to a manual process. For the de-husking process, people use sharp tools which consume more time and also this is a risky process, because a lack of concentration may lead to serious injury (Mohd Azwir Azlan, 2020).

Current traditional methods employed for de-husking the coconut leaves much to be desired. One of the traditional methods of de-husking coconut is using a machete. This is done by using human energy. This method is risky and boring and yet requires skills. The use of the machete contributes a great danger to the worker (R. Navaneethan, 2020).

Based on previous studies, the existing coconut de-husking machine is expensive and it is difficult to be handled (R, 2017). Therefore, the proposed coconut de-husking machine is following a basic design process starting from the identification of needs, conceptual design, embodiment design, and detailed design. Meanwhile, for proof-of-concept testing, the proposed machine concept has been developed to test its functionality and capability.

Many varieties of machinery were developed worldwide and a proper review of all the available machines was carried out looking into all aspects of cost, ease of use, and viability. Some machines were large, power-consuming, unsafe, economical, and time-consuming. All these limitations should be developed and designed through some modifications. Suitable mechanisms should be selected depending on the necessity (L.E. Jackson, 2007).

Today there are many techniques are used for de-husking the coconut. These techniques have many limitations in the process. Despite these techniques being widely used for de-husking. Those techniques are manual de-husking, Pedal operated de-husking, Hydraulic operated de-husking, and Pneumatic operated de-husking (S. Shamsudin, 2018). There are some machines were implemented to de-husk the coconut and The performance evaluated in terms of de-husking capacity, de-husking efficiency, percent nut damage and energy consumption at different angular speeds of de-husking rollers (Krishnan.R1, 2018), (R, 2017), (R. Navaneethan, 2020)



Figure 1.Existing De-husking machine.

4. Material and Methodology

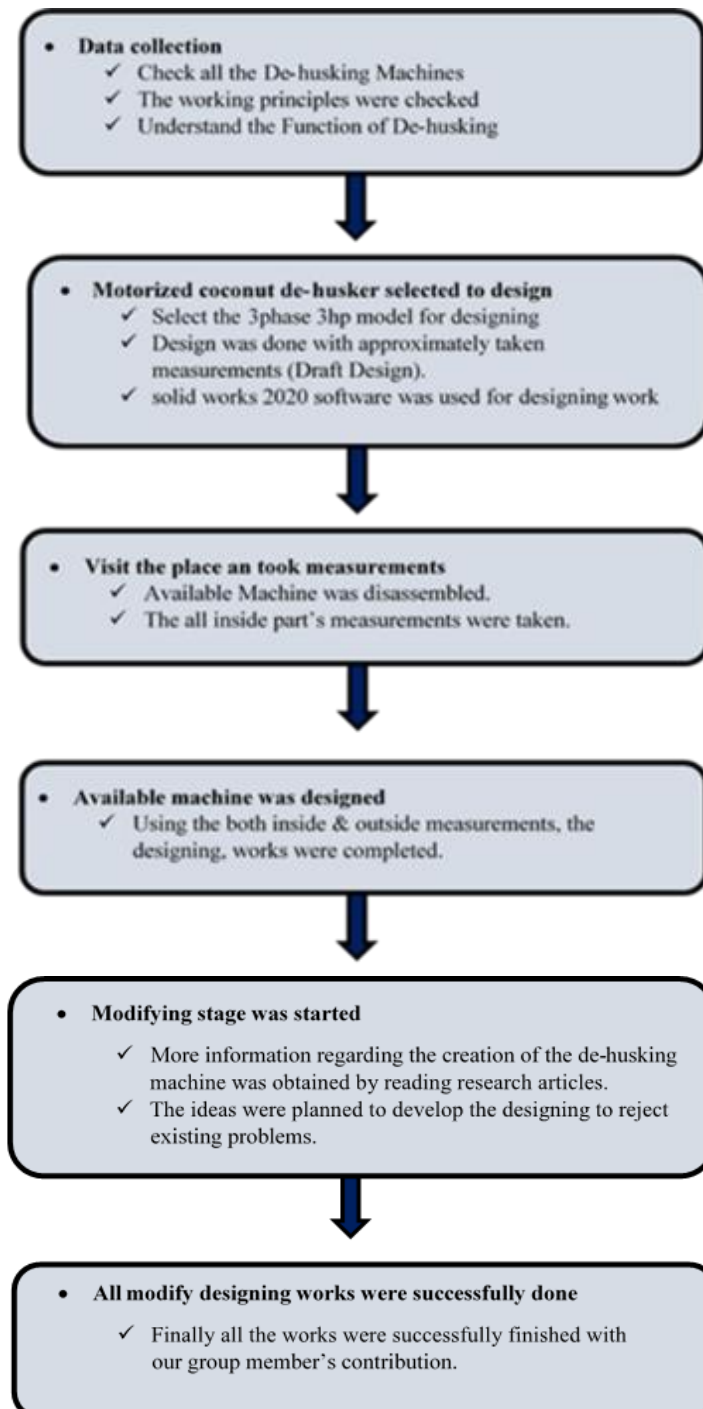


Figure 2: Method sequence.

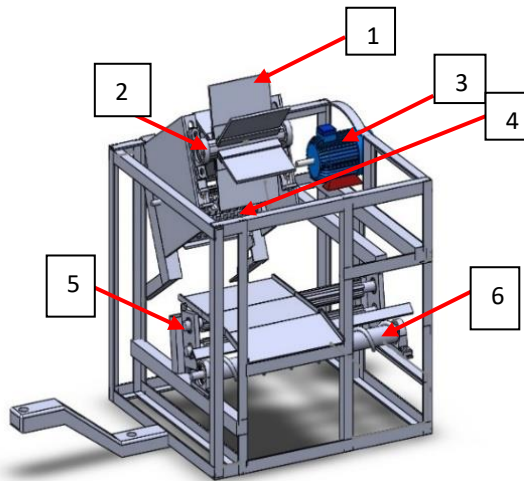


Figure 3. Design of existing De-husker.

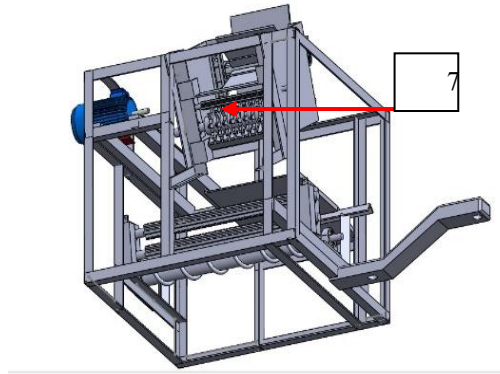


Figure 4. Primary shaft of the machine.

5. Results and Discussion

5.1 3D design of the de-husking machine

The detailed design of the presently used coconut de-husking machine was done using Solid-works software. Due to some shortcomings, modifications have done for the existing coconut de-husker as follows;

Table 1: Parts description

Part No	Description
1	Rubber roller shaft
2	Bearing
3	Electric motor
4	Sprocket shaft
5	Secondary knife shaft
6	Screw conveyer
7	Primary shaft

5.2 Main parts of the machine and their functions

1. Rubber roller shaft: It creates a force on the coconut and helps to hold the coconut until the husk removes from the coconut.

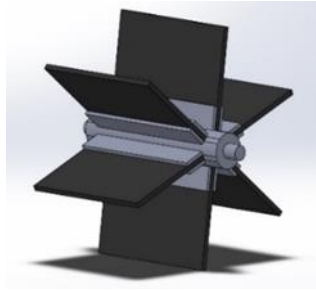


Figure 5. rubber roller shaft.

2. Bearing: It helps to give a rotational force to the rubber roller shaft.

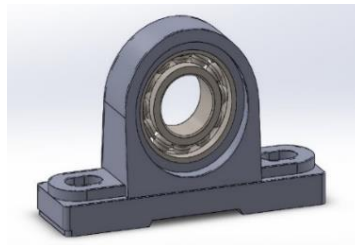


Figure 6. Bearing.

3. Electric motor: It gives power to the whole machine's process.

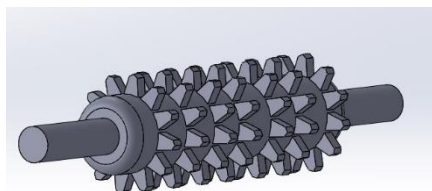


Figure 7. Electric motor.

4. Sprocket shaft: It peels the husk from the coconut.

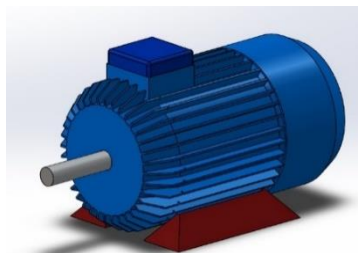


Figure 8. Sprocket shaft.

At the husk-shell contact, separation takes place due to the stronger adhesion between fibers in the husk compared to that between the shell and the husk. The fiber thickness ranges from 20 to 40mm. The tines' dimensions should be chosen carefully in order to achieve optimal coconut penetration. Welding and fasteners can be used to attach the tines to the cylindrical rollers.

5. Secondary knife shaft: It removes the top cone part of the coconut.



Figure 9. Secondary Knife shaft.

6. Screw conveyor: It moves the coconut to the outside.

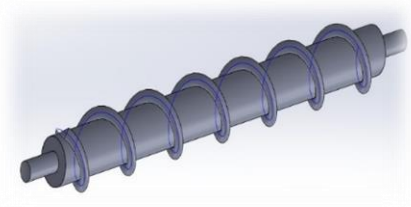


Figure 10. Screw conveyer.

7. Primary shaft: It separates the husk and nut

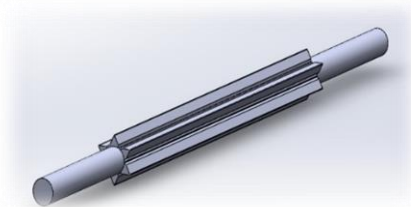


Figure 11: Primary shaft.

5.3 Shafts drawings and their correct measurements

1. Primary Knife Shaft

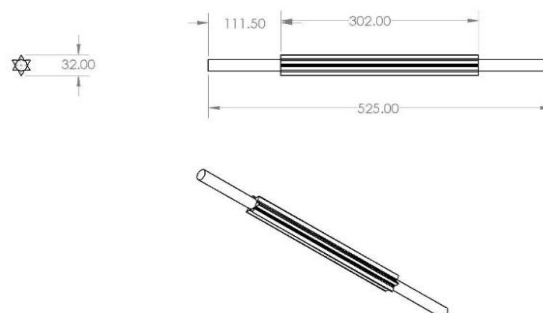


Figure12. Primary knife shaft.

2. Secondary Knife Shaft



Figure 13. Secondary knife shaft.

3. Roller Shaft

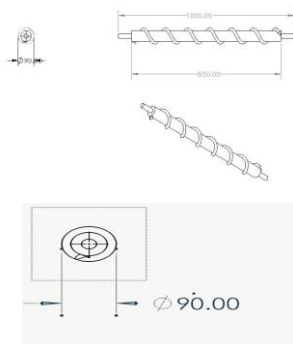


Figure 14. Roller shaft.

4. Sprocket Shaft

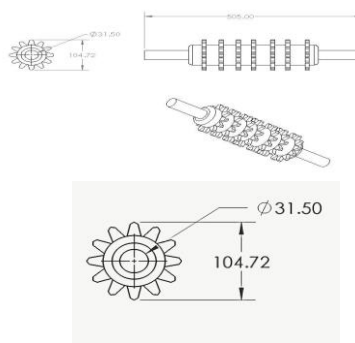


Figure 15. Sprocket shaft.

5.4 The modified design of the coconut de-husking machine

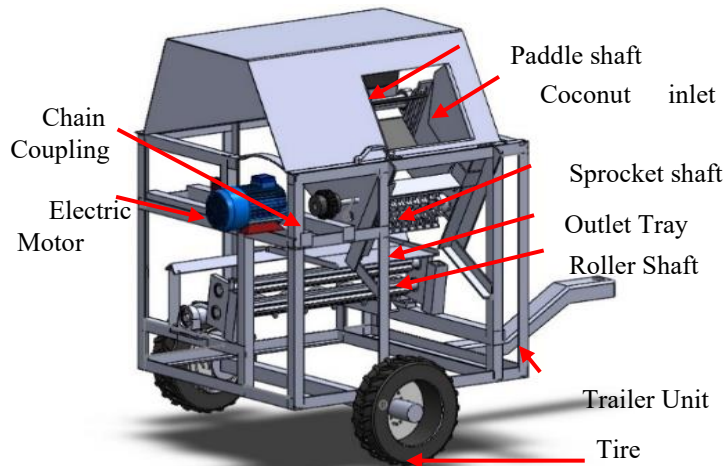


Figure 16. 3D Model of the modified machine.

The detailed Solidworks models of the modified coconut de-husking machine is described in figures. As some modifications, major parts were added such as a VFD device, rubber layers, and collecting bag stands to improve the performance of the existing machine.

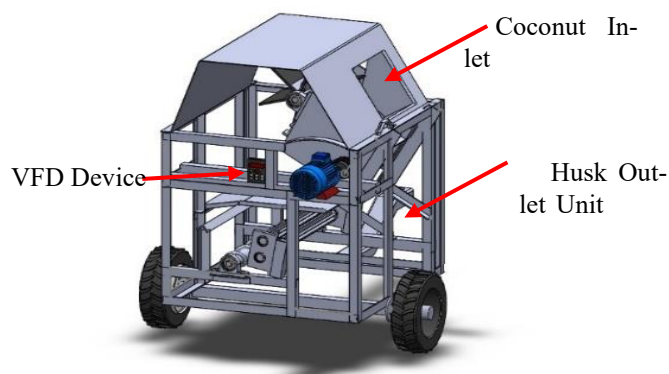


Figure 17. Detailed design of the modified machine.

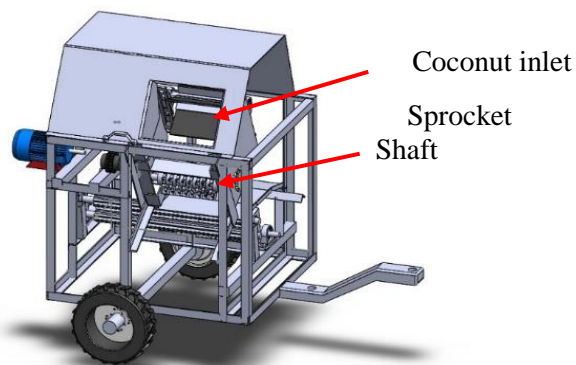


Figure 18. Detailed design of the modified machine.

5.5 Modified parts and functions

1. VFD device

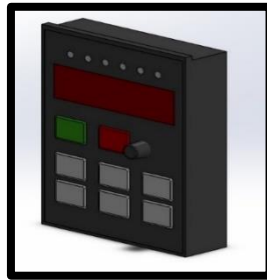


Figure 19.VFD Device.

Any kind of rpm can be produced by this device. Therefore, a proper rpm can be gained and its rpm has not changed. So that the breakage percentage can be reduced and the damage to the coconuts can be eliminated. The VFD device is included in the modified coconut de husker as following.

2. Fixing rubber layers

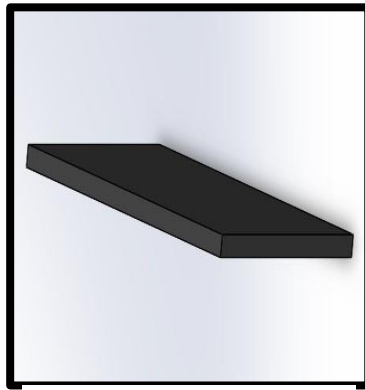


Figure 20.Rubber Layers.

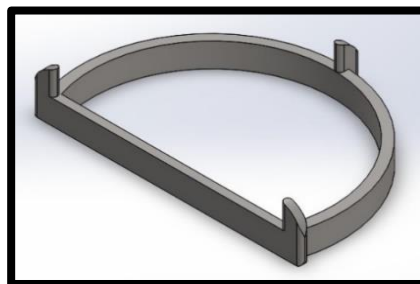


Figure 21: Collecting bag stand.

Coconuts are damaged due to the construction of the roller shaft of existing machine as it is made of metal plates. In some places, coconuts were fallen down and then it was moved from one place to another place. During this situation, coconuts were damaged and broken. Therefore, the rubber layers can be fixed in such kind of places as a solution. The following Figure 21 illustrates that. Then coconuts damaging or breaking percentage can be reduced and the noise can be reduced during the de-husking process.

3. Collecting bag stand

Here, all the de-husked coconut can be easily collected into the bags. Then the coconuts can be easily packed and transported from one place to another place.

6. Experimentation and Testing

Some observations were taken from the existing industrial coconut de-husker as follows;

- The average feed rate was observed as 793 to 797 nuts/h
- The de-husking capacity is varied from 752 to 763 nuts/h.
- De-husking efficiency of the machine was found to be 94.3 to 96.2 %.
- Coconut crown removing efficiency was observed as 93.3 to 93.4 %.
- Percentage of broken nuts was varied from 12% to 14 %.
- Average power consumption of the machine was 0.79 to 0.87kWh.

7. Conclusion and Recommendations

7.1 Conclusion

The objective of design and modification of a motor-driven coconut de-husking machine was successfully achieved to enhance the efficiency of the de-husking process. The design of the already available coconut de-husking machine was successfully completed using solidworks. The modified motor-driven coconut de-husking machine was also designed through some modifications. The number of coconuts de-husked per hour will be increased, the damage percentage will be reduced, and the efficiency of the de-husking machine will be increased in comparison to other machines on the market. The occurrence of accidents during this process has also been minimized. Furthermore, there has been a notable reduction in labour expenses associated with coconut de-husking, which can be optimized even furthermore.

7.2 Recommendations

- There's a possibility of incorporating a variable feed rate control mechanism that can dynamically adjust the feed rate based on the machine's performance and load. This could help ensure a consistent and efficient de-husking process, minimizing downtime due to jams or overloading.
- To reduce the percentage of broken nuts in this coconut de-husking machine, design or operating parameters can be developed. As an example, adjusting the speed, angle, or force at which the nuts are subjected to the de-husking mechanism.
- To reduce power consumption, it's needed to develop or update control algorithms that optimize the machine's operation to reduce energy consumption during start up, operation, and shutdown. Also, the machine design can be implemented to power using renewable energy sources.

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COST-EFFECTIVE RANCIDITY ASSESSMENT IN FRYING OIL: A CUSTOM-BUILT MOBILE APP-INTEGRATED APPROACH FOR THE CATERING INDUSTRY IN SRI LANKA

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Abstract: This study introduces a novel approach to assessing frying oil rancidity, specifically tailored for the catering industry in Sri Lanka, through the development of a custom-built test kit and a mobile application. Deep-fat frying, a prevalent cooking method, demands vigilant monitoring of oil quality to ensure both food safety and economic feasibility. While conventional methods rely on expensive test kits, this research proposes a more cost-effective solution. The approach involves utilizing a Vito oil tester to determine total polar materials (TPM %), a titration method to determine the acid value, and a digital colorimeter to analyze color values ($L^* a^* b^*$) of oil samples. Strong positive correlations were observed between TPM (%), $L^* a^* b^*$ values, and acid values, underscoring the effectiveness of color analysis in assessing oil quality. Based on these results, a mobile app was designed and developed using React Native software and compatible with Android devices. It was developed to predict TPM, acid value, and determine acceptance or rejection for further use of unknown oil samples. In addition to the mobile application, a studio box for image acquisition and a chemical solution that can change the color after the addition of an unknown oil sample, indicating the acid value of the oil sample, were also developed. Finally, the mobile application was validated by comparing TPM (%) values obtained from both the mobile application and the Vito oil tester. Statistical analysis revealed no significant difference ($p > 0.05$) between the TPM (%) values obtained by the two methods. Overall, this study demonstrates that the proposed method offers a precise and cost-effective alternative for accurately detecting rancidity levels in frying oil. By providing a more accessible and affordable solution, it has the potential to enhance food safety and profitability in the catering industry.

Keywords: Deep frying; Reheating; Rancidity; Test kit; Mobile application

1. Introduction

The food service industry, encompassing a wide array of businesses involved in food preparation and delivery outside the home, has seen remarkable growth and evolution over the centuries. Originating with the emergence of restaurants in 18th century France, this industry has become a cornerstone of modern society, catering to diverse culinary preferences and dietary needs (Sebastian *et al.*, 2014).

Among the various cooking techniques employed in the food service industry, deep-fat frying stands out as a popular method worldwide. With its ability to impart delectable flavors, vibrant colors, and crispy textures to food, deep-fat frying has become a staple in kitchens around the globe (Choe & Min, 2007). However, the high temperatures involved in this process trigger complex chemical reactions within the frying oil, leading to hydrolysis, oxidation, and polymerization (Nanayakkara *et al.*, 2020). These reactions can significantly impact the sensory attributes, shelf life, and nutritional quality of both the fried food and the frying oil itself (Schaich *et al.*, 2015).

In the catering industry, where the reuse of frying oil is a common practice aimed at optimizing cost-efficiency while maintaining food quality and safety standards, the assessment of oil rancidity becomes paramount (Esfarjani *et al.*, 2019). Rancid oil not only compromises the sensory properties of fried foods but also poses health risks to consumers (Goswami *et al.*, 2016). Traditionally, food establishments rely on expensive testing methods and kits to monitor the quality of frying oil, presenting financial and logistical challenges, especially in regions facing economic constraints.

Sri Lanka, like many countries, has been grappling with economic hardships exacerbated by the COVID-19 pandemic. With significant budget deficits and restrictions on imports, the hospitality sector, including the hotel industry, has been particularly affected (Ministry of Finance, 2022). In this context, the need for cost-effective solutions to maintain food quality and safety standards becomes imperative.

To address these challenges, the Cinnamon Hotel Management System has embarked on a pioneering initiative to develop a novel custom-built methodology for assessing frying oil quality that is both economically viable and technologically advanced. The objectives of this research endeavor include determination of the fatty acid content of frying oil up to the point of rejection using existing test kits utilized in the hotel industry and development of a test kit capable of detecting rancidity based on observable color changes, eliminating the need for expensive equipment. Final objectives include the design and implementation of a mobile application that utilizes the Lab* color scale to accurately measure and quantify color changes in frying oil, and validation of the developed test kit and mobile application to ensure their accuracy and precision in assessing oil rancidity, thereby safeguarding food quality and consumer safety. By combining scientific principles with technological innovation, this research aims to revolutionize rancidity assessment in frying oil, offering a practical solution tailored to the needs of the catering industry in Sri Lanka and beyond.

2. Materials and Methodology

2.2 Sample Collection and Total Polar Materials Analysis

The experiment focused on analyzing frying oil, specifically refined, bleached, and deodorized palm oil. Samples were obtained from the kitchen of Cheers Pub, located within the Cinnamon Grand Hotel in Colombo. A designated deep fryer was utilized for the frying process, with 7 to 10 liters of oil added for each frying cycle. Throughout the experiment, oil samples were collected at various stages of frying, ranging from fresh to rejected status. Three categories of fried

foods were selected: French fries, chicken, and mixed items. Sampling was conducted periodically during the frying cycle. The decision to reject oil was based on the Total Polar Materials (TPM) %, determined using a test kit (Vito Oiltester, Germany). Each oil sample was standardized to 150 mL and collected at temperatures between 170°C to 180°C, then allowed to cool to room temperature (27°C to 30°C) before being transferred to glass containers. Prior to transport to the laboratory, samples were stored in a chiller at 4°C to maintain their integrity.

2.3 Sample Preparation

The oil samples, maintained at a chilled temperature of 4°C, were transported to the laboratory facilities of the Department of Food Science and Technology at the University of Peradeniya. Oxidation of oil can be controlled with low temperatures (Cristina *et al.*, 2015). Upon arrival, the samples were subjected to a controlled heating process using a water bath (Mettler, WNB14, Germany) set to 60°C until they reached a liquid state. Subsequently, the oil samples were allowed to cool naturally to the ambient room temperature of 27°C within the laboratory environment. Following the cooling process, color analysis of the oil samples was conducted. For this analysis, 20 mL of oil was carefully transferred into small Petri dishes. These Petri dishes had dimensions of 4.5 cm in diameter and 1.8 cm in height, ensuring standardized conditions for the color assessment.

2.4 Colour Analysis of Oil Samples

Collected oil samples were taken into petri dishes (20 mL) for colour analysis. The quantity which was taken to the analysis was an important factor, because the colour of the oil sample was changed with the depth of the oil sample in the container. The instrument used for this purpose was a calorimeter (CS – 10, HangZhou CHNSpec). Prior to analysis, the colorimeter was calibrated with pure white and pure black color tiles to ensure accuracy. The oil samples, contained in Petri dishes, were placed on a pure white paper surface for analysis. Six readings were taken for each oil sample to account for variability, and the mean values of the Lab* factors were calculated. Following the colour and TPM analysis, correlations between the color values obtained and the Total Polar Materials (TPM%) were determined using software, specifically Microsoft Excel 2016. This allowed for a quantitative assessment of the relationship between oil color and its degree of degradation.

2.4. Determination of Acid Value

The acid value of oil samples was determined following AOCS guidelines using titration with 0.05 N Sodium Hydroxide and ethanol-diethyl ether solvent. Phenolphthalein served as the indicator. Results were calculated based on the volume of NaOH required, expressed in milliequivalents of the predominant fatty acid (AOCS, 2013).

Calculations:

$$\%FFA \text{ (g oleic acid/100g)} = \frac{V \times N \times 282}{W} \times 100 \quad (1)$$

Where,

V = Volume of NaOH titrant (mL)

N = Normality of NaOH titrant (mol/1000 mL)

282 = MW of oleic acid (g/mol)

W = Sample mass (g)

2.5. Development of Relationship Between Acid Value and Colour for Frying Oil Quality Assessment

The correlation between acid value (%FFA) and L* a* b* values was investigated to develop a mobile application for assessing frying oil quality. A chemical solution sensitive to free fatty acid percentage was prepared with Sodium Hydroxide, Phenolphthalein, and diethyl ether. Oil

samples were added to the solution in petri dishes, and resulting color changes were analyzed using a digital colorimeter. Correlations between color values and free fatty acid percentage were determined. These findings were instrumental in developing a mobile application for efficient frying oil quality assessment based on color analysis. The exact concentrations of the chemical solution were undisclosed due to confidentiality. This method offers a promising approach for monitoring oil quality in food catering industries, contributing to enhanced safety and customer satisfaction.

2.6. Development of the Test Kit

The test kit comprised four essential components: a studio box, containers for oil handling, chemical solution bottles, droppers (5 mL), and a traveling pouch. The studio box was crafted from box boards and covered with pure white drawing papers to ensure consistent lighting conditions. Its dimensions measured 17 cm × 18 cm × 12.5 cm, providing ample space for conducting tests. The upper wall of the box featured a 3 cm diameter round hole, strategically designed to accommodate samples and facilitate observation. To ensure optimal illumination, two pure white LED light strips, each containing 45 LED lights, were affixed to the inner wall of the box's upper side. These lights were powered by a 9 V direct current connection, delivering uniform and glare-free lighting for accurate analysis. The traveling pouch was specifically designed to securely carry all the components of the test kit. Its design aimed to provide convenience and portability, allowing users to transport the kit effortlessly to different locations for testing purposes.

2.7. Development of Mobile Application

The development of the mobile application proceeded through several key phases:

Planning and Analysis Phase: This initial phase involved comprehensive planning and analysis to define the project scope, objectives, and requirements. It encompassed understanding user needs, identifying features, and outlining the functionality of the mobile application.

Design Phase: In this phase, the visual and structural aspects of the mobile application were designed. This included creating wireframes, user interface (UI) designs, and defining the user experience (UX) flow. Design considerations were made to ensure an intuitive and visually appealing interface for the end-users.

Implementation Phase: The actual development of the mobile application took place during this phase. Based on the design specifications and requirements gathered earlier, the application was built using React Native, a popular framework for cross-platform mobile app development. React Native allows for efficient development across multiple platforms, including Android, which was the target operating system for this application.

Validation and Delivery Phase: Once the mobile application was developed, it underwent validation to ensure that it met the specified requirements and functioned correctly. This phase involved rigorous testing to identify and resolve any bugs or issues. Once validated, the mobile application was prepared for delivery, which included packaging for distribution through the Android platform. The results of the mobile application were validated using randomly selected oil samples and TPM (%) values were determined by both mobile application and Vito oil tester. Results were analyzed using R statistical software.

The mobile application leveraged image analysis, utilizing data correlations among Total Polar Materials (TPM) (%) values, Free Fatty Acid (FFA) (%) values, and Lab* color values. These correlations were derived from data obtained through two different methods: a direct method and a chemical method. The relationships between the results of these two methods were

integrated into the mobile application's functionality, enabling users to analyze frying oil quality effectively. The mobile application development process involved careful planning, design, implementation using React Native, and validation before delivery to users.

3. Results and Discussion

3.1. Sample collection

Frying oil samples were collected in the Cheers Pub kitchen of Cinnamon Grand hotel and the sampling method was selected to minimize the sampling errors. The details of oil samples are shown below. (Table 1). Apart from the oil samples which were fried French Fries, chicken and mixed items fried oil samples were collected separately.

Table 1: Details of frying oil samples

Sample	Details of frying oil samples			
	Frying duration (t/min.)	Frying temperature (°C)	Colour of the oil	Total polar materials (%)
French fries				
(Fresh)	0	176	Slightly yellow	1.5
(Rejected)	230	177	Reddish brown	23.0
Chicken				
(Fresh)	0	176	Slightly yellow	2.0
(Rejected)	245	177	Dark brown	24.0
Mixed food items				
1 (Fresh)	0	176	Slightly yellow	1.5
9 (Rejected)	160	176	Reddish brown	23.0

The alteration of frying oil color from light yellow to dark reddish-brown (Figure 1), can be attributed to various factors. Hydrolysis of oil, leading to the production of free fatty acids, is a significant cause (Schaich *et al.*, 2015). Additionally, the presence of fried food particles adhering to hot pan surfaces can promote overheating, resulting in the formation of minute particles acting as colorants. Another proposed explanation involves phospholipids released from fried foods, contributing to oil browning. These hypotheses are supported by research findings by Atani and Amaguchi in 2016. Understanding these mechanisms is crucial for managing frying oil quality and ensuring the visual appeal of fried foods while avoiding potential health risks associated with overheated or degraded oil.



Figure 1: The color range of frying oil, ranging from light yellow to dark reddish-brown.

As the frying duration increased, total polar materials (TPM %) in the fried oil samples also increased, showing strong positive correlations exceeding 0.90 in linear regression (Figure 2). Specifically, the French Fries fried oil sample displayed this trend, as illustrated in Figure 2.

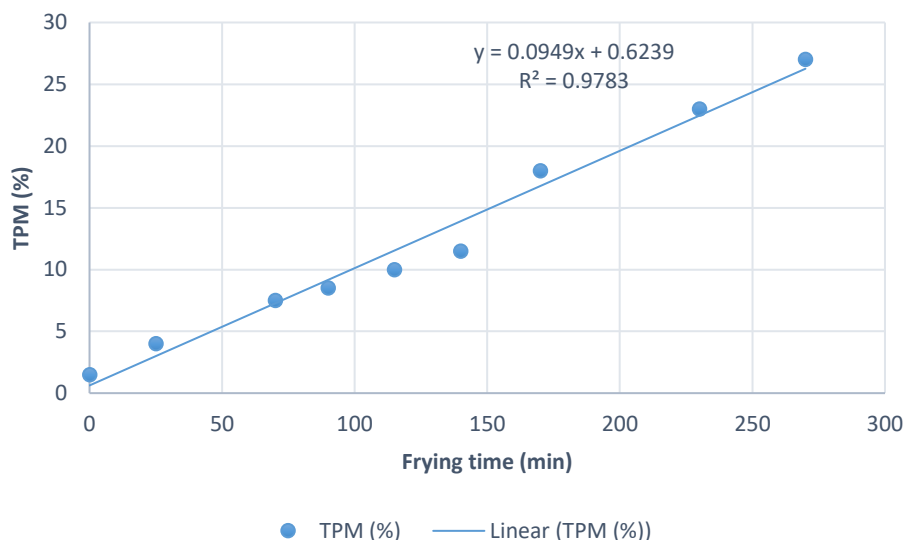


Figure 2: Relationship between Frying Time and Total Polar Materials (TPM %) of Oil Used to Fry French Fries

3.2. Colour of Oil Samples

In the direct method for assessing frying oil quality, a digital colorimeter was employed to analyze the oil color according to the L^* , a^* , b^* scale. The objective was to investigate whether there existed a significant relationship between the color values and the Total Polar Materials (TPM) (%) values of the frying oil samples. Subsequently, a mobile application was developed based on the findings of the color analysis. The L^* -axis of the color space represents lightness, ranging from 0 for black to 100 for white, with shades of grey falling in between. The a^* -axis denotes the green-red axis, while the b^* -axis ranges from blue ($-b^*$) to yellow ($+b^*$). Each color point in the color space is described by its coordinates (L^* , a^* , b^*), with six values recorded for each factor in every oil sample to ensure data accuracy. Color analysis was conducted for each oil category selected after frying French fries, chicken, and mixed food items separately. As one example, the results of the color analysis for French fries fried oil samples are presented in Table 2. After analyzing the color values of oil samples fried with different food types, critical color values were identified (Table 3). These critical values served as rejection points during the development of the mobile application.

Table 2: Results of Color Analysis for Oil Used in French Fries Frying Process

Sample number	Colour analysis of oil which was fried French fries			
	TPM (%)	L^* value	a^* value	b^* value
1	1.5	57.65±0.32	(-4.83) ±0.11	8.78±0.28
2	4.0	57.45±0.10	(-4.50) ±0.06	11.19±0.08
3	7.5	55.43±0.21	(-3.98) ±0.12	13.15±1.01
4	8.50	54.50±0.10	(-3.77) ±0.08	14.91±0.32
5	10.0	55.90±0.14	(-3.48) ±0.06	19.90±0.30
6	11.5	53.31±0.09	(-1.34) ±1.57	27.51±0.27

Sample number	Colour analysis of oil which was fried French fries			
	TPM (%)	L* value	a* value	b* value
7	18.0	49.77±0.07	1.12±0.06	37.71±0.24
8	23.0	44.44±0.05	5.88±0.07	46.75±0.32
9	27.0	39.26±0.36	12.99±0.08	51.51±0.48

The correlation analysis revealed a strong positive relationship between the TPM (%) value and the L*, a*, b* factors, indicating that changes in oil color were indicative of variations in TPM levels (Table 4). These findings formed the basis for the development of the mobile application, which leverages color analysis to assess frying oil rancidity levels.

Table 3: Critical Color Values of Oil at the Rejection Point

Critical colour values of the oil at the rejection point			
Food item	L* value	a* value	b* value
French fries	44.43±0.05	5.87±0.07	46.74±0.32
Chicken	43.73±0.23	10.22±0.15	37.17±0.31
Mixed items	44.37±0.08	2.29±0.34	33.41±0.19

Table 4: Relationship between TPM (%) and Mean L* a* b* Values of Oil Fried with French Fries

Food item	Colour Value	R ²	Equation
French fries	Mean L*	0.9517	y = -0.7115x + 60.7
	Mean a*	0.9823	y = 0.66x - 8.3152
	Mean b*	0.9756	y = 1.8353x + 3.1769
Chicken	Mean L*	0.9539	y = -0.5654x + 59.8
	Mean a*	0.9779	y = 0.6227x - 8.3303
	Mean b*	0.9703	y = 1.6563x + 0.2634
Mixed items	Mean L*	0.9645	y = -0.5146x + 57.268
	Mean a*	0.9634	y = 0.3671x - 6.4248
	Mean b*	0.9590	y = 1.3972x + 3.064

3.3. Acid value of Oil Samples

Free fatty acid percentage was determined according to the chemical method. Acid value expressed as milliequivalents of the predominant fatty acid present in the sample. For plant-based oils/fats oleic acid is commonly used (Collison & Daniels, 2019). L* a* b* values were obtained for the color change observed in the oil sample treated with the developed specific chemical solution. After that the correlations between the acid value (% FFA) and L* a* b* values were determined by using analysing software (Table 5). Then the analyzed data was used to develop the mobile application for determining the acid value in a given oil sample.

Table 5: Relationship between acid value and Mean L* a* b* Values of Oil Fried with French Fries

<i>Food item</i>	Colour Value	<i>R</i> ²	<i>Equation</i>
French fries	Mean L*	0.9772	$y = -72.9x + 61.7$
	Mean a*	0.9519	$y = 72.9x + 61.72$
	Mean b*	0.9506	$y = 107.22x - 42.5$
Chicken	Mean L*	0.9540	$y = -52.9x + 55.8$
	Mean a*	0.9779	$y = 23.8x + 7.01$
	Mean b*	0.9730	$y = 49.08x - 24.99$
Mixed items	Mean L*	0.9545	$y = 23.19x + 4.15$
	Mean a*	0.9634	$y = -63.09x + 61.975$
	Mean b*	0.9590	$y = 23.81x - 28.99$

3.4. Development of mobile application

A mobile application was developed as a novel approach to assess the rancidity level of frying oil, particularly after repeated heating cycles (Figure 3). The application's design was based on the L* a* b* color values of the oil, a common method for quantifying color perception in various industries, including food processing. Leveraging image analysis techniques, the application provides a user-friendly interface for rapid and accurate oil quality assessment. During the development phase, results from both direct methods (such as the Vito oil tester) and chemical methods based on the developed specific chemical solution were utilized to inform the design and functionality of the application. By incorporating data from established techniques, the mobile application aims to provide reliable and consistent assessments of frying oil rancidity, mainly giving TPM, acid value, and acceptability level for further use. Using the React Native framework for the user interface development ensures compatibility with Android operating systems, making it accessible to a wide range of users. The application offers multiple options for capturing images, allowing users to either take new photos or upload existing ones from their device's gallery. This flexibility enhances usability and accommodates varying user preferences.

The results interface of the application (Figure 4) is designed to present comprehensive information to users. It displays color values obtained from the image analysis, along with an assessment of the oil sample's acceptability. The acceptability status is categorized into three stages: fresh, intermediate, or rejected, providing clear guidance on the condition of the frying oil. By leveraging the capabilities of mobile technology, this

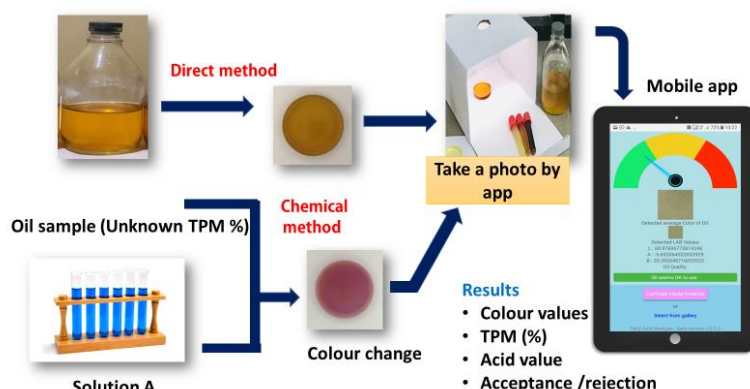


Figure 3: Steps for Determining Oil Quality Using the Mobile Application.

innovative tool offers several advantages over traditional methods of assessing frying oil quality. Its user-friendly interface and compatibility with mobile devices enable easy integration into food service operations, allowing for rapid on-site analysis by any responsible personnel without the need for specialized training.

Overall, the mobile application represents a promising alternative for monitoring frying oil quality, particularly in settings where access to traditional laboratory-based testing may be limited. Its accuracy, precision, and ease of use make it a valuable tool for ensuring food safety and quality in the food service industry.



Figure 4: Screenshots of the Results Interface Showing Three Stages (Fresh, Intermediate, Rejected) of Frying Oil in the Mobile Application.

3.7. Validation of the Mobile Application

The comparison between TPM (%) values obtained through the mobile application and the Vito oil tester revealed no significant difference ($p > 0.05$), as illustrated in Figure 5. This finding underscores the validity and reliability of the proposed method as an alternative for detecting the rancidity levels of frying oil with high accuracy. The results suggest that the mobile application offers comparable performance to established tools like the Vito oil tester, providing a convenient and accessible means of assessing oil quality. This similarity in results validates the utility of the mobile application as a practical solution for food service establishments and culinary professionals seeking to monitor and maintain the quality of frying oil.

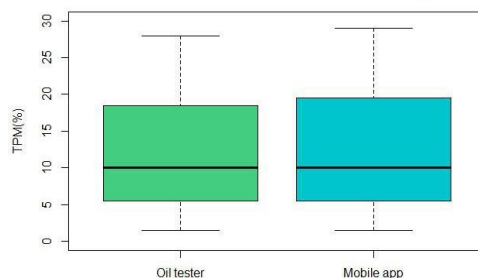


Figure 5: Validated Results of the Mobile Application for Assessing Rancidity Levels in Frying Oil.

4. Conclusion

The test and accompanying mobile application offer a practical solution for assessing the rancidity levels of unknown fried oil samples, particularly in light of increased import costs and economic challenges. This method presents an economically feasible alternative, with the mobile application demonstrating higher accuracy and precision compared to traditional tools like the Vito oil tester. Notably, the test's simplicity enables its execution by any responsible individual in the food catering industry within minutes, without the need for specialized knowledge. The direct method provides swift results, indicating whether the oil is acceptable or requires rejection, while the chemical method can offer deeper insights into the oil's composition if necessary. Overall, this approach offers a rapid and accessible means of ensuring oil quality in food service settings.

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MULTI-FUNCTIONAL PORTABLE DIGITAL TESTER

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Abstract: This communication engineering project presents a multifunctional diagnostic device designed to enhance the efficiency and reliability of communication systems. The device incorporates three key functionalities to address critical aspects of communication infrastructure. Firstly, its cable continuity testing feature swiftly assesses the integrity of various multiwire cables used in communication systems, enabling prompt identification of breaks or faults in cables such as RJ9, RJ11, RJ45, HDMI, and Micro USB. Secondly, the DC router charger measurement capability ensures the correct functionality and voltage output of chargers designed for DC Wi-Fi routers. By safeguarding the stability of Wi-Fi-based communication systems, this feature contributes to consistent and reliable router performance. Lastly, the device offers Landline phone handset error detection, enabling professionals to scrutinize the microphone and speaker components of landline phone handsets. Early detection of faults in these components facilitates timely intervention to address issues affecting call quality, ensuring optimal performance of landline phone systems. Collectively, these functionalities make the diagnostic device an indispensable tool for communication professionals, streamlining troubleshooting processes, minimizing downtime, and ultimately supporting seamless operation within diverse communication networks. Also, this project represents a significant leap forward in communication engineering, offering a comprehensive solution to ensure the seamless and dependable operation of modern communication systems.

Keywords: Communication system; Diagnostic device; Reliability enhancement; Cable charger measurement; Cable continuity testing

1. Introduction

In today's interconnected world, where technology is an integral part of our lives, troubleshooting and diagnosing issues with various electronic devices and cables can be a time-consuming and challenging task. To address this problem, a portable tester has been designed to automate the testing process and provide accurate results quickly. This innovative device combines three essential troubleshooting operations by using an Arduino mega microcontroller board with an Atmega2560 microprocessor. The combination of three troubleshooting-related operations are,

1. Continuity testing in multiple wires.
2. DC charger measurement.
3. Landline phone handset error detection.

The initial operation of the portable tester is centered on continuity testing across various everyday cables, including RJ9, RJ11, RJ45, HDMI, and Micro USB. This versatile device facilitates the seamless detection of faults and breaks in cable continuity. The user-friendly interface allows for simultaneous connection to both ends of the cable, eliminating the need for manual testing and significantly reducing troubleshooting time. Users can effortlessly select the cable type through the device buttons, initiating a continuity check displayed on the device screen. In the event of a non-functional cable, the device promptly signals the issue on the display and emits a distinctive buzzer alarm. This integrated approach ensures efficient and user-friendly cable diagnostics, making the portable tester a valuable tool for swift and effective issue identification and resolution.

The second crucial operation of the tester revolves around measuring the output voltage of DC chargers (0V - 30V) specifically designed for DC Wi-Fi routers. This functionality is paramount in ensuring the correct functionality and voltage output of the chargers, thereby playing a crucial role in maintaining the stability and reliability of communication systems that depend on Wi-Fi routers. The tester's ability to accurately assess the charger's performance contributes to the overall robustness of these communication systems, promoting consistent and reliable operation. The third operation of the portable tester focuses on error testing in landline phone handsets. By connecting the phone handset to the tester, it can assess the functionality of the microphone and speaker. This feature allows users to verify the audio capabilities of their landline phone handsets, ensuring clear communication without any audio-related issues.

The combination of these three troubleshooting operations into a single portable tester offers a comprehensive solution for diagnosing and resolving issues related to cables, chargers, and landline phone handsets. With its microcontroller and display, the device streamlines the testing process and provides users with immediate feedback on the testing results. The block diagram of the designed system is shown in Figure 1.

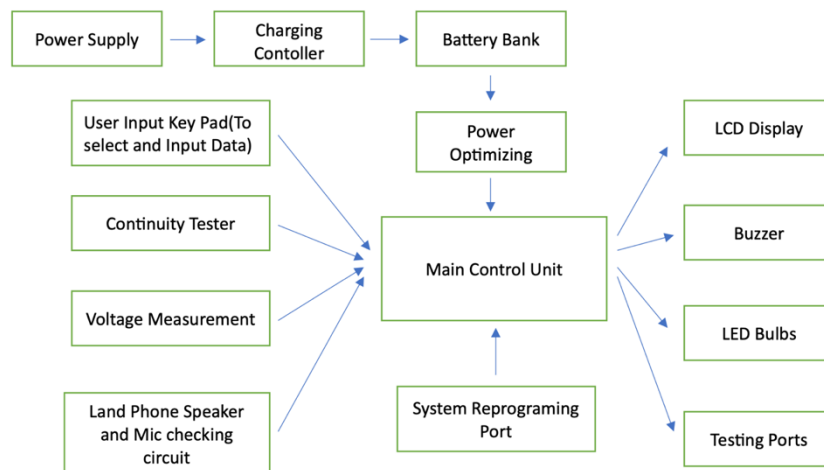


Figure 1: Block diagram of the designed system.

2. Literature Review

(Yang. at el, Oct 2012) provided a comprehensive analysis of short-circuit and ground faults in voltage-source converter (VSC)-based DC networks, proposing fault location methods crucial for effective protective schemes, with a focus on evaluating fault distance and resistance through simulation-based analysis. In their work, (Mansingh. at el, April (2017)) presented a fault detection system utilizing CT Theory, microcontroller calculations, and IoT devices to determine underground cable faults by analyzing voltage variations resulting from faults like short circuits. (Yakub. et al, January 2017) proposed a fault detection system utilizing Arduino microcontroller kits and current sensing circuits to accurately locate faults in underground cable lines, aiding in efficient repair processes and employing potential future enhancements for detecting open-circuited cables. In their research, (Umadevi. at el, April 2018) proposed a fault detection system utilizing switches for fault creation, relay control for fault simulation, and Arduino microcontroller kits interfaced with ADCs and LCDs to accurately locate open-circuit faults in underground cable lines from the base station in kilometers. Introduced a cable fault location sensor utilizing an Arduino-based kit and Varley loop principle, achieving up to meter-level accuracy in detecting underground cable faults, with an achieved accuracy of approximately 85% after calibration and testing (Rynjah. at el, 2019). Designed a circuit using Arduino technology and Ohm's law to identify the faults and abnormalities that occur in the underground cables

It can be noticed that most of these researches were targeted at designing a device for checking the continuity of an underground cable. Some worked on single-wire continuity testing and some worked on multi-wire continuity testing. The difference between the past research and the current research presented here is that past research concentrated on finding the solution to a particular problem while the current research intended to address more than one problem with a single device. In other words, the device is designed to answer the problems that have a high probability of occurring while testing a circuit.

3. Methodology

Technicians currently facing time delays in testing a circuit for any irregularities. This is due to the usage of various equipment for fault finding in the industry, which the technicians are not comfortable with. This paper aims to minimize this problem by providing a single device to check and solve three different problems. The main controller module design consists of testing three functions that are frequently used in industry.

The specifications of the ATmega2560 microprocessor are shown in Table 1. This microcontroller IC is very small, cheap, and has a high clocking speed. It has a larger number of input

ports and output ports for external connections as shown in Fig. 2. The circuit of the multi-functional portable digital tester is designed using this particular IC which is the main controller unit. Different input modules are attached here with the main controller unit for controlling and switching. The display module is also connected to the ATmega2560 microprocessor IC to display the processed information as a visual-based output.

Table 1: Specification of Atmega2560 microcontroller IC

Parameters	Range
Microcontroller	Atmega2560
Operating Voltage	5V
Programmable I/O Pins	86
Clock Speed	16MHz
Flash Memory	256 KB

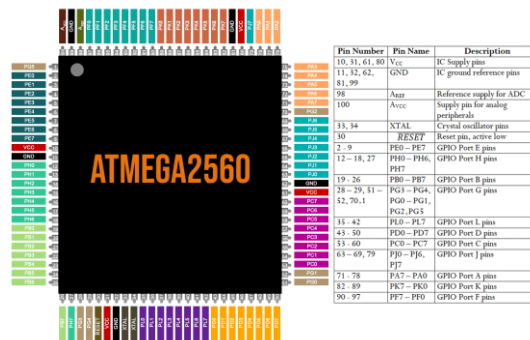


Figure 2: Atmega2560 microprocessor.

3.1 Charging Controller

12 V supply voltage is supplied from the power supply to the battery through the charging controller. The charging controller module is used to cut off the connection between the power supply and the battery once the battery is fully charged. The charging controller protects the battery from overcharging. On one side of the device, there is a green and red LEDs. The green LED indicates the fully charged state and the red LED indicates the charging state of the charging controller. A diode is connected to avoid the discharging of the battery once it is fully charged and disconnected from the supply. The charging controller is shown in Figure 3.

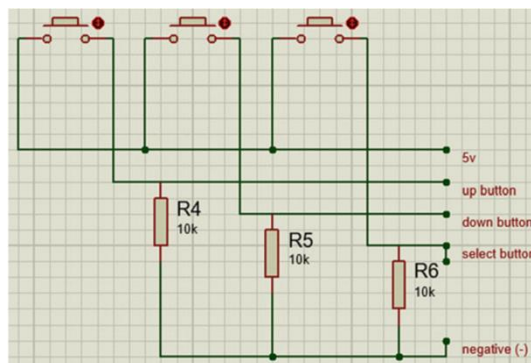


Figure 3: Charging controller module.

3.2 User Input Key Pad

The keypad is created using three push buttons: an up button, a down button, and one select button. 5 V supply is supplied to each button terminal and the last terminal is the signal output terminal. The signal input terminal is connected with a 10k resistor in series. The signal pin is grounded and it is connected with an analog pin of the ATmega2560 microcontroller. The user input keypad is shown in Figure 4.

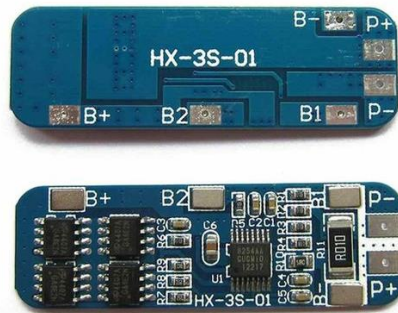


Figure 4: Keypad Array.

3.3 Continuity testing in multiple wires

In this continuity testing circuit using an ATmega2560 microcontroller, two female ports are linked to separate pins. The ATmega2560 generates a signal on one pin, transmitting it through the cable (cable which wants to check the continuity) to the other pin connected to the female port. A buzzer's positive terminal links to another pin, and its negative terminal connects to the ground, while an LED, coupled with a resistor, is connected to yet another pin. When a chosen cable undergoes continuity testing, the microcontroller checks for uninterrupted signal flow. If the circuit displays continuous flow, the LED illuminates, and the display conveys a message indicating that the cable is working properly. In the event of an interruption, the LED remains unlit, a buzzer emits a sound, and the display signals that the cable is not working properly. This integrated system offers a streamlined approach to cable continuity checks, providing immediate visual and auditory feedback, and enhancing troubleshooting efficiency in communication systems. The buzzer and LED circuit are used to indicate the output as sound and visual output as shown in Figure 5.

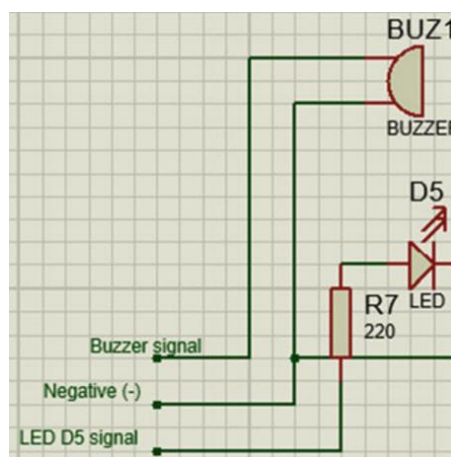


Figure 5: Buzzer and LED indicators.

3.4 DC Charger measurement

Measure the output voltage of DC chargers (0V - 30V) specifically designed for DC Wi-Fi routers by using a DC Voltmeter. According to Ohm's law, the voltage across a resistance is precisely proportional to the current traveling through it. When a full-scale current runs through a basic meter, there is a potential difference across its terminals. That difference is displayed on the voltmeter. This functionality is paramount in ensuring the correct functionality and voltage output of the chargers, thereby playing a crucial role in maintaining the stability and reliability of communication systems that depend on Wi-Fi routers. The visual output is shown in Fig. 6.



Figure 6: Voltage Measurement of a DC Charger

3.5 Landline phone handset error detection

In a simple setup to test the functionality of a landline phone's microphone and speaker, the headphone receiver, which houses both components, is connected to the testing device using an RJ9 cable. Each component (speaker and mic) has two wires, making a total of four wires for both. Focusing on the microphone, one side of the mic is connected emitter of a BC547 transistor, and the other one is connected positive side of the battery through the RJ9 cable. Other circuit connections are shown in Fig.7. By blowing air into the mic, assess its responsiveness and the connected LED serves as a visual indicator of its sensitivity. This uncomplicated setup allows for a quick check of the microphone's functionality by observing the LED response to the blown air.

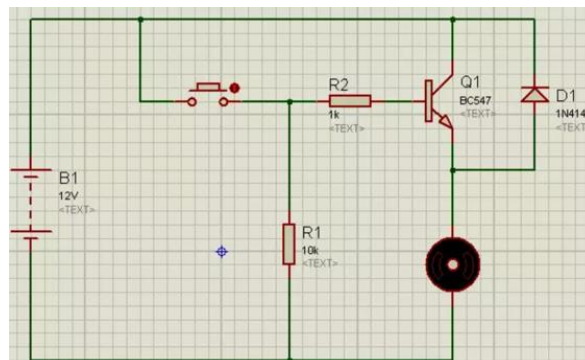


Figure 7: Mic Checking Circuit

To test the functionality of the handset's speaker, a straightforward setup is implemented. One side of the speaker is connected to the signal pin of the microcontroller, and the other side is linked to the ground. The microcontroller generates a noise signal, which is then sent to the speaker. This setup allows for a practical evaluation of the speaker's working condition by observing its response to the noise generated by the microcontroller. The emitted sound serves as a clear indicator of the speaker's

performance, providing a simple yet effective method for testing and ensuring its proper functionality. The circuit is shown in Figure 8.

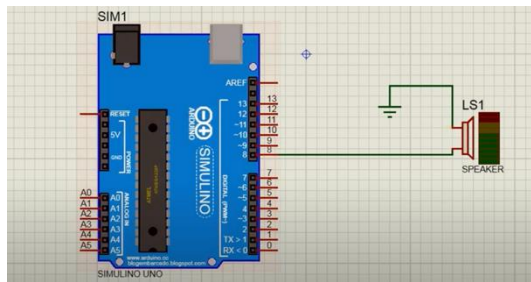


Figure 8: Speaker Checking Circuit

4. Conclusion

In conclusion, this project introduces a versatile portable tester, driven by an Arduino Mega microcontroller with an Atmega2560 microprocessor, designed to address troubleshooting challenges in communication systems. The integration of cable continuity testing, DC charger measurement, and landline phone handset error detection into a single device offers a holistic solution for diagnosing and resolving issues with cables, chargers, and phone handsets.

The project's practical implications are noteworthy, emphasizing the efficiency gained in the field of communication engineering. The seamless integration of multiple testing operations simplifies the trouble-shooting process, reducing downtime and enhancing overall system reliability. The device's adaptability to various cable types and its ability to measure DC charger output contributes to the stability of communication systems, particularly those relying on Wi-Fi routers.

In essence, this project's outcomes underscore the practicality and effectiveness of the portable tester in streamlining communication system maintenance. The immediate feedback mechanisms and comprehensive testing capabilities make it an indispensable asset for communication professionals, ensuring swift issue resolution and optimal system performance.



Figure 9: RJ9 & HDMI Cable continuity checking



Figure 10: Landline Phone Checking.



Figure 11: DC Charger measurement



Figure 12: Both sides of the device.

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**SMALL AND MEDIUM ENTREPRENEUR/CHALLENGES TO
INNOVATION AND INVENTION/ TECHNO-
ENTREPRENEURIAL SKILLS**

ICSD 012

**CUSTOMER'S PERSPECTIVE ON SUSTAINABLE BANKING IN SMALL AND
MEDIUM SECTOR AND POTENTIAL TO DEVELOP SUSTAINABLE FINANCE
PRODUCTS IN SRI LANKA**

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Abstract: Commercial banks expanded their activities to achieve sustainable development through introducing sustainable banking concepts. However, the concept is new to Sri Lankan business community and there is an information gap on sustainable finance opportunities. This study aimed at understanding this gap and providing recommendations to the banking sector. Small and Medium Enterprises (SME) in Western province of Sri Lanka has been selected as the target population. Data has been collected using non-probability convenience sampling method from 150 SME businesses selected through contacts. Awareness about sustainable banking among the respondents is at a low level. Respondent's education level significantly impacts selection of sustainable banking products and willingness to implement sustainability in their organizations. Loans for renewable energy, improving supply chain, purchasing electric vehicles and Deposits where funds will be used by the banks exclusively for sustainable loan products are identified as viable sustainable banking options. Banks can introduce sustainable finance products aimed at establishing UNSDG targets and NDCs such as Green Bonds. To enhance customer awareness, banks may organize awareness programmes for the SME sector. Knowledge on SDG targets and NDCs among the credit staff to be improved as they have been identified as promoters of sustainability concepts. Banks shall develop selling points (enabled access to EU markets, brand reputation, resource efficiency etc.) for sustainable banking products. Recognizing customers who incorporated best sustainable business practices is also recommended. Banks shall promote good ESG practices through defining eligibility criteria to apply for sustainable banking products. For large investments, banks may follow frameworks such as Climate Bond Criteria, but for smaller investments, it is recommended to introduce benchmark criteria. Banks shall introduce low interest loan schemes for sustainability initiatives through accessing internationally available sources of low-cost funds such as the Green Climate Fund.

Keywords: Sustainable development; Small and medium enterprise; Sustainable banking

1. Introduction

Investments of financial institutions (FIs) are often used for activities which cause pollution, destruction of biodiversity, threats to human health and safety or displacement of livelihood. Therefore, FIs have a responsibility to control and minimize those impacts which arise through their business activities. Banks in the world realized that ignoring social and environmental issues could considerably increase their credit risk, reputational risks and repercussions due to non-compliance. Therefore, they have adopted principles of sustainable development into their business activities by introducing sustainable banking concept (Gelder, 2012). Sustainable Banking Network (SBN) explains that, there are three components in the sustainable banking concept; 1. Environmental and Social (E&S) risk management in investment and lending processes 2. Lending/ investment to green industries seeking positive E&S impacts and 3. Managing own E&S footprint, such as greening their facilities and undertaking corporate social responsibility initiatives. (SBN, 2017) In 2016, the Central Bank of Sri Lanka (CBSL) joined the International Finance Corporation (IFC)-supported Sustainable Banking Network (CBSL, 2019). In 2019, CBSL launched Sustainable Finance Roadmap, which aims to provide guidance and support FIs to effectively manage environmental, social and governance (ESG) risks associated with projects they finance, and increase support to businesses that are greener, climate-friendly and socially inclusive (CBSL, 2019). According to IFC, more than 90 per cent of companies globally are SMEs, accounting for more than half of all employment (Gandhi et al., 2018). In Sri Lankan economy SMEs represent a large part, accounting for 80 per cent of all businesses, providing employment generation and contributing growth of GDP in the country (National Human Resources and Employment Policy, 2012). According to the Industrial Development Board, SMEs are, the establishment whose capital investment in plant and machinery does not exceed Rs.4 million (US\$ 42,000) and total number of regular employees does not exceed 50. The World Bank defines SMEs in Sri Lanka considering the number of employees: those with fewer than 49 are small; 50-99 are medium-sized; and those with more than 100 employees are large (Gamage, 2003).

1.1 Justification of the study

Today the world is facing complications such as climate change, biodiversity loss, energy crises and natural disasters. Root cause for most of these problems has been identified as 'development' related environmental degradation. Most of these developments are supported by FIs. The CBSL has launched its Sustainable Finance Roadmap in 2019, but the concept is new to the Sri Lankan. Also, there is an information gap on sustainable finance opportunities in the country and so far, fewer studies have been carried out on customer perspective on sustainable finance in Sri Lanka. Banks introduce new products according to the customer demand. Due to lack of information, customer demand for sustainable finance products is low. Therefore, banks have less or no motivation to introduce new sustainable financial products. SMEs contribute significantly to growth, employment, innovation and social cohesion across the country. They are also a major driver of innovation for sustainable development. In order to accelerate the sustainability transition, further attention should be given to the financial needs of SMEs. Through the present study, it is expected to fulfill the above information gap to a certain extent whilst getting an overview of the customer's understanding about the sustainable banking concept in Sri Lanka that will be useful in operationalizing the CBSL Sustainable Finance Roadmap. The study will also help to identify the sustainable financial products which can be promoted among the SME customers. Furthermore, the results of this study will serve as a basis for additional research in the field of Sustainable Banking.

1.2 Scope of the study

This study has been carried out to understand the knowledge level about Sustainable Banking among the SME customers of Western Province of Sri Lanka. This segment is selected considering the fact that corporate customers have various drivers to implement sustainability such as the pressure from international buyers, stock-exchange regulations for listed companies and requirements of the rating agencies and certification bodies, however, such requirements are rarely identified in the SME and micro sectors. On the other hand, micro finance customers, due to the size of their operations, do not

create significant environmental or social negative impacts compared to corporate and SME clients. Mainly, Small and medium enterprises are concentrated in Colombo, Kalutara and Gampaha districts in Sri Lanka (Nishantha, 2018). Therefore, the study carried out in western province of Sri Lanka.

1.3 Objectives

- i. To determine customer perception on sustainable banking in Sri Lanka
- ii. To study the awareness level of sustainable banking and sustainability concepts relate to sustainable banking among the respondents
- iii. To determine the awareness of respondents on various sustainable finance products offered by banks in Sri Lanka
- iv. To analyze the factors that affects use of sustainable banking among customers

2. Methodology

In this study a descriptive research design has been adopted. A single cross-sectional research design is formulated to gather information from a selected sample of the target population. This information was used to derive conclusive decisions by examining relationships between variables. The primary data has been collected using a well-structured questionnaire. The questions were mainly based on the study by Nilsson & Schwerin, 2019 as well as conversations with industry professionals in the banking sector. 10 hypotheses were used to analyze the results, and these are mentioned in the results section. The target population for the study was Small and Medium (SME) size business owners in the western province of Sri Lanka. The data has been collected using non-probability convenience sampling method. List of SMEs was identified through contacts from licensed commercial banks, Non-banking financial institutions and business associations of SME enterprises.

Around 350 questionnaires were distributed with the assistance of Google form and the interviews were conducted with consented respondents though teleconferencing or by way of physical site visits, as desired by the respondents. The data has been analyzed and results have been interpreted based on 150 respondents. The data was collected from the respondents from 1st of June 2022 to 30th of November 2022. Data collected from the sample of the population in order to test the study hypotheses. Statistical analysis of quantitative data was done using SPSS software. Descriptive statistic technique that summarizes data in an organized manner by describing the relationship between variables in the sample has been used in this study for data analysis. Mean, standard deviation and skewness are main statistics used in descriptive statistics.

3. Results

3.1 Demographic Characteristics of Respondents

The demographical features of respondents are demonstrated in Table 3.1.

Table 3.1-Demographic Characteristics of Respondents

Characteristics	Category	Percentage (%)
Gender	Male	86
	Female	14
Age	Between 21-30	10
	Between 31-40	28
	Between 41-50	49.33
	Between 51-60	12
	More than 60	0.67
Education Level	Up to GCE O/L	4
	GCE A/L	18
	NVQ	8

	Graduate	54.67
	Post graduate	15.33

3.2 Information of Organizations

Table 3.2-Demographic Characteristics of Respondents

Characteristics	Category	Percentage (%)
Field of activity or sector	Information technology	5.33
	Wholesale and retail trading	5.33
	Manufacturing	34.00
	Health care development	7.33
	Apparel	4.00
	Transport and storage	1.33
	Energy	4.67
	Agriculture	13.33
	Tourism	6.00
	Construction	8.00
	Education	1.33
	Other	9.33
Number of employees	Below 100	67.33
	100-200	22.67
	200-300	4.67
	More than 300	5.33
Revenue	Below 100Mn LKR	27.33
	100-250Mn LKR	18.00
	250-500Mn LKR	8.00
	500-750Mn LKR	4.00
	Above 750Mn LKR	5.33
	Not responded	37.33

3.3 Customers' awareness on available sustainable banking products

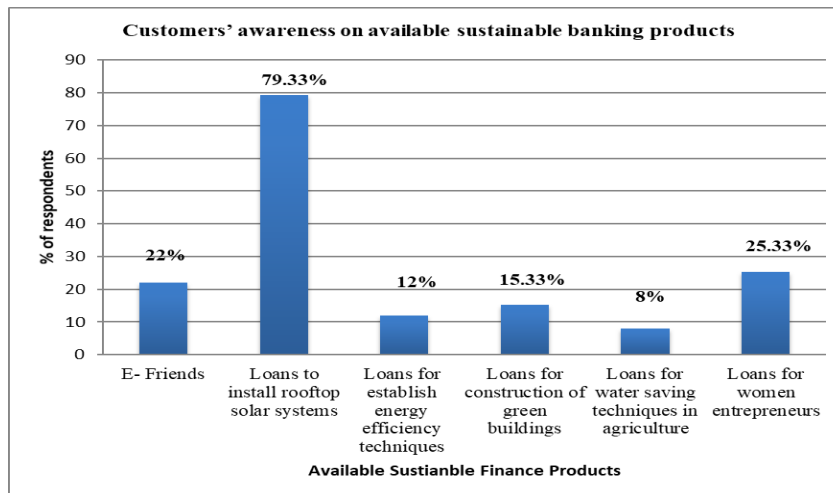


Figure 3.1-Customers' awareness on available sustainable banking products.

3.4 Preliminary Analysis

3.4.1 Awareness on sustainability concepts and frameworks

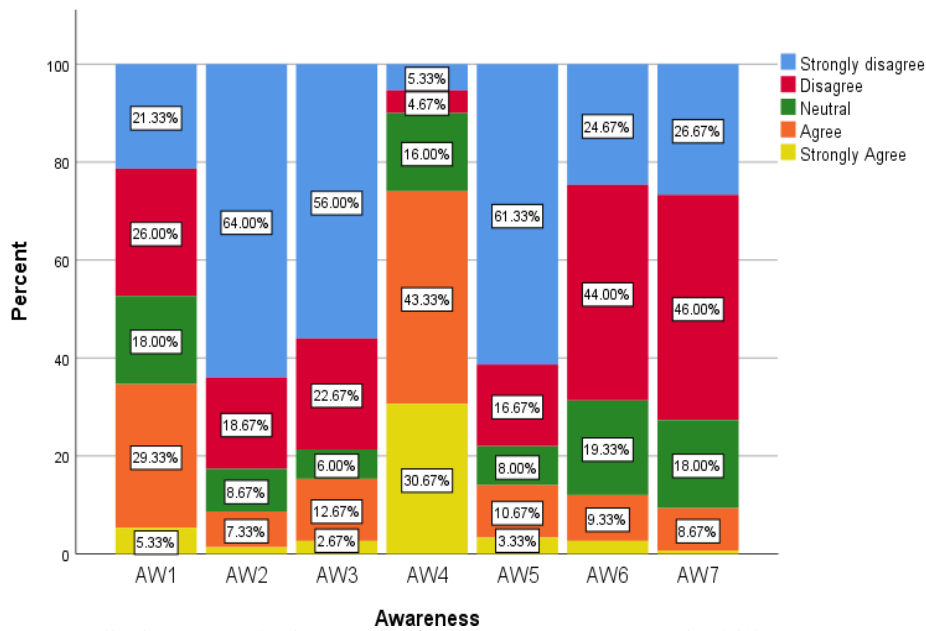


Figure 3.2- preliminary Analysis Results for Awareness on sustainability concepts and frameworks.

Description of statements

- AW1 I am aware of Sustainable Development Goals introduced by United Nations
- AW2 I am aware of IFC performance standards develop by IFC for project developers
- AW3 I am aware of ADB safeguard policies develop by Asian Development Bank
- AW4 I am aware of National Environmental policies and environmental regulations in Sri Lanka
- AW5 I am aware of Sustainable Banking Concept
- AW6 I have knowledge of how my bank work with sustainability issues
- AW7 I have good knowledge of sustainable banking products

3.4.2 Customer's desired relationship with bank on sustainable banking

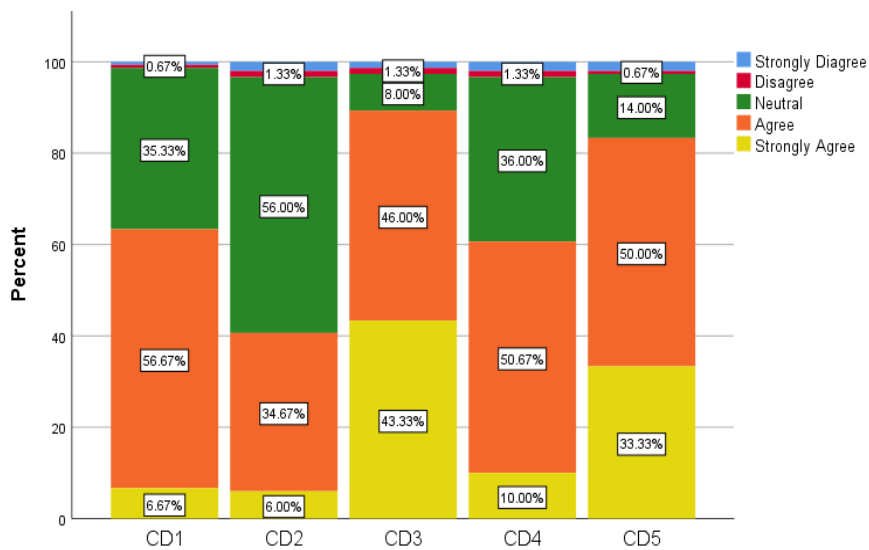


Figure 3.3-Preliminary analysis results for customer desired relationship with the bank on sustainable banking.

Description of statements

- CD1 If I am considering applying for a new banking product, I am more willing to apply if the product is sustainable
- CD2 I'd prefer having several sustainable banking products on the same bank
- CD3 I would be more willing to make a green investment if there was a specific loan with lower interest rates
- CD4 It is more likely that I would recommend my bank if it had a sustainable product range
- CD5 I am willing to produce more information to the Bank on my entity if the bank evaluate my sustainability performances to give me feedback on further improvements

3.4.3 Customer desire to select a bank with sustainable banking product

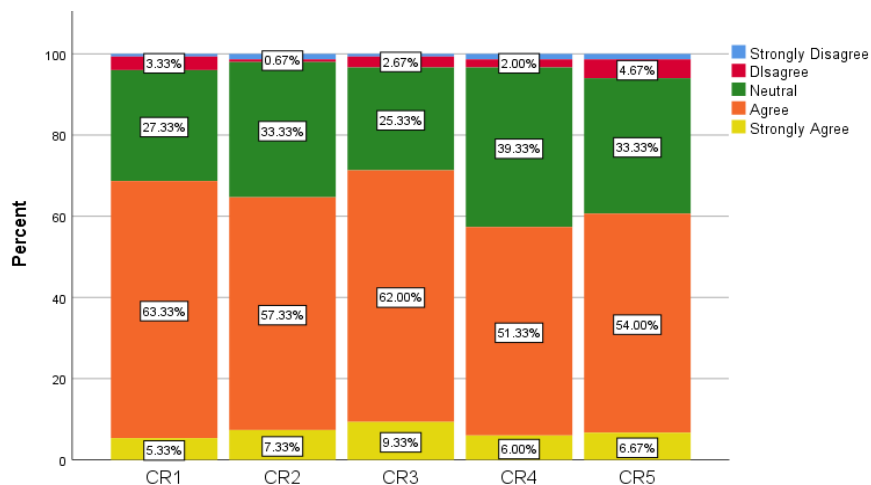


Figure 3.4-Analysis Results for Customer desire to select a bank with sustainable banking products.

Description of statements

- CR1 If I want to change bank, I am more willing to switch to a bank with a broad sustainable product range
- CR2 I would get higher confidence in a bank that offers a broad sustainable product range
- CR3 I would be more satisfied with my current bank with the introduction of a broad sustainable product range
- CR4 I would be less satisfied with my current bank if it did not offer sustainable banking products while all other banks offered it
- CR5 I would be less willing to switch from a sustainable banking product to typical banking product

3.4.4 Willingness to implement sustainability in respondents' organization

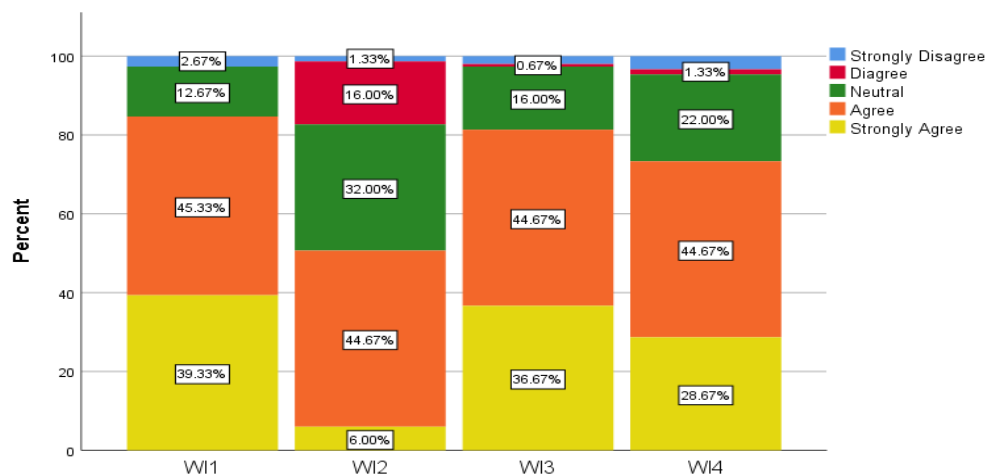


Figure 3.5- preliminary Analysis Results for Willingness to implement sustainability.

Description of statements

- WI1 I am Environmental Environmentally consciousness person
- WI2 I choose sustainable products whenever possible irrespective of price
- WI3 I think it is important that business take a responsibility in environmental conservation
- WI4 I would like banks to expand their sustainable products range

3.5 Descriptive statistics of variables Table

Table- 3.4 Descriptive statistics of variables

Descriptive Statistics							
	N	Min-imum	Max-imum	Mean	Std. Deviation	Skewness	
	Statis-tistic	Statis-tistic	Statis-tistic	Statis-tic	Statis-tic	Sta-tistic	Std. Error
AW	150	1.00	4.57	2.3105	.77979	.781	.198
CR	150	1.00	5.00	3.6667	.57167	-.810	.198

CD	150	1.00	5.00	3.8307	.55599	- 1.021	.198
WI	150	1.00	5.00	3.9100	.73118	- 1.161	.198
Valid N (listwise)	150						

The sample size is 150. Means of AW, CR, CD and WI are 2.31, 3.67, 3.83 and 3.9 respectively. All mean values close to 4 expect AW. Therefore, majority of respondents have positive idea about these variables and have negative idea about AW. The standard deviations of the variables of AW, CR, CD and WI are 0.78, 0.57, 0.56 and 0.73 respectively. The results indicate that variables have a low standard deviation depicting that the data are close to mean data, this means that the data is more reliable. The skewness of the AW is 0.781 which is close to one. That is AW variable has skewed to right distribution. The skewness of the CR, CD and WI are -0.810, -1.021 and -1.161 which are close to minus one. That is AW variable has skewed to left distribution.

3.6 Demands for Sustainable Banking Products

The highest demand (78%) is for Loan products to install renewable energy options while lowest demand is for loans to improve employee and public safety at business premises.

3.7 Testing of Hypothesis

Hypothesis developed are tested based on major findings of the study resulted that 10 hypothesis are accepted (P-value >0.05) while 3 hypothesis were not accepted (P-value < 0.05).

4.0 Discussion

Most of the respondents were graduates (Table 3.1). Well educated people showed positive attitudes to exchange information about sustainable banking. High percentage of respondents were in the manufacturing sector (Table 3.2). According to the Department of Census and Statics (2015) highest number of manufacturing industries are located in the Gampaha and Colombo districts of Western province, hence this situation can be justified. From this study tried to analysis relationship between annual revenue of SMEs with their level of sustainability implementations. But most of the respondents have not disclosed their annual revenue (Table 3.2). Disclosed information was not enough to analysis the data. Respondents' awareness about the loan scheme provide by banks to install rooftop solar systems was good. This scheme was offered by selected commercial banks in Sri Lanka at low interest rate with Asian Development Bank (ADB) funding. However, use of renewable energy in respondents' business premises is not prominent compared to the level of awareness. Restrictions from the Ceylon Electricity Board towards the rooftop solar installations may be the main reason for this result. Figure 3.1 shows the awareness level of respondents on Sustainable Banking products offered by Banks. Water from the National Water Supply and Drainage Board comes at a subsidized price and therefore, pipe-born water is cheaper than other sources of water available in the country. At the same time, due to the low cost of water, the pay-back period of the implementation of water saving techniques is considered as too extensive. Also, they have a low awareness on loan schemes to establish water saving techniques in agriculture such as drip irrigation and sprinkler irrigation systems. The study was carried out in the western province where agricultural activities in the western province are relatively low compared to many other provinces in the country. Low awareness on loan schemes to established water saving techniques in agriculture may be due to this reason. If the study extended to agricultural provinces such as North Central, North Western, Eastern or Northern, this result may show different values. Most of the commercial banks In Sri Lanka have introduced financial products especially focusing on women and they promote their products using different media. Therefore, awareness level about these loan schemes is high. "E-Friends" is another loan scheme that facilitate

environment friendly initiatives in SME business. This scheme is popular among most of the relationship officers of banks and they can offer these facilities to the eligible customers at a lower price. This may be the reason that most of the respondents are aware of it. As per the results most of the respondents are with the intention of increasing the brand reputation and market access through implementing sustainability practices. Banks may use this finding as a promotional tool to persuade their SME customers to implement sustainability. 65% of the respondents have an expectation of easy approval process for the entities with sustainability practices while more than 50% of the customers expect easy access to low cost funds and less complicated documentation process when applying for credit facilities. Banks need to consider this in designing sustainable banking products. Nulkar (2019) pointed out that the pressure from international buyers, regulators and investors significantly influences implementation of sustainability in SMEs in India while Banks have not significantly influenced environmental performance of the SME customers. However, since all the Sri Lankan banks signed for the Sri Lanka Sustainable Banking Principles, there is a possibility that a collective effort from banks towards enhancing sustainability performances of SMEs would yield better results.

Results of the preliminary analysis show that awareness on sustainability concepts and frameworks among the respondents show low value (Figure 3.2). The majority of respondents do not aware about Sustainable Development Goals introduced by United Nations. IFC performance standards develop by International Financial Cooperation for project developers those applied by some banks to their projects with high environmental and social risks and ADB safeguard policies develop by Asian Development Bank are most relevant sustainability concepts to the banking sector. But the awareness about these concepts is very low among the respondents. Especially ADB provides funds to the banks to provide loans for environment friendly businesses at low interest rate. Mainly SME sector businesses take advantage from these loan schemes. But their knowledge about ADB safeguard policies is very low. The bank staff dealing with the customers need to convey these requirements to the customer at the time of evaluating the project. Awareness on National Environmental policies and environmental regulations in Sri Lanka was satisfactory among the customers. The developers need to obtain an Environmental Protection License (EPL) for their projects and to annually renew it. Therefore, the developers need to have a basic understanding on these aspects. The result confirms the results of a study on attitudes, awareness and environmental management practices of SMEs in Sri Lanka by Weerasiri and Zhengang (2011). Out of the respondents the majority does not aware of sustainable banking concepts and they do not have knowledge on how their banks work with sustainability issues. But their desire to apply for a new sustainable banking product to implement sustainability in their organizations is significantly high (Figure 3.3), especially, to apply for green investments if it offers at lower interest rates by their banks. Therefore, if banks introduced more sustainable finance products and increased their promotions on these products, the banks will be in a position to attract more business. Providing more information to their banks to get a feedback on how to enhance their sustainability performance is another key highlighted area. Through this process, banks can enhance their customers' E&S performances while reducing E&S risks on their lending portfolios. As per figure 3.4, banks can improve their brand reputation, while enhancing their customers' loyalty and confidence towards a bank. A large majority responded that businesses should take a responsibility in environmental conservation (Figure 3.5). But low percentage of respondents stated that they had good knowledge of sustainable banking products or knowledge of how banks work with sustainability issues. This shows that banks have been unsuccessful in communicating their environmental and social policy to customers. Awareness of respondents on sustainability concepts and frameworks such as SDGs, ADB safeguard policies, IFC Performance standards and sustainable banking have a relationship with their willingness to implement sustainable strategies in their business. This is possible because, a clear understanding about current E&S issues and how it can affect their business, motivate people to introduce sustainability practices in their organizations. It confirms the finding of a study by Hillary (2004) that environmental knowledge plays an important role in generating support and ideas which lead to the creation of sustainable business. Also, they have a proper understanding on how sustainable businesses discover opportunities especially from international markets.

Awareness of respondents on sustainability concepts and frameworks have a relationship with customer's desired relationship with the bank on sustainable banking. This is also possible due to above described factors. There is a relationship between respondents' education level and awareness on sustainable banking and other sustainability concepts. When considering the education level, graduate and postgraduate level is the group which has a highest percentage of customers with an awareness on existing sustainability concepts and frameworks including sustainable banking. Nowadays, most graduates and post graduate study programs are giving importance to the sustainable development related topics in their academic courses. As per the results education level of the respondents has a relationship with willingness to implement sustainability in their business. According to the above paragraph, well-educated respondents have good knowledge about sustainability. Customer's desire to select a bank with sustainable banking products and customer desired relationship with the bank on sustainable banking have significant relationship with education level. This is also possible according to the above discussed factors. Siraje and Mbowa (2018) show from their study that quality education about sustainable development contributes to achieve sustainable development in a variety of ways. This supports above findings. There is a relationship between age of respondents and awareness on sustainability concepts and frameworks. Age group of 21-30 has more awareness on sustainable development and other related sustainability concepts than other groups. This might be due to the rapid technological advancement of the days and younger generation could have opportunities to be aware on the concept through social media. Therefore, banks can promote their sustainable products using social medias rather than use of conventional media. Also, bank should increase awareness among their elderly customers. Young male and female awareness positively correlated with the environmental knowledge and behavior as compared with the older age people (Ziadat, 2010). However, the present study revealed that there is no relationship between the age of the respondents and willingness to implement sustainability in their organization, customers desired relationship with the bank on sustainable banking and desire to select a bank with sustainable banking products in Sri Lanka.

5.0 Conclusions and Recommendations

The results reveal that SME customers believe in sustainability concepts, and expressed willingness to implement sustainability strategies. Customers' awareness on available sustainability concepts including sustainable banking is at a very low. However, awareness on areas where banks offered concessionary funding was satisfactory. A high percentage have either implemented or expressed willingness to implement policies to address ESG. Sustainability practices covered under the EPL regulation are in place in most of the organizations. Only a few Sustainable Banking products are found Sri Lanka and the customers are aware of the loan products that directly linked to their profitability. The most popular product is the ADB funded loan scheme to install rooftop solar systems. Initiatives that reduces costs while contributing to sustainability are also popular among the respondents. Installing energy saving machinery is the most popular initiative. Improved market access, enhanced brand reputation and easy project approval process are the top 3 expectations of the customers through implementing strong sustainability practices. Education level of the respondents significantly effect on awareness implementation of sustainability concepts. Finding of research state that lack of awareness and high interest rates are prominent constraints face by customers while accessing sustainable banking products.

5.1 Recommendations to the financial regulators

CBSL shall set targets to the licensed banks to introduce sustainable banking products aimed at achieving UN Sustainable Development Goals (UN SDGs). CBSL may also introduce regulations on evaluating ESG risks of lending projects of banks, and to manage negative ESG impacts as a compulsory covenant to the loan agreement. Also, CBSL may define additional priority sectors in the CBSL Green Finance Taxonomy, aimed at achieving UNSDG targets as well as the Nationally Determined Contributions (NDCs) towards achieving the Paris Agreement. The CEA shall introduce industry specific sustainability related KPIs into the EPL renewal procedure and the customers shall demonstrate year-on-year improvements in these areas.

5.2 Recommendations to Banks

Since the customers show their willingness to implement sustainability, banks can promote this by way of introducing sustainable finance products aimed at establishing UNSDG targets and NDCs for different sectors. It is recommended to re-introduce the loan scheme for Solar rooftop conversion as well. Banks may initiate introducing Green Bonds for the for this purpose. To enhance the awareness of the SME clients on sustainability, banks may collectively or individually organize awareness programs for the SME sector. The Sri Lanka Banks Association's Sustainable Banking Initiative is a good platform to organize such programs for the sector. Level of awareness on SDG targets and NDCs among the credit staff is also recommended as the credit staff has been identified as promoters of sustainability concepts through introducing sustainable banking products to the customers. Banks shall develop selling points for sustainable banking products and enhance the skills of the credit staff in promoting these products to the customers. Reduction of costs, enabled access to EU markets, brand reputation and resource efficiency etc. can be used as selling points. Introduction of programs to identify and give recognition to the customers those who incorporated best sustainable business practices is also recommended to increase the customer's brand reputation. Banks shall promote good ESG practices through defining eligibility criteria to apply for sustainable banking products. For large investments, banks may follow international frameworks such as Climate Bond Criteria, but for smaller investments, it is recommended to introduce benchmark criteria such as having an ESG policy, safety plan, grievance redress mechanism etc. Banks shall explore possibilities to introduce low interest loan schemes to establish sustainability related initiatives while accessing internationally available sources of low-cost funds such as the Green Climate Fund.

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ICSD 071

ROLE OF SOCIO ECONOMIC ON CONSUMERS PURCHASE INTENTION OF STREET FOOD

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Abstract: The Sri Lankan Street food industry, established nearly two years ago, swiftly garnered acceptance among Sri Lankans. Consequently, the favourable impacts on the Sri Lankan economy, attributed to the street food sector, were witnessed in the post-COVID-19 landscape. This study aimed to explore the street food industry, examine consumer perceptions towards purchasing street food, and identify social and economic factors influencing consumer street food purchases. One hundred and thirty-nine responses were meticulously collected, including feedback from fifty vendors operating in Aluthkade and Kibulawala Street food locales within the Colombo district. Methodologically, this research carefully gathered data through a combination of interviews and a structured questionnaire, employing the Correlation Analysis method. The study's findings revealed that the Sri Lankan Street food industry operated without any form of governmental assistance, and consumer dietary preferences, particularly those correlated with age, demonstrated a discernible negative impact (sig. 0.036). Importantly, a significant proportion of the younger demographic displayed a penchant for street food consumption (Age 18-24: 21.6%/ Age 25-34: 41%). In light of these insights, proactive measures are advocated by the author from the Sri Lankan government to incentivize and motivate street food vendors, alongside the establishment of regulatory frameworks for street food registration. Additionally, the study underscores the imperative for consumers to enhance their understanding of the intricacies within the street food industry.

Keywords: Consumer; Impact; Street food; Sri Lankan

1. Introduction

“Street foods are described as ready-to-eat foods and beverages prepared at home or on streets and consumed on the streets without further preparation or with a little preparation” (VikasGupta, 2018)

“Walking on the street of any major city in Italy – and often also in smaller urban centers – it is impossible not to be intrigued by the growing popularity of what Italians now call street food, in English, sold on the street proper, from trucks, and in small brick-and-mortar storefronts. The relatively new and trendy expression in a foreign language refers to the contemporary evolution of what used to be called *cibo di strada* (street food, in Italian) and included anything sold by peddlers carrying baskets and other portable containers, various kinds of vehicles, as well as out of temporary or permanent stalls and kiosks.” (Parasecoli, 2021) “In the past, numerous studies have been conducted in many countries to explore the impacts of street food on tourism” (Tran Vinh Thuan, 2019) “SF acting an important role in meeting the food demands of the low-income GROUP with a wide variety of foods” (Thatchinamoorthy C*, 2017) “Street food (SF), according to FAO is defined as ready-to-eat-food and beverages that are prepared or sold by street vendors or hawkers in the public places with various types of food stalls such as push carts, roadside stands, balance basket, etc; and about 2.5 billion people eat street food every day (FAO, 2007).” (Panama2, 2016) “Any conversation revolving around street food begins and ends with Thai cuisine. After all, there’s a reason why cities like Bangkok are called “the world’s kitchen” – the flavors, ingredients, and care put into each dish are second to none! Dishes like fried pork and rice porridge stand out as local favorites that frequently blow away the taste buds of millions of travelers annually” (My Everyday Table, 2023)

World-famous traditional street food is owned by Thailand, which has a significant presence in the street food industry. In Sri Lanka, the street food industry was not widely embraced until 3 to 4 years ago. After the COVID-19 pandemic reached Sri Lanka, a considerable number of people, particularly those in the tourist sector and hotel industry, lost their jobs. Consequently, they turned to the street food industry. According to the Department of Census and Statistics and the Ministry of Economic Policies and Plan Implementation in Sri Lanka, 12.7% of agricultural self-employment ceased, and 14% of non-agricultural self-employment saw the closure of their economic activities. (htt).

2. Conceptual Framework

In The relationship between the consumption of street food and other key variables is visualized by the conceptual framework utilized in this research. According to this figure, the consumption of street food is identified as the dependent variable, while the socio-economic status of the consumer is designated as the independent variable. Moderator variables, mediator variables, and control variables are encompassed by other variables. In this conceptual framework, moderator variables encompass the preference for eating street food and features of street food. Mediator variables involve income level, lifestyle, knowledge, and the availability of street food. Control variables consist of climate change and the hygiene of the seller. A significant relationship is observed between each of these variables. In this context, the decision is not affected by the socio-economic status of the consumer; thus, it remains independent. Conversely, the consumption of street food is influenced by every other variable, rendering it the dependent variable. The variables 'preference for eating street food' and 'features of street food' play a role in establishing a relationship between the socio-economic status of the consumer and the consumption of street food; hence, they become moderator variables. Income level, lifestyle, knowledge, and the availability of street food are key features of the independent variable and exert a direct influence on the dependent variable, categorizing them as mediator variables. Control variables, such as climate change and the hygiene of the seller, are encompassed within these variables. While consumers cannot control them, these variables impact the consumption of street food.

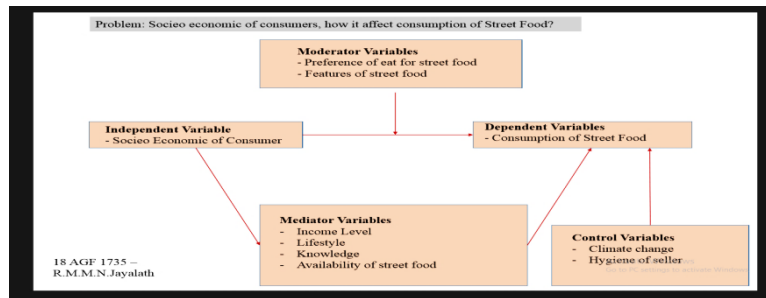


Figure 1: Conceptual Framework.

2.1 Context of published research on street food market

Table 1: Context of published research on Street Food Market

Authors	Published Year	Research Objectives	Key Findings
1. Tran Vinh Thuan 2. Ngugen Thi Phuong Chi 3. Ngugen Thi Trung	2019	To measure the effect of Street Food on international tourists' satisfaction when visiting Ho Chi Minh city	Cronbach Alpha assesses scale reliability. Results from 40 items reveal independent variables' impact on tourists' street food satisfaction.
Thatchinamoorthy C*, Meenambigai J	2017	To illustrate and analyze why customers come back to the identical street food sector and preferences towards buying street food	Study explores street food vendor-consumer relationship, retention. Quality services, satisfaction crucial for customer return, market share, emphasizing CRM.

3. Methodology

The research employed the stratified sampling method to target specific street food areas, namely the Aluthkade and Kibulawala street food areas in the Colombo district. Two distinct strata were identified in alignment with the stratified sampling approach: Aluthkade street food area and Kibulawala street food area, encompassing both customers and vendors. The sample size was set at 170, comprising 50 samples drawn from street food vendors (25 vendors from each of the Aluthkade and Kibulawala locations) and 120 samples obtained from consumers (60 consumers from each of the Aluthkade and Kibulawala locations). However, the data collection process yielded 139 consumer responses. To gather primary data, a combination of pre-tested structured questionnaires and in-depth interviews was employed. In line with the research objectives, the questionnaire was bifurcated into two sections. The first objective centered on collecting data from the vendor's perspective, while the second and third objectives

were tailored to focus on gathering data from customers. Additionally, YouTube videos served as primary data sources, offering valuable insights into the dynamics of the Sri Lankan street food industry. Furthermore, the research incorporated secondary data collected from the literature review as a complementary data collection method. The qualitative data in this research were analyzed using IBM SPSS, and the quantitative data were analyzed using NVIVO software in this research.

The development of the questionnaire was guided by the author's supervisor, who recommended consulting previous international street food-related research questionnaires. To ensure the questionnaire's relevance to the local context, the author tailored it to the specific characteristics of the Sri Lankan street food industry. Following the supervisor's approval of the finalized questionnaire, the author printed it and embarked on a data collection process spanning from September 20, 2023, to September 25, 2023. The author visited street food areas in Aluthkade and Kibulawala, strategically selected to capture a representative sample of the street food scene in Sri Lanka. Data collection employed a multifaceted approach, combining questionnaire administration with in-depth interviews conducted with both customers and vendors. The selection of the sample size was a collaborative effort between the author and the supervisor, who carefully considered the unique limitations posed by the relatively small number of street food stalls in Sri Lanka. After thorough deliberation, the supervisor established a sample size of 50 vendors and 120 customers as appropriate for achieving the study's objectives. The author's data collection efforts exceeded the target sample size, successfully gathering data from 139 customers. This overachievement reflects the author's dedication to collecting a comprehensive dataset that accurately represents the diversity of perspectives within the Sri Lankan street food industry.

In order to examine the intricate relationship between the independent and dependent variables, the IBM SPSS correlation analysis was meticulously employed. Age, education level, monthly income, number of family members, social status, living area, gender, and marriage status were meticulously identified as the independent variables. The dependent variable, the reasons for purchasing street food, was rigorously defined. This comprehensive research endeavored to delve into the multifaceted motivations behind street food consumption. It sought to ascertain whether dietary preferences were thoughtfully considered when making street food purchases. Additionally, the research aimed to gauge the extent to which recommendations from friends and family influenced street food purchase decisions, a factor that could significantly impact an individual's street food consumption patterns. Furthermore, the research endeavored to determine the significance of trust in street food vendors or stalls for regular patrons, a crucial element that could contribute to customer loyalty and repeat business. Finally, the research meticulously analyzed the relationship between the independent and dependent variables, shedding light on the underlying factors that drive street food consumption behavior.

4. Result and Discussion

An examination of the socioeconomic factors influencing consumer behavior and their subsequent impact on street food consumption revealed three primary objectives within the framework of the dependent and independent variable relationship. Data collection efforts were conducted in the Aluthkade and Kibulawala Street food areas to gather relevant information. This study meticulously identified customers and vendors representing diverse age groups, social classes, and education levels. Consequently, this comprehensive analysis delved into the intricate relationship between consumer socioeconomic factors and their street food purchase intentions. Furthermore, the utilization of vendor-side data proved instrumental in elucidating the multifaceted interactions between the street food industry and consumer socioeconomic factors. The results of this study are elaborated upon under the following three main objectives:

1. To Explore The Street Food Industry
2. To Identify Consumer Perception To Purchase In Street Foods
3. To Identify Social And Economic Factors Affects To The Consumer Street Food Purchase

4.1 To explored street food industry.

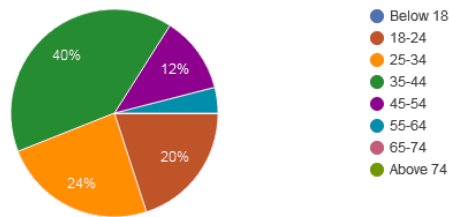


Figure 1: Results and Discussion in Age.

An examination of the age distribution among street food vendors, as illustrated by the pie chart, revealed that no vendors were identified within the Below 18 age group. Data collection efforts meticulously conducted during this study indicated that 20% of vendors fell within the 18-24 age category, representing a significant portion of the vendor population. Additionally, 24% of vendors belonged to the 25-34 age group, demonstrating a substantial presence of vendors in this age bracket. Notably, 40% of the total vendor population was found to be within the 35-44 age range, highlighting the dominance of this age group among street food vendors. The 45-54 and 55-64 age groups comprised 12% and 4% of vendors, respectively, indicating a smaller representation of vendors in these age brackets. Interestingly, the 65-74 and Above 75 age groups were not represented by any vendors, suggesting a limited presence of older vendors in the street food industry. Consequently, the 35-44 age group accounted for the largest proportion of vendors (40%), solidifying their position as the most prominent age group among street food vendors. In contrast, the 55-64 age group represented the smallest percentage (4%), indicating a less prevalent presence of vendors in this age bracket. These findings provide valuable insights into the demographic characteristics of street food vendors and their distribution across various age groups.

The feasibility of these claims can also be demonstrated using SPSS, as shown in the following tables.

Table 2: Relationship between age and gender

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.0	6	12.0	12.0	12.0
	2.0	44	88.0	88.0	100.0
Total		50	100.0	100.0	

Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.0	10	20.0	20.0	20.0
	3.0	12	24.0	24.0	44.0
	4.0	20	40.0	40.0	84.0
	5.0	6	12.0	12.0	96.0
	6.0	2	4.0	4.0	100.0
	Total		50	100.0	100.0

A study found that the predominant demographic of street food vendors consists of males in the 35-44 age group

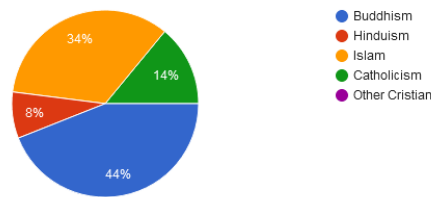


Figure 2: Result and Discussion in Vendor Religion.

A comprehensive analysis of the religious affiliations of street food vendors reveals that Buddhism stands as the most prevalent faith, embraced by 44% of vendors. Islam follows closely behind, accounting for 34% of vendors. Catholicism and Hinduism hold respective shares of 14% and 8% among the vendor population. This data underscores Buddhism's dominance as the primary religious identity among street food vendors.

Further scrutiny unveils a notable pattern in the religious distribution across different street food areas. In the Kibulawala Street food area, Buddhism reigns supreme, with the majority of vendors identifying as Buddhist adherents. Conversely, the Aluthkade Street food area exhibits a stark contrast, with Islam emerging as the predominant faith among vendors operating in that region.

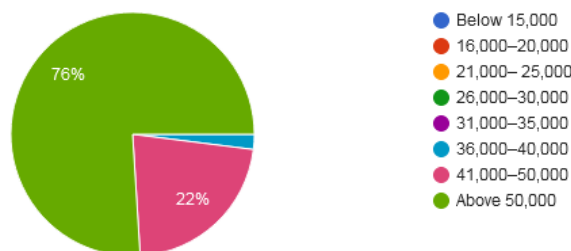


Figure 3: Result and Discussion Income Level of Vendor.

An analysis of the income distribution among street food vendors reveals that a majority (76%) earn above Rs.50,000. Another 22% of vendors fall within the income range of Rs.41,000 to Rs.50,000, while the remaining 2% earn between Rs.36,000 and Rs.40,000. It is further noted that street food vendors experienced a decline in income following the economic downturn in Sri Lanka. Prior to the economic crisis, many vendors enjoyed higher income levels. However, the economic instability has led to a reduction in their earnings. The observed income distribution among street food vendors highlights the varying financial realities faced by this group. While a significant portion earns a relatively high income, others struggle to make ends meet. The economic downturn has exacerbated these disparities, emphasizing the need for measures to support street food vendors and ensure their financial well-being.

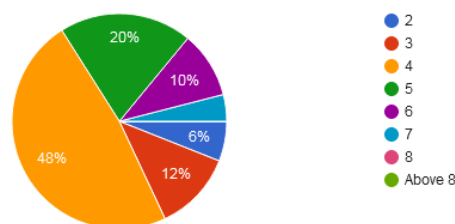


Figure 4: Result and Discussion in Vendors Number of Family Members.

An analysis of the distribution of street food vendors based on the number of family members involved in their business reveals a notable pattern. As depicted in the pie chart, the majority of vendors (48%) rely on the support of four family members to operate their businesses. This is followed by 20% of vendors who have five family members involved, 12% with three family members, 10% with six family members, and 6% with two family members. The remaining 4% of vendors have seven or more family members engaged in their business operations.

This tendency that has been noticed points to the importance of family involvement in the success of street food companies. The significant number of suppliers that have four or more family members working for them suggests that family support is a highly valued resource in this industry. This support can take many different forms, including monetary contributions, labor-sharing agreements, and active participation in the business's general management. It is necessary to conduct additional research to examine the particular dynamics of family engagement in street food vending. Comprehending the elements that constitute prosperous family-owned street food enterprises might yield significant perspectives for policy measures and assistance programs intended to improve the standard of living for street food sellers and family members.

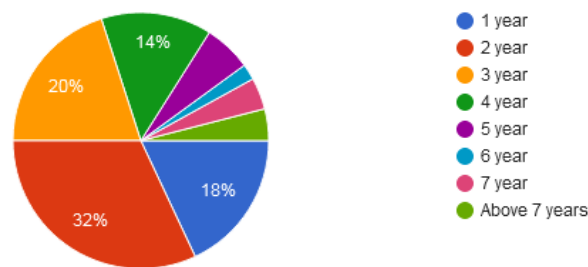


Figure 5: Result and Discussion in Experience Years.

The pie chart illustrates the distribution of street food vendors based on their years of experience in the industry. It is observed that 32% of vendors have been engaged in the street food industry for two years, the highest proportion among all experience levels. This is followed by 20% of vendors with three years of experience, 18% with one year of experience, 14% with four years of experience, and 6% with five years of experience. A small percentage of vendors (4%) have been in the industry for seven or more years, with an equal distribution between those with seven years and those with more than seven years of experience. The remaining 2% of vendors represent the lowest experience level, with six years in the industry.

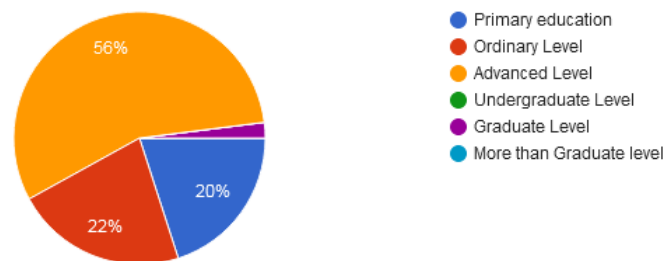


Figure 6: Result and Discussion Education Level.

The distribution of street food vendors based on their educational level is depicted in the pie chart. It is observed that the majority (56%) of vendors have completed the Advanced Level, indicating a relatively high level of education among street food vendors. This is followed by 22% of vendors who have completed the Ordinary Level and 20% who have only completed their primary education. A small percentage (2%) of vendors have graduated.

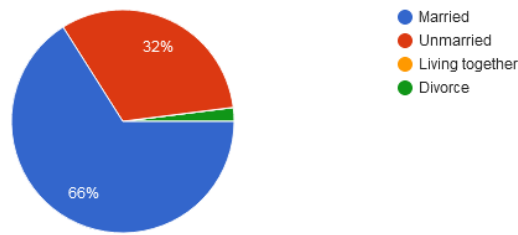


Figure 7: Result and Discussion in Married Status.

The marriage status of street food vendors is depicted in this pie chart. It is observed that the majority of vendors are married, constituting 66% of the chart. Additionally, 32% of street food vendors are identified as unmarried, while 2% are noted as divorced. The pie chart illustrates the primary motivations driving individuals to pursue a career in street food vending. It is observed that the majority (94%) of street food vendors were drawn to this profession due to the perceived likelihood of success and the opportunity to establish their own businesses. This sentiment was echoed by 66% of vendors, who specifically mentioned the desire for self-employment as a key factor in their decision.

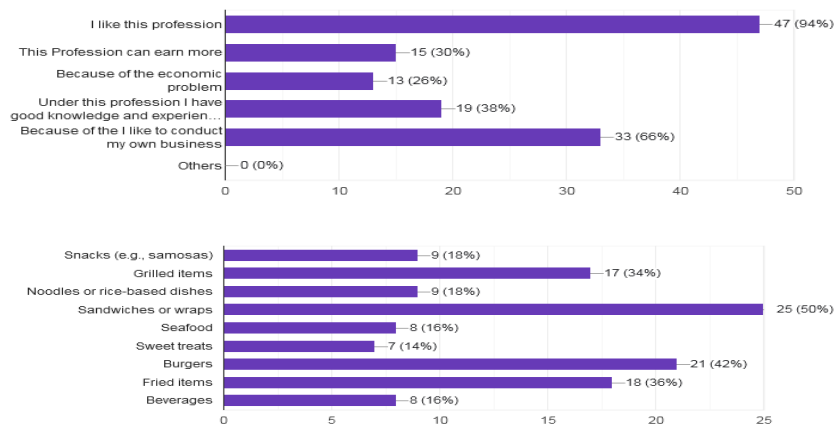


Figure 8: Result and Discussion Commonly prepare food and their reason in this Profession.

The chart depicts the types of street food most commonly prepared by street food vendors. It is observed that the majority (50%) of street food vendors prepare sandwiches or wrap-based items, indicating a strong preference for this type of cuisine. This is followed by 42% of vendors who prepare burgers, 36% who prepare fried items, and 34% who prepare grilled items.

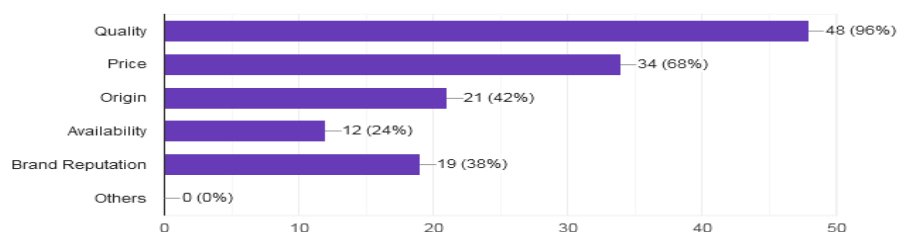


Figure 9: Result and Discussion in Raw Material Purchasing.

An analysis of the factors considered by street food vendors when purchasing raw materials reveals that quality is of paramount importance, with 96% of vendors prioritizing this aspect. Price is also a significant consideration, with 68% of vendors taking it into account when making purchasing decisions. For

certain raw materials, such as chicken, brand reputation plays a role, with 38% of vendors giving it weight. The emphasis on raw material quality stems from the recognition that inferior ingredients can negatively impact the taste and shelf life of street food items.

Table 3: Correlation between age and How long have you been in this profession?

Correlations			
		Age	How long have you been in this profession?
Age	Pearson Correlation	1	.471**
	Sig. (2-tailed)		.001
	N	50	50
How long have you been in this profession?	Pearson Correlation	.471**	1
	Sig. (2-tailed)	.001	
	N	50	50

** . Correlation is significant at the 0.01 level (2-tailed).

The Pearson Correlation Coefficient (r) for the relationship between age and years of experience in street food vending is 0.471. This value signifies the strength and direction of the linear association between the two variables. The positive sign indicates a positive correlation, meaning that as age increases, the number of years spent in street food vending also tends to increase.

The p-value (Sig.) associated with the correlation coefficient is 0.001. The p-value assesses whether the observed correlation is statistically significant. A p-value less than or equal to the significance level (usually 0.05 or 0.01) indicates statistical significance. In this case, with a p-value of 0.001, the correlation is considered statistically significant at the 0.01 level (2-tailed).

Table 4: Correlation between Monthly Income

Correlations			
		Monthly Income	Are you satisfy about your financial situation?
Monthly Income	Pearson Correlation	1	-.756**
	Sig. (2-tailed)		.000
	N	50	50

Are you satisfy about your financial situation?	Pearson Correlation	-.756**	1
	Sig. (2-tailed)	.000	
	N	50	50

** . Correlation is significant at the 0.01 level (2-tailed).

Pearson Correlation Coefficient (r):" was changed to "A strong negative correlation between monthly income and satisfaction with financial situation was identified using the Pearson correlation coefficient (r = -0.756)."

For Monthly Income and Are you satisfied about your financial situation? the correlation coefficient is -0.756." was changed to "This correlation indicates that as monthly income increases, satisfaction with financial situation tends to decrease. In this case, the negative sign (-) suggests a strong negative correlation, implying that as Monthly Income increases, the satisfaction with financial situation tends to decrease. Was changed to the high correlation coefficient, coupled with a p-value of 0.000, suggests that this relationship is statistically significant at the 0.01 level (2-tailed). Significance (Sig.):" was removed as it was already addressed in the previous sentence. The p-value (Sig.) associated with the correlation coefficient is 0.000. was changed to "The p-value of 0.000, as the phrase associated with the correlation coefficient" is redundant. In this case, with a p-value of 0.000, the correlation is considered highly significant at the 0.01 level (2-tailed). Was changed to the high correlation coefficient, coupled with a p-value of 0.000, suggests that this relationship is statistically significant at the 0.01 level (2-tailed).

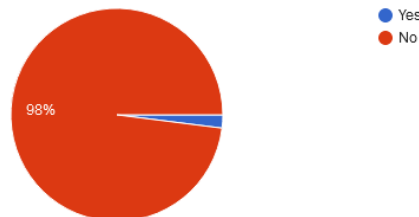


Figure 10: Result and Discussion in Government Support.

A recent survey of street food vendors in Colombo, Sri Lanka, revealed a stark contrast in their perceptions of government support. As depicted in the accompanying pie chart, a staggering 98% of vendors do not believe they receive any meaningful support from the government. This sentiment is particularly prevalent among vendors operating in the Kibulawala street food area, where a government-mandated closure order has thrown their livelihoods into disarray. The mere 2% of vendors who expressed a positive perception of government support primarily cited the government's Public Health Initiative (PHI) and the designated Kibulawala street food area as examples of supportive measures. However, even these vendors acknowledged that these initiatives fall far short of providing adequate support for their businesses and overall well-being.

The survey findings underscore the urgent need for a more comprehensive and inclusive approach to government support for street food vendors. These vendors play a vital role in the city's informal economy, providing affordable and accessible food options for a large portion of the population. However, their contributions are often overlooked and undervalued by policymakers.

The government's recent closure order in the Kibulawala street food area serves as a stark reminder of the challenges faced by street food vendors. This action, taken without adequate consultation or consideration of alternative solutions, has caused significant hardship to the vendors and their families

4.2 To identify consumer perception to purchase in street food.

Table 5: Correlation between How much frequency street food buy in a week and When you buy street food do you considered about that stall physical appearance

		How much frequency street food buy in a week?	When you buy street food do you considered about that stall physical appearance?
How much frequency street food buy in a week?	Pearson Correlation	1	-.186*
	Sig. (2-tailed)		.028
	N	139	139
When you buy street food do you considered about that stall physical appearance?	Pearson Correlation	-.186*	1
	Sig. (2-tailed)	.028	
	N	139	139

*. Correlation is significant at the 0.05 level (2-tailed).

A correlation analysis was performed to examine the relationship between the frequency of street food purchases per week and the consideration given to the physical appearance of the stall when purchasing street food. The Pearson correlation coefficient was calculated to be -0.186, indicating the strength and direction of the linear relationship between the two variables. The negative sign (-) suggests a weak negative correlation, implying that as the frequency of street food purchases increases, there is a slight tendency for consideration of the stall's physical appearance to decrease. To assess the statistical significance of the observed correlation, a significance test (Sig.) was conducted. The resulting p-value of 0.028 indicates that the correlation is significant at the 0.05 level (2-tailed). The sample size for both variables was 139.

A correlation analysis was conducted to investigate the relationship between the frequency of street food purchases per week and the consideration given to dietary preferences when purchasing street food. The Pearson correlation coefficient was calculated to be -0.178, indicating the strength and direction of the linear association between the two variables. The negative sign (-) suggests a weak negative correlation, implying that as the frequency of street food purchases increases, there is a slight tendency for consideration of dietary preferences to decrease. The statistical significance of the observed correlation was assessed using a significance test (Sig.). The resulting p-value of 0.036 indicates that the correlation is significant at the 0.05 level (2-tailed). A sample size of 139 was used for both variables.

4.3 To identify social and economic factors affects to the consumer street food purchase.

Table 6: correlation between age and How much do recommendations from 2s, 3 influence your street food purchase decision

		Age	How much do recommendations from 2s, 3 influence your street food purchase decision?
Age	Pearson Correlation	1	.220**
	Sig. (2-tailed)		.009
	N	139	139
How much do recommendations from 2s, 3 influence your street food purchase decision?	Pearson Correlation	.220**	1
	Sig. (2-tailed)	.009	
	N	139	139

** . Correlation is significant at the 0.01 level (2-tailed).

An exploration of the relationship between "Age" and "How much do recommendations from friends, family (2s, 3) influence your street food purchase decision?" was conducted using Pearson correlation analysis. The correlation coefficient, a measure of the strength and direction of the linear relationship, was determined to be 0.220. The positive correlation coefficient indicates a weak positive association, suggesting that as age increases, the influence of recommendations from friends and family on street food purchase decisions tends to increase slightly. This observation is exemplified by the tendency of parents to purchase street food based on their children's preferences.

Conclusion

The study examines socioeconomic factors influencing street food consumption in Sri Lanka, primarily focused on Colombo's Aluthkade and Kibulawala areas. Despite its growing popularity, street food lacks widespread acceptance across Sri Lanka. Vendors, predominantly male, with a 35-44 age group majority, often lack government support. Consumer preferences, influenced by age, income, and dietary choices, show a positive correlation with recommendations and income spent on street food. However, concerns remain regarding data accuracy and governmental support. Collaboration between street food and tourism industries could benefit Sri Lanka. Recommendations include increased government backing, encouraging female participation, and allocating specific zones for street vendors in urban areas.

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**PROCESSED FRUIT AND VEGETABLE INDUSTRY IN SRI LANKA:
POTENTIALS, CHALLENGES, AND PROSPECTS**

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Abstract: Sri Lanka has the potential to produce processed fruit and vegetable products for both domestic and export markets since we are blessed with an abundance of highly diverse and delectable tropical fruit varieties. The main objective of this study was to analyze the present situation, processing potentials, and constraints for the locally processed fruit and vegetable sector. Both primary and secondary data were collected. Purposive sampling was employed and a pre-tested structured questionnaire was used to interview the selected processors and traders in the Colombo, Gampaha, and Kandy districts. Key informant interviews and case studies were also conducted. Descriptive analysis, compound growth rate analysis, instability analysis, and constraint-faced index were applied in the data analysis. Processed fruit and vegetable exports in the country have shown positive growth from 2011 to 2021. A majority (93.33%) of the sample processors are willing to expand their production capacity in future. Regular customer base, high demand for special products, regular supply of quality raw materials by producers, and skilled labour force were identified as key strengths. Most of the of the sample processors (57%) send their products to both the local and export markets. The local markets provide about 110 international and 172 local brands of fruits and vegetables. Dehydrated fruit and vegetable products have the highest potential in both domestic and export markets. The Middle East, Europe, America, Oceania, and Asia are the most potential export regions for Sri Lankan processed fruit and vegetable exports. According to the constraint-faced index results, issues pertaining to the production process rank highest among the challenges faced by fruit and vegetable processors. In order to enable processors to access either the domestic or export markets, it is necessary for the administrative and institutional infrastructures, together with the legal framework, to be continuously developed.

Keywords: Barriers; Compound annual growth rate analysis; Constraint-Faced index; Export market; Tropical fruits and vegetables

1. Introduction

Organizations today frequently struggle to make substantial, long-term changes. Simultaneously, the related organizational approach lacks a readily available agreement on basic change management procedures and concepts. Practitioner dependence on common conceptual frameworks that more frequently use expert opinion over actual research as their foundation was one result of this. A few of the factors that drive organizations and their membership to embrace and make an effort to manage planned change include modern technology, transforming labor, competitive challenges, and globalization (Stouten et al., 2018). In an organization, it is necessary to have elements that help people achieve their goals effectively. Research conducted by (Cumings and Worley, 2014) concluded that a professional organization has many characteristics, including leadership and work motivation. These indicators could decide the direction of an organization's policies. Similarly, (Smither et al., 2016) studied organizational performance and aspired to achieve high levels of professionalism and to perform duties within the domains in which they were concerned. Furthermore, the objective was to generate high-performance achievements while expanding relationships and work engagement, focusing on social interest. Finding strategies to implement significant and long-term planned change was complicated. One explanation for this difficulty was a lack of agreement in the scientific literature on basic renovation mechanisms. The fragmented research on organizational management might make identifying and using scientifically supported concepts challenging. The fundamental obstacle regulated management practitioners encounter is the difficulty of learning from experience. According to research on the development of expertise (Stouten et al., 2018), learning and subsequent performance increases occur gradually through repeated practice in a given domain and direct feedback on results.

A leader is crucial to an organization's efforts to accomplish a predetermined objective. Research conducted by Paais and Pattiruhu (2020) clarified that a leader can influence followers through their actions or personality, depending on effective leadership. The technique entails attitude, movement, conduct, assertiveness, friendly gestures, strength, and the ability to do well. Effective leadership is a mix of ideas, abilities, attributes, and attitudes that a leader frequently employs while seeking to manipulate the performance of subordinates. Likewise, Parulian et al., (2021) characterized leadership abilities as the characteristics—such as attitude, habits, philosophy, and character—that set a leader apart while interacting with others. To accomplish the business's vision and objective and be ready to enhance performance, an organization should adopt the proper skills to cope with any adjustments that may arise (Ichsan et al., 2021). An organization can be transformed from the present state to the intended future through organizational transformation to improve performance (Lai et al., 2020).

The research was analyzed and addressed the influence of leadership behaviors and the changing context in which organizational performance occurs. Thus, the primary objective was to investigate the motivational factors at workplaces and the impact of leadership on organizational performance within Eritrea. The research made an apparent effort to observe how Eritrean organizations changed their leadership styles and regulations over time.

2. Literature Review

Leadership is frequently characterized as persuading people to complete a job by offering a sense of purpose, direction, and drive (Arif et al., 2019). A competent leader establishes the strategy, organizes resources, ensures everyone understands “what is happening,” orients the entire team, and then lets them go (Farahnak et al., 2020). Relationships are essential in leadership, not all concerning products, technological advancement, or generating results; it is more of a human achievement (Arif et al., 2019). Performance leadership is an organized, goal-oriented management and leadership style for high-performing groups, teams, and individuals.

Leaders may help their organizations flourish by defining a vision and supporting transformation. The resulting vision should be well-expressed, understandable, and realistic. The organization's long-term objectives ought to be well understood by leaders, who should also assess the present organizational beliefs and identify the activities needed to reach those goals (Belias and Koustelios, 2014). Consequently, an organization or corporation requires a leader who can serve as an example for the firm's internal members.

Alternatively, work motivation refers to a set of factors that motivate a person to act to achieve their objectives. Work motivation provides energy to someone, causing him to do certain activities to satisfy their requirements (Arif et al., 2019). Work motivation is an emotional state that pushes employees to exert effort to generate goods or services to accomplish a goal. A research conducted by Saputra, (2021), workers should connect their potential effectively to achieve the corporate vision and objectives with greater efficiency. Work motivation is essential for educators and lecturers who work in a professional organization. Contrary to this (Ufaira and Hendriani, 2020), high motivation is problematic since few possess the characteristics necessary to motivate solid interests.

According to Paais and Pattiruhu, (2020), autonomous motivation denotes that organizational management is concerned with every choice to improve employees' well-being and motivate people. Motivated individuals are more oriented toward autonomy and independence and are more self-motivated than less motivated individuals, which benefits their growth chances (Demircioglu and Chen, 2019). Work motivation can be intrinsic or extrinsic. Intrinsic motivation is linked to self-esteem through accomplishment, acknowledgment, acceleration, employment, responsibility, and personal development. Extrinsic motivation develops when motivating variables are not internal to the individual, such as safety, working environment, corporate policy, status, remuneration, and interpersonal connections (Mitchell et al., 2020).

According to management literature, organizational performance is complex and multifaceted (Al Khajeh, 2018). When compared to expected outcomes, goals, and objectives, actual organizational outputs, or results, are considered to constitute an organization's performance. Research conducted by Rehman et al., (2019) stated that organizational performance influences how an organization accomplishes its goal. The organization's overall goal is to improve performance by boosting revenue. Although a crucial concept in previous studies, organizational effectiveness has a vague definition since it evaluates the different organizations to identify different business objects. Organizations use performance to determine the level of their effectiveness. The capacity to create goals and objectives and improve overall organizational performance is unquestionably the most crucial organizational aim and objective (Pang and Lu, 2018). Researchers find defining and quantifying success difficult because organizations usually have several, often conflicting aims. According to Ahmad, (2019) investigation, performance is widely used to evaluate overall organizational wellness and the success of its relevant policies. Organizations, however, are dynamic structures that change with the social, interpersonal, and cultural environments. Numerous recommendations can be maintained through this continuity since some may be specified in the future.

2.1 Conceptual Framework and Hypothesis

As illustrated in Fig. 1, the dependent variable in the study was organizational performance, whereas the independent factor was leadership, with work motivation as a mediator. According to researchers Eliyana and Ma'arif, (2019), Kammerhoff et al., (2019), and Meng and Berger, (2019), there was a significant relationship between leadership function and organizational performance.

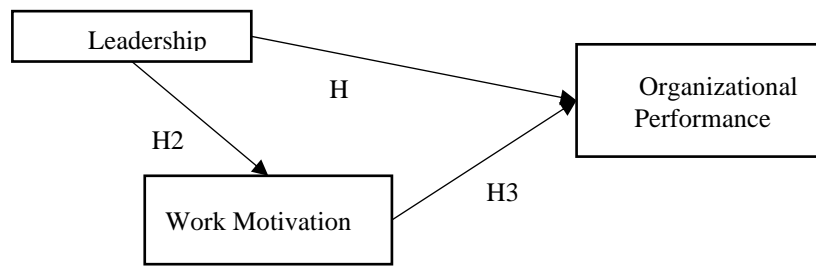


Figure 1: Conceptual framework.

In achieving a goal, the leader's role is extremely significant to the organization's standard; a plan can function efficiently regardless of the cooperation between the leader and the organization; so, leadership is a cause and a consequence, and the influence of any aspect may be collaboratively addressed (Suriyanti, 2020). The influence between a leader and the organization makes a difference and produces observable outcomes representing shared objectives. As a result, future research on the subjects mentioned earlier should be conducted to give a supplementary comprehensive understanding of the relationship between organizational performance and leadership. This leads to the following hypothesis:

H1: *Leadership has a positive and significant influence on organizational performance.*

Being a leader means knowing how to accomplish tasks correctly; to accomplish the goals, someone requires the trust and obedience of others. Additionally, there is a need to encourage workers when individuals are essential to trust and act on behalf of the organization. Theories suggest that followers and leaders inspire each other to reach greater moral and motivational heights (Rukmani et al., 2010). Motivation is just a basic leadership quality. It comes from desiring to act in the best interests of both the organization and the individuals. Thus, further research into these topics is necessary for establishing a more comprehensive picture of the relationship between leadership and work motivation, resulting in the underlying hypothesis:

H2: *Leadership has a positive and significant influence on work motivation.*

People with solid motivation possess various traits, including having realistic objectives, daring to take chances, having high personal accountability, looking for ways to carry out the plans that have been made, and having a clear work schedule (Saputra, 2021). To better understand the relationship between work motivation and organizational performance in various situations, some academics advise conducting additional to-setting investigations (Suriyanti, 2020). While data suggests a positive relationship between work motivation and organizational performance, disagreements and objections remain. Future studies should thus continue investigating these issues and provide a more complete picture of how work motivation and organizational performance are related, leading to the following hypothesis:

H3: *Work motivation mediates the relationship between Leadership and organizational performance*

3. Research Methodology

Research methodology is essential in all forms of research to evaluate the investigation's objectives. Researchers paid attention to this section since it establishes the objective of the research. Proper analysis methodologies are necessary to accomplish research goals and answer theoretical and practical issues. Consequently, we used a quantitative approach and a cross-sectional design for this research to better grasp the nature, goals, and research problems. Additionally, we decided to use a survey to gather data.

SPSS 27 and Amos 23 were applied to analyze the research's theoretical foundation and data. There is no obligation to match the normality criteria with subtlety, and previous research has shown that the SPSS and Amos techniques are the most efficient in managing both complex huge and straightforward models (Hair et al., 2021). Furthermore, some researchers suggested that the partial least squares structural equation modeling (PLS-SEM) technique outperforms another covariance-based strategy in estimating the findings and demonstrating variable validity (Afthanorhan, 2013; Hair et al., 2021). The PLS-SEM approach estimates the measurement model and the structural model. Both were used in the current research evaluation.

Creating the necessary leadership and managerial models, organizational structures, and procedures as required to efficiently and successfully manage massive organizational changes (Sanda, 2017). It has been predicated on the idea that in a context of technological transition, worldwide competitiveness, and social responsibility, management would need to be someone who possesses the integrate accordingly: the capacity to function efficiently as a self-aware and contemplative leader, the capability to comprehend organizational behavior and how to enhance productivity and effectiveness, and the capacity to usher in change.

3.1 Research Instruments

The conceptual foundation of the research included four components. Different objects were used to measure each component. A few earlier investigations employed modified build components. Leadership was composed of 6 factors that were developed by Paais and Pattiruhu, (2020); work motivation was composed of 6 questions that were adapted from Pang and Lu, (2018); and organizational performance was composed of 6 questions that were adapted from a research conducted by Rehman et al., (2019).

3.2 Population Sampling

This research centers on Eritrea's public organizations; respondents were senior managers from various Eritrean organizations. Due to the shorter duration available for data collection, online questionnaires were used to collect. Data has been collected using a five-point Likert scale since, compared to alternative strategies like a seven-point Likert scale, it decreased respondents' levels of annoyance when completing surveys (Naik et al., 2010). The range of this scale was from strongly disagree (1) to strongly agree (5); the mainstream studies favored this scale, which improved response rate and quality (Prakash, 2019). Furthermore, the basic random sampling approach used to gather data from necessary respondents gave each responder an equivalent chance of being selected (Sekaran and Bougie, 2016). In addition, a straightforward random sample method employed most of the earlier studies and yielded broadly applicable conclusions.

4. Data Analysis and Results

4.1 Demographic Profile

Among the respondents to Eritrea's government enterprises, 43.7% are females and 56.3% are males. The majority holds bachelor's and master's degrees. 75.8% of the workforce were between the ages of 30 and 50, with most respondents having five to ten and eleven to fifteen years of experience. Governments, public organizations, and educational institutions were among the employers of respondents.

4.2 Statistical Analysis Results

The Reliability Statistics for the significance of each variable were checked by Cronbach alpha ($C\alpha$). The $C\alpha$ value for the significance of the factors was 0.858, indicating that the accuracy of such variables has high internal consistency. In addition, the $C\alpha$ value for the significance of the group component of the total dataset is 0.848, deemed excellent.

Table 1 illustrates the regression weight and validity of the study variables by comparing the value of the Critical Ratio (C.R.) and the estimated value to the Standard error (S.E.) value considered modest. Factor (**L4**) was used to examine the impact of Confirmatory factor analysis (CFA) on the regression value for the highest critical leadership variable. Similarly, factor (**M4**) was the factor that made up most of the motivational factors. As a result, when considering endogenous factors performance variables, **P5** was the most significant factor. The measurement of the variables can be considered valid and reliable based on the consideration of the factors.

Table 1: Confirmatory Factor Analysis (CFA)

	RW	SRW	S.E.	C.R.	P	Results
L6	1	0.686				
L5	0.779	0.617	0.126	6.179	***	Valid
L4	0.809	0.568	0.139	5.808	***	Valid
L3	0.634	0.449	0.133	4.766	***	Valid
L2	0.508	0.366	0.128	3.972	***	Valid
L1	0.426	0.317	0.152	2.806	0.005	Valid
P1	1	0.61				
P2	0.721	0.521	0.132	5.45	***	Valid
P3	0.793	0.486	0.163	4.853	***	Valid
P4	1.027	0.679	0.155	6.614	***	Valid
P5	1.213	0.73	0.176	6.912	***	Valid
P6	0.433	0.312	0.124	3.502	***	Valid
M6	1	0.549				
M5	1.156	0.664	0.191	6.055	***	Valid
M4	1.442	0.747	0.222	6.492	***	Valid
M3	1.168	0.601	0.205	5.682	***	Valid
M2	1.201	0.579	0.217	5.539	***	Valid
M1	1.391	0.667	0.226	6.148	***	Valid

Note: RW= Regression Weight; SRW=Standardized RW; L= Leadership; P= Organizational Performance; M= Work Motivation *** is significant at 0.01 in a statistic.

Furthermore, in testing model feasibility, the model was modified by linking error variables to lines and covariates, as shown in Figure 2. The appropriate value for relative chi-square, CMIN/DF, should be as high as 5, which was utilized to lessen sample size reliance. On the other hand, TLI, CFI, NFI, and IFI's cut-off points range from 0 to 1, as shown in Table 2. The measurement of the model's feasibility has been practicable after evaluating the second stage using modification indices.

Table 2: Goodness of Fit Model

The goodness of the Fit index	Cut-off Value	Result of Modification Indices	Info
Chi-Square	Ex-pected small	324.944	Fit
Probability	≤0.05	0.000	Significant
CMIN/DF	≤ 3.00	2.621	Acceptable Fit

RMSEA	\leq 0.08	0.079	Acceptable
NFI	0 to 1	0.688	Moderate
IFI	0 to 1	0.781	Moderate
TLI	0 to 1	0.720	Moderate
CFI	0 to 1	0.773	Moderate
DF	124		

Testing the hypotheses, as shown in Table 3, indicates that, the results of the hypothesis test with a *p*-value of 0.047 for hypothesis one (H1) which is positively significant. Similarly, Hypotheses, H2 and H3 were positive and significant, with *p*-values of less than 0.01.

Table 3: Hypothesis Test Results

<i>Hypothesis</i>	<i>RW</i>	<i>SRW</i>	<i>S.E.</i>	<i>C.R.</i>	<i>P</i>	<i>Info</i>	<i>Result</i>
H1 L → P	0.245	0.266	0.123	1.987	0.047	Significant	Support
H2 L → M	0.448	0.679	0.093	4.843	***	Significant	Support
H3 M → P	0.827	0.595	0.217	3.811	***	Significant	support

Note: RW= Regression Weight; SRW= Standardized Regression Weight; *** is significant at 0.01 in a statistic.

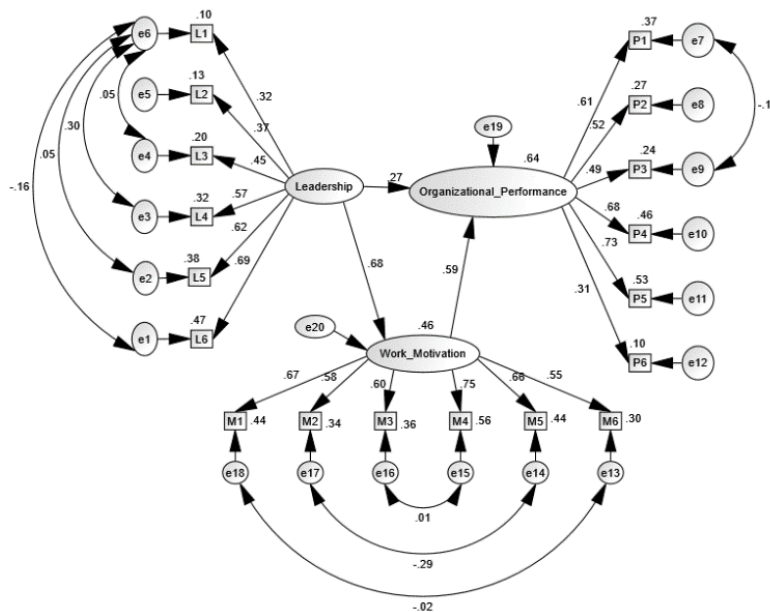


Figure 2: The Structural Equation Model.

5. Discussion

Work motivation has a substantial psychological influence on the public organization as a basis for boosting organizational performance. Giving a significant incentive for each successful job measurement signifies business professionalism (Saputra, 2021). Additionally, it is essential to inspire employees so that they pursue their goals in the workplace. This is the primary incentive for an employee to stay with the firm, as shown through career pathways that the organization deems appropriate. Work motivation is also affected by the workplace environment and social

relationships (Paais and Pattiruhu, 2020). A precise, measurable, and planned training and incentive system demonstrates that leadership has a positive and substantial influence on job motivation and direct and indirect effects on organizational performance. These might be regarded as necessary leadership elements for organizations to attain job motivation. Leadership is being able to guide, mobilize, and persuade personnel to improve organizational performance for carrying out the primary activities and functions of the work process.

The evidence demonstrates that for organizations to function well, leaders in all guises—personal, non-personal, democratic, authoritarian, paternalistic, etc.—are required (Kammerhoff et al., 2019). Leaders frequently modify the character of management when confronted with personnel situations and organizational dynamics. The significance of previous research findings and the results of such a study could be explained by an indicator of the leadership style that improves overall organizational performance in public companies (Suriyanti, 2020). First, the style of leadership that can be inferred from the personality displayed is that of a manager who is curious about the many job motives and staff activities. Managers often play a close-knit role with their staff when giving instructions, enforcing rules, or considering issues of employees' concerns to improve job performance. Managers constantly have dialogues with employees about various work activities topics to enhance organizational performance in public organizations. Adopting leadership styles can be acceptable when the nature of the workforce is understood. The type of organizational nature, organizational culture, employment-based employment, and the degree of internal organizational knowledge all influence the leadership pattern.

6. Conclusions and Recommendations

The study places significant emphasis on the crucial nature of maintaining a balance between extrinsic and intrinsic rewards within the upper echelons of management structures in Eritrea. It posits that segregating personal challenges from those that are job-related can exert a positive influence on work motivation, thereby impacting the overall performance of the organization. Firms that offer high wages but fail to provide intrinsic rewards tend to suffer from subpar labor performance. Additionally, the study sheds light on the indirect advantages of effective leadership in enhancing organizational performance, thereby urging public companies to reconsider their strategies. Work motivations serve as a vital resource within an organization, yielding significant benefits in terms of performance. Drawing upon the resource orchestration theory, organizations are urged to effectively gather, leverage, and package their resources to enhance performance. The study amalgamates organizational resources with strategic leadership in a comprehensive manner, thereby bolstering work motivation and achieving superior outcomes. The results obtained lend support to the hypothesis of resource orchestration, suggesting that senior executives should evaluate the organizational skills to gauge the success of public organizations. The research concludes that the government in Eritrea must dedicate efforts towards establishing a transparent and proactive leadership strategy that inspires and retains dedicated leaders who contribute positively to the growth of public organizations within the nation. The study also proposes future directions for the successful and long-term management of public organizational performance through effective leadership. Nevertheless, it is crucial to recognize that the research does have a few limitations, such as its exclusive focus on Eritrea, its relatively brief duration, and its dependence on work motivation as a mediating factor.

Declaration of Conflicting Interests

The author(s) stated no potential conflicts of interest concerning the research, writing, and publishing of this article.

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HOW DOES FINANCIAL LITERACY EFFECT ON PERFORMANCE OF SMALL AND MEDIUM SIZED ENTERPRISES OF SRI LANKA

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Abstract: The research explores how financial literacy levels influence various indicators of firm performance, including profitability, growth, and sustainability, within the context of SMEs. The performance of the SME will be measured as an indicator of their business performance. The study analyzed the financial literacy of SME owner-managers, specifically focusing on their financial behavior and handling, financial knowledge, financial attitudes, and financial awareness in relation to their firms' performance. Thus, a quantitative investigation using the Prospect Theory and Exchange Theory as a foundation has been carried out. In order to get the necessary data, a representative convenient sampling method was utilized on a sample of 170 SMEs in the Colombo district. The study was conducted using primary data collected through a questionnaire. Structural Equation Modelling and a reliability and validity test were used as analysis methods. The study's conclusions showed a positive correlation between business performance and financial literacy. As a result, independent variables like financial behavior and handling, financial knowledge, financial attitudes, and financial awareness impact how well SMEs do in business. This study demonstrates a strong correlation between financial awareness, knowledge, attitudes, behavior and handling, and firm performance. It was determined that financial literacy had a significant direct impact on the performance of sustainable businesses. The results confirmed that having a strong understanding of finance significantly improves a company's performance. Consequently, it can be inferred from the results of this study that increasing financial literacy is crucial for developing a successful plan for enhancing entrepreneurial performance. Financial knowledge, awareness, behavior, and attitudes are all linked to business performance. This study also concluded that business owners and staff ought to have greater levels of education. It should encourage knowledge sharing among employees and the hiring of more skilled workers, according to the exchange theory's rationale. Therefore, policymakers and business owners should set up training programs to advance financial literacy.

Keywords: Small and medium Enterprises; Financial literacy; Structural equation Modelling; Prospect theory; Exchange theory

1. Introduction

Small and medium-sized enterprises (SMEs) have a substantial impact on a nation's economic growth, and the literature is clear about this (Samuel Kwaku Agyei & Christian Nsiah, 2018). Despite the role that SMEs play in economic development, study has shown that their performance is lower in underdeveloped countries, which prevents them from fulfilling their share of the responsibility for the economy's growth (Jianmu Ye & KMMCB Kulathunga, 2019) (Omiunu, 2019). In general, it was found that barriers to SME performance included a lack of capital and credit facilities, a lack of skilled labour, a lack of raw materials, poor infrastructure, a lack of workforce with the necessary management skills, and restrained use of new, emerging, and constantly changing technologies (Judit Oláh, Sándor Kovács, Zuzana Virglerova, Zoltán Lakner, Maria Kovacova & József Popp, 2019) (Jie Wu & Steven Si, 2018).

SMEs, which account for 80% of all companies in Sri Lanka, are crucial to the country's economy. These can be found in the economy's primary, secondary, and tertiary sectors and provide jobs for both skilled and unskilled employees. Enterprises that engage in the production of herbs, fruits, and vegetables, as well as manufacturers who take part in a variety of industrial operations, make up about 20% of all businesses that are defined as SMEs. SMEs make up the majority of service suppliers because they account for about 35% of all jobs, SMEs are essential to the industry. SMEs play a critical role in promoting broad-based economic success. However, as mentioned, Sri Lanka's SMEs contribute more than 90% of its GDP (Bamunusinghe, 2022). SMEs in Sri Lanka generate roughly 52% of the country's GDP and 5% of its exports. Sri Lanka is currently experiencing an economic crisis, which has prompted the government to intervene and initiate numerous new regulations to protect the market and the nation's diverse companies (Bamunusinghe, 2022).

Financial literacy seems to be the main challenge for societies in the near future; financial knowledge and skills are quite poor worldwide and affect the growth of economies. Evidence shows that many individuals are not well-equipped to make sound financial decisions (Allgood, Sam, and William Walstad, 2013). Sri Lanka has been experiencing lower economic progress over decades for several reasons. In 2021, the Sri Lankan economy grew by only 3.3 percent in real terms (World Bank, 2021). (Aslam, Fahim, Kulasena & Hashan, 2017) denoted that lower financial literacy among the general public is another reason for this situation. Most of the financial concepts designated under personal financing apply to the nation's financial health. Though the government investment, borrowing, and taxation policies are also driven by finance fundamentals, due to a lack of financial literacy, people did not question the viability of certain economic decisions made by present and former governments (Weerakoon, 2017). Financial literacy is crucial for a business to perform better, and it would also offer an entrepreneur an advantage when making financial or investment decisions. In a fast-paced business environment, entrepreneurs face various obstacles that can be overcome by developing their financial literacy. Numerous studies have shown that entrepreneurs with financial literacy are more successful than those without it, but few such studies are in the Sri Lankan context. In fact, most SMEs in the informal sector are financially illiterate, have little to no primary education, and many business owners don't maintain records. To answer the study question, "How does financial literacy influence the firm performance of SMEs?" It is interesting to look into whether financial literacy impacts SMEs' performance.

In this regard, the current research gap is intended to be filled to achieve the goals that are stated regarding how financial literacy impacts the business performance of Small & Medium-scale Enterprises (SMEs) of the Colombo area in Sri Lanka. As a result, this research aims to investigate the relationship between financial variables like financial behavior, knowledge, attitude, and financial awareness skills and company performance.

2. Literature review

Financial literacy is the ability to use knowledge and skills to make effective and informed money management decisions, balance the chequebook, manage a credit card, prepare a budget, take a loan, and buy insurance. Financial literacy makes personal finance decisions in real estate, insurance, investing, saving, tax planning, and retirement. It also involves intimate knowledge of financial concepts like compound interest, financial planning, the mechanics of a credit card, advantageous savings methods, consumer rights, the time value of money, etc. (Chijwani, 2014). Financial behaviour can be defined as any human behaviour relevant to financial management, whereas common financial behaviours include budgeting, credit utilization, and saving (Rahman, Isa, & Masud, 2021). According to Hidajat, personal finance is the application of the principles of finance to the monetary decisions of an individual or family unit (Hidajat, 2015). It addresses the ways in which individuals or families obtain, budget, save, and spend monetary resources over time, taking into account various financial risks and future life events. Moreover, it denotes components of personal finance might include savings accounts, credit cards and consumer loans, retirement planning, investments and insurance policies and income tax management. A firm's ability to survive depends on both its financial behaviour and the efficient use of its financial resources (Abiodun & Harry, 2016). Financial behaviour includes choices that aim to increase wealth, sales, profits, and market share. Financial behaviour such as debt management, cash flow management, and for small and medium enterprises, savings and investment methods that optimize returns all have a positive correlation with financial literacy (Grohmann, Menkhoff, & Storck, 2015).

H₁: financial behaviour has a significant positive impact on performances of SMEs.

In order to achieve a quality life as working adults, money management skill plays an important role because students' spending habits on campus will influence the way they manage money throughout their lives (Iqbal, Ahmad, & Riaz, 2014). As a result, money management is considered as one of the dimensions that could affect the financial literacy level. Successfully managing money is an important learned skill for individuals as financial resources and financial conditions affect their quality of life and social relationships. Investment involves postponing the consumption today in order to put savings to work and also investment can be described as the bridge between having surplus cash and reaping returns. In other words, investment has the potential to move the surplus funds of one person to another who needs or requires those funds (Tawiah, 2015). To make investment decisions, individuals require knowledge beyond fundamental financial concepts including relationship between risk and return; how bonds, stocks, and mutual funds work (Lusardi, 2008). Interest rates, the size of the monthly payments for installments loans, expectations regarding future income, and wealth are all factors which affect individuals' decisions to borrow (Klapper, Lusardi, & Panos, 2011).

H₂: financial handling has a significant positive impact on performances of SMEs

A person who is conscious of their financial capabilities can take action to alter their financial outcomes by being financially awareness (Pahlevi & Nashrullah, 2020). A business owner needs financial literacy as a fundamental financial concept to manage finances and make short- to long-term investment choices (Damayanti, Al-shami, S.S.A.; Rahim; Rahim, Marwati, & Malaysia, 2018). The company owner's behavior in terms of how they handle money is influenced by their financial awareness. Understanding the financial market and how new product development can satisfy the changing demands on the financial market is also helpful (Dalkilic, & Kirkbesoglu, 2015) According to (Taviti Naidu, 2020), issues with the economy and financial markets promote the use of novel financial products. As a consequence, the effectiveness of financial awareness will be impacted by new products developed "to satisfy new needs in financial markets" (Eniola, & Entebang, 2017). Since finances are central to small companies' social lives, owners are realizing how crucial it is to manage financial situations (Dalkilic, & Kirkbesoglu, 2015). A small company owner's choice of which financial advisor to consult when

facing financial difficulties is influenced by their financial literacy as well (Eniola & Entebang, 2017). For SME owners, having financial knowledge aids in retirement planning. According to (Esiebugie, Richard & Emmanuel, 2018), education level and business courses completed have an impact on people's awareness of financial products. The owner of a SME may make poor financial decisions that have an effect on the expansion of their company. In this respect, financial literacy training for SME owners is essential for the expansion of their companies. Depending on the type of SME, a different degree of financial awareness may be required. Owners and managers must, however, comprehend fundamental financial reports and accounting principles, cash flow and profit, customized reporting to meet the unique needs of the type of SME, assistance in identifying weaknesses in key operational areas of SME, monitoring of year-over-year income and expenditure, and locating automation options to save time and money.

H₃: Awareness has a significant positive impact on performances of SMEs.

Small business managers will perform better for their businesses if they are eager to increase their bottom lines by becoming more knowledgeable about financial management. It has been suggested that having understanding of finances is a requirement for a manager to have sound financial attitudes (Hathaway, & Khatiwada, 2008). According to one theory, a manager's financial attitudes will advance if they have a solid understanding of these attitudes (Eniola, & Entebang, 2017). According to studies, developing the proper financial mindset in terms of, among other things, instruction, tolerance for risk, and time orientation can improve financial literacy. (Abiodun & Harry, 2016) noted that business activities like being capable of obtaining various forms of finance and growing capital, to name a few, are affected by the manager of SMEs' attitude toward financial matters. Furthermore, it was asserted that successful people were financially literate, having made long-term investments and savings to guarantee their future well-being.

H₄: Financial attitudes has a significant positive impact on the performance of SMEs.

Financial knowledge, as described by (Huston, 2017), is the capacity to comprehend the key financial concepts and terms that an individual or organization needs for carrying out everyday activities. (Potrich, Kelmara, & Wesley, 2016) provided a slightly different definition for financial knowledge, referring to it as a particular type of capital that a person can acquire and including the ability to handle managing expenses, incomes, and savings in a secure manner. The organization for economic cooperation and development (OECD, 2011) also claims that questions relating to concepts like inflation, risk and return, simple interest, and compound interest are crucial in determining a person's degree of financial literacy (OECD INFE, 2011). For both individuals and businesses, having a solid understanding of finances is crucial when making financial decisions. It is generally asserted that increasing financial literacy will lead to better financial choices because it encourages more responsible financial behaviour. (Tang & Morteza, 2015). A higher degree of knowledge is positively correlated with people exhibiting a number of financial "best practices," according to empirical research.

H₅: Financial Knowledge has a significant positive impact on performances of SMEs.

3. Methodology

The study attempts to investigate the financial knowledge of SME owners, which may be influenced by their financial behavior on firm performance that emanates from individuals, and aims to identify which aspects of financial literacy they consider to be of the extreme significance to them in determining higher performance in making financial decisions. As a result, the population for this study consisted of all Colombo district manufacturing SMEs, and data was collected in a single time period rather than multiple time periods. First, the sample frame for the study was limited to enterprises classified as manufacturing. The sample frame (14,185 SMEs) was then used to select 170 SMEs using the sample size determination formula with convenient sampling method.

A semi-structured questionnaire covering six areas, respondent personal information, financial behavior, financial handling, financial attitude, financial understanding and financial performance, is created in order to gather data. The Structural Equation Model is used to achieve the research objectives. Confirmatory factor analysis (CFA) was used to examine the construct reliability of the measurement models for each variable. Before performing CFA, it is critical to conduct an exploratory factor analysis (EFA). To confirm EFA, the Kaiser-Meyer-Olkin (KMO) value, Bartlett's Test of Sphericity for sample adequacy, and factor loadings for internal consistency were calculated. The integrity of fit of the measurement model was assessed using Chi-square/df3, GFI > 0.9, AGFI > 0.9, CFI > 0.9, and RMSEA 0.08 values (Hair et al., 2010). When the overall statistical method is accepted (Chi-square/df 3, fit indices >0.9, and RMSEA 0.08), all factor loadings are greater than 0.5, and discriminant validity is met, the structural model is developed, and goodness-of-fit is assessed. The SMARTPLS Software, SEM was then used to test and validate hypotheses.

4. Results and Discussion

Based on specified goals, this section presents and interprets the data that was acquired. The results were then considered to see if they agreed or disagreed with the literature that had been analyzed. Measurement items' one-dimensionality is accounted for through factor loading. For an established item, the factor loading value should be 0.7 or higher. If items' factor loadings are low, they must be eliminated one at a time from the measurement model. Due to low factor loadings, one item (from the FK (2)) was removed from the current analysis. All of the remaining item loading are above the suggested value, as shown in Figure 1.

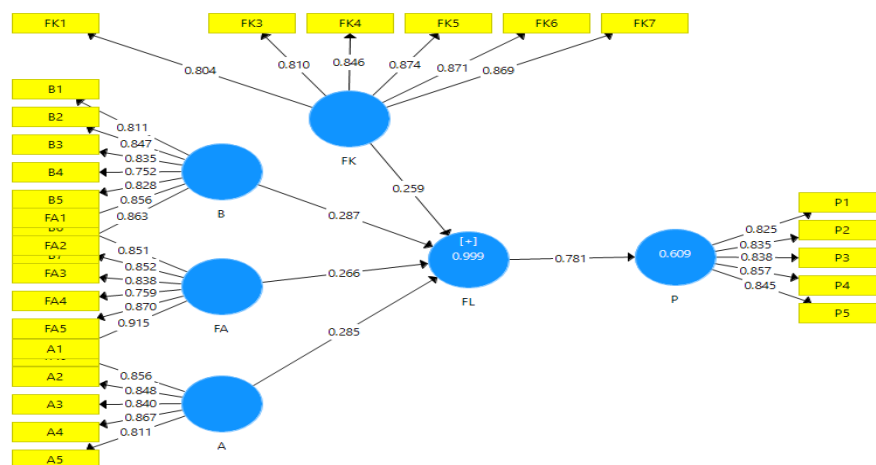


Figure 1: Structural Model.

Note: A= Financial Awareness, B= Financial Behavior, FA=Financial Attitudes, FK=Financial Knowledge, FL=Financial Literacy, P =Performances

The measurement model was tested utilizing construct reliability, convergent validity, and discriminant validity, according to Hair et al. (2010). The construct reliability of the model was measured using composite reliability and Cronbach alpha. The measurement model's composite reliability ranged from 0.923 to 0.951, while the construct's factor loading value ranged from 0.752 to 0.934 (above the threshold level (>0.5)). The measurement model is fit and trustworthy for additional testing (Hair et al., 2014). Fornell and Larcker (1981) used the average variance extracted (AVE) to assess the convergent validity of each component. The AVE values of all constructs exceeded the threshold value of >0.5. There is no multicollinearity issue between the indicators if the VIF values of all the indicators are less than 5.0.

Hypothesis Testing and Testing Association

Following the direct relationship, it shows the evaluation of structural path for the evaluation of path coefficients (relationships among study constructs) and their statistical significance (Table 1). H1 and H2 assess if financial conduct and management have a significant and positive impact on the performance of SMEs. Financial conduct and handling have a significant and beneficial impact on the performance of SMEs ($\beta=0.223$, $t = 16.962$, $p = 0.001$). As a result, H1 and H2 were supported. H3 assesses if Financial Awareness has a significant and positive impact on the performance of SMEs. Financial Awareness has a significant and beneficial impact on the performance of SMEs, according to the findings ($\beta=0.224$, $t = 13.399$, $p = 0.001$). As a result, H3 was approved. H4 assesses if Financial Attitudes have a significant and positive impact on the performance of SMEs. Financial Attitudes had a significant and beneficial impact on the performance of SMEs ($\beta=0.208$, $t = 12.296$, $p = 0.001$). As a result, H4 was approved.

Table 1: Direct relationships

Relationship	β	SD	T Statistics	P Values	Result
H1 B -> P	0.223	0.013	16.962	0.000	Supported
H2 B -> P	0.223	0.013	16.962	0.000	Supported
H3 A -> P	0.224	0.017	13.399	0.000	Supported
H4 FA ->P	0.208	0.017	12.296	0.000	Supported
H5 FK -> P	0.202	0.013	15.603	0.000	Supported
H6 FL -> P	0.781	0.058	13.458	0.000	Supported

H5 assesses if Financial Knowledge has a significant and positive impact on the performance of SMEs. Financial Knowledge has a significant and beneficial impact on the performance of SMEs, according to the findings ($\beta=0.202$, $t = 15.603$, $p = 0.001$). As a result, H5 was approved. H6 assesses if Financial Literacy has a significant and positive impact on the performance of SMEs. Financial Literacy has a significant and favorable impact on the performance of SMEs, according to the findings ($\beta=0.781$, $t = 13.458$, $p = 0.001$). As a result, H6 was approved.

Table 2: Specific Indirect relationship

Relationship	β	Standard Deviation	T Statistics	P Values
A -> FL -> P	0.223	0.013	16.962	0.000
B -> FL -> P	0.224	0.017	13.399	0.000
FA -> FL -> P	0.208	0.017	12.296	0.000
FK -> FL -> P	0.202	0.013	15.603	0.000

According to the specific indirect relationship (Table 2) , there is a significant relationship between financial awareness, financial behavior, and handling, financial attitudes, and financial knowledge with financial literacy and firm performances. Hence all the p values are less than 0.001

The conclusion that financial literacy has a strong favorable impact on business performance is supported by other studies as well (Purnomo , 2019). This study also supports the findings of (Memon , Yong., &Memon, 2019), who found that managers with financial literacy are better able to spot possibilities and innovative solutions that may enhance performance. Thus, this study's findings that financial knowledge, awareness, behavior, and attitudes are related to firm performance have led to the conclusion that improving financial literacy is essential to creating a successful strategy for boosting entrepreneurial performance (Adomako &Danso, 2014); (Kojo & Oseifuah, 2010); (Glaser,& Walther, 2013). The results, therefore, differ from those of (Potrich, Kelmara, & Wesley., 2016), who came to the view that the financial behavior of SMEs has a significant impact on the performance of the organization. Despite the fact that the majority

of owner-manager respondents indicated a high correlation between financial knowledge, awareness, and attitudes and business success, financial awareness (skill) also appears to be associated with firm performance. According to (Sucuahi, 2013), financial awareness (SKIL) may benefit a company's future. This conclusion is consistent. Contrary to what was discovered here, (Chatterjee, & Das,2016) study concluded that microbusinesses had a detrimental impact on the economy. The future of the company could benefit from financial awareness (Sucuahi, 2013). Additionally, numerous studies have demonstrated that human capital and financial literacy (SKIL) are unquestionably the main forces behind SME growth (Parisa , Mohammad, & Morteza , 2018); (Perks, 2010). In several studies, it has been demonstrated that business performance improves economic, environmental, and social results (Eltayeb, Zailani,S. & Ramayah, 2011).This study discovered a strong link between financial literacy and firm performance, which is consistent with their findings. This result is consistent with a previous study's explanation of a connection between financial literacy and firm performance. According to certain studies, there is a causal link between literacy and firm performance that extends both in the negative (from firm performance to literacy) and the positive (from Literacy to firm performance) directions. Additionally, a company's engagement in sustainability initiatives will change depending on how well it performs financially in one era. Strong financial performance in the past increases the likelihood that a business will use the extra funds to give sustainability projects top priority. Sustainability activities are less likely to be prioritized by a company with a poor financial history. According to certain studies, a business will fare well in terms of sustainability if it is doing well financially.

A study by (Chang & Kuo,2008) found a correlation between the two ideas; stronger financial performance tends to be associated with sustainable policies, and vice versa. This study found that owner-managers are helpful in selecting a financing choice, budgeting, estimating costs, and deciding on output.

5. Conclusion

Examining how financial literacy affects the performance of small and medium-sized businesses in the Colombo area was the main goal of this study. Owner-managers of SMEs are the essential decision-makers who steer the company in the right direction. One of the key ideas to consider while assessing business performance is financial literacy. The study's findings indicate that the four aspects of financial literacy knowledge, awareness, behavior and handling, and attitudes have a considerable impact on small and medium-sized enterprises (SMEs) firms' success. Additionally, this study shows a substantial correlation between financial awareness, financial knowledge, financial attitudes, financial conduct, and financial handling and firm performance. Taking into account the aforementioned findings, the researcher suggested that efforts be made by banks, microfinance institutions, as well as government agencies in an effort to improve the literacy levels of business owners. The researcher also suggested that financial education programs be organized in order to increase the awareness of SME managers on various financial matters, including but not limited to demonstrating knowledge about all kinds of finance for businesses in their infancy. Such measures would result in the growth and expansion of SMEs, particularly in areas where they had previously failed.

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ICSD 204

NAVIGATING INNOVATION BARRIERS IN SRI LANKAN SMES: A COMPREHENSIVE CASE STUDY

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Abstract: Small and medium Enterprises (SMEs) in Sri Lanka, while integral to economic development, face a distinctive set of challenges hindering their ability to innovate and engage in invention. This research addresses the critical problem of identifying and understanding the barriers hindering innovation within the unique context of Sri Lankan SMEs. The overarching aim is to contribute actionable insights that can empower SMEs, policy-makers, and industry stakeholders to foster a more innovation-friendly environment. In-depth case study was conducted by combining qualitative research methods such as interviews, surveys, and document analysis for the data collection. A diverse selection of SME cases across sectors and regions were studied to capture the complexity and nuances of the innovation landscape in Sri Lanka. By exploring funding constraints, skill gaps, regulatory complexities, technology adoption challenges, and the impact of market competition, the research aims to uncover the interconnected web of barriers that hinder the innovative capacities of SMEs. The principal conclusions would highlight the specific barriers that significantly impede innovation, and the research would propose strategies to mitigate these challenges. The overall impact of this work lies in its potential to stimulate a shift in the innovation paradigm for SMEs in Sri Lanka, contributing to economic growth, increased competitiveness, and a more resilient SME sector capable of navigating the complexities of the global marketplace. This research seeks not only to illuminate the hurdles faced by SMEs but to provide a foundation for transformative actions that will shape the future innovation in Sri Lanka's entrepreneurial landscape.

Keywords: Innovation barriers; SMEs; Strategic solutions; Innovation and Invention

1. Introduction

Small and Medium Enterprises (SMEs) constitute a vital segment of Sri Lanka's economy, serving as engines of growth, innovation, and employment generation. As key contributors to economic development, SMEs play a crucial role in driving innovation, fostering entrepreneurship, and enhancing the country's competitiveness in the global marketplace (Jayawickrama & Kumarasiri, 2020).

Innovation is widely recognized as a catalyst for sustainable growth and competitive advantage, particularly for SMEs operating in dynamic and rapidly evolving business environments. By introducing new products, processes, and business models, innovative SMEs can enhance productivity, expand market reach, and adapt to changing consumer preferences more effectively (Dissanayake, 2019).

However, despite their significance, SMEs in Sri Lanka face a distinctive set of challenges that hinder their ability to innovate and realize their full potential for economic contribution. These challenges, collectively referred to as innovation barriers, encompass various factors such as funding constraints, skill shortages, regulatory complexities, technology adoption hurdles, and intense market competition (Wickramasinghe & Jayathilaka, 2021).

The identification and understanding of these innovation barriers within the unique context of Sri Lankan SMEs constitute a critical research problem that requires systematic investigation. By unraveling the complexities of these barriers, researchers, policymakers, and industry stakeholders can gain valuable insights into the underlying challenges hindering innovation in SMEs and devise targeted interventions to address them effectively.

The overarching aim of this research is to contribute actionable insights that empower SMEs, policymakers, and industry stakeholders to foster a more innovation-friendly environment in Sri Lanka. Specifically, the objectives of the study are as follows:

- 1 To identify the specific barriers hindering innovation within Sri Lankan SMEs.
- 2 To understand the interconnected web of innovation barriers and their impacts on SMEs.
- 3 To investigate the extent to which innovation barriers vary across different sectors and regions within Sri Lanka.
- 4 To propose actionable strategies for mitigating innovation barriers and fostering a more innovation-friendly environment for Sri Lankan SMEs.

By addressing these objectives, this research aims to contribute to the development of evidence-based policies, programs, and initiatives aimed at overcoming innovation barriers and enhancing the innovative capacities of SMEs in Sri Lanka.

2. Literature Review

2.1 Introduction

The literature on innovation barriers in Small and Medium Enterprises (SMEs) globally provides valuable insights into the multifaceted challenges faced by these businesses in fostering innovation. Understanding the global landscape of innovation barriers is essential for contextualizing the specific challenges encountered by SMEs in Sri Lanka and informing targeted interventions to address them effectively.

2.2 Overview of Existing Literature on Innovation Barriers in SMEs Globally

Research on innovation barriers in SMEs has identified a wide range of challenges that impede their ability to innovate and compete in the marketplace. According to a study by Hsu, Chen, and Chen (2016), common barriers include limited financial resources, lack of access to technology and knowledge, risk aversion, and organizational inertia. These barriers often stem from SMEs' resource constraints, limited absorptive capacity, and risk-averse organizational cultures.

Furthermore, a meta-analysis conducted by Laforet and Tann (2006) highlights the significance of external factors such as market conditions, industry characteristics, and regulatory environments in shaping innovation barriers for SMEs. Market competition, for instance, can exert pressure on SMEs to prioritize short-term objectives over long-term innovation investments, while regulatory complexities can create compliance burdens and deter innovation initiatives.

2.3 Review of Relevant Studies on Innovation Challenges Specific to Sri Lankan SMEs

In the context of Sri Lanka, several studies have shed light on the innovation challenges faced by SMEs in the country. For example, Fernando and Jayaratne (2018) emphasize the importance of addressing funding constraints and skill shortages to enhance SMEs' innovation capabilities. They argue that access to finance and human capital are critical determinants of SMEs' ability to invest in research and development (R&D) and adopt innovative practices.

Moreover, Wickramasinghe and Jayathilaka (2021) highlight the role of regulatory frameworks and institutional support in shaping innovation outcomes for SMEs in Sri Lanka. They argue that streamlining regulatory processes, providing incentives for innovation, and strengthening support mechanisms can create an enabling environment for SME innovation.

2.4 Conceptual Framework: Understanding Innovation Barriers Within the Context of SMEs

Building on existing literature, our conceptual framework for understanding innovation barriers within the context of SMEs in Sri Lanka integrates both internal and external factors influencing innovation outcomes. Internal factors such as financial resources, human capital, organizational culture, and innovation capabilities interact with external factors including market dynamics, industry characteristics, regulatory frameworks, and institutional support to shape the innovation landscape for SMEs.

This framework emphasizes the interconnectedness of innovation barriers and underscores the importance of adopting a holistic approach to address them effectively. By addressing both internal and external barriers in a coordinated manner, policymakers, industry stakeholders, and SMEs themselves can create a more conducive environment for innovation and entrepreneurship in Sri Lanka.

3. Methodology

SMEs were selected based on criteria such as industry sector, size, and geographical location to ensure diversity in the sample. A purposive sampling approach was employed to select SMEs that could provide rich insights into the innovation barriers faced within the Sri Lankan context (Creswell & Poth, 2018). The participants in this qualitative study comprised 10 Small and Medium Enterprises (SMEs) operating across diverse sectors and geographical areas within Sri Lanka (Patton, 2015). The characteristics of the selected SMEs, including their location, number of employees, industry sector, years in operation, annual revenue, and ownership structure, are summarized in Table 1 below.

Table 1 Characteristics of Selected SMEs

No	Location	No of Emp	Industry Sector	Years in operation	Annual Revenue	Ownership Structure
1	Colombo	200	Manufacturing	8	600M	Family
2	Galle	150	Service	6	350M	Privately
3	Kandy	280	Tech	10	200M	Privately
4	Jaffna	180	Manufacturing	12	550M	Public Traded
5	Kurunegala	90	Service	4	250M	Family

6	Matara	120	Manufacturing	7	500M	Privately
7	Negombo	160	Tech	5	550M	Family
8	Ratnapura	220	Service	9	250M	Family
9	Trincmalee	245	Service	11	375M	Privately
10	Anuradhapura	190	Manufacturing	6	400M	Privately

Potential participants were contacted through professional networks, industry associations, and referrals. Information about the study's objectives, procedures, and confidentiality measures was provided to potential participants, and their consent to participate was obtained.

Semi-structured interviews were conducted with key personnel, including owners, managers, and employees involved in innovation-related activities within the SMEs. The interviews were designed to explore the specific innovation barriers faced by the SMEs, including funding constraints, skill gaps, regulatory complexities, technology adoption challenges, and the impact of market competition.

The interview protocol was developed based on the themes identified in the literature review and refined through pilot testing. Open-ended questions were used to allow participants to provide detailed insights into their experiences and perspectives on innovation barriers (Denzin & Lincoln, 2018).

Qualitative data from the interviews were analyzed using thematic analysis, a method for identifying, analyzing, and reporting patterns (themes) within data (Braun & Clarke, 2006). The transcripts were coded line-by-line to identify recurrent themes related to innovation barriers. Codes were then organized into broader themes to develop a comprehensive understanding of the data.

4. Results

4.1 Overview of SMEs Included in the study.

The study included a diverse selection of SMEs across various industry sectors and geographical regions in Sri Lanka. The distribution of SMEs by sector and region is summarized as below:

Sector Distribution

The SMEs included in the study represented a range of industry sectors, including manufacturing, services, and technology. Table 2 provides a breakdown of the distribution of SMEs by sector.

Table 2 Sector Distribution of Selected SMEs

Sector	Number of SMEs
Manufacturing	4
Services	4
Technology	2

Region Distribution

Geographically, the selected SMEs were located across different regions of Sri Lanka, ensuring representation from urban and rural areas. Table 3 presents the distribution of SMEs by region:

Table 3 Region Distribution of Selected SMEs

Region	Number of SMEs
Western Province	4
Southern province	3

The distribution of SMEs across sectors and regions demonstrates the diversity of the sample and ensures a comprehensive understanding of the innovation landscape within the SME sector in Sri Lanka.

4.2 Objective 1 (To identify the specific barriers hindering innovation within Sri Lankan SMEs)

The findings of this shed light on the specific barriers hindering innovation within Sri Lankan SMEs. Through a comprehensive examination of various factors, including funding constraints, skill gaps, regulatory complexities, technology adoption challenges, and the impact of market competition, can be summarized as below,

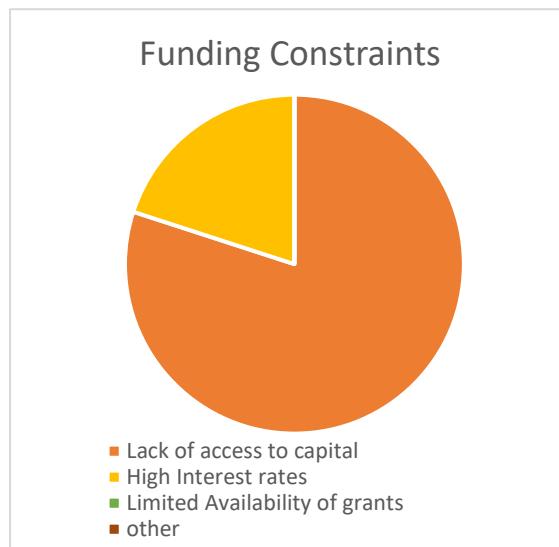


Figure 1 Funding Innovation Initiatives Challenges.

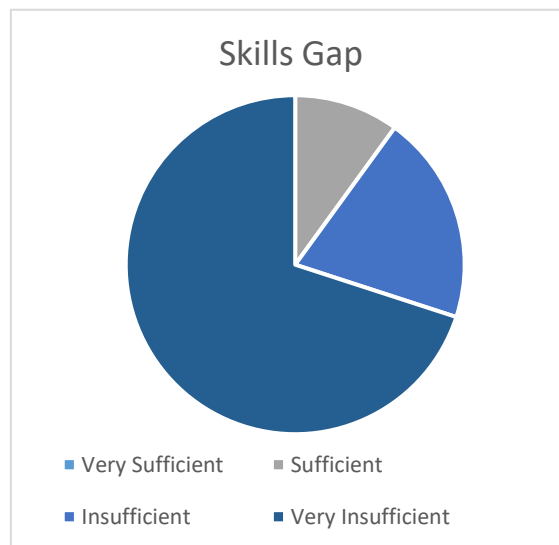


Figure 2 Availability of Skilled Workforce.

According to the above figure 1, funding constraints emerged as a pervasive challenge, with 8 out of 10 companies citing limited access to capital as a major barrier to innovation. Many SMEs reported difficulties in securing loans due to high interest rates and stringent collateral requirements. Across the

surveyed SMEs , A majority of SMEs (9 out of 10) expressed concerns regarding the availability of skilled workforce for innovation-related activities. Skill shortages were particularly acute in specialized areas such as technology development and product design, hampering the SMEs' ability to innovate effectively as shown in the figure 2.

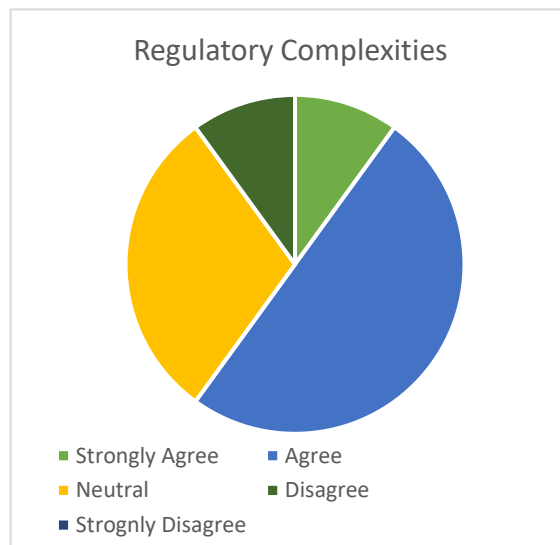


Figure 3 Regulatory Complexities.

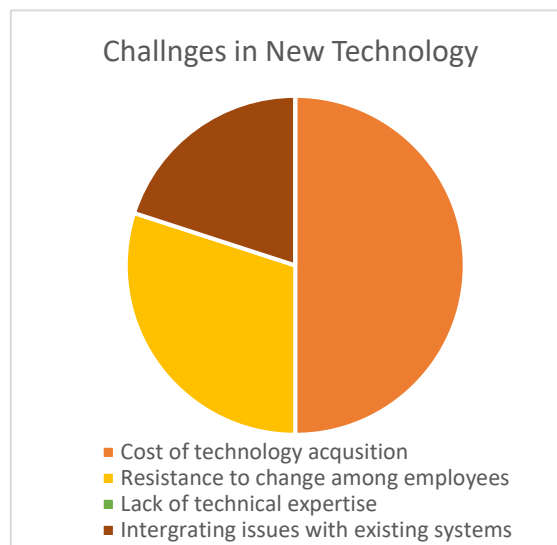


Figure 4 Challenges adopting in new technology.

Based on the data gathered, Regulatory hurdles were identified by 6 out of 10 SMEs as impediments to innovation. Compliance with bureaucratic procedures and obtaining necessary permits were cited as time-consuming processes that often delayed innovation projects as presented in Figure 3. In the Figure 4 indicated the challenges occurred in adopting new technologies to enhance the innovation in SMEs and half of the surveyed SMEs highlighted challenges in adopting new technologies to enhance innovation capabilities. Cost of technology acquisition was a common concern, along with resistance to change among employees and integration issues with existing systems.

Across the surveyed SMEs, the majority of SMEs (7 out of 10) acknowledged the negative impact of market competition on their ability to innovate. Intense competition from larger firms with greater resources was cited as a significant barrier, constraining SMEs' investment in innovation initiatives as shown in the figure 5.

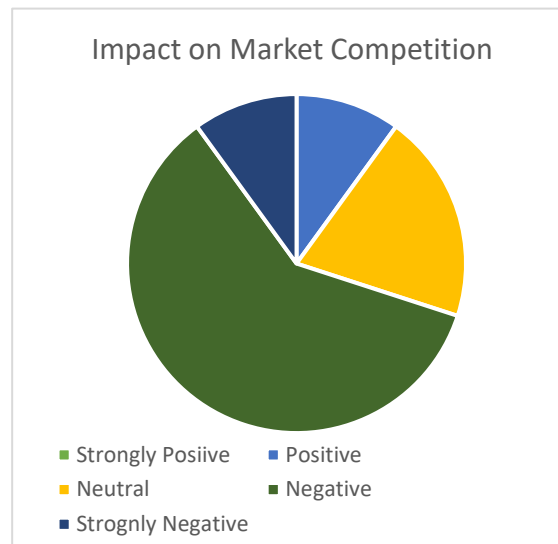


Figure 5 Impact of Market Competition.

4.3 Objective 2 (To understand the interconnected web of innovation barriers and their impacts on SMEs)

In pursuit of a comprehensive understanding of innovation barriers within Sri Lankan SMEs, Objective 2 aimed to explore the interconnectedness of these barriers and how they interact to exacerbate challenges faced by SMEs. Thematic analysis of qualitative data gathered from interviews and surveys revealed intricate relationships between different innovation barriers, highlighting the complex dynamics at play within the SME sector.

Theme 1: Interplay Between Barriers

The data uncovered a complex interplay between various innovation barriers, illustrating how they often intersect and compound each other to create formidable challenges for SMEs. Funding constraints emerged as a central barrier, with many SME owners expressing frustration over their limited access to capital for innovation initiatives. One participant lamented, "Securing funding for our innovation projects has been a constant struggle. High interest rates and stringent collateral requirements make it difficult for SMEs like ours to obtain the necessary financial resources."

Moreover, the analysis revealed how funding constraints directly impact other barriers, such as skill gaps and technology adoption challenges. Several SMEs noted that their inability to invest in training programs due to financial constraints exacerbated skill shortages within their workforce, hindering innovation efforts. As one respondent pointed out, "We recognize the importance of upskilling our employees for innovation, but limited financial resources restrict our ability to invest in training programs. It's a Catch-22 situation."

Furthermore, regulatory complexities were identified as another barrier that interacts with funding constraints and technology adoption challenges. SME owners highlighted the burdensome nature of bureaucratic procedures and the time-consuming process of obtaining permits for innovation projects. "Navigating through regulatory requirements is a daunting task," shared one participant. "It adds unnecessary delays and costs to our innovation initiatives, making it harder for us to compete."

Theme 2: Overall Impact of Interconnected Barriers

The thematic analysis underscored the cumulative impact of interconnected barriers on the innovation capabilities of SMEs. SME owners expressed frustration over the compounding effects of funding constraints, skill gaps, regulatory complexities, and technology adoption challenges, which collectively hindered their ability to innovate effectively. One participant summarized the sentiment, stating, "It's not just one barrier that's holding us back; it's a combination of factors working against us. Funding constraints limit our ability to invest in skills and technology, while regulatory hurdles add layers of complexity to the process."

Moreover, the analysis highlighted the need for a holistic approach to addressing innovation barriers, rather than treating them in isolation. SMEs emphasized the importance of comprehensive strategies that tackle multiple barriers simultaneously. "We need support from policymakers and industry stakeholders to overcome these challenges," remarked one respondent. "Addressing individual barriers in isolation won't suffice. We need integrated solutions that address the root causes of our innovation challenges."

By delving into the nuanced dynamics of interconnected barriers and incorporating quotes from SME owners, the analysis provides a detailed understanding of the challenges faced by Sri Lankan SMEs in fostering innovation. These insights underscore the importance of adopting a holistic approach to innovation policy and support, aimed at addressing the multifaceted barriers hindering SME innovation.

4.4 Objective 3 (To investigate the extent to which innovation barriers vary across different sectors and regions within Sri Lanka)

Objective 3 focus to explore the variability of innovation barriers across different sectors and regions within Sri Lankan SMEs. Thematic analysis of qualitative data gathered from interviews and surveys revealed distinct patterns in the nature and severity of innovation barriers, highlighting the diverse challenges faced by SMEs across sectors and regions.

Theme 1: Sectoral Differences

The data highlighted significant variations in the innovation barriers encountered by SMEs across different sectors. While funding constraints and skill gaps were identified as common challenges across all sectors, the severity of regulatory complexities varied significantly. Manufacturing SMEs, for instance, faced more stringent regulatory hurdles compared to service-oriented SMEs. One participant from the manufacturing sector lamented, "Compliance with regulatory requirements is a major headache for us. The bureaucratic procedures are time-consuming and often delay our innovation projects, impacting our competitiveness."

Moreover, technology adoption challenges were found to be sector-specific, with technology-focused SMEs facing unique integration issues. SME owners in technology-intensive sectors expressed concerns about the compatibility of new technologies with existing systems and the high costs associated with technology acquisition. "Integrating new technologies into our operations is a daunting task," shared one participant. "We need solutions that seamlessly integrate with our existing systems without disrupting our workflow."

Theme 2: Regional Disparities

The analysis also revealed disparities in innovation barriers between SMEs located in urban and rural areas. While urban SMEs generally had better access to support services and networking opportunities, rural SMEs faced unique challenges related to access to funding and skilled workforce. A participant from a rural SME noted, "Access to funding and skilled labor is limited in our region, which hampers our innovation efforts compared to businesses in urban areas. We often struggle to find employees with the necessary skills for innovation."

Moreover, regulatory complexities were found to impact SMEs differently based on their geographical location. SMEs in remote rural areas reported difficulties in complying with regulatory requirements due to limited access to government offices and support services. "Navigating through regulatory procedures is particularly challenging for us," remarked one respondent from a rural SME. "We have to travel long distances to obtain necessary permits, which adds to the time and cost of our innovation projects."

By examining the sectoral and regional differences in innovation barriers and incorporating quotes from SME owners, the analysis provides valuable insights into the diverse challenges faced by Sri Lankan SMEs. These insights underscore the need for tailored policy interventions and support mechanisms to address the unique needs of SMEs operating in different sectors and regions.

4.5 Objective 4 (To propose actionable strategies for mitigating innovation barriers and fostering a more innovation-friendly environment for Sri Lankan SMEs)

Objective 4 aimed to propose actionable strategies to mitigate innovation barriers within Sri Lankan SMEs. Thematic analysis of qualitative data gathered from interviews and surveys identified key recommendations from SME owners for addressing innovation challenges and fostering a more innovation-friendly environment.

Theme 1: Recommended Strategies

The data revealed several recommended strategies from SME owners to mitigate innovation barriers and enhance the innovation capabilities of SMEs in Sri Lanka. Policy interventions emerged as a top recommendation, with SME owners calling for streamlined regulatory processes and incentives for innovation. One participant emphasized, "Government support through grants and subsidies can significantly boost innovation in SMEs and level the playing field with larger competitors. We need policies that encourage innovation and reward risk-taking."

Capacity-building initiatives were also highlighted as crucial for addressing skill gaps within the workforce. SMEs emphasized the importance of training programs and partnerships with educational institutions to develop the necessary skills for innovation. "Investing in the skills of our employees is essential for innovation," remarked one respondent. "We need training programs that equip our workforce with the technical and creative skills needed to drive innovation."

Moreover, improved access to finance was identified as a key strategy for overcoming funding constraints. SME owners called for the establishment of specialized financing mechanisms tailored to the needs of SMEs, such as venture capital funds or government-backed loan programs. "Access to finance is critical for innovation," shared one participant. "We need financial instruments that offer flexible terms and lower interest rates to support our innovation initiatives."

Theme 2: Envisioned Impact of Strategies

SME owners expressed optimism about the potential impact of the proposed strategies on fostering innovation within the SME sector. They envisioned these strategies contributing to economic growth, enhanced competitiveness, and job creation. "With the right support and incentives, SMEs can become engines of innovation," remarked one respondent. "Investing in innovation not only drives business growth but also creates employment opportunities and contributes to the overall development of the economy."

Moreover, SME owners emphasized the broader societal benefits of fostering innovation within the SME sector. They highlighted the role of SMEs as drivers of social innovation and inclusive growth, particularly in addressing pressing societal challenges. "Innovation is not just about business success; it's also about making a positive impact on society," shared one participant. "SMEs have the potential to innovate solutions to social and environmental issues, creating a more sustainable future for all."

By proposing actionable strategies to address innovation barriers and incorporating quotes from SME owners, the analysis provides valuable insights into the potential pathways for fostering innovation

within the SME sector in Sri Lanka. These insights can inform policy-making, resource allocation, and capacity-building efforts aimed at creating a more innovation-friendly environment for SMEs.

5. Discussion

The findings from the case study offer valuable insights into the innovation landscape of Small and Medium Enterprises (SMEs) in Sri Lanka, highlighting significant barriers and their interconnected nature. This discussion synthesizes the key findings and explores their implications for fostering innovation within the SME sector.

Funding constraints emerged as a pervasive challenge, hindering SMEs' ability to invest in innovation initiatives. High interest rates and stringent collateral requirements further exacerbated the difficulties in accessing capital, underscoring the urgent need for financial support mechanisms tailored to the needs of SMEs (McGrath & MacMillan, 2000). Skill gaps were identified as a critical barrier, particularly in specialized areas such as technology development and product design. The shortage of qualified workforce impedes SMEs' capacity to leverage new technologies and implement innovative practices effectively, emphasizing the importance of investing in skill development programs (OECD, 2018). Regulatory complexities were cited as time-consuming hurdles that often delayed innovation projects. Streamlining regulatory processes and providing clearer guidelines could alleviate the compliance burdens faced by SMEs, enabling them to focus resources on innovation activities (Stiglitz, 2019). Challenges in adopting new technologies were compounded by resistance to change among employees and integration issues with existing systems. Overcoming these barriers requires not only technological support programs but also organizational change management strategies to foster a culture of innovation (Damanpour, 1991). The impact of market competition was significant, with SMEs facing intense pressure to compete against larger firms with greater resources. Policymakers should consider measures to level the playing field and create a conducive environment that supports the innovation efforts of SMEs (Porter, 1998).

The interplay between different innovation barriers amplifies the overall challenges faced by SMEs in fostering innovation. Addressing individual barriers in isolation may not be sufficient, underscoring the importance of adopting a holistic approach to overcome interconnected challenges (Teece, 2010). Investing in strategies that simultaneously address multiple barriers, such as capacity-building initiatives that encompass skill development, technology adoption, and regulatory compliance, could yield more effective outcomes (Pavitt, 1984).

While funding constraints and skill gaps were consistently identified as primary challenges across sectors, the nature and severity of regulatory complexities varied depending on the industry. Policymakers should tailor interventions to address sector-specific challenges effectively (Fagerberg, 2005). Regional disparities in access to support services and networking opportunities highlight the importance of targeted initiatives to promote innovation in rural areas. Strengthening infrastructure and enhancing connectivity can mitigate some of the challenges associated with innovation in these regions (Rodrik, 2004).

The recommended strategies, including policy interventions, capacity-building initiatives, access to finance mechanisms, and technological support programs, hold promise for fostering a more innovation-friendly environment in Sri Lanka. However, their successful implementation requires collaboration among policymakers, industry stakeholders, and SMEs (Mansfield, 1988). SMEs expressed optimism that these proposed strategies could enable them to overcome barriers and unleash their full potential for growth and competitiveness. Moving forward, continuous monitoring and evaluation of these initiatives will be essential to assess their impact and make necessary adjustments (Cohen & Levinthal, 1990).

6. Conclusion

The findings of this study shed light on the intricate challenges hindering innovation within Small and Medium Enterprises (SMEs) in Sri Lanka and underscore the critical importance of addressing these barriers to foster economic growth and competitiveness. Through an in-depth examination of funding constraints, skill gaps, regulatory complexities, technology adoption challenges, and the impact of market competition, this research has provided valuable insights into the multifaceted nature of innovation barriers and their interconnectedness.

The pervasive nature of funding constraints highlights the urgent need for financial support mechanisms tailored to the unique needs of SMEs. High interest rates and stringent collateral requirements pose significant hurdles to accessing capital for innovation initiatives, limiting SMEs' ability to invest in research and development, technology adoption, and skill development.

Furthermore, the shortage of skilled workforce in specialized areas such as technology development and product design represents a formidable barrier to innovation. Addressing skill gaps through capacity-building initiatives and partnerships with educational institutions is essential to equip SMEs with the necessary expertise to leverage new technologies and implement innovative practices effectively. Regulatory complexities add another layer of challenge, with compliance burdens and bureaucratic procedures often impeding innovation projects. Streamlining regulatory processes and providing clearer guidelines can alleviate these barriers, enabling SMEs to focus resources on innovation activities and accelerate the pace of innovation.

Challenges in adopting new technologies are compounded by resistance to change among employees and integration issues with existing systems. Overcoming these barriers requires not only technological support programs but also organizational change management strategies to foster a culture of innovation within SMEs.

Moreover, the intense market competition poses a significant threat to SMEs' innovation efforts, with larger firms possessing greater resources and market power. Policymakers must consider measures to level the playing field and create an enabling environment that supports the innovation endeavors of SMEs.

In conclusion, addressing innovation barriers within the SME sector is paramount for driving economic growth, enhancing competitiveness, and fostering sustainable development in Sri Lanka. By implementing a comprehensive set of strategies that address the interconnected nature of these barriers and tailor interventions to the specific needs of SMEs, policymakers can create an environment that empowers SMEs to innovate, thrive, and contribute to the country's prosperity in the global marketplace.

This study serves as a call to action for policymakers, industry stakeholders, and SMEs themselves to collaborate effectively in overcoming innovation barriers and unlocking the full potential of SMEs as engines of innovation and economic growth in Sri Lanka.

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BUSH FIRES AND ECOTOURISM: AN INNOVATIVE COMMUNITY-BASED COPING MECHANISM

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Abstract: Ecotourism in the central highlands of Sri Lanka is positioned as niche, catering to both local and foreign tourists, utilizing its unique natural resources in unplanned landscapes. Rural agricultural communities are struggling for survival due to adverse impacts of natural disasters and associated risks while ecotourism provides an alternative livelihood opportunity. Bushfires are an annual disaster event connected to a chain of adverse impacts; landslides induced by heavy rains and winds. Our approach focused on exploring the ecotourism of disaster-proven land, risks, and vulnerabilities while investigating the innovative coping mechanisms adopted by the locals. The sample comprised of 18 ecotourism hotels and destinations of Imbulpe and Haldummulla DS divisions of the eastern slope of central highlands. Field visits, focused group discussions, storytelling exercises, expert opinions along structured questionnaires were used for primary data collection. The overall impact of bushfires, landslides, and extreme weather events on ecotourism was negative and threatened the sustainability of the business. Bush fires and landslides were frequent natural disasters that crippled the system and speakers effects of disasters directly affected tourist arrivals. Education, training, and capacity building on bushfire management was zero while communities followed lifelong learning to manage the incidents. Nature travel, hiking, accommodation, tours, attractions, experiences, excursions, and meals were common services available to tourists. An innovative community-based coping mechanisms were backfire systems, an informal community-supported bush fire management system, setting up fire belts as early preparedness, replantation initiatives using local trees, and removing fire-loving introduced plantations, Pine and Eucalyptus.

Keywords: Bushfires; Central highlands; Ecotourism; Innovative practices

1. Introduction

Sri Lanka is an island nation that offers diverse ecosystems, including lush rainforests, pristine beaches, and wildlife-filled national parks (Fernando and Kaluarachchi, 2016). The central highlands of Sri Lanka, are declared as a world heritage natural site characterized by lush forests, rolling hills, and biodiversity hotspots with several exotic plant and animal species. The central highlands are renowned for full of such natural beauty and biodiversity making it an ideal setting for tourism ventures and ecotourism has emerged as a niche market catering to both local and foreign visitors.

Nevertheless, beneath the picturesque landscapes and unspoiled wilderness the central highland faces an array of challenges, particularly for communities running eco-tourism ventures struggling with the adverse impacts of natural disasters, which can devastate ecosystems and disrupt travel plans. These areas are susceptible and prone to the destructive events of nature, including bushfires and natural disasters such as landslides, and other extreme weather events.

Bushfires have become a crucial factor in deforestation and forest degradation in Sri Lanka. Annually, 100 to 2500 hectares of forest resources are damaged due to forest fires in Sri Lanka, and over the past few years, forest fire impacts on forest resources have increased (Heenatigala, 2021). According to previous studies, it can be proven that the central highlands is highly susceptible to bushfires. Even though the area has a short dry season, the risk of fire is highest because of low humidity and the topography of the area. In a study conducted by Basanayake et al. (2021), it was revealed that the natural resources within the Belihuloya mountain range face significant vulnerability to man-made bushfires on an annual basis, particularly during the dry season spanning from August to September. Further, the study results of Heenatigala (2021) indicated that Badulla districts show the highest forest fire vulnerability among the studied areas. Further, the forest fire damage also intensified with climate change (Heenatigala, 2021). A study (Tam, 2019) found that Sri Lanka's tourism sector is not prepared for climate change and identified tourism as one of the most vulnerable sectors to climate change. Hence, due to the impacts of bushfires, the rural communities in these areas in central highlands indeed depend on eco-tourism as a significant source of income and livelihood; which poses substantial threats not only to the environment but also to the livelihoods of the local communities who rely on it.

The importance of the role of the community has been widely recognized in recovery efforts worldwide, for both fires and other disasters (Clode, 2010). Empowering community groups and sustaining self-reliance have been identified as sustainable tools for enhancing resilience against bushfire management. Facilitating community-led discussion of issues, community leadership, and the provision of information in these community forums, risk management strategies are more likely to embed the processes by which adaptive capacity is developed into the fabric of community life (Paton, 2006). Further, community-led initiatives are identified as vital for natural disaster mitigation as they leverage local knowledge and resources to build resilience and implement tailored solutions. However, in Sri Lanka, a limited focus was placed on strengthening the local communities through awareness and education programs, training, developing community-based innovative mitigation measures, capacity building through providing equipment, etc. (Basnayake, 2021).

Moreover, Sri Lanka gives less priority to fire-related research and studies even though those damages make significant contributions to addressing the forest resource damage (Heenatigala, 2021). Further, none of the research has been carried out to assess the impact of bushfires on Ecotourism and the resilience against bushfires where the policymakers should pay attention.

Hence his study attempts into the complexities faced by ecotourism ventures in the central highlands of Sri Lanka, focusing on the Imbulpe Ds Division, located in Ratnapura District and Haldumulla Divisional Secretariate (DS) Division in Badulla district, where ecotourism activities intersect with the challenges posed by natural disasters like bushfires. By examining the impacts of bushfires, landslides, and extreme weather events on ecotourism establishments and local communities, this research fills the gap

in the literature and seeks to shed light on the vulnerabilities inherent in eco-tourism ventures in these areas. The central aim of this study is to investigate the innovative coping mechanisms adopted by local communities in response to the recurring threats of bushfires.

Overall, this study will serve as a comprehensive exploration of the intersection between ecotourism and natural disasters in the central highlands of Sri Lanka, offering insights into the challenges, opportunities, and adaptive strategies shaping the sustainability and resilience of eco-tourism ventures. By understanding the dynamics of ecotourism in disaster-prone areas, policymakers, practitioners, and local communities can work together to foster a more resilient and sustainable tourism industry that benefits both people and the planet.

The concept of the study builds with modelling the bushfires and other natural disasters (Eg: heavy rainfalls, landslides, and storms) affected on eco-tourism ventures in central highlands by identifying the risk and vulnerabilities and resilience levels in each location focusing on innovative community-based coping mechanisms developed and implemented jointly.

The conceptual framework discussed in Figure 1 is based on 3 stages. First, identify the disasters affecting on community and especially on eco-tourism ventures second, identify the risk and vulnerability levels and third identify the resilience against bushfire occurrences.

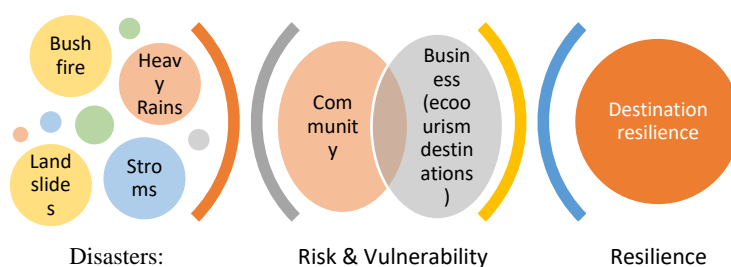


Figure 01. Conceptual framework.

2. Methodology

The study approach focused on exploring the ecotourism of disaster-proven land, risks, and vulnerabilities while investigating the innovative coping mechanisms adopted by the locals. The sample comprised 18 purposively sampled ecotourism hotels and destinations of Imbulpe and Haldummulla DS divisions of the eastern slope of central highlands. Primary data collection was instrumented via field visits, focus group discussions, storytelling exercises, and expert opinions along with interviewer-administered structured questionnaires.

Focus group discussions with eco-tourism business owners and in-depth interviews with key informants (Divisional secretariat, Grama Niladhari officers, Officers of the armed forces, and representatives of the hotel association in Belihuloya, forest department regional officers) were undertaken. Four series of field visits were made to different locations of Imbulpe and Haldummulla DS division's eco-tourism destinations between the period November to February 2024 and photographs and drone imageries of the locations were captured for the photographic analysis. Digital storytelling technique was utilized in two rounds of focus group discussions with 10 eco-tourism owners. The recorded discussions were analyzed to gain insights into the business owners' point of view on the risk, and vulnerability of natural and man-made disasters and their impact on the business, and the mitigatory steps taken in managing the identified risks. As the next stage of the process, key informant interviews were used to develop case studies to gain a deeper understanding of the existing situation in the locality with respect to natural/man-made disasters, reasons for occurrences, and community initiatives in managing the disaster

risk vulnerabilities. Interviewer-administered structured questionnaires were instrumented on the selected 18 eco-tourism destinations by visiting the individual locations during January 2024. Secondary data required for the analysis and the development of the disaster risk map was obtained from the “Sampath Pethikada” in each of the two Divisional Secretariats, from the regional offices of the Forest Department and Disaster Management Centre, Badulla. Figure 02 denotes the location of the eco-tourism destinations along with the identified disaster risks in the two DS divisions.

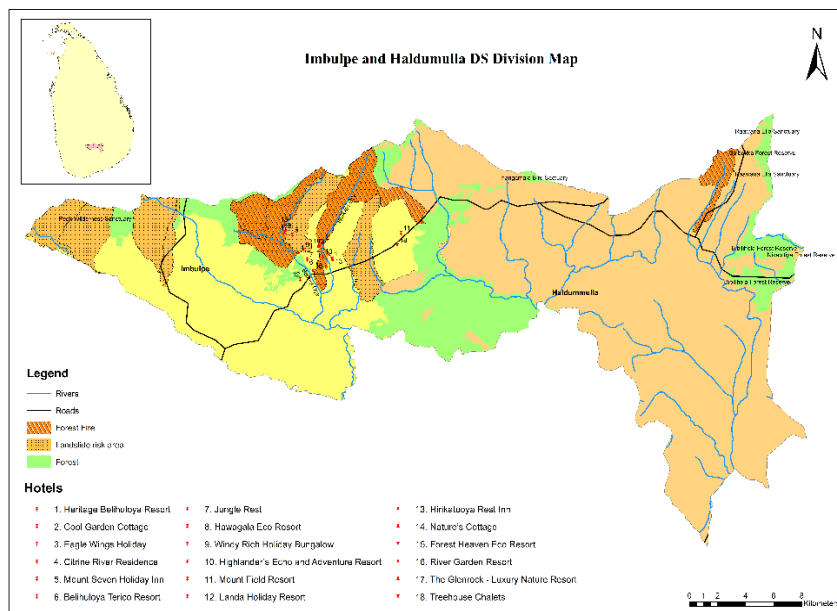


Figure 02: Location of the eco-tourism destinations along with the identified disaster risks in the two DS divisions.

3. Results and Discussion

3.1 Ecotourism of Eastern Slope of the Central Highlands

Ecotourism involves traveling to natural destinations with the aim of enjoying nature, gaining knowledge, supporting conservation efforts, and promoting sustainability (Fareena, 2023). Ecotourism in the eastern slope of the central highlands of Sri Lanka offers a unique experience, attracting both local and foreign tourists with its rich natural resources and picturesque landscapes. In this study, 18 ecotourism hotels/destinations were selected, with 10 (56%) being resorts, and 2 (11%) being each of cottages, inns, and bungalow types (Figure 03).

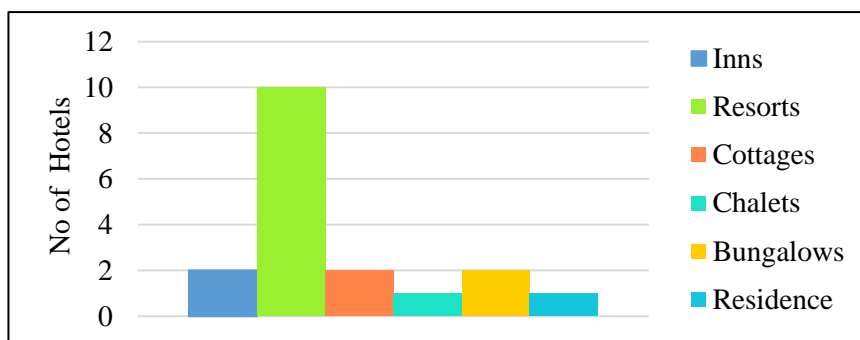


Figure 03: Types of Ecotourism Hotels.

In a recent study, Tissera and De Silva (2021) stated that Eco-hotels, also referred to as 'green hotels,' are meeting the needs of environmentally aware travelers. They prioritize eco-friendly hospitality while

ensuring customer satisfaction and comfort. Various services were provided to customers by these ecotourist hotels to increase customer satisfaction. Common services available to tourists included nature travel, hiking, accommodation, tours, attractions, experiences, excursions, and meals, as depicted in Figure 04.

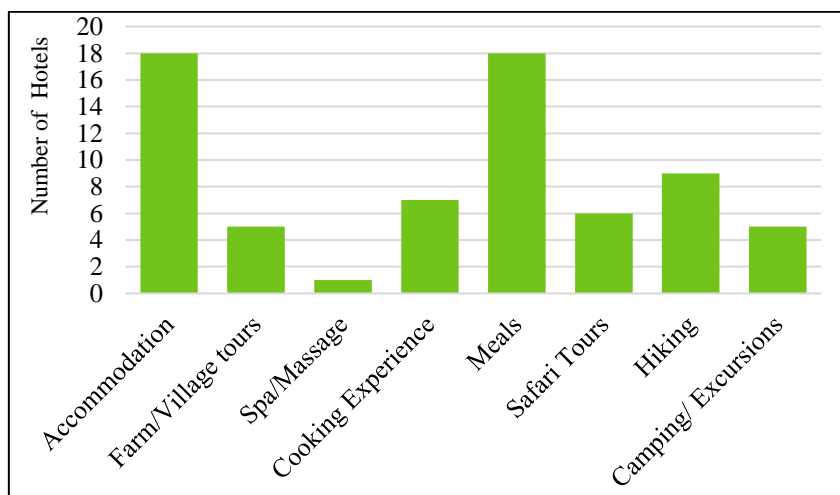


Figure 04: Types of services provided by the Ecotourism hotels.

Various online platforms are preferred by hotel guests for sharing their experiences and opinions. Some of these platforms provide hotel ratings and recommendations to online customers based on previous guest reviews and place considerable trust in online reviews (Cherapanukorn & Charoenkwan, 2017). A content analysis was conducted on online review comments to interpret text data through a systematic classification process involving coding and identifying themes and patterns. The results of this analysis, as depicted in Figure 04, for 18 ecotourism hotels in the Imbulpe and Hadummulla DS divisions, the Content analysis revealed that the place, ecotourist destination most frequently appeared while food and staff of the service provider appeared as second most frequently counted.



Figure 05: Word cloud representing customers' online review comments.

3.2 Impact of Natural Disasters on Ecotourism

The study revealed a predominantly negative impact of bushfires, landslides, and extreme weather events on ecotourism in the central highlands of Sri Lanka, Heavy rainfall, and landslides as recurring natural disasters, significantly impacting the ecotourism industry (Figure 06). Bush fires and heavy rains are rated as frequently occurring disasters in the location. These disasters not only pose immediate risks to the safety of tourists but also disrupt the fragile ecosystems and scenic landscapes that attract visitors to the region. Concerning the point of view of the owners of eco-tourism destinations, during peak bushfire/forest fire times, eco-tourism hotels were closed, due to the presence of fire dust and smoke

from the forest fires. In instances of heavy windy seasons, particularly in the Haldummulla DS division, damage to roofs and properties was identified in some eco-tourism destinations. Furthermore, during heavy rainy seasons, landslides are common resulting in road blockages and ultimately reducing tourist arrivals to eco-tourism destinations during these periods of natural disaster. Such fluctuations in tourist arrivals have ripple effects on the local economy, affecting livelihoods dependent on tourism-related activities, and affecting local communities by reducing employment opportunities and income from fresh produce supplies.

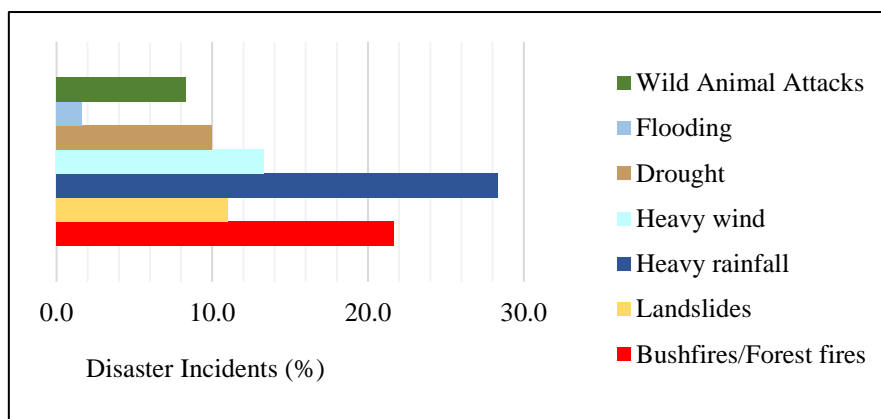



































Figure 06: Types of disasters affected.

Table 01 depicts the seasonal patterns of tourist arrival and the occurrence of bushfires and other disaster events. Foreign tourists predominantly arrived during the period from December to April, while local tourists frequented hotels in April, August, and December. Even during months characterized by low rainfall, a significant number of tourists visited hotels. From the perspective of hotel owners, following the COVID-19 pandemic, there has been a shift in the demographic composition of foreign tourists, with a significant decrease in arrivals from Germany and an increase in visitors from Russia, India, and China. Local tourists typically seek relaxation with their families during their hotel stays, whereas foreign tourists often arrive to experience nature and engage in activities such as trekking.

Table 1: Tourist season and bushfire and other disaster event season

	DS Division/ Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Main Cropping Season		Maha Season			Maha Season							Maha Season	
Average Rainfall (mm)	<i>Imbulpe</i>	124 	105	88	145 	108 	50	76	66	96	214 	323 	255
	<i>Haldummulla</i>	64	45	53	124 	88	59	103	93	123 	234 	272 	145
Average Wind Speed (km/h)	<i>Imbulpe</i>	7	5	4	5	10 	12 	12 	12 	10 	7	5	6
	<i>Haldummulla</i>	12 	9	7	6	10 	12 	11 	11 	4	7	6	10

Average High Temperature (°C)	<i>Imbulpe</i>	25	26.7	27.5	27.6	27.3	27	27.2	27.1	27.1	26	24.8	24.3
	<i>Hal-dum-mulla</i>	25.3	26.3	28.0	28.1	27.7	27.4	27.5	27.5	27.6	26.5	25.7	24.6
Disaster Occurrence	<i>Imbulpe</i>												
	<i>Hal-dum-mulla</i>												
Tourist Season													

- Landslides 
- Heavy Rain 
- Heavy Wind 
- Bushfires 

Source: meteoblue

Note: The highest values for the relevant weather indicators were indicated by an icon

3.3 Coping Mechanisms and Resilience Strategies

Of the sample, none of the eco-tourism ventures, both owners and employees, didn't receive education, training, or capacity building on bushfire management while communities followed lifelong learning experiences to manage the incidents.

Despite the lack of formal education and training on disaster management, the study identified innovative coping mechanisms adopted by local communities to mitigate the impact of natural disasters on ecotourism. One such initiative was the establishment of backfire systems, informal community-supported mechanisms aimed at managing bushfires. These grassroots efforts demonstrate the resilience of rural communities in the face of environmental challenges and their commitment to safeguarding their livelihoods.

Another adaptive strategy observed in the study area was the creation of fire belts as part of early preparedness measures. These fire belts act as a barrier against advancing forest fires, helping to safeguard ecotourism destinations and infrastructure. Additionally, replantation initiatives using indigenous tree species and the removal of fire-prone introduced plantations, such as Pine and Eucalyptus, establishing natural stone walls: retaining walls, terracing, stone walls supported terraces, using non-flammable building materials, clear vegetation and rubbish away from buildings, establishing independent water tank, pumps, sprinkler system, Establish non-inflammable landscape: vegetable garden, plants and trees of different heights, keeping clear area immediately around buildings like measures contribute to enhancing the resilience of ecosystems to bushfires. These initiatives have contributed to the preservation of biodiversity, which is a key attraction for eco-tourists visiting the region.

Table 02 presents an overview of the findings regarding the coping strategies employed by hoteliers/businesses in the ecotourism sector.

Table 2. Coping strategies of hoteliers/tourism business

Disaster	Effect on the business	Coping strategy
1. Bush fire	<ul style="list-style-type: none"> • Threat of life and property • Dust and smoke from the fire. • Damage to assets and landscape. • Loss of biodiversity: habitat, both plants and animals (essential ecotourism products) • Damage to water and electricity supply. • Disturb supplies and issue of visitor safety. • Disturb activities: camping, hiking, bird watching, etc. • Decline tourist arrivals. 	<ul style="list-style-type: none"> • Establish fire belts before the onset of the annual windy season or bushfires • Use backfires. • Establish fire preventive landscape: forest belts of local trees, and forest patches, remove inflammable trees, and introduce local noninflammable forest trees, i.e. Pine, Accesia, Eucalyptus, • Establish natural stone walls: retaining walls, terracing, stone walls supported terraces, • Use non-flammable building materials. • Clear vegetation and rubbish away from buildings • Establish independent water tanks, pumps, and sprinkler systems. • Establish a non-inflammable landscape: vegetable garden, plants and trees of different heights, • Keep clear areas immediately around buildings.
2. Land slides	<ul style="list-style-type: none"> • Damage to the buildings, boundary walls, and landscape. • Damage to water supply and drainage system. • Damage to electricity supply. • Damage to the roads and disturb transportation. <p style="margin-left: 40px;">Decline tourist arrivals, disturb supplies and safety of visitors</p>	<ul style="list-style-type: none"> • Establish natural stone walls in boundaries. • Cultivate terraces protected by stone walls. • Replanting: establish agroforestry system, mini forest patches, natural forest trees • Retaining walls with drainpipes • Plant fast-growing grass and shrubs
3. Heavy wind	<ul style="list-style-type: none"> • Damage to buildings: roof, doors and windows. • Damage to landscape. 	<ul style="list-style-type: none"> • Establish a safe roof: roof-wall connection and roof deck attachment (tiled roof connected with cement,

	<ul style="list-style-type: none"> • Intense bushfire spread along with smoke and ash. • Spread sand, dust, and tree debris making visitors' lives difficult. • Damage to external structures and landscape. • Decline tourist arrivals and outdoor activities 	<ul style="list-style-type: none"> • metal roof tightly connected with timber frame, weights on the roof) • Manage trees around the property: remove risky trees, branches, and trees away from buildings through string wires, • Natural wind barriers: establish a forest patch away from buildings as a wind barrier. • Landscaping for wind-breaks
4. Heavy rain	<ul style="list-style-type: none"> • Triggering landslides, soil erosion, falling trees, threat of increased water flow through streams, waterfalls, etc • Blocking the roads and supplies • Decline tourist arrivals and outdoor activities • 	<ul style="list-style-type: none"> • Establish landscape for indoor activities • Clear the indoor-outdoor margin through doors and windows (sightseeing) • Indoor gardens • Establish huts, tents,
5. Flooding	<ul style="list-style-type: none"> • Blocking the roads and supplies 	<ul style="list-style-type: none"> • Cottages built on concrete poles. • Alternative routes have been created.

Photographs of coping strategies



Figure 07: Bushfire/Forest fire: a.| Establish fire belts b.| Forest belts c.| Use non-flammable building materials d.| Establish independent water tank f.| Establish non-inflammable landscape.

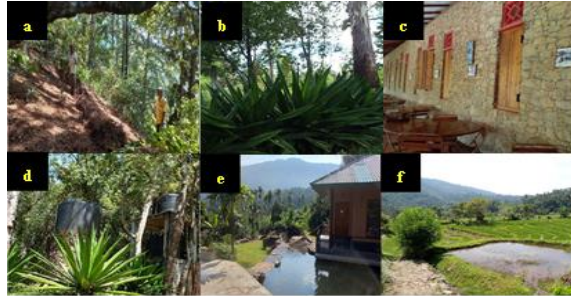


Figure 08: Landslides: g.) Establish natural stone walls in boundaries h.) Cultivate terraces protected by stone walls i.) Plant fast growing grass and shrubs j.) Replanting.

3. Conclusion

This study attempts into the complexities faced by ecotourism ventures established in the eastern slope of central highlands of Sri Lanka, focused on exploring the Imbulpe and Haldumulla DS divisions, where ecotourism activities intersect with the challenges posed by natural disasters. The central aim of this study was to investigate the innovative coping mechanisms adopted by hoteliers and local communities in response to the recurring threats of bushfires. The combined impact of bushfires, landslides, and extreme weather events on ecotourism has predominantly been negative, posing a threat to the sustainability of businesses operating in affected areas. The frequency of bushfires and landslides, as recurring natural disasters, has severely disrupted the local ecosystem and directly impacted tourist arrivals. Unfortunately, there has been a lack of emphasis on education, training, and capacity building in bushfire management, leaving communities ill-prepared to handle such incidents. However, communities have shown resilience through continuous learning and adaptive measures. The range of services offered to tourists, including nature travel, hiking, accommodations, tours, attractions, experiences, excursions, and meals, remains prevalent despite the challenges posed by these natural disasters. Innovative community-based coping mechanisms have emerged, such as backfire systems and informal community-supported bushfire management initiatives. Early preparedness measures like setting up fire belts and replantation initiatives utilizing local tree species have also been implemented to mitigate future risks. Efforts to remove fire-prone introduced plantations, such as Pine and Eucalyptus, are underway to restore ecological balance and enhance resilience against future disasters.

4. Recommendations

To address the high disaster risk and vulnerabilities coupled with weak adaptive capacity and resilience-building mechanisms in ecotourism communities facing bushfire threats, several key recommendations can be implemented. Comprehensive awareness-building campaigns are essential to educate communities about the nature of bushfires and the potential impact on eco-tourism ventures. Utilizing various communication channels, such as community workshops and digital media, can effectively disseminate this crucial information. A combination of formal and informal education approaches should be employed, integrating disaster management modules into school curricula and organizing community discussions. Early warning systems tailored for bushfires must be established, involving collaboration with meteorological departments and regular drills to test effectiveness. Moreover, providing training and capacity-building opportunities, incorporating innovative approaches and indigenous knowledge will empower communities with practical skills for disaster prevention and response. Promoting community engagement and participation in decision-making processes fosters a sense of ownership and collective responsibility. Further, it is essential to removing fire-loving introduced plantations, Pine and Eucalyptus.

By implementing these recommendations, ecotourism communities can enhance their resilience to bushfires, safeguarding both their livelihoods and the natural environment upon which they depend.

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