

1ST INTERNATIONAL CONFERENCE ON TRANSFORMATIVE APPLIED RESEARCH

**“BREAKING BOUNDARIES: PIONEERING SOLUTIONS
FOR GLOBAL CHALLENGES”**

FOCUSING

- CT01 - AI and Data Science Synergy
- CT02 - Future of Information Systems and Security
- CT03 - Smart Living and Communication
- ET01 - Power, Energy, and Communication
- ET02 - Automation, Manufacturing, and Industries
- ET03 - Civil, Construction, and Architectural Design
- ST01 - Food, Agriculture, and Environmental Science
- ST02 - Biomedical Advances
- ST03 - Advanced Materials
- MT01- Business Functions, Management, and Leadership

Organized by
NSBM Research Council
NSBM Green University
Colombo, Sri Lanka
31st January, 2025

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CONFERENCE AGENDA

- 08:30 AM **Registration**
- 09:00 AM **Arrival of Guests & Welcome**
- 09:30 AM **Inaugural and Lighting of the Traditional Oil Lamp**
- 09:45 AM **Welcome Address**
Dr. Rasika Ranaweera
Conference Chair – ICTAR 2024
- 09:50 AM **Research Council Milestones for Shining NSBM**
Documentary Story Film
- 10:00 AM **Keynote Address I**
Prof. Bogdan Ghita, Associate Dean (International),
Faculty of Science and Engineering, University of Plymouth,
United Kingdom
- 10:30 AM **Launch of Conference Proceedings**
In collaboration with Taylor and Francis Publishers
- 10:40 AM **Keynote Address II**
Prof. Neelika Malavige
Senior Professor, University of Sri Jayawardhanapura,
Sri Lanka
- 11:30 AM **Concluding Remarks**
Dr. Damayanthi Dahanayake, Head of the Research Council
- 11:40 AM **Poster Presentations**
- 12:00 PM **Lunch**
- 01:00 PM **The Inception of the Conference Parallel Sessions**
onwards Oral Presentations and Poster Presentations

PREFACE

On behalf of the Organizing Committee of the 1st International Conference on Transformative Applied Research (ICTAR) 2024, it is our great pleasure to welcome all the authors and delegates to this pioneering event hosted by the Research Council of NSBM Green University, Sri Lanka. This conference is a culmination of international collaboration and academic excellence, dedicated to addressing pressing global challenges through applied research and innovation.

Under the theme of “**Breaking Boundaries: Pioneering Solutions for Global Challenges,**” the conference provides a dynamic platform for academics, researchers, and professionals to present and exchange their ideas, and discuss cutting-edge research that spans a wide range of disciplines to reshape communities and industries. Throughout the event, we aim to foster dialogue and explore innovative solutions on a variety of themes that drive progress in the modern world.

The papers included in these proceedings underwent a rigorous double-blind review process, ensuring that the contribution reflect

the highest standards of scholarship and innovation.

We are also pleased to highlight that the highest-scoring papers are published in a special issue by Taylor & Francis, further amplifying the impactful research presented at the conference. These efforts demonstrate the conference’s commitment to academic integrity.

We extend our heartfelt gratitude to our chief guest, keynote speaker, panelists, and participants whose insights and experiences have greatly enriched our discussions. We also wish to acknowledge the tireless efforts of the organizing committee, the reviewers, and the volunteers who made this conference a success. We are confident that the research shared here will inspire new ideas and collaborations that will pave the way for a more sustainable and innovative future.

We wish all participants a stimulating and rewarding conference experience.

The Conference Organizing Committee
ICTAR 2024



MESSAGE FROM VICE-CHANCELLOR



PROF.E.A.WEERASINGHE
VICE-CHANCELLOR
NSBM GREEN UNIVERSITY
HOMAGAMA, SRI LANKA

In today's era defined by rapid advancements and unprecedented global challenges, fostering a scientific culture is fundamental in driving innovation, shaping policy, and providing solutions to complexities that impede progress. In this transformative process, universities act as epicenters of knowledge generation and innovation, fostering inquiry and collaboration that ultimately influences global growth trajectories.

To contribute to this goal, the Research Council at NSBM Green University has taken the initiative to host its inaugural International Conference on Transformative Applied Research (ICTAR). This conference provides a valuable platform for exchanging ideas, building collaborations, and shaping the future of applied research.

ICTAR 2024 is unfolding in an era world as a whole faces shared challenges that are increasingly interconnected and demand urgent solutions. Within this context, ICTAR 2024, themed **“Breaking Boundaries; Pioneering Solutions for Global Challenges”** emphasizes the need for collaborative and innovative approaches that transcend national and disciplinary lines to facilitate knowledge exchange and develop effective solutions for the benefit of humanity. Consequently, I believe this international conference is timely, bringing together a diverse community of scholars to explore innovative methods and breakthroughs in applied research across various fields.

I am confident that ICTAR 2024 will benefit the university's research culture through significant enhancement and contribute to the development of our nation. Hence, I would like to make this an opportunity to extend my heartiest congratulations to the organizing committee for establishing this platform for experts in different fields to gather.

Most importantly, I express my sincere appreciation to all the presenters and delegates for enriching ICTAR 2024 with their insightful presentations, engaging discussions, and collegial relationships. I wish you all a highly informative and productive conference and genuinely hope that you create many fond memories during your time with us, as this conference is poised to continue for many years to come.

Thank You..!

MESSAGE FROM DEPUTY VICE-CHANCELLOR



PROF. CHAMINDA RATHNAYAKE
DEPUTY VICE-CHANCELLOR
NSBM GREEN UNIVERSITY
HOMAGAMA, SRI LANKA

It is with great pleasure that I share this message for the first-ever International Conference on Transformative Applied Research (ICTAR) 2024, organized by the Research Council at NSBM Green University. This conference signifies an important milestone not only for the university but also for the broader academic community and society at large.

We are undeniably living in an era that calls for concerted efforts and innovative solutions from scholars, researchers, and practitioners alike to address significant challenges and build a sustainable foundation for future generations.

As a premier academic hub in the region, NSBM Green University is always dedicated to inspiring current and future generations of leaders, fostering an environment that encourages the creation of new knowledge through cutting-edge research and innovation, and contributing proactively to shaping the direction of a sustainable world.

With the theme “**Breaking Boundaries; Pioneering Solutions for Global Challenges,**” ICTAR 2024 represents a new chapter for NSBM and encapsulates our commitment to exploring novelty and innovation across a wide range of disciplines. By providing such a vital knowledge platform, we aim to cultivate and share profound, thought-provoking ideas and discussions among a wide array of local and international scholars.

As we embark on this exciting journey together, I eagerly anticipate a fruitful conference of timely and informatively essential. I extend my warmest wishes to the organizing committee for their hard work and dedication, as well as to all attendees of ICTAR 2024. I sincerely hope this inaugural endeavor marks a significant milestone in NSBM’s history and lays the groundwork for many more successful conferences in the years to come.

Thank you..!

MESSAGE FROM THE CONFERENCE CHIEF ADVISOR



PROF. J. BARATHA DODANKOTUWA
CHIEF ADVISOR, ICTAR-2024
HEAD- ACADEMIC DEVELOPMENT &
QUALITY ASSURANCE
NSBM GREEN UNIVERSITY
HOMAGAMA, SRI LANKA

It is with great pleasure and immense pride that I am extending my warmest greetings to the International Conference on Transformative Applied Research (ICTAR) 2024 at NSBM Green University. Building on the success achieved through numerous international conferences hosted by NSBM over the years, I sincerely hope that this inaugural initiative, organized by the Research Council, will leave a lasting impact by fostering new knowledge and developing strategies that inspire decisive actions. At the core of NSBM's ethos is a robust research culture that is both impactful and socially relevant.

Since its inception, the university has dedicated itself to addressing pressing issues faced by communities by nurturing both new and existing knowledge across a variety of disciplines. ICTAR 2024 stands to play a crucial role in these ongoing efforts, bringing together local and international experts eager to engage in meaningful discussions on transformative actions that can positively impact society and contribute to a more sustainable future.

Embracing the responsibility of steering development through sustainable solutions, ICTAR 2024 has been organized under the theme **“Breaking Boundaries; Pioneering Solutions for Global Challenges.”** This theme aims to foster scientific solutions that effectively tackle pressing challenges while delivering measurable real-world benefits.

I express my heartfelt appreciation to the Organizing Committee for their tireless efforts in bringing this significant event to fruition. As I congratulate all participants of ICTAR 2024, I genuinely hope that this conference will be another rewarding endeavour that brings us closer to addressing some of the complex challenges facing humanity today. Together, let us seize this opportunity to collaborate, innovate, and inspire one another in our quest for a brighter future for all.

Thank You..!

MESSAGE FROM THE CONFERENCE CHAIR



DR. RASIKA RANAWEERA
CONFERENCE CHAIR, ICTAR-2024
DEAN, FACULTY OF POSTGRADUATE
STUDIES & PROFESSIONAL
ADVANCEMENT
NSBM GREEN UNIVERSITY
HOMAGAMA, SRI LANKA

It is with great honor and pleasure that I welcome you to the inaugural International Conference on Transformative Applied Research (ICTAR) 2024, hosted at NSBM Green University. This event represents a significant step forward in our collective commitment to advancing applied research and fostering collaboration among scholars, practitioners, and industry leaders.

We are excited to showcase a diverse array of articles submitted by both local and international researchers. Following a rigorous double-blind review process, we look forward to presenting the best works, which will be published in Taylor and Francis. This not only highlights the quality of research being conducted but also positions our conference as a vital platform for sharing innovative ideas and findings.

The theme of this year's conference, **“Breaking Boundaries: Pioneering Solutions for Global Challenges,”** is designed to inspire meaningful discussions that bridge gaps across multidisciplinary research areas. In these challenging times, we must come together to share insights and develop solutions that drive progress and innovation.

I would like to express my heartfelt gratitude to several key individuals who have played an instrumental role in making this conference possible. My sincere thanks go to our Vice Chancellor, Prof. E. A. Weerasinghe; Deputy Vice Chancellor, Prof. Chaminda Rathnayaka; and Prof. J. Baratha Dodankotuwa, Head of Academic Development and Quality Assurance. Their unwavering support and vision for enhancing research capabilities at our university have been invaluable. My sincere gratitude goes to our chief guest, Prof. Sivalingam Sivananthan, and keynote speaker, Prof. G. Neelika Malavige. I also want to acknowledge the hard work of the organizing committee members and the research council of NSBM Green University whose dedication has ensured that every detail of the conference has been meticulously planned. Your efforts are truly appreciated.

Finally, I extend my gratitude to all participants for contributing to the success of ICTAR 2024. I hope you find the sessions enriching and leave with lasting memories of your time with us. We look forward to seeing you at NSBM Green University in the near future.

Thank You..!

MESSAGE FROM THE CONFERENCE EDITOR-IN-CHIEF



DR. DAMAYANTHI DAHANAYAKE
EDITOR-IN-CHIEF, ICTAR-2024
HEAD- RESEARCH COUNCIL
NSBM GREEN UNIVERSITY
HOMAGAMA, SRI LANKA

It is with great enthusiasm that I welcome you to the 1st International Conference on Transformative Applied Research (ICTAR) 2024, hosted by the Research Council of NSBM Green University, Sri Lanka. This event marks a significant milestone in our university's academic calendar, focusing on international collaboration and innovation under the theme **“Breaking Boundaries: Pioneering Solutions for Global Challenges.”**

ICTAR 2024 has received an impressive 150 full paper submissions across ten tracks, representing fields like Computer Science, Engineering, Science, and Management.

Through a rigorous double-blind review process, the top papers have been selected for publication by Taylor and Francis, a testament to our commitment to academic excellence. This process highlights the hard work of our national and international reviewers, ensuring the high standard of the conference proceedings.

As Editor-In-Chief, I am honored to lead this conference, bringing together esteemed academics and forward-thinkers from around the world. I extend my heartfelt gratitude to our leadership team, including the Vice-Chancellor, Deputy-Vice Chancellor, Head of Academic Development and Quality Assurance, Deans of the faculties, and the Conference Chair, for their unwavering support. I also extend my heartfelt gratitude to our chief guest, keynote speaker, the organizing committee, and everyone involved in making this event a success. A special thanks to our Associate Editor, reviewers, and co-chairs for their meticulous efforts in ensuring the quality of the review process.

I proudly present the top-selected proceedings of ICTAR 2024, which reflect cutting-edge research and spirited discussions. I hope these inspire further collaboration and innovation, propelling us toward a sustainable and brighter future in applied research.

Thank You..!

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MESSAGE FROM THE KEYNOTE SPEAKER I



PROF. BOGDAN GHITA

ASSOCIATE DEAN (INTERNATIONAL),
FACULTY OF SCIENCE AND
ENGINEERING, UNIVERSITY OF
PLYMOUTH, UNITED KINGDOM

Recent advances in computer processing power and the utilization of more complex machine learning models have extended the availability and applicability of AI-based technologies to all areas of modern life, from technical and research challenges to daily repetitive tasks. This presentation provides an overview of the history and current research efforts in AI, with a focus on networking and IT security.

The discussion will begin with a historical perspective, describing how machine learning has evolved over time and how the advent of complex models, including large language models, has provided a basis for theoretical concepts to reach daily use and applications.

From an accuracy perspective, intelligence fundamentally relies on the data it is presented with and may deliver inaccurate answers when not backed by human oversight.

The strength of machine learning comes from increased computational capacity, which provides a greater degree of granularity when replicating the features of a dataset. In parallel with its positive impact, AI may also have negative effects on society, such as misleading the public through deepfakes or making incorrect decisions due to insufficient data or incomplete examples.

The main part of the keynote presentation will focus on a series of studies that employed AI to strengthen the analysis of large datasets and uncover more complex behaviour, including application response speed under various network conditions, user profiling for better service delivery, identification of security threats, and AI artifacts such as deepfakes.

The talk will conclude with a brief encouragement to embrace the benefits of AI in research by applying existing methods to publicly available datasets to investigate their efficiency and accuracy.

Thank You..!

MESSAGE FROM THE KEYNOTE SPEAKER II



PROF. G. NEELIKA MALAVIGE

DEPARTMENT OF IMMUNOLOGY &
MOLECULAR MEDICINE,
FACULTY OF MEDICAL SCIENCES,
UNIVERSITY OF SRI
JAYEWARDENEPURA, SRI LANKA

Many lower-middle-income countries (LMICs) such as Sri Lanka, face significant challenges due to non-communicable diseases and infectious diseases. Climate change and rapid urbanization worsen the burden of vector-borne infections such as dengue, zika, and chikungunya, while lifestyle changes are significantly increasing the burden due to cardiovascular disease, diabetes, and dementia and taking a toll on mental health. To navigate these existing and emerging challenges globally, all countries must carry out research and innovations to overcome these challenges. Unfortunately, very limited investments are being made for research and development (R and D) in Sri Lanka, as seen in many low-income and LMICs. Limited investments in R

and D leads to limited funds for research, poor infrastructure, limited access to technology, which subsequently leads to lack of innovations, limited career progress for scientists, brain drain and the existing problems getting worse each day. The situation is further worsened by highly bureaucratic procurement processes, limited supply chains, high taxation of research reagents and again the lengthy process and multiple permissions required in grant approvals, and clearing of research reagents. All these setbacks make countries like Sri Lanka, less competitive in the global research market. Furthermore, inequalities in research collaborations, colonial science, biases towards scientists by policy makers in their own countries, further complicate the existing challenges. The solutions to these problems cannot happen overnight.

While multiple challenges exist to limit progress, this does not mean that it is impossible to carry out impactful research in countries like ours. It is important to find our strengths and weaknesses and where we have a strategic advantage. We should encourage international collaboration are done in a manner where there is true capacity building, technology transfer and led or co-led by our scientists. Most importantly, we must have a culture of nurturing each other and especially younger scientists, who find it extremely difficult to obtain funds and establish themselves in the modern highly competitive world. It is a culture of collaboration and not unhealthy competition, that will help us to face the existing and evolving challenges.

Thank You..!

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Optimization of Stability Assays for Chitin Nanofiber-Based Cosmetic Formulations: Enhancing Skin Rigidity

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Abstract— The attraction to improve skin rigidity, particularly in older adults, is a major focus in cosmetic applications, which are often handled with skin-invasive procedures. Maintaining the stability of cosmetic formulations is vital for product safety, efficacy, and longevity. This study focuses on the stability of chitin nanofiber-based formulations supposed to promote skin rigidity. Several stability tests were conducted including pH measurement, physical examination by centrifugation, light exposure testing, in vitro cytotoxicity, and accelerated aging studies. The pH values of the developed formulations were 4.6 and 4.8, which are within the normal range of 4.5 to 6.0 for human skin. Toxicity assessments implementing brine shrimp mortality revealed minimal toxicity, with values of 2.14g/mL for chitin nanofiber dispersion, 2.64g/mL for chitin nanofiber with PVA and glycerol, and 2.5g/mL for chitin nanofiber with PVA, glycerol, and Cyclopentasiloxane. Comprehensive evaluation results demonstrated that these formulations are extremely stable under a variety of situations, including physical stress, light exposure, and accelerated aging. These findings indicate that chitin nanofiber-based formulations have the stability and safety characteristics required for efficient inclusion into cosmetic products. The shown stability across different variables indicates their potential for consumer acceptance and efficacy, rendering them optimum choices for non-invasive cosmetic applications targeted at increasing skin rigidity.

Keywords— *chitin nanofiber, cosmetics, formulation, stability*

I. INTRODUCTION

Cosmetics are important in treating many skin issues, including decreased skin strength, dryness, wrinkles, and overall skin weakness. These concerns are frequently caused by reduced antioxidant capacity and skin attractiveness changes, substantially impacting psychological health. Skin aging is characterized by a decrease in collagen, elastin, fibroblast function, and vascularity, as well as an increase in matrix metalloproteinase enzyme activity. These alterations cause cellular and extracellular deterioration, visible as aging skin [1]. Researchers are conducting extensive research into the development of innovative cosmeceutical agents made from biocompatible, biodegradable, renewable, and sustainable materials. Among these materials, chitin and its derivatives are gaining popularity due to their promising characteristics and growing demand in the cosmetics industry [2]. Chitin is the second most commonly found biopolymer in the ecosystem, only surpassed by cellulose. This natural polymer is an important component of many biological structures observed in different species. This material is

important to the animal kingdom since it is mostly found in the exoskeletons of mollusks and crustaceans, the backbone of squids, and the cuticles of insects [3]. In recent years, attraction to chitin as a source of nanostructured materials has grown significantly. Nanostructured chitin, particularly in the form of nanofibers and nanocrystals, has distinct features from its bulk form. These nanoscale forms of chitin provide increased mechanical strength, biocompatibility, and functionality, making them perfect for various advanced processes [4]. The research aims to characterize the stability of chitin nanofiber-based cosmetic formulations which chitin nanofiber dispersion, chitin nanofiber with PVA and glycerol incorporation (CPG) to increase film forming, and chitin nanofiber with PVA, glycerol, and cyclopentasiloxane (CPGC) incorporation to increase rapid drying that develops to enhance skin rigidity by employing these readily available materials. Chitin nanofiber-based film formulations are important to rapid increase of skin rigidity while reducing aging concerns like wrinkles and fine lines.

II. LITERATURE REVIEW

Cosmetic delivery systems based on nanotechnology encompass a variety of innovative approaches designed to enhance the effectiveness and precise distribution of active ingredients in skincare products. These advanced systems enable better penetration and absorption of active compounds, improving their efficacy and targeting specific skin concerns more efficiently [5]. Nanotechnology-based delivery systems, such as liposomes, nanoemulsions, and nanocapsules [6], provide a controlled release and protect sensitive ingredients from degradation, offering significant advantages in the formulation of modern skincare products.

A. Chitin

The second most prevalent biopolymer in the world, chitin, is an excellent instance of the complex biochemical adaptability found in nature. This long-chain polymeric polysaccharide, observed for its exceptional structural stability, is an essential component of the biological matrix found in many living organisms. Its numerous applications, ranging from biomedical to industrial, emphasize its relevance [6]. Chitin's strong structure and multifunctional characteristics provide it with an indispensable material, helping to advance in a variety of industries, including cosmetics, where it improves product stability, efficacy, and sustainability [7]. One of chitin's most notable characteristics is its processing adaptability, which allows it to be formed into

a variety of structures such as gels, membranes, and nanofibers. Chitin's versatility makes it a beneficial material in a variety of applications, increasing its utility across industries. The structural integrity and functional qualities of chitin can be modified based on individual needs, whether in the form of strong membranes, absorbent gels, or fine nanofibers, demonstrating its potential in novel product development and advanced material research [6].

B. Chitin nanofiber

Chitin nanofibers have an important role in biological tissues, contributing to the structural integrity of many species. These nanofibers frequently interact with inorganic compounds and proteins, resulting in complex composite materials with superior mechanical, thermal, and functional properties. This interaction provides materials that are strong, durable and flexible in their applications, which range from therapeutic to industrial. The capacity of chitin nanofibers to combine with other materials to improve their properties emphasizes their value in both natural and synthetic applications [8]. Chitin nanofibers are unique nanomaterials that retain the fundamental characteristics of chitin while also providing multiple advantageous aspects for a variety of applications. These nanofibers have a remarkable aspect ratio—usually greater than 100—indicating that their length greatly exceeds their diameter. This elongated structure gives chitin nanofibers superior mechanical properties, increasing their tensile strength and toughness. These characteristics provide them with the perfect possibilities for reinforcing structural components and composite materials, resulting in greater durability and performance in a wide range of applications [9].

C. Applications of chitin nanofiber in cosmetics

Chitin nanofibers, formed from the abundant biopolymer chitin, are currently gaining popularity due to their numerous applications in cosmetics and personal care products. These nanofibers have distinct physicochemical characteristics such as a large surface area, biocompatibility, and film-forming capacity, which present several potential for innovation in skincare, hair care, and makeup formulations. Their ability to produce stable compounds and resist degradation provides them with an ideal ingredient for improving product performance and stability in a variety of cosmetic applications. The expanding study on chitin nanofibers in the cosmetics industry demonstrates their enormous potential and versatility. Continuous improvements and innovations in chitin nanofiber technology are opening the way for exciting cosmetic developments, providing sustainable and biocompatible treatments to satisfy changing customer demands. This development establishes chitin nanofibers as a significant component in future cosmetic compositions.

III. METHODOLOGY

A. Materials

The crab shells were purchased from the seafood markets of Beruwala and Panadura, Western Province, Sri Lanka. Sodium Hydroxide and Hydrochloric Acid were obtained from Sigma-Aldrich Co. (St. Louis, Missouri, USA). Glacial acetic acid was obtained from Sigma-Aldrich Co. (St. Louis, Missouri, USA). Glycerol (99.0% purity) was purchased as a plasticizer from Thermo Fisher Scientific, MA, USA. PVA

was purchased as film film-forming agent from HiMedia Laboratories Pvt. Ltd., India. All other chemicals utilized in the study were analytical and procured from HiMedia Laboratories Pvt. Ltd. (Mumbai, India). In developing and evaluating film formulations, the following steps were performed: A solution containing chitin nanofiber, solution with chitin nanofiber, PVA (1%), and glycerol (1%), and a solution with chitin nanofiber, PVA (1%), glycerol (1%), and cyclopentasiloxane (5%) was prepared by dissolving the ingredients for 30 minutes. The solution was sprayed onto a heated non-stick pan at 60°C, where it transitioned into a liquid state. The pan was then dried at 60 °C for about 5 minutes to evaporate the dispersions. This spraying and drying process was repeated until the desired film was achieved, taking 15 to 30 minutes. Finally, the films were allowed to dry for 1 to 2 hours before being peeled from the pan. Some physicochemical studies were carried out, such as pH measurements, centrifugation, light tests, cytotoxicity assays, and accelerated stability tests.

B. Determination of pH

Using a digital pH meter, the following pH values of formulations based on chitin nanofibers were determined: After dissolving 0.5 g of gel in 50 mL of distilled water, it was left on for two hours. Every formulation's pH was measured three times, and the average results were determined. Throughout the 15-day test period, the pH values of the formulations were tested while they were being stored [10].

C. Centrifugation test

A 5 g sample was centrifuged (TD4C) for 30 minutes at room temperature at of 3000 rpm to conduct the centrifugation test. The chitin nanofiber-based formulations were evaluated for phase separation at the end of the centrifugation period [10].

D. Light test

A daylight lamp with a photoperiodicity system (16 hours of light and 8 hours of darkness) was used to expose the chitin nanofiber-based formulations to intense light over 15 days while they were stored in clear plastic containers. The samples were inspected for changes in physical characteristics, including appearance, clarity, color, and liquefaction, after the exposure time [10].

E. In vitro cytotoxicity assay using brine shrimp (*Artemia salina*)

Eggs of *Artemia salina* were incubated in prepared artificial saltwater (Table 1) (10). After being incubated for 48 hours at room temperature (25–30 °C), brine shrimp eggs were put to artificial seawater in an Erlenmeyer and maintained under constant aeration and light source. The larvae (nauplii) were drawn to one side of the Erlenmeyer by a light source and collected using a pipette.

TABLE 1: ARTIFICIAL SEAWATER UTILIZED FOR THE HATCHING OF *ARTEMIA*

Medium composition	Amount (g/L)
NaCl	5.0
NaHCO ₃	2.0
MgSO ₄	1.3
MgCl ₂	1.0
CaCl ₂	0.3
KCl	0.2

A range of chitin nanofiber-based formulation concentrations (0.5%, 1%, 1.5%, and 2%) was developed, and the final volume was brought to 40 mL using previously produced artificial seawater. Following the addition of 10 mL of each concentration to Petri dishes, 20 nauplii were chosen and added to each sample well. Following 24 hours, the microplates were inspected under a magnifying lens to determine the quantity of living and dead nauplii in each well. If a larva did not move externally within a few seconds of observation, it was deemed dead. Experiments were carried out in a set of plates per dose with varying concentrations of the test chemicals and artificial seawater as the control. The percentage of mortality (M %) was calculated using the following formula proposed by previous studies (10).

$M\% = \text{Percentage of survival in the blank control} - \text{the percentage of survival in the treatment or positive control.}$

The optimal line produced by linear regression analysis of the percentage lethality vs the concentration was used to calculate the concentration that caused 50% lethality to the nauplii (LC50) [11].

F. Study of Accelerated Stability

For two weeks, two relative humidity environments were used, with $75 \pm 5\%$ RH and $60 \pm 5\%$ RH, for accelerated stability testing on all chitin nanofiber-based formulations. The temperatures were $40^\circ \pm 2^\circ \text{C}$ and $25 \pm 2^\circ \text{C}$, respectively. Following 14 days, the cosmetic compositions underwent an organoleptic examination, evaluating their color, scent, texture, consistency, phase separation, and pH level. When the storage term came to a close, this process was repeated [10].

G. Data and variables

To assess the differences in the dispersion formulations' characteristics, analysis of variance (ANOVA) was used. The statistical analysis was conducted using MINITAB 17 software, and differences were considered statistically significant if the p-value (p) was less than 0.05.

IV. RESULTS & DISCUSSION

Stability studies for cosmetics are vital to ensure that products achieve high safety, efficacy, and quality standards throughout their shelf life. These studies are important for formulation development and enhancement, as they assist manufacturers in verifying their products. Stability assessments provide necessary information by monitoring physical and chemical characteristics over time, ensuring that products remain effective and safe for consumers.

A. Determination of pH

The pH values of formulations are important for determining their compatibility with human skin. pH values for studied formulations were 4.51 ± 0.03 for chitin nanofiber dispersion, 4.63 ± 0.03 for chitin nanofiber, PVA, and glycerol and 4.76 ± 0.03 for chitin nanofiber, PVA, glycerol, and cyclopentasiloxane. The results are within the usual pH range for human skin, which is 4.5 to 6.0.

The chitin nanofiber, PVA, and glycerol formulation have a pH of 4.63 ± 0.03 , which is slightly acidic and similar to the pH of human skin. Glycerol, which is recognized for its moisturizing properties, functions effectively within this pH

range by providing hydration and improving the skin's barrier function. PVA promotes film development, protecting the skin and stabilizing moisture levels. With a pH of 4.76 ± 0.03 , chitin nanofiber, PVA, glycerol, and cyclopentasiloxane formulation are also within the optimal range for skin compatibility. cyclopentasiloxane is a silicone-based compound that provides a silky, smooth texture, improving the application and feel of the product on the skin.

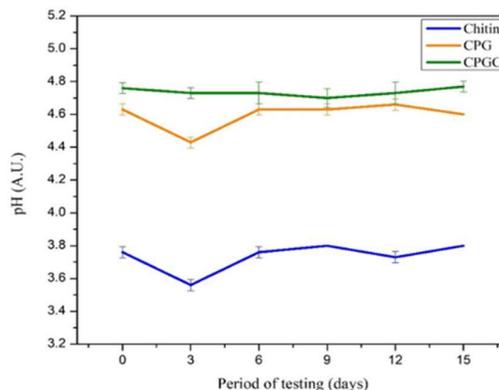


Fig. 1. Variation of pH over time

B. Centrifugation test

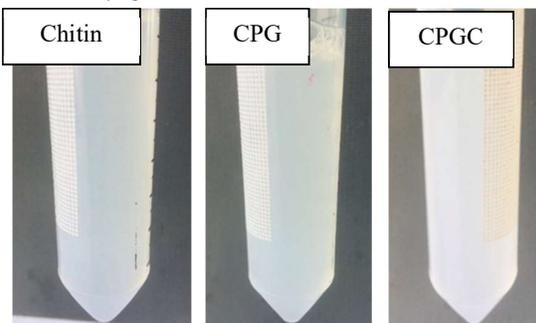


Fig. 2. Physical evaluation (centrifugation) of aspect formulations

The centrifugation test is a key method for assessing the stability of cosmetics because it subjects samples to stress that resembles higher gravity forces. This mechanism increases particle mobility within the formulation, indicating probable instabilities early. Researchers may utilize such stress to identify difficulties such as precipitation, phase separation, caking, or formation that normally develop over time [10]. Following centrifugation, samples are visually examined, and each formulation's physical stability is evaluated using criteria such as homogeneity, clarity, and the lack of phase separation.

The dispersion of chitin nanofibers demonstrated remarkable stability, with no evidence of phase separation or other instability characteristics. This stability shows that chitin nanofiber dispersion can be an effective basis or component in various cosmetic applications. The combination of chitin nanofibers, PVA, and glycerol forms a strong matrix that prevents phase separation and other instabilities, even when centrifuged. This shows that the formulation could be used in products that require structural support from chitin, film-forming capabilities from PVA, and soothing properties from glycerol.

Moreover, cyclopentasiloxane is known for its volatility and smooth texture, which did not impair the formulation's stability. This means that cyclopentasiloxane can be added to formulations including glycerol, PVA, and chitin nanofibers for benefiting products requiring rapid drying. This broadens the potential applications of these ingredients in cosmetics, enhancing their versatility and functionality.

C. Light test

The combination of ultraviolet (UV) radiation and oxygen may produce free radicals, highly reactive molecules that can initiate oxidation processes. These oxidative processes can destroy key components in cosmetic compositions, resulting in notable color and odor changes [10].

To follow in real-life light exposure, the formulations were placed in a photoperiodic environment for two weeks, with 16 hours of light and 8 hours of darkness. Following this period, the formulations were visually inspected for any physical or chemical interventions, such as odor, color, pH, and overall appearance. The formulations showed remarkable stability in simulated daylight conditions, with no obvious changes to color, odor, or appearance after the two-week exposure period. In particular, the chitin nanofiber dispersion remained stable, highlighting its resistance to UV radiation and oxidation.

D. *In vitro* cytotoxicity assay using brine shrimp

The safety of every ingredient in a cosmetic product significantly impacts its level of stability. As a result, one of the most important objectives in assuring the safety of a product is to examine the toxicity of the basic substances used in this formulation. The current study focused on the acute toxicity of chitin nanofiber and the relationships between the components in the formulations. PVA, glycerol, and cyclopentasiloxane weren't examined for toxicity due to their extensive use in cosmetics and common perception of safety; nevertheless, their interaction in the formulation was investigated. A brine shrimp mortality test was used at various dosages to investigate the potential toxicity of chitin nanofiber and its formulations. This assay serves to determine the toxicity range and determine whether any toxicity may limit the cosmetic application of these compounds. The products examined in the study had values of LC50 greater than 1 g/mL, indicating that they are safe for cosmetic application [10].

The concentration of substances that kill 50 % of *Artemia* was determined through the equation of the linear regression line of each sample. The values of LC50 for the mortality percentage of brine shrimp treated by the samples were found 2.14 g/mL, 2.64 g/mL, and 2.5 g/mL for chitin nanofiber dispersion, formulation of chitin nanofiber, PVA, and glycerol, and formulations of chitin nanofiber, PVA, glycerol, and cyclopentasiloxane, respectively. The results of the lethality assessment on brine shrimp indicate that chitin nanofiber shows low toxicity when used alone or in

The combination of chitin nanofibers, PVA, and glycerol demonstrated exceptional stability under light exposure, making it perfect for a variety of cosmetic applications. It retained its integrity and performance, demonstrating dependability in maintaining its pleasing appearance and activity. Furthermore, adding cyclopentasiloxane to the chitin nanofiber, PVA, and glycerol dispersion had no impact on its stability when exposed to light. This composition remained constant, demonstrating its suitability for products that require stability when exposed to light.



Fig. 3. Visual appearance after light test

combination with additional components, with LC50 values above the safety threshold. This indicates that chitin nanofiber and its formulations are unlikely to cause serious toxicological risks in cosmetic applications.

E. Accelerated Stability studies

The study assessed the physicochemical stability of various formulations stored under controlled conditions to evaluate their long-term durability. The formulations were kept for two weeks at two different temperature and humidity settings: $40\pm 2^\circ\text{C}$ and $75\pm 5\%$ relative humidity, and $25\pm 2^\circ\text{C}$ and $60\pm 5\%$ relative humidity. Stability was evaluated weekly, focusing on pH levels and organoleptic properties such as smell, color, and overall appearance. According to the results in Tables 3 and 4, there were no significant differences in the evaluated characteristics. Although the pH levels of the formulations decreased slightly under both conditions, the changes were not significant, indicating that the pH remained relatively stable over the two weeks. The formulations' odor, color, and overall appearance remained consistent throughout the evaluation period. This consistency in sensory characteristics is critical to product efficacy and consumer approval. Furthermore, the study examined phase separation, which is a typical sign of instability in emulsified or multiphase systems. No phase separation was observed at any point, regardless of storage circumstances, indicating the formulations' stability. This consistent distribution and integration of components indicate exceptional physicochemical stability when stored under the specified conditions, ensuring that the formulations maintain their intended properties, performance, and shelf life.

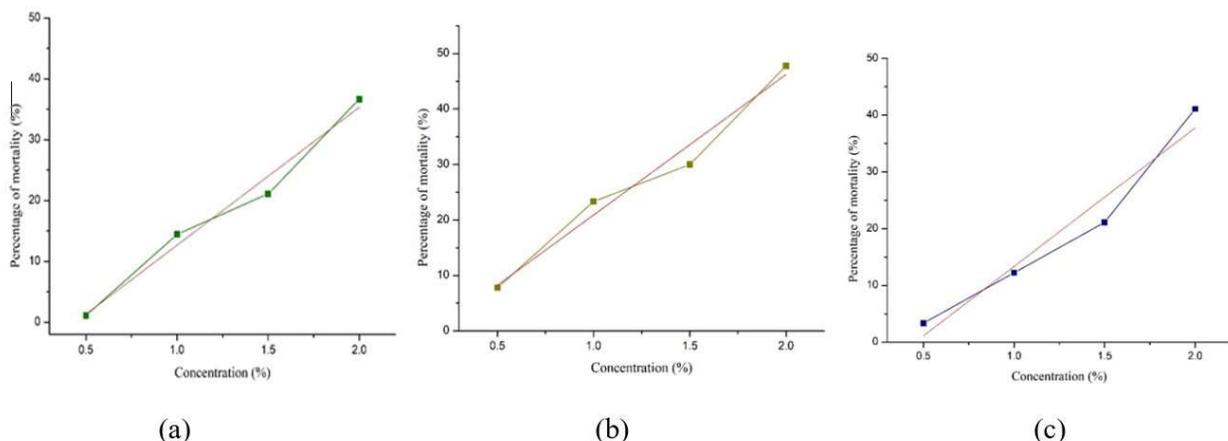


Fig.3: Evaluation of acute toxicity of chitin nanofiber dispersion (a), formulation of chitin nanofiber, PVA, and glycerol (b), formulations of chitin nanofiber, PVA, glycerol, and cyclopentasiloxane (c) (n=3)

TABLE 2: RESULTS FROM THE LIGHT TEST PERFORMED ON THE VARIOUS FORMULATIONS

Observed characteristic	Before the light test is started			After 14 days, the light test is started		
	Chitin	CPG	CPGC	Chitin	CPG	CPGC
Color	C	C	C	C	C	C
Smell	N	N	N	N	N	N
pH	3.83 ± 0.03	4.63 ± 0.05	4.76 ± 0.02	3.73 ± 0.04	4.56 ± 0.04	4.73 ± 0.03
Phase separation	-	-	-	-	-	-
Overall appearance	S	S	S	S	S	S

Color: C – Colorless, CC – Color Change; Smell: N – Noticeable, SS – Strong Smell; Phase separation: –No phase separation + Phase Separation; Overall appearance: S –Smooth, V – Viscous

TABLE 3: RESULTS OF THE ACCELERATED STABILITY TESTS CARRIED OUT OVER THE FIRST WEEK ON THE DIFFERENT FORMULATIONS

Observed characteristic	Relative humidity conditions: 75±5% RH, Temperature of 40 ± 2 °C			Relative humidity conditions: 60±5% RH, Temperature of 25 ± 2 °C		
	Chitin	CPG	CPGC	Chitin	CPG	CPGC
pH	3.84 ± 0.02	4.63 ± 0.03	4.75 ± 0.05	3.73 ± 0.04	4.51 ± 0.03	4.72 ± 0.04
Smell	N	N	N	N	N	N
Color	C	C	C	C	C	C
Phase separation	-	-	-	-	-	-
Overall appearance	S	S	S	S	S	S

Smell: N – Noticeable, SS – Strong Smell; Color: C – Colorless, CC – Color Change; Phase separation: –No phase separation, + Phase Separation; Overall appearance: S –Smooth, V – Viscous

TABLE 4: RESULTS OF THE ACCELERATED STABILITY TESTS CARRIED OUT OVER THE SECOND WEEK ON THE DIFFERENT FORMULATIONS

Observed characteristic	Relative humidity conditions: 75±5% RH, Temperature of 40 ± 2 °C			Relative humidity conditions: 60±5% RH, Temperature of 25 ± 2 °C		
	Chitin	CPG	CPGC	Chitin	CPG	CPGC
pH	3.84 ± 0.02	4.63 ± 0.03	4.75 ± 0.05	3.73 ± 0.04	4.51 ± 0.03	4.72 ± 0.04
Smell	N	N	N	N	N	N
Color	C	C	C	C	C	C
Phase separation	-	-	-	-	-	-
Overall appearance	S	S	S	S	S	S

Smell: N – Noticeable, SS – Strong Smell; Color: C – Colorless, CC – Color Change; Phase separation: –No phase separation, + Phase Separation; Overall appearance: S –Smooth, V – Viscous

V. CONCLUSION

Based on the comprehensive evaluation performed in this study, it is possible to infer that the developed chitin nanofiber-based formulations have promising cosmetic stability. The study, which includes pH, physical strength to centrifugation, resistance to light exposure, in vitro cytotoxicity, and accelerated stability examinations, all demonstrate excellent stability under a variety of conditions. These findings indicate that the formulations have the potential for successful integration into cosmetics by providing stability and safety features that are critical for consumer acceptance and product efficacy. Long-term stability tests and real-world application trials would be useful in determining their appropriateness for commercial use.

ACKNOWLEDGMENT

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Enhanced Functional Properties of Chitosan-Based Edible Films Loaded with Ascorbic Acid and Cinnamon (*Cinnamomum zeylanicum*) Essential Oil: A Comparative Investigation

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Abstract—The increasing need for sustainable packaging has prompted the development of biodegradable materials that reduce environmental pollution, enhance safety, and extend food shelf life. This study investigates chitosan-based edible films with varying concentrations (0.5, 1.0, and 1.5) % of ascorbic acid (AA) and cinnamon essential oil (CEO) using the casting method. The films were evaluated for their physical, mechanical, optical, antioxidant, antimicrobial properties, and biodegradability. Higher concentrations of AA and CEO resulted in thicker films and reduced moisture content. Chitosan films with CEO (Chn+CEO) exhibited significantly higher water resistance ($p < 0.05$) compared to those with AA (Chn+AA), due to CEO's hydrophobic nature. Biodegradability tests showed that Chn+AA films had increased degradation rates with higher AA concentrations compared to Chn+CEO films, while Chn+CEO films had reduced biodegradability with more CEO. Despite these differences, all films had over 70% biodegradability within 28 days. Increasing AA and CEO concentrations decreased tensile strength, while CEO addition increased elongation at break, indicating a plasticizing effect. Both film types significantly increased in total color difference (ΔE) with higher active ingredient concentrations. The Chn+CEO films exhibited superior antimicrobial activity against *Bacillus cereus* and *Escherichia coli* compared to the Chn+AA films. The DPPH free radical scavenging activity was higher in 1.5% Chn+AA films ($IC_{50} = 0.17$ mg/mL) than in 1.5% Chn+CEO films ($IC_{50} = 0.22$ mg/mL), indicating stronger antioxidant properties. These findings highlight the potential of AA and CEO-incorporated chitosan films as innovative, sustainable packaging materials with excellent antioxidant and antimicrobial properties, contributing to improved food safety and environmental sustainability.

Keywords—antimicrobial, antioxidant, ascorbic acid, chitosan films, cinnamon essential oil

I. INTRODUCTION

Food packaging is crucial for safeguarding food products from physical, chemical, and biological factors, thereby maintaining the safety, quality, and extended shelf life of the food supply chain. However, the widespread use of non-renewable, non-biodegradable synthetic packaging materials has led to significant environmental concerns, primarily due

to their environmental persistence and their contribution to pollution. These materials, derived from petroleum-based sources, do not degrade easily and accumulate in landfills and natural habitats, causing harm to wildlife and ecosystems. Given these concerns, there is increasing interest in creating sustainable alternatives that can reduce the environmental footprint of food packaging. Among these alternatives, edible and biodegradable films have emerged as promising solutions that can mitigate the adverse impacts of synthetic packaging [1]. These innovations not only contribute to reducing environmental pollution but also offer functional benefits in preserving food quality and safety. Edible packaging is created using various biopolymers, such as alginate, agar, chitosan, carrageenan, and lipids [2]. These biopolymers are derived from natural sources and offer numerous advantages, including biodegradability, biocompatibility, and non-toxicity. Among these materials, chitosan has attracted considerable interest for its superior film-forming abilities and its potential as a functional ingredient in food packaging. Chitosan is derived from the deacetylation of chitin, a substance presents in the exoskeletons of crustaceans such as shrimp, crabs, and lobsters. The conversion of chitin to chitosan results in a biopolymer with unique properties, including biodegradability, biocompatibility, non-toxicity, and antimicrobial activity [3]. These characteristics make chitosan an ideal candidate for developing edible packaging films that can help preserve food quality and extend shelf life.

In addition to their intrinsic properties, chitosan-based films can be enhanced through the incorporation of active substances, leading to the development of active packaging. Active packaging involves embedding active ingredients directly into the packaging material, rather than introducing them into the food. This strategy aims to improve the preservation of food products by extending their shelf life and maintaining their sensory qualities. Natural active compounds, such as essential oils (EOs), have shown great potential in this regard due to their inherent antimicrobial and antioxidant properties. When integrated into edible packaging films, essential oils can enhance antimicrobial efficacy, improve vapor resistance, reduce water solubility, and slow down lipid oxidation in the packaged product [4].

Cinnamon essential oil stands out among essential oils for its rich concentration of bioactive compounds, including cinnamaldehyde and eugenol. These compounds impart strong antimicrobial and antioxidant properties to the oil, making it an excellent additive for active packaging films [5]. Integrating CEO into chitosan-based films can lead to the development of active packaging materials that offer enhanced protection against microbial contamination and oxidative degradation. Furthermore, the addition of ascorbic acid, a potent antioxidant, can further augment the functional properties of these films by providing additional antioxidant capacity and improving the overall stability of the packaging material.

The present study aims to investigate the effects of adding various concentrations of CEO and ascorbic acid to chitosan-based edible films. The research will focus on evaluating the physical, optical, mechanical, antimicrobial, and antioxidant properties of the resulting composite films. Additionally, the biodegradability of these films will be assessed to determine their environmental impact. By comprehensively examining these parameters, this study seeks to advance the understanding of how natural active ingredients can enhance the performance of edible packaging films, ultimately contributing to the development of sustainable packaging solutions that address both food preservation and environmental sustainability challenges.

II. METHODOLOGY

A. Preparation of Chitosan-Based Active Films

The method outlined by [3] was followed to synthesize chitosan-based films, with minor adjustments to maximize the film's qualities. Initially, chitosan (2% w/v) and glycerol (0.75 g/g chitosan) were dispersed in a 1% (v/v) glacial acetic acid solution to form the film-forming solution. Various concentrations of cinnamon bark essential oil (CEO) (containing trans-cinnamaldehyde and eugenol as the major compounds) (0.5, 1.0, and 1.5% v/v of the total volume) and ascorbic acid (AA) (0.5, 1.0, and 1.5% w/v of the total volume) were incorporated into the film-forming solutions separately, along with Tween 80 (0.20% of essential oil) to facilitate the dispersion of the oil. The mixtures were homogenized using a homogenizer to ensure a uniform dispersion of all components. After homogenization, the solutions were degassed under a vacuum to remove any trapped air bubbles. The degassed film-forming solutions were then poured into glass molds and allowed to dry under ambient conditions. After drying, the films were gently taken out of the molds and stored in an environment with a relative humidity of 50±5% and a temperature of 25±2 °C until they were ready for further analysis.

B. Evaluation of Physical Properties

The physical properties of the films, including thickness, moisture content, and water solubility, were analyzed using established methods. Thickness was measured with a digital micrometer at five random points on each film sample, following the procedure described by [6]. Moisture content and water solubility were assessed based on the procedures described by [4]. The films were dried until they reached a consistent weight, and the weight loss during this drying process was measured.

C. Evaluation of Optical Properties

The optical characteristics of the films, such as surface color difference (ΔE) and whiteness index, were assessed using a colorimeter. The methods described by [7] were followed to determine these parameters. The ΔE was computed by comparing the color values of the film samples to those of a standard white tile, while the whiteness index was assessed to evaluate the visual appearance of the films.

D. Evaluation of Mechanical Properties

Tensile strength and elongation at breakage were among the mechanical parameters of the films that were assessed using the ASTM D882-10 standard test procedure. Film samples were cut into strips and tested using a universal testing machine. Tensile strength was calculated by dividing the maximum force by the initial cross-sectional area, while elongation at break was expressed as the percentage increase in length at the point of rupture.

E. Biodegradability Testing

The biodegradability of the films was assessed using the soil degradation method described by [8]. Film samples were buried in soil and maintained under controlled conditions of moisture and temperature. The weight loss of the films was measured at regular intervals to determine the degradation rate.

F. Antioxidant Activity

The film samples were assessed for their antioxidant activity using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging assay, as described by [9]. The film samples were incubated with a DPPH solution, and the decrease in absorbance was measured spectrophotometrically. The antioxidant activity was quantified by calculating the percentage of scavenging DPPH radicals.

G. Antimicrobial Activity

The antimicrobial efficacy of the chitosan-based films was quantitatively assessed using the liquid culture medium assay method described by [10]. The films were tested against two food-borne pathogenic bacteria: *Bacillus cereus* (gram-positive), and *Escherichia coli* (gram-negative), which were isolated from spoiled fruits and vegetables. The films were incubated with bacterial cultures, and the reduction in bacterial growth was measured to determine the antimicrobial efficacy.

H. Statistical Analysis

All experiments were conducted in triplicate to ensure the accuracy and reliability of the data. Analysis of variance (ANOVA) was performed to evaluate the variations in the physical, optical, mechanical, antioxidant, and antimicrobial properties of the chitosan-based edible biodegradable packaging films. The statistical analysis was carried out using MINITAB 17 software, and differences were regarded as statistically significant when $p < 0.05$.

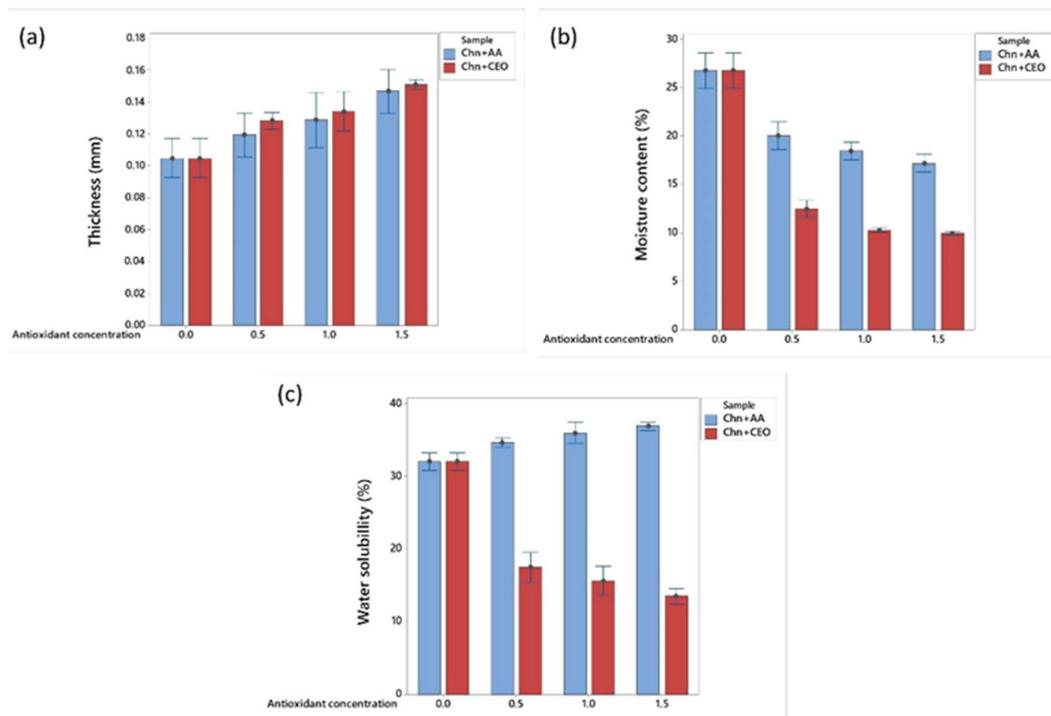


Fig. 1. (a) Thickness, (b) moisture content (%), (c) water solubility (%), and (d) swelling degree (%) variations of Chn+AA and Chn+CEO film

III. RESULTS AND DISCUSSION

A. Physical Properties of Films

Film thickness

The addition of cinnamon essential oil (CEO) and ascorbic acid (AA) to chitosan-based film-forming emulsions resulted in a noticeable increase in the thickness of the films compared to the control samples, as illustrated in Fig. 1. The film thickness exhibited a positive correlation with the concentration of CEO and AA, ranging from 0.11 mm to 0.15 mm. The presence of dispersed micro-droplets of essential oil within the polymeric matrix contributes to the film's overall structure, requiring a longer path for the matrix to form a cohesive film, thus resulting in increased thickness. The interaction between the oil molecules and the chitosan matrix likely influences the kinetics of film formation, leading to a more structured arrangement of molecules within the film [11]. AA also plays a crucial role in further increasing the film thickness. As a hydrophilic compound, AA can interact with the chitosan matrix through hydrogen bonding and electrostatic interactions. These interactions can lead to a more compact and denser network, thereby increasing the overall thickness of the film.

Moisture content

The addition of CEO and AA significantly reduced ($p < 0.05$) the moisture content (MC) of the chitosan-based films, lowering it from 26.81% to 9.97% (Fig. 1). This reduction was especially noticeable in the Chn+CEO films. Due to chitosan's inherent hydrophilicity, the control films

without active ingredients exhibited the highest MC. This was caused by increased molecular entanglement and viscosity in pure chitosan solutions, which led to greater water retention during the drying process. In contrast, the incorporation of AA or CEO formed covalent bonds with the functional groups of the polymeric matrix, reducing polysaccharide-water interactions via hydrogen bonding and thus resulting in lower moisture content in the films [12]. This suggests that incorporating CEO and AA improves the films' moisture-repelling properties, which is advantageous for food packaging that requires reduced moisture content to maintain product quality.

Water solubility

The films exhibited a notable reduction in solubility ($p < 0.05$) with increasing concentrations of CEO and decreasing concentrations of AA, as illustrated in Fig. 1. This suggests that Chn+CEO films exhibited greater water resistance compared to Chn+AA films. The likely reason for this improvement is the increase in hydrophobicity due to the addition of CEO [13].

B. Optical Properties of Films

Surface color difference (ΔE) and whiteness index

Both films showed a substantial increase in total color difference (ΔE) compared to the control film, with ΔE rising as the concentration of the active ingredient increased ($p < 0.05$) (Fig. 2). Adding AA and CEO to chitosan-based films led to a significant reduction ($p < 0.05$) in the film whiteness index (WI), with a more pronounced decrease

observed in the Chn+AA films. AA, a reducing agent, can oxidize upon exposure to oxygen or other oxidizing agents, transforming into dehydroascorbic acid and other intermediate compounds. These oxidation reactions produce colored compounds and degradation products that affect the film's color. Consequently, these changes contribute to the

increase in ΔE and decrease in WI. The color variation induced by CEO could be due to molecular alterations in the chitosan. The yellow tint in Chn+CEO films may result from interactions between chitosan and pigment compounds in CEO, such as cinnamaldehyde [14].

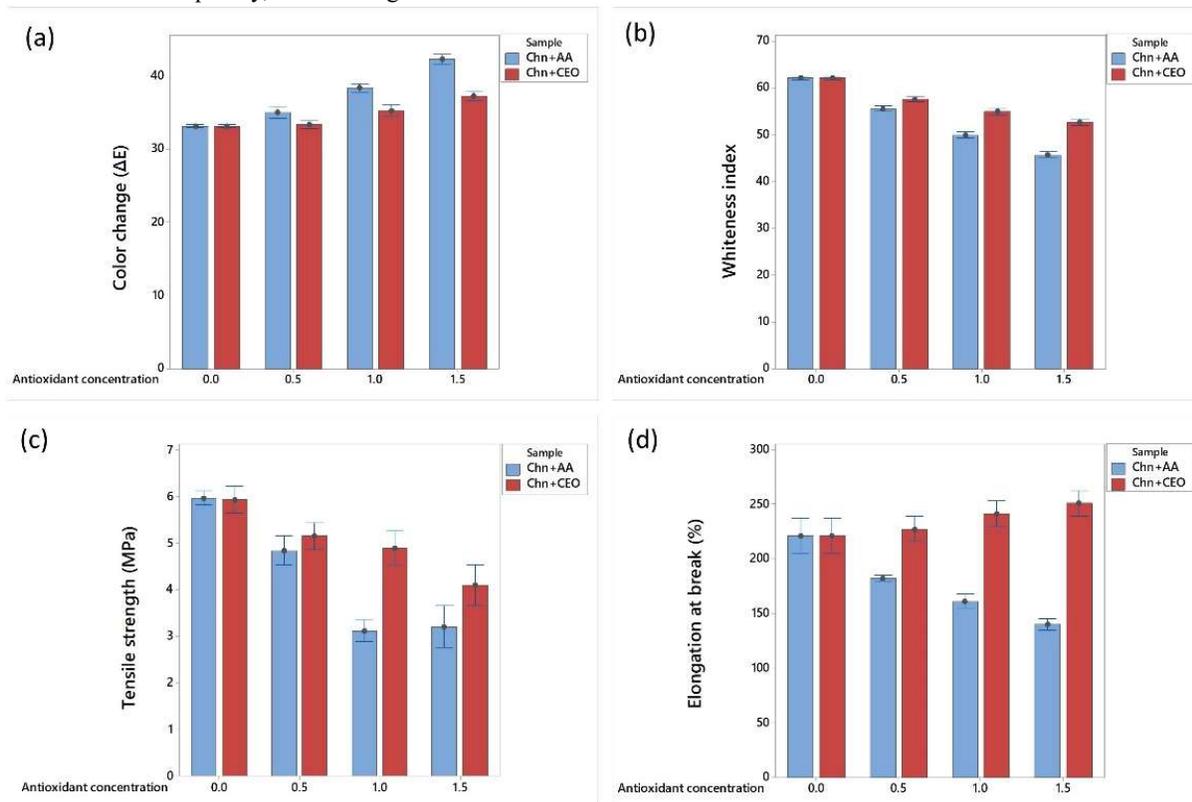


Fig. 2. (a) Color change (ΔE) and (b) whiteness index, (c) tensile strength (MPa), and (d) elongation at break (%) variations of Chn+AA and Chn+CEO films

C. Mechanical Properties of Films: Tensile strength and elongation at break

As the concentrations of AA and CEO increased, the tensile strength (TS) of the films decreased. In contrast, the elongation at break (EB) values varied depending on the type of additive used. Specifically, the EB values of Chn+AA films decreased, whereas those of Chn+CEO films increased with higher concentrations of AA and CEO, respectively (Fig. 2). The rise in EB values for Chn+CEO films can be linked to the pronounced plasticizing effect of CEO, which improves the flexibility of the films. On the other hand, the decrease in EB values for the AA-incorporated films may be due to the stronger destructive impact of AA on the crystalline structure of the chitosan matrix [15]. These findings suggest that while both additives decrease TS, they have opposite effects on film flexibility, with CEO increasing and AA decreasing the EB.

D. Biodegradability Properties of Films

The film's biodegradability is mainly influenced by its moisture content and chemical composition, as indicated by

the observed weight changes over time (Fig. 3). After 28 days, the control films showed the greatest weight loss percentage compared to the Chn+CEO and Chn+AA active films. Chitosan, a naturally biodegradable macromolecular polymer with hydrophilic characteristics, facilitates the easy penetration of soil moisture into its polymer network. This penetration weakens the polymer chains, increasing their vulnerability to hydrolysis by soil microorganisms. The Chn+AA films displayed a greater percentage of weight loss in comparison to the Chn+CEO films over 28 days. This difference can be attributed to the Chn+AA films' inherent hydrophilic properties, which facilitated the infiltration of soil moisture into the polymer network. This, in turn, led to the weakening of polymer chains and subsequent hydrolysis by soil microorganisms. However, the addition of AA and CEO reduced the films' biodegradation rate relative to the control. This decrease in biodegradability is attributed to the stronger intermolecular interactions and decreased microbial compatibility of the films when higher amounts of AA and CEO are present.

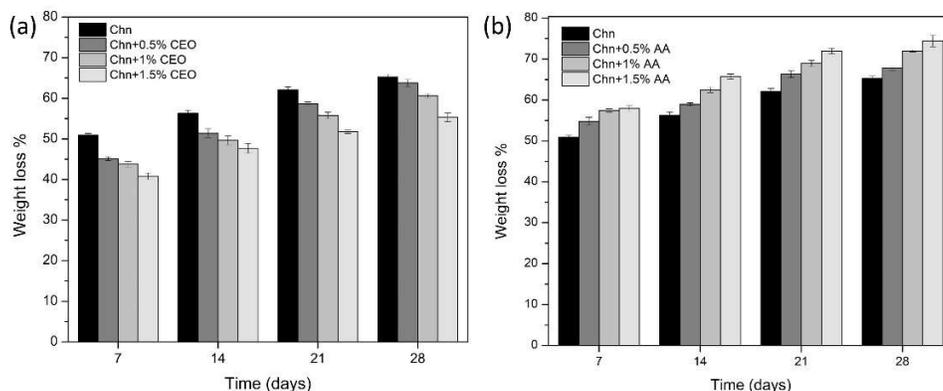


Fig. 3. The soil biodegradability of chitosan-based films (Chn) incorporated with 0.5% (v/v), 1% (v/v), and 1.5% (v/v) of CEO (Chn+CEO) and AA (Chn+AA) at different day intervals

Antioxidant Activity (DPPH-Free Radical Scavenging Assay)

The control films exhibited the highest IC₅₀ values, reflecting the lowest level of antioxidant effectiveness (Fig. 4). The DPPH scavenging activity for all Chn+CEO samples was consistently lower compared to the Chn+AA samples, with the greatest activity found in films containing 1.5% AA. The addition of AA and CEO significantly influenced ($p < 0.05$) the DPPH free radical scavenging activity and IC₅₀ values, boosting the antioxidative efficacy of the films. This enhanced radical scavenging activity, especially prominent in the CEO films, is linked to the presence of bioactive compounds such as cinnamaldehyde and eugenol [16], which are recognized for their strong antioxidant properties. These compounds contribute significantly to the remarkable antioxidative potential observed in the CEO-incorporated films.

E. Antimicrobial Properties of Films

The films containing AA and CEO both demonstrated enhanced antimicrobial efficacy compared to the chitosan control films, but there were notable differences in their effectiveness. During the stationary growth phase, the optical density at 650 nm (OD_{650nm}) for bacterial suspensions of *B. cereus* and *E. coli* without edible films was about twice as high as that for films containing 1.5% active ingredients. Comparatively, Chn+AA films exhibited significant inhibitory effects on *B. cereus* (OD_{650nm} at 0.433) and *E. coli* (OD_{650nm} at 0.565) at 1.5% AA concentration. On the other hand, Chn+CEO films also showed notable antimicrobial properties, with OD_{650nm} values of 0.433 for *B. cereus* and 0.507 for *E. coli* at 1.5% CEO concentration. The Chn+CEO films demonstrated superior antimicrobial effectiveness against *E. coli* compared to the Chn+AA films with lower OD_{650nm} values, indicating better bacterial inhibition. However, both film types exhibited similar inhibitory effects on *B. cereus* at the same concentration level (1.5%). The results suggest that while both AA and CEO enhance the antimicrobial properties of chitosan films, CEO has a marginally higher overall effectiveness, especially in inhibiting *E. coli* growth.

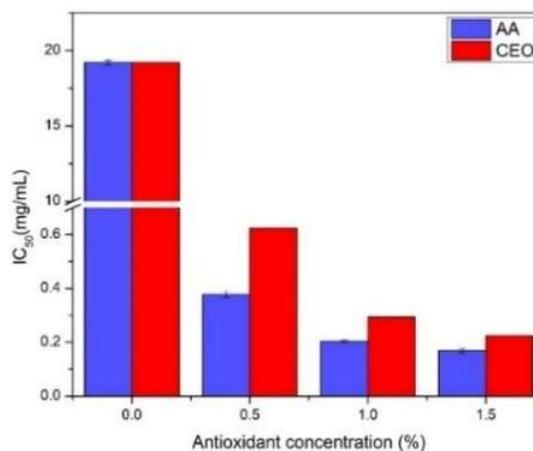


Fig. 4. Antioxidant activity (IC₅₀ in mg/mL) of Chn+AA and Chn+CEO films

IV. CONCLUSION

Chitosan-based films incorporating various concentrations of active ingredients, such as ascorbic acid (AA) and cinnamon essential oil (CEO), were developed and characterized. As the concentration of active ingredients increased, the tensile strength of the film significantly decreased. However, the elongation at break was enhanced by the addition of CEO, likely due to its plasticizing effect. Both AA and CEO exhibited significant inhibitory effects against food-borne pathogenic bacteria, including *Bacillus cereus* and *Escherichia coli*. Among the two, CEO was more effective than AA, attributed to its higher antimicrobial activity.

Furthermore, the Chn+1.5%AA films demonstrated superior antioxidant activities compared to the Chn+CEO films, indicating their potential as new active food packaging materials. Consequently, the development of edible films from chitosan, cinnamon essential oil, and ascorbic acid presents innovative methods to enhance microbial safety and prolong the shelf life of food products.

ACKNOWLEDGMENT

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A Mini Review on Dengue: Advances in Management, Vector Control, and Vaccination Strategies

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Abstract— More individuals are affected by dengue than any other vector-borne viral disease around the world. Dengue is an infectious disease, mainly transmitted by the mosquito *Aedes aegypti*, predominant in tropical and subtropical climates. Symptoms of the disease range from mild fever to severe dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS). The diagnosis process contains serological testing, nucleic acid identification, and virus isolation. Current management focuses on fluid management, monitoring for early warning signs of serious disease, and supportive care. There are still no certified vaccines or antiviral medications. Currently recommended methods for preventing dengue include controlling vectors, using insecticides, and promoting the use of personal protective equipment. This mini review points out the need for better management practices to minimize dengue fever globally and the challenges and future directions for research.

Keywords- dengue, diagnosis, management, vaccine

I. INTRODUCTION

Dengue fever is a highly prevalent mosquito-borne disease affecting millions globally [1]. The illness has the highest worldwide morbidity rate [2]. In the past 50 years, dengue fever prevalence exploded, with over 50% of the global community living in high-risk zones across 100 nations [3]. Approximately 50 to 100 million people are infected worldwide each year [4]. The precise incidence of dengue remains unclear; however, estimates indicate that the annual number of cases ranges from 284 to 528 million, with 96 million of those classified as confirmed cases [3, 5, 6]. According to the World Health Organization, 75% of the global dengue cases in 2012 were reported in Asia [3]. During the period from 1991 to 2008, dengue epidemics took place every 3 to 5 years, gradually spreading to various regions of Sri Lanka [5, 7]. In 2009, a notable epidemic occurred, resulting in 35,008 suspected cases and 346 fatalities [4]. Dengue fever emerged as a significant public health concern from 2010 to 2016, marked by a consistent rise in the number of cases. The mortality rate is 1-5% without therapy and less than 1% with treatment [4].

Dengue is caused by the dengue virus (DENV), which belongs to the Flavivirus genus within the Flaviviridae family [1]. Flaviviruses are RNA viruses characterized by a single-stranded, positive-sense structure [8]. It is spread by mosquitoes belonging to the *Aedes* genus, particularly *Aedes aegypti* and *Aedes albopictus* [1]. The illness arises from

infection by four related, yet distinct dengue viruses known as DENV1, DENV2, DENV3, and DENV4 [2]. The RNA genome of flaviviruses encodes a singular polyprotein which is dismantled by both host and viral proteases, yielding seven nonstructural proteins: NS1, NS2a, NS2b, NS3, NS4a, NS4b, and NS5. Additionally, three structural proteins are present, namely the core, membrane, and envelope proteins [9]. Beginning in 2017 Sri Lankan epidemic attributed to the DENV2 serotype, on an annual basis dengue instances consistently surpassed 50,000, reaching a peak marking the highest number of cases and deaths (186,101 reported cases and 440 deaths) [7, 10]. DENV1 was the predominant serotype until mid-2016 but was replaced by DENV2 in 2017. In 2019, there were 114,240 cases recorded, with a gentle increase annually. DENV3 was identified and observed to transpire after 2019 [5, 11].

Effective management strategies are critical for managing and preventing dengue fever because they provide integrated treatments to optimize effect and achieve better outcomes. This review offers the importance of effectively managing dengue fever in reducing morbidity and mortality, preventing outbreaks, current updates about pharmacological management and vaccination strategies, and improving global health outcomes.

II. METHODOLOGY

This literature review was comprehensively conducted to analyze existing scholarly articles, research papers, and clinical trials related to dengue virus management and prevention. Primary sources were gathered from databases such as PubMed, Google Scholar, and Web of Science. Two main areas were addressed: the effectiveness of supportive care strategies in reducing morbidity and mortality, and emerging antiviral therapies. Studies on vaccine development and vector control measures were also included. Key findings were compiled to highlight trends in dengue management and pinpoint research gaps. Both qualitative and quantitative data from recent studies were used to ensure a comprehensive evaluation of the current state of dengue treatment and prevention efforts.

III. DIAGNOSTIC CHALLENGES AND CLINICAL MANIFESTATIONS

Dengue virus (DENV) is transmitted to humans primarily by *Aedes* mosquitoes, particularly *Aedes aegypti* [12]. Upon

a mosquito bite, the virus enters the bloodstream, targeting skin cells like immature Langerhans cells and keratinocytes [13]. Infected cells migrate to the lymph nodes, where monocytes and macrophages are recruited, spreading the virus throughout the lymphatic system. Various immune cells, such as myeloid dendritic cells, splenic and hepatic macrophages, and blood-derived monocytes, become infected during this primary viremia [14, 15].

Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you. Following a 4–10-day incubation period, DENV infection symptoms typically appear within 2–7 days [16]. While most infections are asymptomatic, DENV can cause a range of clinical symptoms, from mild flu-like dengue fever (DF) to severe conditions like dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS), which can result in hypovolemic shock [16]. DF usually lasts for 3 to 7 days and may include symptoms like headache, muscle pain, and fatigue [17]. In newborns and children, DF often manifests as a maculopapular rash, while adults may experience more severe symptoms such as fever, intense headache, joint pain, and gastrointestinal discomfort. Bleeding, such as petechiae, nosebleeds, and bleeding gums, is also common, along with laboratory indicators like leukopenia, thrombocytopenia, and elevated liver enzymes [18].

Less than 3% of individuals who are infected develop DHF. It is characterized by vascular leakage and thrombocytopenia, which is a low platelet count of $\leq 100,000$ mm³. DHF is more likely to occur in infants born to mothers who are immune to DENV [9]. In children, DHF typically presents as a rapid rise in body temperature, face flushing, and worsening symptoms after the fever subsides. If left untreated, DHF can progress to DSS, which is characterized by a rapid, weak pulse or low blood pressure, cold skin, and faintness. Without proper treatment, DSS can lead to fatal shock within 12 to 36 hours [19]. The development of DHF/DSS is believed to be influenced by a complex interaction between the virus, the host's genetics, and immune factors [20].

Diagnosing dengue based solely on clinical symptoms can be unreliable due to overlapping symptoms with other viral infections, like chikungunya and Zika [3, 21]. To confirm DENV infection, a combination of medical history, physical examination, and blood tests is crucial, especially in dengue-endemic regions [21–23]. Various tests are used depending on the stage of the infection. During the early stages (less than five days post-infection), virus isolation, RNA detection (via nucleic acid amplification tests, NAAT), or antigen detection (NS1) are used. As viremia declines after five days, serological methods are employed to detect antibodies, particularly IgM and IgG [3, 23, 24].

Three main diagnostic approaches for DENV include molecular techniques, serological tests, and direct virus detection. Molecular techniques such as NAAT, particularly RT-PCR, are highly sensitive and considered the gold standard for the early detection of viral RNA [25]. However, these methods are costly, prone to contamination, and require trained personnel [3, 22, 26]. Virus isolation is another

specific method, involving the inoculation of clinical specimens onto cell cultures, but it is time-consuming and requires specialized laboratory facilities [3, 22]. The most sensitive method for virus isolation involves mosquito inoculation, although low DENV viremia levels limit its effectiveness [27, 28].

Antigen detection, specifically of the NS1 protein, is significant for early detection of DENV [22, 29]. NS1-based tests, such as ELISA and immunochromatographic assays, can detect primary and secondary infections within nine days of symptom onset. However, these tests are less sensitive during secondary infections and for certain DENV serotypes [22, 23]. Monoclonal antibody-based NS1 ELISA tests have improved serotype specificity and can differentiate between primary and secondary infections [27].

Serological tests, like ELISA and hemagglutination inhibition assays, are commonly used due to their low cost and ease of use. These tests detect IgM and IgG antibodies, with higher IgM titers indicating primary infection and higher IgG titers indicating secondary infection. The IgM: IgG ratio helps distinguish between primary and secondary infections [22, 23]. Plaque Reduction and Neutralization Tests (PRNT) are another method used to detect neutralizing antibodies, providing greater specificity by differentiating DENV antibodies from cross-reactive flavivirus antibodies [3, 21].

Various diagnostic methods are available for dengue virus detection, each with its limitations. Virus isolation is a time-consuming process that necessitates specialized facilities. Molecular techniques such as RT-PCR are costly and require skilled technicians. While antigen detection and serological tests serve as practical alternatives, they may not be as sensitive in cases of secondary infections or for specific DENV serotypes. Ultimately, a combination of diagnostic approaches is often required to confirm DENV infection [22, 23].

IV. MANAGEMENT OF DENGUE PATIENTS

A. Supportive care

At present, there are no targeted therapies available for the remedy of dengue [2]. The therapy remains mainly supportive, focusing on fluid management [30].

Dengue fever care relies heavily on fluid resuscitation, especially during the crucial period when the rate of fluid delivery matches the rate of plasma leakage [31]. Some guidelines suggest calculating a fluid quota for the critical phase, which includes both maintenance of fluid and a 50 mL/kg fluid deficit (up to 50 kg) over 48 hours [31]. Managing severe dengue requires replacing plasma lost due to increased vascular permeability, especially during the critical period [32]. Dengue fever treatment requires the administration of two categories of volume expanders: crystalloids, which are water-soluble molecules, and colloids, which consist of water-insoluble molecules, to restore lost fluids [32].

To prevent hypovolemic shock caused by plasma leakage in dengue hemorrhagic fever, vigorous intravascular volume repletion is necessary [4]. Oral rehydration may suffice in moderate instances, especially with prompt medical treatment [4]. For individuals who have already experienced fluid loss,

intravenous fluid treatment is advised, and blood transfusion is recommended for significant bleeding [4].

The fluid management of dengue-infected individuals still faces substantial problems due to the lack of reliable indicators for predicting severe disease development [33]. Patients who can take oral fluids and have no complications may be discharged home [33].

B. Pharmacological management

Currently, there are no certified medications by the Food and Drug Administration (FDA) for the treatment of dengue [3]. Clinical studies have evaluated several anti-dengue treatment drugs, including carbazochrome sodium sulfonate, which is utilized to mitigate capillary leakage, oral prednisolone, which provides anti-inflammatory effects, and statins, which are employed for their anti-DENV properties and their role in alleviating endothelial inflammation [3]. Other anti-DENV medicines, including balapiravir which is a nucleoside analog and polymerase inhibitor, and celgosivir which is a glucosidase I inhibitor, have also been explored in studies [3]. Indian research has shown that *Cocculus hirsutus* has potential anti-dengue efficacy in vitro and in vivo trials in mouse models and additional research is now underway [34]. Drugs licensed for other illnesses, including chloroquine, prednisolone, lovastatin, ivermectin, and ribavirin, are examined for possible anti-DENV properties. However, no benefits have been established thus far [34]. Corticosteroids have been used to treat uncommon dengue complications, which are believed to be immune-mediated rather than virus-related [35].

According to the clinical trials conducted, carbazochrome sodium sulfonate reduces the number of patients who are experiencing pleural effusion [3]. Significantly fewer people developed dengue hemorrhagic fever and vomiting after using chloroquine [3]. The study found that steroid medication during the early acute phase of dengue did not increase or prolong viremia. Furthermore, there were no notable side effects, save for a trend toward hyperglycemia in the high-dosage group [36]. The experiment found that celgosivir was typically safe and well-tolerated, but did not lower viral load or fever burden in dengue patients [36].

There are many challenges in developing an effective anti-dengue treatment. It is difficult to identify an inhibitor that is active against four dengue serotypes [3]. Creating antibodies that give equal protection against all serotypes is another challenge [3]. In addition, there is no realistic animal model that replicates human DENV pathogenesis, hindering the development of a safe and effective therapy [3].

The ideal dengue therapeutic should have pan-serotype activity, swift symptom relief, minimal toxicity, large-scale distribution, minimal adverse effects, and tolerability for adults, children, infants, pregnant women, and patients with co-morbidities [3].

V. VACCINES

The characteristics of sustained effectiveness, dependable safety, and cross-immunity against all serotypes are essential for the perfect dengue vaccine [37]. However, the advancement in dengue vaccine research is hampered by the antibody-dependent enhancement (ADE) impact after

infection with different strains and the absence of appropriate animal models [37]. There have been studies conducted on five different dengue vaccine formulations; DNA vaccine, live attenuated vaccine, inactivated vaccine, recombinant subunit vaccine, and viral vectored vaccine [38]. They mainly respond by increasing the body's immune response to the dengue virus (DENV) envelope protein and non-structural protein 1 (NS1) [39, 40].

A. Live attenuated vaccines

A live attenuated vaccination is made from a live pathogen that has been designed to be less virulent or avirulent, acting as an antigen component [41]. These vaccines highlight the advantages of distributing a collection of defensive antigens while offering long-term immune protection [41]. The initial licensed tetravalent dengue vaccine is CYD-TDV (Dengvaxia®), and two second-generation vaccines, TAK-003 (DENVax) and TV003/TV005, are currently in phase 3 trials [41]. There are variations among these vaccines in terms of their backbone structure, non-structural proteins, and chimeric elements [28]. These vaccinations have been shown to trigger B-cell responses, but T-cell immune responses to dengue virus nonstructural antigens are modest [42]. The approved chimeric tetravalent vaccines have demonstrated insufficient effectiveness against hetero-serotype DENVs, probably because of an absence of cellular immunity [42, 43]. The NS1 peptide, which has a conserved wing domain, is intended to minimize pathogenic cross-reactivity while remaining immunogenic. Antibodies against the modified NS1 peptide protected mice from dengue virus, avoiding hemorrhage or death [40].

B. Inactivated vaccines

Inactivated vaccines are made from inactivated microorganisms treated with materials like formaldehyde to inhibit their infectivity [44, 45]. This vaccine is deemed safe, with a low chance of pathogen reactivation following inoculation [44, 45]. Obtaining high virus concentrations by in-vitro cell culture made the dengue inactivated vaccine unsuitable. Despite obstacles, DENV-2 was successfully reproduced at elevated levels in Vero and FRhL-2 cell cultures, resulting in pure and inactivated dengue vaccines [44, 45]. Inactivated dengue vaccines require larger immunization doses or frequency to induce virus neutralizing antibodies [46, 47]. They typically include C, M, E, and NS1 proteins as antigenic elements to enhance immune response. However, composite vaccinations provide better defense than single-type vaccines [48].

C. Recombinant subunit vaccines

Recombinant subunit vaccines use prokaryotic or eukaryotic cells to produce antigenic proteins, resulting in long-lasting immune responses for protection or therapy [48, 49]. DENV's E proteins are the key candidates for subunit vaccines [48].

D. Viral vector vaccines

Less virulence vaccinia virus, adenovirus, and alphavirus are commonly used to deliver DENV antigens [38, 50]. The first two viruses are the highest frequently employed viral vectors because of extensive research and their ability to trigger a strong immune response against their antigens.

Recombinant vaccinia virus-producing dengue type 2 virus E protein has been shown to provide substantial protection against infection [51]. The 80% greatly immune-stimulating C-terminally shortened E proteins of DENV4 and DENV2 were expressed using a safer, host-specific modified vaccinia Ankara (MVA) virus vector. The study found that modified vaccinia Ankara recombinant producing 80% of the dengue virus 2 E protein induced significant anti-E antibodies in mice, but insignificant levels in rhesus monkeys [52].

E. DNA vaccines

A DNA vaccination is a plasmid that encodes specific antigens and may be administered into the body to induce immunological responses [53]. Kochel et al. (1997) reported that BALB/c mice were intradermally vaccinated with a DNA vaccine-producing precursor membrane (prM), 92% of the E protein of DENV2, and all the mice tested optimistic for anti-dengue antibodies [53]. DNA vaccines are inexpensive, stable, also suited for large-scale manufacturing, but they lack immunogenicity. Plasmid modification with enhanced promoters, alternate transmission techniques, several dosages, and simultaneous vaccination with adjuvants might be solutions to this problem [54].

Although five alternative dengue vaccine formulations have been studied, the only currently approved dengue vaccine is Dengvaxia (CYD-TDV). However, it is only recommended for people aged 9 to 45 with a documented history of past dengue infection, as it increases the risk of severe dengue in seronegative people. Recent evidence reveals that the overall efficacy of Dengvaxia declines with time, decreasing to 61.2% after 54 months, with variable efficacy rates based on the serostatus of recipients—64.2% in dengue-immune persons and 53.5% in seronegative individuals [55]. Developing candidates, such as TAK-003 (Qdenga), have shown encouraging outcomes in clinical studies. The CDC's Advisory Committee on Immunization Practices recently reviewed its performance, noting that it effectively protects seropositive recipients against all dengue types and provides some protection for seronegative recipients against DENV-1 and DENV-2 infections, though its efficacy against DENV-3 is uncertain [55]. Considering these advances, the development of a dengue vaccine still faces significant difficulties. The dengue virus's four unique serotypes impede the development of a universally effective vaccine. Issues such as antibody-dependent enhancement (ADE) and the lack of a clear immunological correlate of protection make vaccination effectiveness studies more difficult. Furthermore, the high cost of vaccines and the necessity for serological testing before immunization limit access in endemic locations, where the economic impact of dengue is most prominent [56].

While existing dengue vaccines, especially Dengvaxia, give some amount of protection, their limits need continuous research into more effective and broadly applicable vaccinations. The continuous research into novel options such as TAK-003 provides promise for better dengue preventive techniques. However, addressing the challenges of serotype diversity, safety, and cost-effectiveness will be crucial for the successful implementation of dengue vaccination programs worldwide [57].

VI. PREVENTION AND VECTOR CONTROL

Vector control mainly targets larvae and adult mosquitoes for elimination or to alleviate hazards [15]. Vector control methods encompass the removal of breeding grounds, the application of chemical insecticides and larvicides, and the utilization of microorganisms such as *Bacillus thuringiensis* [58]. Mosquitoes may reproduce in even small amounts of clear stagnant water, such as between the trunk and leaves of huge plants, making it challenging to eradicate them and such ecosystems are nearly tough to remove [58]. Dengue control has grown increasingly problematic due to urbanization, population expansion, greater international travel, and inadequate vector control programs in dengue-endemic countries [59].

For control of larvae, critical interventions include clearing breeding locations, community mobilization and education, management of the environment, and regulations [56]. Organic synthetic insecticides, insect growth regulators like methoprene and pyriproxyfen, and chitin synthesis inhibitors like diflubenzuron and triflumuron are chemical larvicides that have been shown to have necessary residual effects [42].

Household insecticides and repellents are used to repel adult mosquitoes [60]. Insecticide-impregnated nets or curtains are a key component of community engagement in controlling mosquitoes [60]. Environmental management involves enhancing water supply and storage systems, implementing measures to prevent mosquito breeding in water containers, managing solid waste, organizing community clean-up initiatives, and making necessary structural changes [61].

VII. CONCLUSION

Dengue fever remains a significant global health burden, particularly in tropical and subtropical regions where *Aedes aegypti* mosquitoes thrive. While the current management strategies focused on vector control, supportive care, and symptom monitoring, are effective in minimizing the disease's acute impact, they fall short of addressing the long-term challenge. Through this study, we highlight the critical need for creative methods, such as the development of effective vaccines and antiviral therapies that have yet to be realized.

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Utilization of Enterprise Resource Planning Systems for Material Management in Construction Projects in Sri Lanka

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Abstract— Effective material management is crucial for the successful completion of construction projects. Globally, the construction sector seeks to enhance material management processes due to inefficiencies in conventional methods, leading to excessive material use and waste. Research indicates that investing in improved systems can sustain project profitability. The latest trend in construction management is Enterprise Resource Planning (ERP), a comprehensive system for electronically collecting, managing, and securing critical data. ERP enables efficient management, reduces waste, saves costs, and enhances security by eliminating lost or misfiled documents. Integrating ERP systems with material management strategies can reduce labor-intensive procedures and waste, as ERP software includes material management capabilities. Consequently, material management has become essential in modern construction projects. This study assesses the feasibility of ERP systems for material management in Sri Lankan building projects. However, a few studies have explored ERP usage and material management in Sri Lanka's construction industry. As an initial study, this research evaluates the potential integration of ERP with material management to enhance performance by increasing profits and reducing waste in Sri Lanka's construction sector. As an Analyzing technique qualitative approach was adopted, involving semi-structured interviews with eight industry experts. The study identified key functions of material management, the role of ERP in construction, and the benefits and challenges of its implementation. Findings revealed that while ERP significantly impacts construction material management, Sri Lankan projects do not sufficiently utilize it. Therefore, steps and strategies for integrating ERP with material management are recommended to improve conventional processes, increase profits, and reduce material waste.

Keywords— *enterprise resource planning, construction industry, material management, Sri Lanka*

I. INTRODUCTION

The construction industry is advancing rapidly with the integration of new technologies (Barral & Molavi, 2016). The authors assert that it stands as one of the most promising sectors on a global scale. Moreover, the construction industry plays a vital role in bolstering the economies of developing countries (Rajakaruna, Bandara, & Silva, 2016). Consequently, the industry's development has become both swift and robust (Xueguo et al., 2019).

We are on the brink of a major technological revolution, with economies increasingly transitioning towards an AI-first world. In this context, intelligent machines are capable of processing vast amounts of data to make more efficient and effective decisions. Known collectively as Industry 4.0 technologies, these advancements combine the physical, digital, and biological worlds, poised to disrupt industries, businesses, and lifestyles in unprecedented ways.

The construction industry is invaluable, playing a crucial role in transforming various needs, desires and expectations into reality through the execution of diverse construction projects (Ibrahim et al., 2010). Horta et al. (2012) stated that the construction industry is one of the fastest-growing sectors worldwide, essential for economic growth, development, and overall national progress. However, Dainty et al. (2007) emphasized that poor technology and inadequate management are significant issues hindering the industry's advancement.

According to Okorochoa (2004), construction project success is contingent on finding the right people with the right expertise, equipment, and materials to complete the projects according to the schedule and within the budget. According to Kumar (2018), material management involves overseeing the entire process of planning, assessing project needs, sourcing, purchasing, transporting, storing, and controlling materials. This process aims to minimize waste and optimize material usage to enhance profitability by reducing material costs. Building materials typically account for approximately 60% to 70% of a project's direct costs, while labour costs comprise the remaining 30% to 40% (Haleem et al., 2019). Therefore, effective construction materials management is a vital factor in the accomplishment of successful project completion (Gulghane & Khandve, 2015). Kumar (2018) also pointed out that efficient material management can result in substantial project cost savings. Purchasing materials too early can tie up capital and lead to interest payments on excess inventory.

Ineffective material management leads to the inefficient output of the entire process. Construction material productivity is the measure of the effect (Member & Sanders, 1990). For that reason, Pande et al. (1978) justified that once products or materials are procured from manufacturers, they should be given special attention. Otherwise, as Bernold and Treseler (1991) have shown, the lack of mishandling of materials in construction projects leads to a loss in

productivity as well as resulting in a misspending employer's budget.

Building construction projects are characterized by vast scopes, high capital costs, long durations, uncertainty, high technical demands, specificity, and the complexity of the many units involved (Zidane et al., 2012). As a result, material handling and consumption in these projects also exhibit complexity and specialization (Wu & Chen, 2015). Advances in Information Technology (IT) offer the potential to improve the materials management process, reducing unnecessary losses and enhancing productivity (Kasim, 2011). Hannure and Kulkarni (2014) argued for reform in conventional material management processes, recommending the implementation of Information and Communication Technology (ICT). Kasim (2006) identified issues such as insufficient site storage spaces and small unloading areas as factors leading to inefficient material management. ICT can help reduce confusion regarding material deliveries from suppliers, which is particularly beneficial for large projects (Kasim et al., 2005).

The material management process combines and integrates multiple functions, including requirements planning, material take-off, vendor evaluation and selection, purchasing, expediting, shipping, material receiving, inventory management, material distribution, and even accounting (Bell & Stukhart, 1987). Enterprise Resource Planning (ERP) systems are now recognized as the backbone for integrating organization-wide information systems. These systems connect all operational aspects of an organization, including material management, accounting, finance, and human resources (Haleem et al., 2019).

The complexity of building construction projects demands high material usage causing the materials to be in many types as well as huge quantities. Due to the ever-increasing supplies and distributions, it is better to have a well-designed and updated construction materials management system for every organization (Qader et al., 2006). However, challenges related to managing the flow of materials are common in every organization. The problems in conventional material management procedures are recognised as manual errors, less accuracy, high time consumption, outdated character, etc (Minde, 2017; Yazdani Mehr & Omran, 2013). Swaranjali and Pathak (2017) proved that material management for construction sites using ERP helps to solve the problems listed above and improve the efficiency of the operation. It is found in previous research that the lack of technological knowledge and implementation cost are the major barriers to adopting ERP techniques in the Sri Lankan construction industry (Hewavitharana et al., 2019).

In the context of building construction projects in Sri Lanka, there has been a lack of comprehensive research on the applicability of ERP systems for construction material management. Given Sri Lanka's unique technological advancements compared to other countries, an in-depth analysis is essential to understand the impact of ERP on material management in construction projects. The limited adoption of new technological practices in the Sri Lankan construction industry further highlights the need for such a study.

This study aims to evaluate the applicability of ERP systems for material management in building projects in Sri Lanka, focusing on the following key areas.

- Conventional Material Management Processes in construction projects.
- Role of ERP systems in the Construction Industry.
- ERP techniques for Construction Material Management in Sri Lanka.

II. LITERATURE REVIEW

A. Role of construction

Kokila and Ram (2008) explained that construction materials constitute a significant portion of the cost of a construction project. Furthermore, materials are a central component of any construction project (Madhavi, Mathew, & Sasidhaan, 2013). Typically, the cost allocation for materials is nearly 50% of the total project cost, making it a critical resource to manage and control (JerutoKeitany, Wanyoike, & Richu, 2014).

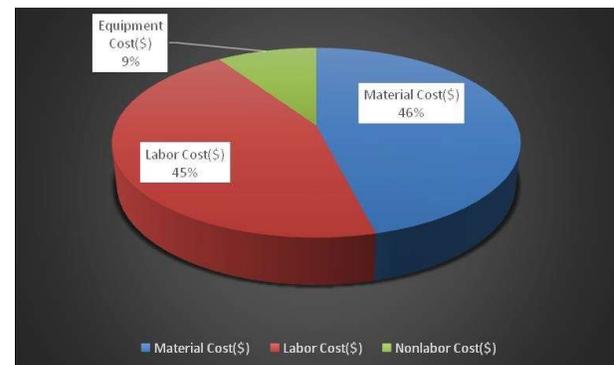


Fig. 1. Percentages of the contribution of different types of Resources to the Construction (Source: (Kumar et al., 2017))

B. Material Management in the Construction Sector

Building materials or construction materials refer to those used in engineered structures (Kokila & Ram, 2008). Material management ensures that materials are available at the right place and time, in the right quality and quantity, to reduce project costs (Daniel, 2019). Effective material management on a construction site can influence the overall cost, timeline, and quality of the project, thereby improving profitability by maximizing resource efficiency (Kasim et al., 2005). It involves planning, organizing, and controlling the flow of materials (Sundaresan & Gopalakrishnan, 2006). This is vital for boosting productivity in construction projects. Proper material management can significantly affect a company's profits and help avoid construction delays (Kasim, 2011).

C. Need for Material Management Return

Material management has become essential for the successful completion of projects over the years (Karoriya & Pandey, 2018). As the construction industry has evolved, effective material management practices have been shown to lower overall project costs and enhance efficiency (Bernold & Treseler, 1991). Abdul-Rahman and Alidrisyi (1994) highlight the critical role of a well-structured material management process. Furthermore, Donyavi and Flanagan

(2015) found that material management ensures timely specification of the correct quality and quantity of materials and equipment. promptly.

Material-related issues, such as delays, damages, shortages, storage problems, and improper handling, can severely hinder project performance (Thomas et al., 2005). Therefore, a method to analyze and evaluate the Material Management Process is essential, as improper management can lead to significant cost overruns (Kokila & Ram, 2008). As Ademorok (1999) further stated, the overall performance of any construction project can become highly uncertain with poor materials management.

D. Objectives of Material Management

Researchers who are interested in this area have shown that in their findings, several objectives can be achieved when performing effective material management. Further Arijeloye and Akinradewo (2016) stated that the estimated objectives can provide solutions for most of the problems in the construction industry.

- Effective material planning aims to prevent project disruptions by ensuring that the appropriate materials are available in the correct quantity, at the right location, and at the right time.
- Establish wise purchasing plans to keep in touch with the inventory.
- Facilitating and guiding the procurement of materials in a competitive environment to maximize profits and benefits for all stakeholders.
- Maintain a smooth storage and inventory control procedure to avoid situations like deterioration, obsolescence, and theft.
- Optimizing the ideal stock levels and controlling the supply and distribution to sustain the low level of waste generation.
- Quality assurance of relationships between internal and external parties.
- Obtain the best value for purchased materials.

E. Existing Situation of Material Management

Construction companies are constantly faced with the challenge of completing projects according to schedules, within the budget, and positively with a reasonable profit while satisfying employers (Das, 2018). Resource management is the best way to adhere to meet the optimum profits from a particular project (Muthuramalingam, 2008). As per previous studies, since the 1970s various managerial approaches have been established for the management and control of materials, plants, and waste generation (Tam et al., 2014). However, the expected benefits are not at a pleasing level in the construction sector (Chen et al., 2002). Controversially, even in developed countries, there are still many issues related to the material management of building construction companies, often involved in ineffective handling of construction resources, including equipment (Silver, 1989).

F. Material Management Process

Kulkarni et al. (2017) explored material management processes concerning the size of construction companies. They found that in small and medium-sized firms, the material management process often aligns closely with general practices, as these companies typically prioritize material management less. The authors further noted that medium and small construction companies often do not solicit multiple quotations; instead, they select material suppliers based on market surveys. Additionally, these companies sometimes neglect to issue proper purchase orders and fail to maintain adequate record-keeping procedures. Consequently, the material management process varies based on different factors, including the origin of the material requirement and the size of the construction company.

According to the authors' explanations, the process begins with the need for materials, which can be illustrated as follows.

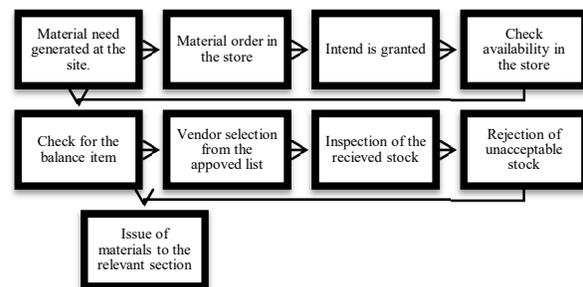


Fig. 2. Material Management Process

G. Functions of the Material Management Process

Material management involves key functions including planning, procurement, logistics, supervision, control, and coordination of activities related to materials (Gulghane & Khandve, 2015). Kulkarni et al. (2017) further identifies essential processes within material management as planning, purchasing, receiving, inspection, stacking and storage, material issuance, and inventory control. To meet these objectives and support the company's overall goals, it is crucial to implement these categorized material management activities effectively, as detailed below.

H. Implementation of ERP in the Sri Lankan Context

The study of ERP system implementation in Sri Lanka is a relatively new area, with limited prior research. ERP solutions are increasingly gaining popularity among businesses globally and locally. In Sri Lanka, the adoption of ERP systems is also becoming more widespread. Organizations in Sri Lanka often make substantial investments in ERP systems to achieve corporate excellence (Jayawickrama & Yapa, 2013). Recently, the country has seen a significant increase in ERP adoption rates, prompting a majority of large-scale and mid-scale organizations to transition to ERP for improved organizational management (Kiriwandeniya et al., 2013).

Apart from ERP suppliers such as Systems Application and Product in Data Processing (SAP), Microsoft, Oracle, and SAGE, Sri Lanka lacks a wide variety of additional ERP

software options (Haleem et al., 2019). In the construction industry, the adoption of ERP systems lags behind that of other industrial sectors. This lag can be attributed to the industry's diversity, encompassing a wide range of specializations, varied company sizes, and significant complexities in project interlinkages (Hewavitharana et al., 2019).

However, according to Rajapakse and Seddon (2005), ERP systems may be deemed unsuitable for many organizations in Sri Lanka due to high costs, cultural factors, integration challenges, and knowledge gaps. Gunasekara et al. (2018) outlined significant reasons influencing the implementation of ERP in the Sri Lankan construction context, including:

- Enhanced competition
- Increased demand for real-time information
- Support for planning and budgeting activities
- Integration of applications
- Generation of information for decision-making
- Production of more user-friendly reports
- Improved customer interaction

I. Material Management, ERP, and Information Technology Synchronization

Paper-based reports are frequently used to document and share information about materials in a supply chain, but they often face problems such as errors and inefficiencies. Embracing emerging technologies is often preferable to mitigate human error and integrate more effectively with project management systems, thereby simplifying and expediting the tracking and management of materials (Kasim, 2011).

Many construction firms have acknowledged the need to improve material management through the use of information technology (Ma et al., 2013). As mentioned earlier, material costs can account for up to 60% of total project expenses. To better manage resources, including materials, some companies have implemented advanced information systems such as ERP systems (China Association of Construction Enterprise Management, 2009). According to the authors, the benefits of ERP systems in material management include:

- Facilitating precise tracking of material consumption
- Providing real-time visibility of material stocks and their locations
- Enhancing accuracy
- Streamlining planning and procurement through comprehensive data access
- Minimizing material waste
- Simplifying workflow
- Reducing manual errors
- Saving time in material management

III. RESEARCH METHODOLOGY

The study adopted a qualitative approach, which is ideal for capturing the thoughts, viewpoints, and experiences of respondents, particularly their expertise and behavior (Bricki and Green, 2007). This approach is suitable for deeply exploring circumstances or behaviors (Willis et al., 2007). However, the ERP system has not gained significant traction in the Sri Lankan construction industry, limiting its popularity as a construction management method. Consequently, the available sample size for this study is relatively small. Willis et al. (2007) suggests that when researchers aim to deeply explore circumstances or behaviours, the qualitative technique is preferable. Hence, this research adopts a qualitative approach.

In the Sri Lankan context, while many professionals possess substantial knowledge of material management, only a small number of construction firms have implemented ERP systems. Consequently, many professionals in the construction sector lack practical experience with ERP systems. Therefore, it is essential to interview ERP experts with extensive ERP knowledge to thoroughly understand this research.

TABLE 1: PROFILES OF INTERVIEWEES IN CASE STUDIES

Interviewee	Experience
Project Manager (R1)	15
Project Manager (R2)	15
Senior Quantity Surveyor (R3)	16
Quantity Surveyor (R4)	10
Civil Engineer (R5)	6
Civil Engineer (R6)	15
Senior Quantity Surveyor (R7)	10
Asst ERP Manager (R8)	10

IV. RESEARCH FINDINGS

A. Current Status of ERP Adoption in the Sri Lankan Construction Industry

Each expert was questioned about the current level of ERP adoption in the Sri Lankan construction industry. It appears that ERP adoption remains limited among construction companies in Sri Lanka, with implementation generally at a minimal level across the industry. Although ERP systems are being introduced, many companies fail to maximize their benefits. They currently only reap a fraction of what ERP systems can offer, primarily due to a reluctance to depart from traditional practices. Achieving targeted ERP goals may take up to a decade post-implementation. Management-level resistance to embracing new technologies, driven by attitudes and a desire to maintain control, remains a significant barrier within the Sri Lankan construction sector.

While ERP systems are well-established internationally, their adoption in Sri Lanka remains sparse, with only a few organizations incorporating ERP into their operations. Among them, all C1 contractors have successfully integrated ERP, though primarily for document and finance management. However, ERP's potential extends beyond these functions to include tendering, cost control, inventory management, and

other areas where ERP systems can assist. According to one respondent, current ERP adoption levels in Sri Lanka's construction industry are below satisfactory, estimated at less than half of its potential usage. For ERP to fully benefit a company, it must be implemented comprehensively across all departments; otherwise, it risks operating as an isolated process rather than an integrated system.

It is evident from respondents' feedback that ERP adoption in Sri Lanka's construction industry is still in its early stages and is gradually gaining traction.

B. Exposure to Material Management Practices

In this section, respondents were asked about their understanding of the material management practices typically expected on construction sites in Sri Lanka. The interview guidelines focused solely on gathering insights specific to the Sri Lankan construction sector. Each expert interviewee responded based on personal experiences in Sri Lanka's building projects.

In essence, the goal of material management is to ensure that the appropriate materials are available at the right location, with the correct quality and quantity. This support is crucial for projects, maintaining construction within estimated cost, time, and quality parameters, which are primary tasks in construction. Effective material management anticipates and provides materials on-site as needed, thereby minimizing disruptions due to shortages in the construction process flow. The findings from the interviews are summarized as follows:

- Materials costs constitute a significant portion of building construction project costs.
- Construction projects contribute significantly to waste generation.
- Profitability from the contractor's perspective is a key consideration.
- Materials are finite resources.
- Projects operate within constraints of time and budget.
- Material management plays a pivotal role in project management.
- Most projects do not achieve expected timelines and profitability.
- The goal is to maintain projects within estimated cost, quality, and schedule.

With the growing involvement in building projects in Sri Lanka, effective material management has become crucial to keeping projects on schedule and within budget, while maintaining quality. Despite this, many construction projects in Sri Lanka often face lower-than-expected profits and extended lead times.

All interviewees concurred that the main goal of implementing ERP systems for material management on construction sites is to minimize costs and reduce waste. They highlighted that effective material management is a key objective when adopting ERP, given its substantial effect on controlling waste in construction projects. During interviews, respondents were asked about the main steps and responsible personnel involved in their material management processes.

The procedures followed at their sites closely align with the literature findings. They often select suppliers they have previously worked with, especially for less costly items. Organizations have established cost thresholds that permit direct purchasing. Additionally, interviewees noted deviations from traditional practices, such as skipping Purchasing Orders (PO) preparation and PO issuance steps, when materials are purchased for the flow of cash.

V. CONCLUSION

Material management and Enterprise Resource Planning (ERP) are distinct yet essential philosophies currently being adopted in the construction industry. Material management is a set of practices and operational strategies designed to minimize waste and enhance the value of projects and products. It encompasses seven core functions: planning, procurement, logistics, inspection, handling, storage, and inventory and waste control, as identified by various researchers. In contrast, ERP systems integrate all business functions into a unified process, aiming to improve efficiency and help organizations remain competitive. This study focuses on developing a synergy between material management and ERP systems to maximize profitability in the Sri Lankan construction industry.

As Conclusion, it reviews the efforts made to achieve each research objective and highlights the key discoveries that support the study's aim. Additionally, the chapter outlines the contributions of this research to advancing knowledge and offers recommendations for further improvements in material management and ERP practices.

Integrating an ERP system with material management can greatly improve project performance by systematically eliminating non-value-adding activities in current practices. Industry professionals are advised to leverage ERP technology and fully utilize their existing ERP system features to address material flow issues throughout the construction process. Based on an analysis of the key outcomes, benefits, and challenges of implementing this integrated approach, several recommendations have been made to maximize profitability in the construction industry.

Firstly, it is essential to encourage management to embrace these new concepts by emphasizing their competitive benefits in today's technologically advanced landscape. Implementing an ERP system can enhance project productivity and efficiency while minimizing waste. Moreover, hosting knowledge-sharing events and training programs for staff will help them become more proficient with the system, thereby reducing potential conflicts between users and departments.

Additionally, companies should establish strategies to effectively implement ERP systems, overcoming associated challenges to boost profitability. Ongoing research into advancements in ERP system functionalities is crucial for enhancing organizational success. By combining the distinctive features of ERP systems with material management practices, project performance can be improved, delivering greater value to clients. This integrated approach is especially recommended for the Sri Lankan construction industry.

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Infant Brain MRI Segmentation and Brain Tissue Classification using WKNN and Transform Multi Kernel SVM

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Abstract— Soft tissue segmentation of newborn brain MRI images is a very difficult task as compared with adults. Conversely, it is very interesting due to the low tissue contrast ratio due to intrinsic partial myelination and maturation. Specifically, at 6 months of age, the pixel intensities in the white matter (WM) and grey matter (GM) are equivalent, consequently in the first postnatal year noticeable to the least image contrast. Due to the complexity of the brain's anatomy, segmentation is an essential preliminary phase for handling a range of issues, such as research on the periodic activity recognition of morphological features and three-dimensional surgery planning visualization. We proposed infant's tissue segmentation method employs ridgelet transform, framelet transform, and WKNN and MKSVM-based classification to segment white matter, grey matter, and cerebrospinal fluid. In this work, grey level co-occurrence matrix (GLCM) and entropy feature-based exploration of ridgelet and framelet coefficients are carried out. The extracted textural features and intensity-based features are employed to train Cerebrospinal Fluid. Suggested technique counterpart the manual ground-truth with abundant greater Dice Ratios than another single-modality.

Keywords— MRI, infants, segmentation, tissue, classifier,

I. INTRODUCTION

Magnetic resonance imaging (MRI) brain segmentation is increasingly being utilized to analyze infants or newborn brain growth and development. In a medical image segmentation framework, feature extraction is important step [1]. The manual segmentation process is a different way of segmenting an image. This approach is not only inconvenient, time-consuming, and costly, but it also generates incorrect outcomes. Furthermore, there is inter- and intra-observer heterogeneity in manual labelling. The limitations of manual techniques make labelling large groups of individuals, which is commonly necessary for neuro imaging investigations, difficult. As a result, an efficient approach for hollowing the brain into numerous areas is required [2]. Infant MRI brain tissue is commonly segmented into White Matter, Grey Matter and Cerebrospinal Fluid. Compared to adult brain tissue segmentation, newborn brain MR images tissue segmentation is significantly more complicated. Due to the newborn brain's small volume, MR images of the neonatal brain usually have a low signal-to-noise ratio and can vary widely in terms of the relationship between brain shape and arrival due to the rapid development of the brain. Furthermore, the partial volume

effect caused by overturned signal intensity in white matter (WM) makes tissue classification more difficult [1]. Identical intensities to those of WM in the growing brain are caused by the partial volume of grey matter (GM) and cerebrospinal fluid (CSF) in the boundaries of either the cortical grey matter [2]. Either at CGM-CSF interface, this partial volume (PV) impact causes voxels to be mislabelled as WM. The methods for generating regions are based mostly on the premise that nearby pixels within an area have comparable values. One of most popular technique is compared a pixel to its neighbours. The pixel can be assigned to one or more of its neighbours in the cluster if a closeness criteria are satisfied.

II. RELATED WORK

Mohamed A. Berbar [3] presented various feature techniques, as well as seven statistical and textural characteristics derived from the Grey level Co-occurrence Matrix. The presented approaches are related to discrete wavelet, ridgelet, curvelet, and wavelet transform multi-resolution feature extraction methods.

Shadi et al. [4] proposed an image segmentation system that can identify regions of interest automatically (ROI). Medical images were collected from a variety of medical scanners, including PET, CT, and MRI. The proposed segmentation uses multiresolution analysis (MRA) with wavelet, ridgelet, and curvelet transformations. Subramaniam et al. [5] have been suggested for enhance images, framelet transform and singular value decomposition are utilized. The picture is decomposed into one low-frequency sub - bands and 8 high-frequency sub bands using the Framelet transform. To obtain the high-resolution image, the inverse framelet transform is used to merge all of the sub bands. The framelet transform is used with the SVD to improve the contrast. Satellite images were used to test the proposed methodology. Peak Signal-to-Noise Ratio, Structural Similarity Index Measure, Universal Quality Index, Entropy, and Quality Score are some of the quantitative metrics utilized.

Sulochana et al. [6] presented a method created on Framelet Transform united with Grey level co-occurrence matrix (GLCM). To extract a feature, a Framelet transform and Grey level co-occurrence matrix combination has been used. Yan-Ran Li, et al. [7] proposed features optimization model framelet features extracted by the model and SVM with a linear kernel is accepted as the feature and classifier.

Thamaraichelvi et al. [8] proposed a method for the Classification of Brain Magnetic Resonance Images (MRI) and Liver Computed Tomography (CT) images. Grey Level Co-occurrence Matrix technique has been used to extract features, and Radial Basis Function - Support Vector Machine classifiers are used for Magnetic Resonance Images and Liver Computed Tomography images for classification.

Na Li [9] presented an ensemble Support Vector Machine structure and a Grey-level co-occurrence matrix (GLCM) texture technique. The SVM-recursive feature elimination approach was used to rank the 112 GLCM features retrieved for each voxel. To distinguish the abnormal volume of tissue from normal brain tissues, researchers used just the top 60 Greyscale characteristics and built an ensemble SVM classifier. Mukambika et al. [10] provide a comparison of two techniques for tumour recognition in MRI images. One is dependent on the Level set technique, which segments the brain tumour from MRI brain images using non-parametric deformed models with active contour. Kanchana et al. [11] presented a histogram bin-based approach, an algorithm for detecting ischemic stroke lesions was reported. With the aid of histogram bins, the visible ischemic stroke lesion zone and the normal region of the same computed tomography picture are segmented and characteristics retrieved. Both areas' first- and second-order statistical characteristics are examined. The variances in characteristics are used to classify the lesion and non-lesion regions.

Venkatesh et al. [12] proposed an algorithm for MRI brain tumour that is segmented using k-means clustering algorithm and various features of the segmented tumour was analyzed using Grey level Co-Occurrence matrix. These features were utilized for k-Nearest Neighbour (k-NN) classifier the accuracy of the obtained was around 85%, respectively, for tumours and non-tumours. Atanu K. Samanta et al [13] reported techniques for segmenting brain tumours from other parts of the brain, such as K-means clustering. Grey level co-occurrence Matrices are used to extract features from this segmented brain tumour region, and the support vector machine was used to categorize input MRI pictures into normal and pathological categories. Manorama Sharma et al. [14] Introduces a K-means and artificial neural network-based efficient method. (Grey Level co-occurrence matrix) was used to extract features. For brain tumour identification, a Fuzzy Inference System is built employing extracted features, thresholding, morphological operators, and Watershed segmentation.

Li Xu et al. [15] Introduce a feature detection and classification methodology based on an optimised deep neural network and wavelet and Grey-level co-occurrence matrix. An optimization technique of the fly search method is used to optimise the classifier network. FLAIR, T1, and T2 datasets are used to test the simulation findings. According to Olfa Ghribi et al. [16], the proposed segmentation methodology is built on volumetric characteristics derived from the Grey-level co-occurrence matrix and Grey-level run length matrix. New voxel-wise methods would be used to retrieve volume characteristics while maintaining connection, spatial, and shape information. In order to retain the genetic algorithm and the support vector machine tool, an optimised feature selection approach was developed. Only the most important

characteristics might be used to distinguish between the major brain tissues and MS lesions in both white and grey matter.

III. DATASET AND ETHICAL CONSIDERATIONS

This study utilized the iSeg 2017 Newborn Brain MRI dataset, which contains MRI scans of infants, specifically T1- and T2-weighted images. The dataset was made available as part of the iSeg 2017 challenge [17] and is accessible for research purposes.

Ethical Approval: The iSeg 2017 dataset is anonymized and publicly available, so no additional ethical approval was necessary for our study. It is assumed that the original data collection adhered to appropriate ethical standards, with informed consent obtained from the participants' guardians.

Inclusion Criteria: The dataset comprises MRI scans of healthy newborns, with participants selected based on the availability of clear, high-quality images.

Exclusion Criteria: Infants with incomplete, low-quality scans or known neurological issues were excluded from the dataset.

Number of Participants: The iSeg 2017 dataset includes MRI data from 10 newborn subjects with an average age of six months.

IV. METHODOLOGY

The architecture of the proposed brain MRI segmentation and classification scheme is represented in Fig. 1.

A. Pre-processing stage

Initially, applied pre-processing step to enhance image quality. We use the Shift-Invariant Wavelet transform to show how cycle-spinning can improve quality significantly, with much of the improvement occurring through averaging shifts of only $n=0$ and $n=1$ on each axis [14].

B. GLCM Method:

The GLCM indicates how often two Grey-level pixels a, b occur at a specific spatial distance d from each other in an image. The component (a, b) in the GLCM matrix records the number of occurrences of a couple of grey levels (a, b) that are divided by d in the sub-image. It converts picture values into g levels, which are integers between 1 and g . The size of the Grey-level co-occurrence matrix is determined by the g numbers of Grey-levels, which is $g \times g$. GLCM is used [3] with changing direction θ and distance. So we will have some d GLCMs, each $g \times g$ in size for each certain θ [3-5].

C. Ridgelet Transform:

Donoho proposed the constant ridgelet transform in 1998 [2] that might be characterized as a 1D wavelet function directed at constant lines and radial directions. One-dimensional (1-D) wavelets are used to produce 2-D wavelets. It still has limitations in terms of directional selectivity. Candès and Donoho introduced a novel transform dubbed the Ridgelet transform in 1999 [5]. After measured in altered directions, the Ridgelet transform provides characteristics with varying values. Straight-line singularities respond well to the Ridgelet transform. Investigate curve singularities whenever employing ridgelet, it's a good indication to reflect partitioning the picture and then applying the Ridgelet transform to the sub-images that result [3].

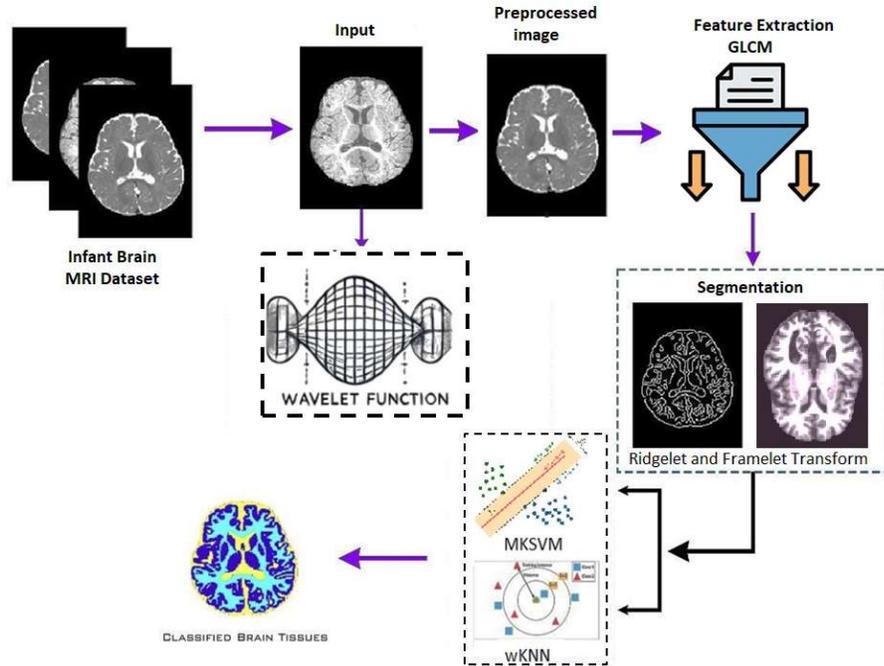


Fig. 1. Architecture of proposed brain MRI segmentation and classification scheme

D. Framelet Transform:

The Framelet Transform [5] (FRT) is like wavelets, although it differs in a few ways. Framelets have two or extra high-frequency filter banks, resulting in additional decomposition subbands. This can improve image processing's ability to specify time and frequency. There is duplication among the framelet subbands, which implies that a variation in one band's coefficients can also be compensated by the coefficients of many other subbands. This means that changes to one coefficient in the reconstruction stage can be counterbalanced by changes to its associated coefficient, resulting in reduced noise in the original image. The uniformity and duplication of a compact frame filter bank enable for approximation shift invariance [5-6].

V. SEGMENTATION

Grey level co-occurrence matrix and entropy feature-based analysis of ridgelet and framelet coefficients carried out from infant's images to segment white matter, grey matter, and Cerebrospinal Fluid. Weighted k-Nearest Neighbour (wKNN) and MKSVM classifiers are used to improve segmentation performance [18-19].

A. Weighted k-Nearest Neighbour (wKNN):

KNN is a classifier that is non-parametric, instance-based, and lazy. Due to a lack of learning stage, KNN is lazy. Instead, K-NN retains everything available training data and uses a distance metric to classify the current test instance. KNN predicts the test instance's class using a qualified majority voting mechanism. It's quite vulnerable to imbalanced data. The closest neighbors receive greater weights in Weighted K-NN than just the distant ones [18]. wKNN accurately

segmented white matter and Grey matter tissue of infants' brain MRI but misclassified Cerebrospinal Fluid (CSF).

B. Multi Kernel-Class SVM Classifier:

Kernel mapping is used by the SVM model to achieve complicated separation in high. A kernel is a comparable function that is given into a machine learning algorithm that uses feature vectors to learn. Linear kernel, polynomial kernel, and Gaussian kernel (or RBF kernel) are the three kernel functions accessible in the literature [19]. One of the most important tasks in achieving greater abstraction capacity in pattern categorization is selecting the proper kernel. The MKSVM classifier is trained using these linear plus Radial Basis Function (RBF) kernels that are the most significant kernels for MRI soft tissue segmentation in infants.

VI. SIMULATION RESULT AND DISCUSSION

The presented methodology has been used to segment soft tissue in infants using MRI. To begin, we used the Shift-Invariant Wavelet transform to denoise the image. After that, ridgelet and framelet coefficients are analysed using textural and intensity-based features such as the Grey level co-occurrence matrix and entropy feature-based analysis.

INPUT	PERFORMANCE METRICS	
	ACCURACY	DICE COEFFICIENT
IMAGE 1	91.89	90.22
IMAGE 2	92.12	91.00
IMAGE 3	92.66	91.22
IMAGE 4	93.66	92.00
IMAGE 5	94.96	92.55

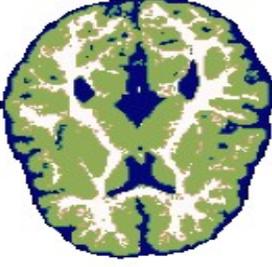
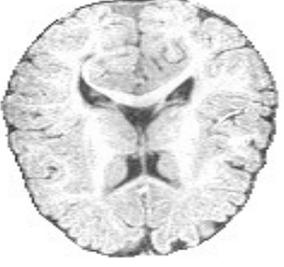
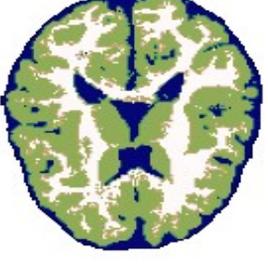
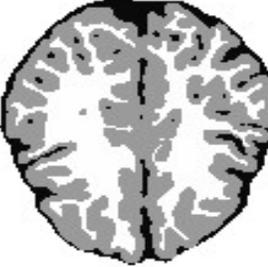
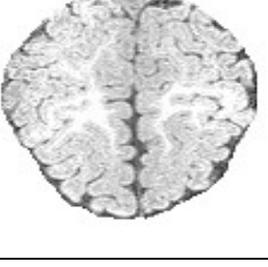
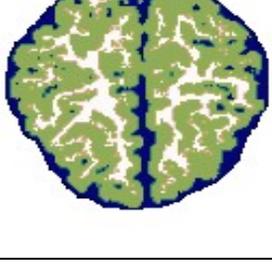
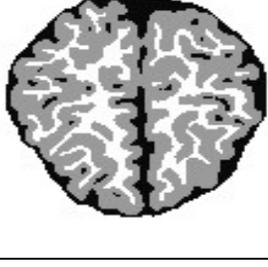
Input image	Segmented image	Annotated image
		
		
		
		
		

Fig. 2. Segmentation Simulation Result

The wKNN and MKSVM classifiers were used to segment white matter, grey matter, and Cerebrospinal Fluid. Figure I shows the results of the segmentation simulation as well as the performance matrices.

Higher accuracy and Dice coefficient values imply greater performance, as seen in Table 1 and Table 2.

PERFORMANCE METRICS

METHOD	ACCURACY	DICE COEFFICIENT
3D-CYCLEGAN-SEG [20]	83.01	90.73
SEMI-SUPERVISED TRANSFER LEARNING [21]	86.28	90.08
MULTI CLASSIFIER APPROACH [22]	89.08	91.50
PROPOSED	93.04	92.15

VII. CONCLUSION

The system designed for segmenting infant MRI soft tissues into categories like white matter, grey matter, and cerebrospinal fluid (CSF) follows a structured four-stage process. The first stage involves pre-processing, where the Shift-Invariant Wavelet Transform is applied to enhance and remove noise from the MRI images, ensuring they are ready for further analysis. In the second stage, feature extraction is performed using the Gray-Level Co-occurrence Matrix (GLCM) along with ridgelet and framelet coefficients, which help in identifying distinct tissue characteristics. The third stage handles segmentation, in which the tissues are classified using a combination of the weighted k-Nearest Neighbour (wKNN) algorithm and the Multiple Kernel Support Vector Machine (MKSVM) classifier to accurately differentiate between tissue types. The final stage, evaluation, assesses the system's effectiveness, achieving an accuracy of 93% and a Dice coefficient of 91%. This comprehensive approach highlights the potential of combining ridgelet and framelet coefficients with wKNN and MKSVM classifiers for precise segmentation of infant brain MRI tissues.

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Impact of Pre-Existing Conditions on Dengue Severity

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Abstract— Dengue fever, a viral disease carried by *Aedes* mosquitoes, presents substantial health hazards worldwide, especially in areas with a high incidence of comorbidity. This literature review seeks to examine the influence of pre-existing conditions, specifically diabetes, obesity, hypertension, and kidney disease, on the severity of dengue. Through an analysis of the current body of data, the objective is to enhance the comprehension of how these underlying health issues can impact the progression and results of dengue infection. It indicates that the coexistence of these concurrent conditions negatively affects the course of dengue fever. Consequently, resulting in serious conditions such as shock, bleeding, and plasma leakage. The research has shown that there is a connection between diabetes and obesity, as well as chronic inflammation and dysregulation of the immune system, which leads to a higher likelihood of experiencing catastrophic results from dengue fever. The combination of hypertension and kidney failure adds more hurdles to the clinical management and prediction of outcomes in patients with dengue, increasing the complexity of the task. Gaining insight into the connections among different variables is essential for enhancing patient outcomes and managing those conditions efficiently.

Keywords—comorbidities, dengue severity, pre-existing conditions

I. INTRODUCTION

Dengue is a disease that is caused by a virus and is primarily transmitted by the *Aedes* mosquito. It ranks as the most common viral infection transmitted by arthropods, impacting roughly 390 million people around the world each year [1]. Symptoms can range from none to a mild fever, or even to severe cases that can be life-threatening. This fever occurs due to infection with the Dengue virus (DENV). DENV belongs to the Flavivirus genus and the Flaviviridae family. There are four distinct variations of DENV, namely DENV-1, DENV-2, DENV-3, and DENV-4. All these types spread through *Aedes aegypti* and *Aedes albopictus* mosquitoes. Symptoms can vary depending on the serotype involved [2]. The main site for neutralizing the virus is found on the surface of domain 3, which differs among serotypes [1]. While this protein remains similar across several dengue serotypes, monoclonal antibodies can still distinguish them. However, cross-reactivity may occur among different genotypes within those serotypes [3], [4]. The genetic material of DENV comprises a singular RNA strand that encodes for three structural proteins and seven nonstructural proteins [5].

Based on the 1997 categorization standards of the World Health Organization (WHO), Dengue cases are categorized into three groups: undifferentiated fever, dengue fever, and

four phases of dengue hemorrhagic fever (DHF), with stages 3 and 4 indicating dengue shock syndrome (DSS). Subsequently, a revised version of the dengue classification was implemented to mitigate the risk of misinterpreting the severity of dengue. This updated classification system effectively doubled the sensitivity in detecting Severe dengue (SD), enabling medical professionals to manage dengue cases and minimize errors more accurately [6].

While dengue fever is often a condition that resolves on its own, certain patients may experience severe complications that pose a risk to their lives. The release of plasma, bleeding, and shock marks these complications [7]. The manifestations and indications of severe illness typically manifest towards the end of the disease progression, during the recovery phase when the patient's fever has diminished, rendering it challenging to anticipate. Although the majority of symptomatic infections may not progress to serious illness, areas with high dengue transmission can see seasonal outbreaks that can quickly overwhelm healthcare services, particularly in tertiary care settings [8]. The current focus is on discovering risk indicators and biomarkers that can reliably predict the severity of the illness during the early febrile episode. This will allow for the timely deployment of interventions and treatment measures for persons at the highest risk.

Furthermore, adult dengue is often linked to severe organ complications, which typically appear later in the course of the disease but progress faster, leaving little time for effective clinical intervention [8], [9]. There is growing evidence that pre-existing comorbidities, such as diabetes, obesity, hypertension, and kidney diseases, are a significant public health problem in countries where dengue is common. So, this literature review will focus on how pre-existing conditions affect the severity of dengue, since this understanding is crucial in the realm of public health, particularly as global incidences of dengue continue to rise. As aforementioned, pre-existing non-communicable conditions such as diabetes, obesity, kidney disease, and hypertension have been identified as significant factors influencing the progression and outcomes of dengue infections and their severity. These characteristics not only make the clinical care of dengue more difficult, but also present significant obstacles in predicting patient outcomes and facilitating recovery. Therefore, by exploring the interplay between these non-communicable conditions and dengue severity, healthcare professionals can better tailor treatment strategies and enhance patient care protocols, thereby mitigating the adverse effects of dengue outbreaks on vulnerable populations.

II. DIABETES AND DENGUE SEVERITY

Diabetes is a significant public health issue characterized by a complex clinical condition. Type 2 diabetes mellitus (T2DM) makes up around 95% of all cases worldwide, and it is particularly problematic in low and middle-income countries where the prevalence of diabetes is expected to increase significantly [10]. Rather than the direct impact on individual health, diabetes has implications for managing other infectious diseases. One area of interest is the relationship between diabetes and the severity of dengue virus infection. This difficulty is compounded by indications that pre-existing diabetes may worsen the clinical course of dengue infection.

Diabetes is acknowledged as a condition affecting the endothelium, caused by high blood sugar levels. If left unmanaged, it leads to extensive damage to blood vessels and is associated with consequences such as diabetic ketoacidosis, diabetic coma, and cardiovascular disease [11]. While the exact pathogenic mechanism remains unclear, some observational studies have identified a connection between diabetes and severe dengue disease (SDD). These studies suggest that molecules like TNF- α , IL-6, IFN- γ , IL-2, NO, T-helper type 1 cells, endothelial or epithelial cells (inflammatory molecules), and cytoskeletal integrity contribute to the chronic inflammatory state seen in diabetic patients and play a role in the development of SDD, particularly through endothelial damage that leads to fluid permeability [12], [13]. Finally, hyperglycemia may promote endothelial activation and vascular injury [14], [15]. Diabetes patients therefore appear to be at a higher risk of acquiring severe dengue, which can lead to life-threatening consequences including conditions like organ damage. This association is therefore especially alarming given the concurrent growth in the diabetes epidemic, particularly in developing countries where dengue is endemic [16]. An analysis of 644 individuals diagnosed with dengue revealed a correlation between diabetes and greater severity of thrombocytopenia during dengue infection. Diabetic patients were found to have a greater likelihood of experiencing more severe forms of dengue illness, specifically DHF/DSS, compared to those without diabetes. Moreover, people who have diabetes exhibited a higher percentage of DHF/DSS and significantly reduced platelet counts, suggesting that diabetes may make them more susceptible to a more serious dengue infection [17]. This increase in mortality and morbidity was mostly caused by reducing the host's defense systems in diabetes patients, which impaired phagocytosis, intracellular killing, and polymorphonuclear leukocyte chemotaxis [18]. Though diabetes mellitus has been linked to immunological and endothelial dysfunction, its exact mechanism leading to DHF remains unclear [15]. But some potential pathways have been proposed. As mentioned earlier, Diabetes induces alterations in the host's defense system, which may compromise the body's capability to produce an efficient antiviral response, resulting in increased viral loads and tissue damage. Furthermore, the metabolic imbalance caused by diabetes, increases the inflammatory cascades and vascular permeability that underlie severe dengue [10]. In addition, microvascular consequences of diabetes, such as neuropathy, and retinopathy, may also contribute to the increased risk of dengue [19].

Addressing the relationship between diabetes and dengue severity will necessitate a diversified strategy, where improving surveillance mechanisms to collect data on the dual burden of these illnesses being an important first step. Simultaneously, enhancing access to appropriate diabetic care and strengthening health systems to control infectious disease epidemics will be also a critical point in reducing the above-mentioned effects.

III. OBESITY AND DENGUE SEVERITY

Obesity leads to harmful physiological changes that impact the respiratory, circulatory, and immunological systems. In numerous infections, it also exacerbates the prognosis [20], [21]. Obesity can exacerbate dengue through four main mechanisms. One key mechanism involves that, obesity can lead to a decrease in adenosine monophosphate activated protein kinase (AMPK) function, resulting in the accumulation of lipids in the endoplasmic reticulum (ER), which in turn increases the proliferation of DENV [22]. AMPK is essential for controlling lipid metabolism, and when it is reduced, cholesterol builds up in the ER, which promotes viral replication [23], [24]. Another mechanism includes the extended secretion of pro-inflammatory adipokines. Usually, obese individuals experience heightened levels of adipokines, such as leptin and resistin, resulting in persistent inflammation and impaired functioning of the endothelium. Chronic inflammation can exacerbate the intensity of DENV by promoting plasma leakage and causing damage to the endothelial cells [15], [25]. Obesity leads to oxidative stress and harm to the glycocalyx layer, which disrupts the functioning of the endothelium, as explained in the third mechanism. This disruption causes an increase in capillary permeability and the leakage of plasma. During the febrile stage of infection, oxidative stress markers, such as HETEs and F2-IsoPs, increase following tissue damage and harm to endothelial cells [25], [26]. The fourth one is hampering the immune response of B-cells, T-cells, and NK cells against viral infections and other cells due to obesity. Obese individuals have a reduced number of anti-inflammatory B-cells, an increased number of pro-inflammatory B-cells, and altered activities of T- and NK cells. This imbalance leads to an increased pro-inflammatory reaction and decreased virus elimination, enabling DENV to multiply more effectively [25], [27].

With these changes in the immune system, DENV can multiply more easily taking advantage of antibody-dependent enhancement (ADE). Furthermore, in comparison to a non-obese patient, an obese patient's immune system could ultimately result in more significant harm to tissues. Thus, obesity worsens the intensity of DENV infections by hindering immunological responses, encouraging persistent inflammation, and leading to malfunction of the endothelial cells. These alterations enhance the viral replication process and elevate the likelihood of severe disease consequences.

IV. KIDNEY DISEASE AND DENGUE SEVERITY

As per the previous studies, severe dengue infections impact various organ systems, including the neurological, renal, respiratory, cardiac, gastrointestinal, and hepatic [5]. Dengue associated acute kidney injury (AKI) is defined as the abnormal reduction in the glomerular filtration rate in which

the incidence is rapidly increasing among the dengue infected patients [28]. Further, it is an atypical complication of severe dengue, which is linked to hemolysis, rhabdomyolysis, or hypotension. Nonetheless, dengue episodes resulting in severe kidney damage lacking these attributes have also been documented. In some situations, the damage is attributed to having most likely been caused directly by the dengue virus (DENV) [29]. However, kidney involvement is not considered as a critical manifestation in dengue infection [30], [31], [32]. Dengue renal involvement can be manifested by variety of clinical outcomes including proteinuria, hematuria, and glomerulonephritis [32]. Kidney issues in DVI usually aren't severe, and the more serious form, acute kidney injury (AKI), is rare. As a result, the causes of this condition remain unidentified [30]. However, several processes, including direct injury, indirect routes involving the immune system, hemolysis (the destruction of red blood cells), and mechanisms linked to low blood pressure, such as shock, have been hypothesized [33], [34]. Kidney injury occurs due to dengue may be because of hemodynamic fluctuations that come across throughout the infection [31], [34]. Infection with the one serotype provides lasting immunity against that specific serotype [35]. Viral infection can lead to kidney damage by directly harming the cells of the kidney tubules and glomeruli. Viral antigens in the glomeruli can initiate an immune-mediated in situ process that damages tissue and deposits immune complexes and antiviral. When the inflammation in the intratubular vessels gets worse, antibodies are generated along with the production of inflammatory mediators [5]. Using immunohistochemistry and in situ hybridization methods, viral antigens were found in tubular epithelial cells in several investigations examining postmortem or biopsy samples from DENV-positive patients [5]. In their study, Jessie et al. used tissue samples from humans infected with DENV-1. They found that while viral RNA was not found in these samples, patients with the infection displayed viral antigens in the form of distinct granular deposits inside tubule lining cells. Conversely, all instances of DENV-4 infections showed substantial quantities of virus particles [36]. According to a study by Basilio-de-Oliveira et al., bleeding may have taken place in the proximal convoluted tubules and glomerular capillaries of an older person who was infected with DENV-3. This patient's condition was fatal. In addition, they noticed areas of bleeding, interstitial swelling, and congested blood vessels, as well as the presence of mononuclear cells invading the renal medullary tissue [37].

V. HYPERTENSION AND DENGUE SEVERITY

Many mechanisms explain how high blood pressure is related to severe forms of dengue. Many studies show high blood pressure results in more significant damage to the endothelium typically for complicated forms. As this occurs, a very complicated medical scenario can arise, and for those who have severe cases, this can result in an uncommon ailment. The way these cells work is altered in the case of severe dengue. When the blood vessels become more porous and as such plasma now begins to get lost in them, the condition of dengue patients worsens as hypertension does not allow endothelium to function [7]. Also, Hypertension can alter the immune system, reducing its ability to fight infections. The chance of severe dengue may rise because of

the immune system's compromised ability to multiply and disseminate more quickly. Studies reveal a link between low-grade chronic inflammation and hypertension, which can worsen the body's reaction to infections. The overproduction of pro-inflammatory cytokines induces a cytokine storm in dengue virus fever, augmented disease severity. And, when the blood pressure rises, it increases the oxidative stress and depresses immune cells' ability, hence hindering their ability to curtail virus replication in vivo [25], [38].

Abnormalities in blood coagulation that link to hypertension may lead to severe bleeding in dengue patients because the latter condition is usually characterized by hypertension-related abnormal clotting of blood, which often results in internal bleeding as well as other serious hemorrhage problems. In addition, there is a predisposition towards hemorrhage within the context of severe dengue fever among patients with high blood pressure, whereby these conditions worsen each other, making their combined effects on the body even more lethal. It has been discovered that patients suffering from hypertension have false rates of coagulation factors. Such high fibrinogen and low anticoagulant proteins make it worse for those who are also suffering from dengue fever due to bleeding being more serious, thus interfering with their health [39].

Therefore, it is crucial to understand the connection between severe dengue and hypertension for both patient care and public health initiatives.

VI. CONCLUSION

The present review aimed to elucidate the noteworthy influence of pre-existing comorbidities on the severity of dengue fever, thereby underscoring the imperative nature of implementing comprehensive clinical management strategies in regions where dengue is endemic. Diabetes, obesity, hypertension, and kidney disease have been identified as significant contributors to the worsening of dengue pathogenesis, resulting in the development of severe and potentially life-threatening complications. The significance of early identification and targeted interventions in mitigating adverse outcomes is highlighted by the interaction between these conditions and the severity of dengue. Given the increasing prevalence of both dengue and non-communicable diseases on a global scale, it is crucial to incorporate this understanding into public health policies and treatment guidelines. This integration is essential for enhancing patient care and mitigating the impact of dengue outbreaks.

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The Impact of the Consumption of Tea on Iron Absorption

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Abstract—One of the most significant trace elements on the planet is iron. Iron is a crucial ingredient for several biological processes, including energy metabolism, cell division, immunity, and oxygen transport. Iron is abundant yet frequently poorly accessible, particularly when it comes to the non-heme form that is present in plant-based diets. The body absorbs heme iron, which comes from animal sources, more easily. Tea serves as a widely used beverage worldwide and includes polyphenols that might cease non-heme iron from being absorbed by creating insoluble complexes in the intestinal lumen. When iron-rich meals are eaten with tea, this inhibitory impact is especially noticeable. However, drinking tea has minimal impact on the absorption of heme iron. Knowing how dietary elements like tea affect iron absorption is important since iron deficiency is common in many countries. Tea polyphenols have been shown to limit iron absorption. However, these effects can be lessened by implementing strategies including drinking tea between meals and increasing dietary heme iron consumption. More scientific study is required to further understand these relationships and create recommendations for people who may be susceptible to iron deficiency. This review aims to give an idea about how the consumption of tea effects on iron absorption in the human body. Research studies with clinical trials, book chapters, and review articles were used to gather information.

KEYWORDS-enterocytes, heme iron, non-heme iron, polyphenols, tea

I. INTRODUCTION

Iron is a vital component of our environment and is required by practically all kinds of life [1]. It is an essential metal for public health nutrition and a crucial ingredient for the population [2]. It includes immunology, energy metabolism, proliferation, and differentiating cells, and circulation of oxygen [2]. In the human body, iron is mostly found within complicated forms that are attached to proteins, including heme compounds including myoglobin or hemoglobin, heme enzymes, and nonheme compounds like transferrin, ferritin, and flavin-iron enzymes [3].

Most people drink tea, which is made from dried *Camellia sinensis* leaves, all over the world [4]. Tea has been shown to offer major health coverage as an anti-inflammatory, antibacterial, anticarcinogenic, neurologically protective, cardiovascular, and potentially cholesterol-lowering diet [5]. Green tea and black tea contain polyphenols such as epigallocatechin

-3-gallate, epigallocatechin, epicatechin-3-gallate, and epicatechin [4]. Additionally, black tea contains polymerized catechins such as theaflavins and thearubigins [4]. These tea polyphenols have a strong binding affinity to metal ions [4]. Therefore, it can cause to reduction in iron intake [4].

The primary target of this effect is non-heme iron, especially when iron and tea are consumed at the same time [4]. However, drinking tea doesn't affect the body's capability to absorb heme iron from cooked meals [4]. This topic was chosen, because tea is widely consumed in several nations where iron shortage is a significant nutritional issue decided to embark on a formal investigation.

II. METHODOLOGY

To explore the effects of tea consumption on iron absorption in the human body, a comprehensive review of literature from research articles, book chapters, and research papers was conducted. The aim was to synthesize current knowledge and identify trends in how tea impacts iron bioavailability. Sources were selected based on their direct relevance to the question. Relevant databases, including PubMed, Google Scholar, and ScienceDirect, were used with the keywords such as "tea consumption," "iron absorption," "iron bioavailability," and "human studies." Key information from each source was extracted, focusing on the effects of tea consumption on iron absorption in different populations, the mechanisms by which tea affects iron bioavailability, and the findings from clinical trials.

III. SIGNIFICANCE OF IRON

Minerals are critical micronutrients that help the body's metabolic processes function properly [6]. Among the microminerals, iron is essential for many physiological processes, including the formation of immune cells, oxidative metabolism, hemoglobin synthesis, and electron transport media in cells. It also helps to prevent anemia [6]. The most frequent forms of iron in our diets are insoluble and poorly bioavailable, despite being one of the metals that are most abundant on our planet [7]. Less than 0.1% of the body's iron concentration is lost by humans daily, and this iron is supplied by dietary iron absorption [7].

Iron deficiency can cause anemia, pale complexion, headaches, exhaustion or drowsiness, and reduced

resistance to infection [6]. Depending on age and gender, 8 to 15 mg of iron should be consumed daily [6]. Iron intake should be limited to 7–11 mg/day for children under the age of 13, 11 mg/day for males and 15 mg/day for females in teens 14–18 years old, 8 mg/day for males and 18 mg/day for females in adults 19–50 years old, and 8 mg/day for senior citizens over 51 years old [6]. Consuming meals rich in iron minerals is the only way to meet the body's requirements for iron, however, not all iron can be utilized due to differences in component bioavailability [6].

IV. BIOAVAILABILITY OF IRON

Heme iron and non-heme iron are the two types of dietary iron [3]. The primary forms of heme iron are derived from dietary meat, poultry, and fish, which include hemoglobin and myoglobin [3]. Cereals, pulses, legumes, fruits, and vegetables may contain non-heme iron [3]. Iron-rich or fortified food such as iron-fortified cereals also contains non-heme iron [2]. Heme iron may account for more than 40% of the entire intestinal iron absorption, because compared to non-heme iron, it is absorbed more easily, with an absorption rate of around 15 to 35% [2]. Because of non-heme iron absorption is influenced by other meal ingredients, it is significantly lower (2–20%) [3]. However, compared to heme iron, which is present in most meals, non-heme iron comprises a considerably greater fraction of the meal. Because of this, although non-heme iron has lower bioavailability than heme iron, it often provides more to iron nutriment [3]. The quantity of iron absorbed is greatly affected by the physical states of ferrous and ferric ions [2].

Most of the non-heme iron in food arrives in the ferric or oxidized form [2]. But enterocytes are more likely to carry ferrous iron [2]. At a pH of zero, ferrous iron is still soluble, but at pH values higher than three, ferric iron precipitates [2]. Accordingly, ferric iron must be dissolved and chelated in the stomach before it can be absorbed in the less acidic duodenum [2]. The other minerals in the meals swiftly complete chelation as soon as the iron is issued in the intestinal lumen. These chelators may act as both enhancers and inhibitors of iron uptake through iron miscibility [2]. Therefore, the composition of food is one of the primary factors causing the absorption of non-heme iron [2].

V. ABSORPTION OF IRON TO THE GUT

The intestinal epithelium can utilize both heme and non-heme iron [8]. If there is minimal demand for iron, it shall be stored as ferritin in the enterocyte and will be released after numerous days, when the enterocytes are shed from the villus tip [8]. When iron is required by the body, the iron carrier protein called ferroprotein allows it to cross the basolateral membrane and enter the bloodstream where it will bind to plasma transferrin [8]. However, the process of heme iron absorption is limited in research work [8].

In mammals, iron absorption may vary due to host-related and diet-related factors such as the

developmental stage and the organism's iron status [9]. Since most of the dietary iron is in ferric form, it demands to be turned into a ferrous form before being utilized. So, the reduction process of food plays a key role in iron absorption in the body [8]. Then, enterocytes should ingest ferrous iron through the apical transporter [9]. Internalized iron is stored as ferritin within enterocytes and subsequently transferred to the intestinal fluids by ferroproteins [9]. The circulatory system then carries iron in the type of transferrin-bound iron across the body [9].

Heme with its globin molecule should be seen as a powerful facilitator of iron intake since the ferrous iron included in the heme-globin particle is considerably easier to absorb than non-heme iron [10]. Even while heme iron makes up a lesser portion of the meal's overall iron content, the fractional absorption is four to six times higher [10]. In diets containing animal meat, roughly 10–15% of the dietary iron in the form of heme is present [10].

About 20 – 30 % of heme iron is absorbed, making it extremely bioavailable [10]. 1–10% of non-heme iron is absorbed and it can be highly individual and greatly altered by facilitators or enhancers of iron absorption in the meal [10]. Therefore, heme iron is known as "super iron" for individuals who are in good health and "poisonous iron" for those who have hemochromatosis [10].

While heme iron absorption is nearly consistent, non-heme iron bioavailability varies greatly [11]. It is usually considered that all non-heme dietary iron that reaches the general iron pool in the gastrointestinal tract is taken in evenly, depending on the concentration of iron absorption amplifiers and inhibitors present in the foods and the individual's iron status [11].

VI. INFLUENCE OF TEA ON IRON ABSORPTION

Phenolic substances might affect the quantity of iron absorbed, with the combination of iron in the Bowel canal and the variation of intestinal permeability [12]. Tannins are phenolic compounds that are included in tea and can lower iron bioaccessibility by creating insoluble complexes inside the intestinal lumen [13]. The most significant problem with large amounts of tannin consumption is, it might reduce the iron absorption from meals due to the presence of galloyl groups in tannins [13].

Studies have stated that tea mainly inhibits the intake of non-heme iron to a considerable scale by the development of insoluble iron complexes in the bowel canal [14]. Black tea possesses a more inhibitive impact on iron uptake even at low concentrations when compared with green tea due to its higher content of tannins [15]. When milk is added to tea, proteins in milk bind to the flavonoids in tea [16]. But tea's iron inhibitory properties are little or not affected by the addition of milk [16]. But tea has no inhibitory effect if hemoglobin is cooked, because cooking can denature the globins without affecting heme iron absorption [14].

Iron absorption from the reference diet ingested with 1 cup of tea was lowered by 59%, whereas intake of 2 cups of tea with the reference diet reduced iron absorption by 67% [17], whereas a 1-hour gap between an iron-containing meal and tea drinking reduces the inhibitory effects on iron absorption [18]. Some studies show that tea consumption may not affect iron status when people have enough iron storage [19]. There seems to be an adverse correlation between consuming tea and iron status, only among groups of persons with borderline iron status [19].

It is reported that black tea polyphenols decrease iron absorption on the meal by 62%, which is more than the inhibitory action of polyphenols from cocoa and wine, due to the high titer of polyphenols with galloyl groups [20]. Figure 1 includes the possible sites (A,B, and C) in which iron can bind with the flavonoids such as catechins found in tea [11]. The complex formed is an unabsorbable iron complex that forms in the intestinal tract [11].

It is claimed that a single iron attaches to three catechol or galloyl groups, with a polyphenol: iron binding ratio of 3:1 which might differ according to the pH of the medium. Additionally, the type of polyphenol, the ratio of iron to polyphenol, and the presence of ascorbic acid also influence the binding ratio [11]. The structure of the polyphenol also has an impact on the complex formation. While bidentate polyphenols, like catechin, bind iron through two sites, they can be quite potent ligands. In contrast, monodentate polyphenols, like phenol, have only one donor atom to bind to the central iron atom, hence form weak complexes with the iron [11]. The inhibitory action of iron absorption in the presence of polyphenols needs to be researched more, as many parameters are accountable for the total activity. The diet type, age, gender, health condition, meal patterns, other food ingredients involved in iron absorption, and many other features are directly linked with the iron absorption from the gut lumen. Thus, more extensive both in vitro and in vivo investigations are required to further understand the link between tea polyphenols and iron absorption.

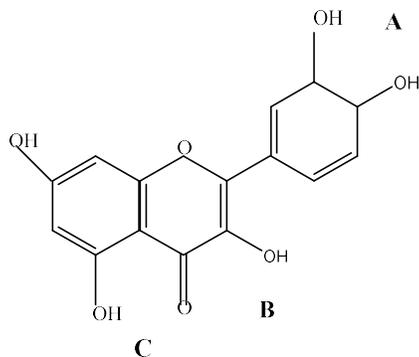


Fig.1: Possible iron binding sites of tea catechins [11]

VII.CONCLUSION

Tea, originating from dried *Camellia sinensis* leaves, processed as green tea, black tea and oolong tea. Tea polyphenols have a great affinity for proteins and minerals, which may impact nutritional status. Phenolic compounds in tea are well known as possible inhibitors of non-heme iron absorption. Phenolic substances incorporate iron within the intestinal lumen, lowering iron bioaccessibility. Because of its greater tannin content, black tea has a more inhibitory effect on iron absorption, even at low doses, than green tea. Tea's iron inhibitory properties are little or not affected by adding milk.

In conclusion, chronic consumption of tea can decrease intestinal penetrability, but it does not affect iron intake if tea is not taken with a meal that contains iron. There is limited evidence to prove the time interval effect because previous studies were conducted in animal models.

The formation of iron tannate complex is the major reason for to reduction of iron absorption. As a result, consuming tea after having a meal that contains iron can lower the amount of iron absorbed, whereas drinking tea before would not. According to the available research, healthy people who are not at risk of iron deficiency should not be recommended to decrease having tea. For people at risk stage of iron deficiency, it is recommended to consume tea between meals and wait at least one hour after eating. Most research did not demonstrate declines in iron status with the use of tannin-rich meals over time, even though tannin consumption limits iron bioavailability. According to the study, those who are at risk of iron deficiency can continue to have tea if they supplement their heme-iron consumption or fortify their meals with iron.

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Ultrasonic-Assisted and Enzyme-Assisted Extraction Techniques for the Identification of Antioxidant Compounds in Natural Plants

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Abstract— This literature review synthesis recent advancements and findings in the extraction of antioxidant compounds using two innovative techniques: ultrasonic-assisted extraction (UAE) and enzyme-assisted extraction (EAE). Antioxidants are molecules that assist in shielding the body's cells from the damaging effects of free radicals, which are unstable molecules produced by internal activities like metabolism and external influences like pollution and UV radiation. Free radicals have the ability to produce oxidative stress, which can result in ageing, cell damage, and a number of diseases, including cancer, heart disease, and neurological problems. The review offers a comprehensive exploration of the principles and applications of these methods in identifying antioxidant compounds from various sources, including plants, fruits, and agricultural by-products. Additionally, it critically assesses studies that compare the effectiveness of ultrasonic-assisted extraction and enzyme-assisted extraction in isolating antioxidant compounds, particularly phenolic compounds. The review discusses the advantages and limitations of each technique in terms of extraction yield, purity, and specificity. Furthermore, it highlights the synergistic effects observed when combining ultrasonic and enzymatic treatments. Overall, this review serves as a valuable resource for researchers, industry professionals, and stakeholders interested in leveraging ultrasonic-assisted and enzyme-assisted extraction methods for the identification and extraction of antioxidant compounds. By synthesizing current knowledge and outlining future research directions, the review aims to advance the field of antioxidant compound extraction and contribute to the development of novel functional ingredients with significant health benefits.

Keywords—Ultrasound-assisted extraction, Enzyme-assisted extraction method, Antioxidant

I. INTRODUCTION

Scientists have identified numerous antioxidant compounds, employing various extraction methods to isolate these bioactive substances. Extraction involves removing desired components from solid or liquid materials by dissolving them in a suitable solvent. This process allows for selective interaction between the solvent and the target compound, enabling separation from the original material. Following extraction, filtration typically separates the extracted substance from remaining components, which may undergo further processing or purification for various applications in chemistry, biology, and other fields.

This review focuses primarily on two extraction methods: Ultrasonic Assisted Extraction (UAE) and Enzyme Assisted Extraction. UAE employs high-intensity ultrasonic pulses. Antioxidants are molecules that assist in shielding the body's cells from the damaging effects of free radicals, which are unstable molecules produced by internal activities like metabolism and external influences like pollution and UV radiation. Free radicals have the ability to produce oxidative stress, which can result in ageing, inflammation, cell damage, and a number of diseases, including cancers, heart diseases, and neurological problems. to induce acoustic cavitation in the extraction medium, breaking down cell walls and enhancing the release of bioactive compounds. This method is renowned for its rapid extraction speed, preservation of labile chemicals, versatility in solvent use, and ecological benefits due to reduced solvent usage [1]. Enzyme Assisted Extraction involves using enzymes such as cellulases, hemicellulases, and pectinases to break down cell wall components and release bioactive substances from natural sources like plants, bacteria, fungi, algae, and animals. This technique is valued for its environmental sustainability, efficiency, and ability to selectively extract desired compounds while maintaining their original potency [2].

The extraction techniques play a crucial role in obtaining bioactive chemicals from natural sources, impacting efficiency, selectivity, and environmental sustainability. This review aims to advance knowledge and promote the development of functional ingredients with potential health benefits.

II. LITERATURE REVIEW

A. Ultrasonic-Assisted Extraction Method (UAE)

Ultrasonic extraction theory posits that high-frequency sound waves can enhance the extraction of bioactive compounds from plant materials. Bioactive chemicals are released into the solvent due to the breakdown of plant cell walls and membranes. Cavitation bubbles create localized high pressures and temperatures, further aiding in the extraction process by increasing the surface area available for mass transfer.

Ultrasonic-assisted extraction (UAE) stands out as a preferred method for extracting bioactive chemicals from plant materials due to its numerous advantages. UAE is also noted for its speed, minimizing the degradation of

thermosensitive chemicals, and its environmentally friendly approach with reduced solvent usage [3].

UAE finds wide application across various industries. In the food sector, it extracts bioactive substances and antioxidants from fruits, vegetables, and herbs, thereby enhancing nutritional profiles and functional qualities of food products. In pharmaceuticals, UAE facilitates the extraction of active pharmaceutical ingredients (APIs) from medicinal plants, aiding in the formulation of pharmaceuticals, vitamins, and herbal remedies. The cosmetics industry utilizes UAE to extract antioxidant and anti-aging compounds from natural sources for skincare, haircare, and makeup products.

In research, UAE is pivotal for extracting and analyzing a diverse range of chemicals, contributing to advancements in biology, pharmacology, and chemistry. Its ability to enhance extraction efficiency, reduce extraction time, and minimize solvent use makes it a preferred choice among scientists and researchers. Optimizing UAE parameters plays a crucial role in improving the extraction efficiency of bioactive compounds from natural sources. Factors such as vessel diameter, sample-to-solvent ratio, extraction temperature and sonication time are carefully selected and managed to maximize the yield of target compounds [4].

For instance, the fruit of *Melastoma sanguineum* Sims was subjected to UAE to extract antioxidants. Fruit powder was mixed with an ethanol aqueous solution and treated with ultrasound under controlled conditions of power, temperature, and time. Mechanical effects produced by ultrasonic energy improved mass transfer and solvent penetration into the sample matrix, enhancing internal and eddy diffusion. Ultrasonic cavitation aided in breaking down cell walls, facilitating the release of antioxidant compounds from the fruit material. In order to optimize the extraction parameters ethanol concentration, solvent-to-material ratio, extraction time, temperature, and ultrasonic power the study successfully applied response surface methodology (RSM). The best extraction conditions for ultrasound-assisted extraction (UAE) were found by using this method, which enabled a thorough investigation of the relationship between these factors.

As compared to traditional techniques like maceration and Soxhlet extraction, the study's findings showed how effective UAE is. In particular, compared to maceration and Soxhlet extraction techniques, UAE showed a notable increase in extraction efficiency. The study also showed how UAE is a more advantageous extraction technique due to its shorter extraction times and lower need for organic solvents [5].

Rhynchosia minima root represents another example where UAE is beneficial. This medicinal herb, shown in figure 1.[6] known for its bioactive components with potent anticancer and antioxidant properties, can be effectively extracted and concentrated using UAE. Optimization of extraction parameters such as exposure time, solvent-to-material ratio, and extraction temperature enhances the yield of bioactive polysaccharides from the root, maximizing extraction efficiency. The bioactive chemicals extracted from *Rhynchosia minima* which is a small, perennial herbaceous plant belonging to the family Fabaceae (the legume or pea family). Root finds applications in functional foods,

nutritional supplements, and pharmaceutical formulations, highlighting its potential to improve human health and well-being [7].



Fig. 1. Pollination of *Rhynchosia minima* (L.) (Aluri and Kunuku, 2019, 116)

The Mediterranean plant *Lavandula stoechas*, known locally as “Ladastacho”, has long been prized in countries like Morocco for its therapeutic benefits. Rich in phenolic substances such as flavone glycosides are a type of naturally occurring compound consisting of flavone aglycone such as apigenin glycosides, disomic and phenolic acids, this plant is associated with a variety of health benefits, including antibacterial, antifungal, anti-inflammatory, and antioxidant properties. Utilizing UAE for *Lavandula stoechas* enhances both the yield and total phenolic content of the plant extract. The abundant phenolic compounds extracted from *Lavandula stoechas* are crucial for their positive impacts on human health, making them valuable in fields such as nutrition, medicine, and healthcare. This approach facilitates the development of products enriched with enhanced anti-inflammatory, antioxidant, and other health-promoting qualities from *Lavandula stoechas* extracts [8].



Fig.2. Flower of *Lavandula stoechas* (Zeynep et al., 2021, 264)

Mahua seeds are particularly well-suited for ultrasonic extraction techniques due to their richness in antioxidants and phytonutrients, which supports the employment of ultrasonic extraction procedures for them. In comparison to traditional techniques, it describes the benefits of ultrasonic-assisted extraction (UAE). A higher oil yield was obtained with the UAE technique, outperforming traditional extraction methods with an oil yield of 56.97% and more than 99% oil recovery. In comparison to Soxhlet and mechanical extractions, oil extracted using UAE showed the highest antioxidant capacity. Multiple antioxidant assays, such as ABTS, DPPH, and FRAP assays, verified this higher efficacy.

The UAE used light energy, a 35-minute extraction period, and a low temperature of 35°C to obtain these remarkable results. Maintaining the bioactive components in the oil was made easier by using a binary mixture of acetone and isopropanol (11 v/v). The research found important phytonutrients in the mahua oil, including tocopherols, phytosterols, terpenoids, and tocotrienols. These compounds have been linked to health benefits like antidiabetic, anti-inflammatory, and anticancer effects. The document presents a consistent comparison between the oil yield and antioxidant capacity of the UAE process and traditional Soxhlet and mechanical extraction methods. Together, these results show how successful ultrasonic extraction methods are for mahua seeds, especially when it comes to obtaining oil that is rich in antioxidants and improved in bioactive compounds, which is ideal for a range of industrial uses.

This process highlights the potential of repurposing and adding value to these underutilized seeds to produce antioxidant-rich mahua seed oil, which is highly valuable for the food and nutraceutical industries. The application of UAE for extracting mahua seed oil has shown higher oil recovery and yield compared to traditional methods like Soxhlet and mechanical extraction, while consuming less energy, requiring shorter extraction times, and operating at lower temperatures. UAE's gentle processing conditions also help preserve the bio actives in the oil. Although mahua oil is currently used primarily in traditional Asian cuisine, advanced extraction techniques like UAE could expand its applications in the food and nutraceutical sectors. The superior performance of UAE in co-extracting antioxidants and improving oil yield suggests it is a viable option for industrial scale-up [9], [10].

According to [11], the UAE method yielded the highest extraction value from the peel and pericarp of *Punica granatum* L. (Nimali variety). These yields were superior to those obtained through traditional boiling, microwaving, and water bath methods. Additionally, UAE extracts demonstrated the highest flavonoid content, "DPPH" free radical scavenging activity, and capacity to reduce ions from Fe³⁺ to Fe²⁺ for both peel and pericarp extracts [11].

Ultrasonic extraction can also be applied to pepper leaves to extract bioactive components. Using ultrasonic waves with an appropriate solvent helps break down cell walls and release desired chemicals from the plant material. Pepper leaves hold significant potential for ultrasonic extraction due to their effectiveness in extracting bioactive components. Compared to conventional methods, ultrasonic extraction allows for higher yields of bioactive chemicals from the leaves,

increasing both production and efficiency. Additionally, this method is more sustainable, as it uses fewer harsh chemicals and is considered a green technology [12].

B. Enzyme - Assisted Extraction Method (EAE)

Enzyme-assisted extraction utilizes enzymes to break down cell wall material and release bioactive compounds from plant materials. Enzymes catalyse biochemical reactions under mild conditions, making them suitable for selectively breaking down target compounds. These plant-derived enzymes work by rupturing cell walls, thereby releasing the desired substances. This technique is commonly used to extract bioactive molecules, polyphenols, antioxidants, and other valuable substances from natural sources, offering an efficient way to obtain these chemicals without compromising their purity or bioactivity [13].

In the case of extracting phenolic compounds from murucizeiro leaves (*Byrsonima crassifolia*), enzymes are used to break down the leaf cell walls, facilitating the release of phenolic compounds. The process typically begins with selecting the appropriate enzymes, such as cellulase, pectinase, or hemicellulase, to target the leaf cell wall components. The leaves are pretreated with the selected enzymes under controlled pH, temperature, and duration conditions to ensure optimal enzymatic activity. This pretreatment weakens the cell walls, aiding the extraction of phenolic compounds. Following enzymatic pretreatment, an appropriate solvent is used to extract the phenolic chemicals from the plant material. The combined action of enzymes and solvent extraction enhances the efficiency and yield of phenolic compounds from murucizeiro leaves. These leaves are rich in phenolic compounds with anti-inflammatory and antioxidant properties, making them valuable for various applications. Furthermore, enzyme-assisted extraction of murucizeiro leaves provides a platform for research and development, allowing for the discovery of new bioactive compounds and applications in the natural products industry.



Fig. 3. Pplant of *O murucizeiro* (Moura et al., 2016, 20)

However, there are challenges to consider when using murucizeiro leaves for enzyme-assisted extraction. The variable concentration of phenolic components in the leaves may impact the consistency and yield of the extraction process. Standardizing the extraction method may require specialized knowledge and adjustments to achieve effective and consistent results. Additionally, the cost of enzymes and extraction equipment could be a factor, especially for large-scale extraction processes. The overall quality of the extracted phenolic compounds may be affected if specific compounds are degraded or if the bioactive properties of the plant material are altered during enzymatic treatment. These challenges underscore the importance of optimizing and carefully considering the use of murucizeiro leaves for enzyme-assisted extraction to maximize benefits and minimize potential drawbacks [14].

Avocado peel is a valuable source of polyphenols with strong antioxidant properties, making it an excellent candidate for enzyme-assisted extraction processes. Researchers aim to utilise this extraction method to harvest the beneficial polyphenols from avocado peel, which are renowned for their potent antioxidant effects. The antioxidant activity of avocado peel is attributed to a variety of phenolic compounds present in the peel. Enzyme-assisted extraction is particularly effective at isolating these compounds. This method extracted a higher concentration of polyphenols compared to traditional extraction techniques, making it a promising approach for obtaining natural antioxidants from avocado peel.

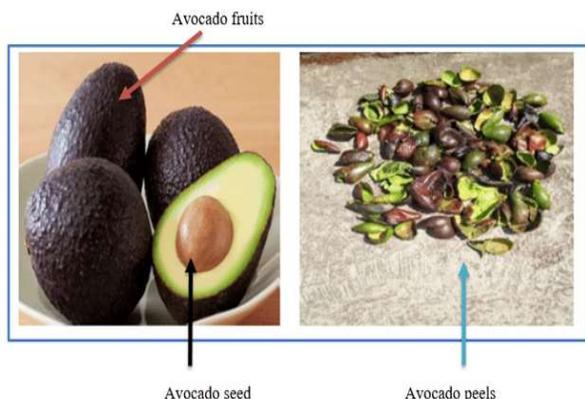


Fig. 4. Avocado-Peels (Tafere 2021, 55)

Overall, the application of avocado peel in enzyme-assisted extraction highlights its potential as a rich source of bioactive chemicals for creating antioxidant-rich extracts for various uses in the food and pharmaceutical industries [15].

Sea cucumbers are also valuable in enzyme-assisted extraction processes, particularly due to their high polysaccharide content. Enzymes such as the cysteine protease papain can effectively release polysaccharides from sea cucumbers. Compared to other extraction methods, this technique offers a more efficient and sustainable way to extract valuable components from sea cucumbers.

Using enzyme-assisted extraction for sea cucumbers has several advantages. It is highly efficient, easy to implement, and environmentally friendly.

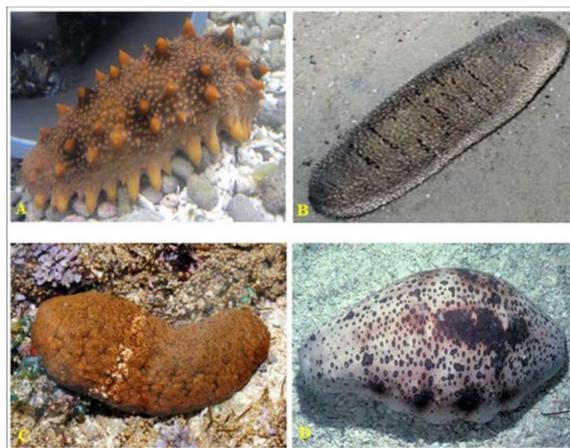


Fig.5. Commercially important species of sea cucumbers in aquaculture (Rahman et al., 2022, 421)

This method also helps preserve the bioactivity and potential health benefits of the extracted compounds by maintaining the polysaccharide structure. By efficiently lysing cells and releasing bioactive components, enzyme-assisted extraction ensures a more comprehensive extraction process, resulting in higher yields of essential compounds from sea cucumbers. Additionally, compounds recovered from sea cucumbers using enzyme-assisted extraction have demonstrated potential antioxidant effects. Sea cucumber polysaccharides exhibit anti-free radical properties, including the ability to scavenge radicals such as superoxide, hydroxyl, “DPPH”, and ABTS 2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid). These antioxidant capabilities suggest that compounds extracted from sea cucumbers could have significant antioxidation potential [16].

Habanero chili pepper seeds, rich in bioactive compounds like capsaicinoids and phenolic compounds, are valuable for enzyme-assisted extraction techniques. Enzyme-assisted extraction (EAE) enhances the efficiency of extracting these beneficial components from seeds. Using enzymes such as cellulase, the extraction process can be optimized to yield higher concentrations of these compounds from habanero chili pepper seeds. This environmentally friendly method of obtaining essential anti-inflammatory chemicals highlights the potential of habanero seeds as a raw material for extracting bioactive compounds with anti-inflammatory properties.

This demonstrates the significance of habanero chili pepper seeds as a valuable source of bioactive substances for developing nutraceuticals and functional foods. Additionally, extracting anti-inflammatory chemicals from habanero chili pepper seeds using enzymes creates opportunities for utilizing by-products that would otherwise be discarded. This research not only increases the value of habanero chili pepper seeds but also helps reduce food waste in the food industry [17].

Raspberry pomace, a by-product of industrial processing, holds significant potential in the food and nutraceutical industries through enzyme-assisted extraction. Raspberry pomace is a valuable source of bioactive compounds such as tocopherols, polyphenols, and polyunsaturated fatty acids,

which are often discarded. Enzyme-assisted extraction effectively isolates these compounds from the pomace, providing a viable method for recovering valuable materials [18].

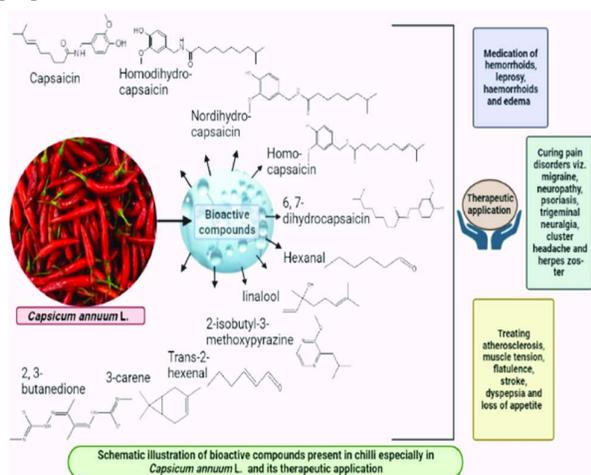


Fig. 6. Bal, Solanki & Sharangi, Amit & Upadhyay, Tarun & Khan, Fahad & Pandey, Pratibha & Siddiqui, Samra & Saced, Mohd & Lee, Hae-Jeung & Yadav, Dharmendra. (2022). Biomedical and Antioxidant Potentialities in Chili: Perspectives and Way Forward. *Molecules*. 27. 6380. 10.3390/molecules27196380.

One major application of enzyme-assisted extraction from raspberry pomace is in the production of nutraceuticals. The extracted bioactive substances, such as ellagitannins, tocopherols, phytosterols, and essential fatty acids, have shown potential health benefits. When incorporated into nutraceutical products, these antioxidant-rich substances may offer various health advantages. This process also enables the efficient recovery of these beneficial molecules, making it a valuable technique for creating functional food ingredients. The isolated bioactive components can be used as industrial additives like antioxidants prevent oxidation in fuel, plastics and rubber (butylated hydroxytoluene-BHT), Plasticizers-Improve flexibility in plastics (phthalates, adipates), Anti-foaming Agents - Reduce foam in industrial processes (silicone oils, polydimethylsiloxane) or ingredients to enhance the nutritional value and functional properties of food products like Flavour Enhancers to improve or intensify the taste (monosodium glutamate - MSG). For instance, the antioxidant properties of the extracted compounds can help extend the shelf life of food products by preventing oxidation. Their natural origins also align with the growing consumer demand for natural and clean-label food ingredients [18].

A systematic approach is essential for identifying antioxidant compounds in brown seaweeds using enzyme-assisted extraction. The selection of appropriate enzymes is crucial. Enzymes like carbohydrase and proteases are typically used to break down the complex polysaccharides in brown seaweeds' cell walls. Preparing the brown seaweeds for extraction involves cleaning and processing them for enzymatic treatment. During the enzymatic extraction process, the selected enzymes hydrolyze the seaweeds, facilitating the release of bioactive substances, including

antioxidants. The enzymatic extracts are then analyzed for antioxidant activity using various techniques. Metal chelating (the process of binding chemicals, known as chelating agents, to metal ions to create a stable, ring-like complex is known as metal chelation), reducing power, radical scavenging, and inhibition of lipid oxidation. These tests help evaluate the antioxidant potential of the isolated compounds. Further fractionation and characterization of the enzymatic extracts can identify specific antioxidant compounds. Analytical techniques like mass spectrometry, spectroscopy, and chromatography are used to study and identify the antioxidant compounds present in the fractions. The cosmetic and personal care industries can also benefit from compounds derived from brown seaweeds. Research has shown that phenolic compounds and antioxidants from seaweeds have anti-aging and skin-protective properties. Incorporating these natural elements into skincare products can offer benefits such as skin hydration, protection against environmental stresses, and anti-inflammatory effects [19].

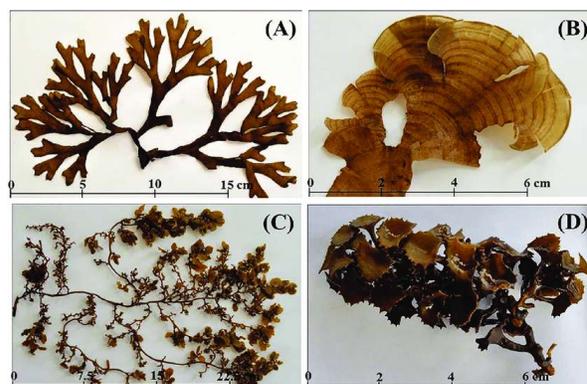


Fig. 7. Brown Seaweeds (Heriyanto et al., 2017, 325)

In the study, the recovery of plant protein and bioactive compounds from sesame bran was enhanced using ultrasonic extraction and enzyme-assisted extraction methods. For the ultrasonic extraction, sesame bran was subjected to ultrasonic waves under vacuum conditions. The key variables in this method include vacuum pressure, vacuum time, and restoration time after vacuum application. These factors were carefully selected and optimized to maximize extraction efficiency, while maintaining constant ultrasonic power and temperature throughout the process. In contrast, the enzyme-assisted extraction method utilized the enzyme alcalase to facilitate the extraction. The sesame bran and water mixture were treated with the enzyme, and the pH was adjusted to enhance enzyme activity. Similar to ultrasonic extraction, this method was also conducted under vacuum conditions to optimize extraction efficiency.

Both techniques, ultrasonic extraction and enzyme-assisted extraction, were employed to extract plant protein and bioactive components from sesame bran. The ultrasonic extraction process disrupted the cellular structure of sesame bran under vacuum using ultrasound waves. This disruption facilitated the release of intracellular compounds, enhancing extraction efficiency. The ultrasonic waves softened plant tissues, making it easier to extract proteins and other beneficial substances. On the other hand, the enzyme-assisted

extraction method used the enzyme alcalase to aid in the extraction process. Enzymes are known to break down complex molecules into simpler forms, making proteins and other bioactive components more accessible.

The enzyme concentration, temperature, pH level, extraction time and enzyme to substrate ratio were optimized to maximize extraction efficiency, targeting specific compounds in sesame bran. While the ultrasonic extraction method focused on physically breaking down the cellular structure, the enzyme-assisted extraction method relied on enzymatic reactions to enhance extraction. The ultrasonic method used mechanical means to disrupt plant tissues, whereas the enzyme-assisted method used enzymatic breakdown to facilitate extraction. Both methods were conducted under vacuum to improve solvent penetration into the cellular components and increase extraction efficiency. Overall, the ultrasonic extraction method and the enzyme-assisted extraction method complemented each other in the study, employing different mechanisms to enhance the recovery of plant protein and bioactive compounds from sesame bran. The goal of combining these techniques under vacuum was to maximize the yields of valuable components from agricultural byproducts such as sesame bran by optimizing the extraction process [20].

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Multisensory Learning Approaches through an Augmented Reality Application for Preschool Language Education

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Abstract - The research investigates the implementation of an augmented reality (AR) spelling application for preschool education, utilizing multisensory learning approaches to enhance student engagement in language learning. Traditional language teaching methods frequently fail to engage preschool kids effectively, providing challenges for preschool teachers and parents. This research aims to introduce an AR-based interactive and immersive application designed to improve children's letter recognition and recall through visual, auditory, and kinesthetic-tactile pathways. The key goals are to identify barriers to preschool language learning, develop a mobile AR application to improve spelling abilities, quantitatively and evaluate its performance compared to traditional techniques. The study uses a mixed methods approach to collect quantitative and qualitative data from parents and preschool teachers in Sri Lanka via questionnaires and interviews. The augmented reality application uses virtual 3D letters and objects to improve visual recognition and memory of phonetic pronunciation to aid auditory processing, and interactive components to encourage kinesthetic engagement. The data show that children who use the AR program perform significantly better in spelling, attentiveness, and understanding than those who use traditional approaches. The immersive and interactive nature of augmented reality makes for a more engaging learning environment, highlighting its potential as an excellent instructional tool. This study demonstrates how combining augmented reality and multimodal learning concepts can provide an effective solution for improving early childhood language and spelling education.

Keywords: *preschool education, multisensory learning, Augmented Reality (AR)*

I. INTRODUCTION

Technology advancements have drastically changed Sri Lanka's educational system. In the field of education, technology has made a profound impact, particularly in early childhood education. Traditional methods for teaching spelling often present several challenges for teachers and parents, leading to a lack of interest and retention among young learners. Limited time, diverse learning styles, and varied learning paces further complicate effective spelling instruction. Moreover, non-native speakers may struggle with teaching correct pronunciation, highlighting the need for more interactive and engaging teaching strategies. Technology has had a significant impact on education, particularly in early childhood. Traditional spelling methods can provide

various obstacles for teachers and parents, resulting in a lack of enthusiasm and retention among young students. Limited time, variable learning styles, and varying learning speeds all prevent successful spelling instruction. Furthermore, non-native speakers can struggle to teach perfect pronunciation, emphasizing the need for more collaborative and engaging methods of learning.

The main problem with current spelling teaching for preschoolers is that it doesn't possess any interactive element; this affects the effective pronunciation of letters as well as memorization. This research aims to solve this issue by designing an innovative solution that applies Augmented Reality (AR) to improve spelling skills and language acquisition in young children. Through AR technology, users can view 2D or 3D images on a mobile screen which are usually manipulated by a finger. AR has been applied in physics, math, and spelling among other subjects showing its versatility and potential. This study focuses on creating an AR-based spelling application for children aged 3-5, emphasizing the improvement of letter recognition, memorization, and pronunciation skills.

By incorporating multisensory learning principles, the application engages visual, auditory, and kinesthetic-tactile pathways to provide a holistic educational experience. Visual elements include virtual 3D letters and objects, auditory features involve letter pronunciation, and kinesthetic-tactile components allow interactive engagement with AR elements.

The key goals of this study are to identify obstacles in early childhood language acquisition, create an Augmented Reality mobile application to improve language spelling skills and evaluate its effectiveness to standard teaching techniques. The purpose of the project is to demonstrate how augmented reality (AR) technology, when combined with multisensory learning, can significantly enhance children's educational opportunities by offering a useful and entertaining substitute for early childhood language and spelling instruction. This study aims to provide a transformative approach to preschool education by overcoming the limits of existing approaches and providing multisensory AR applications, enabling increased engagement, retention, and excitement for learning among young children.

II. LITERATURE REVIEW

A. Related Work

In recent years, the use of computer systems for entertainment and e-learning has grown dramatically, encouraging many institutions to incorporate computers into early childhood education [20]. There are numerous language learning apps for kids, each with its own set of advantages and disadvantages. This review examines well-known language-learning applications for young children, stressing both their advantages and disadvantages. Some apps make learning more interactive and interesting by utilizing cutting-edge technologies like voice recognition, gamification, and augmented reality (AR). But there's a chance that these apps will have problems with user experience, accuracy, and cost. Ultimately, the particular needs and tastes of each parent and child influence the choice of app. The value of games in helping children learn has been extensively investigated.

One study proposed developing an online multiplayer game to convey educational content, arguing that the game's feedback, difficulties, and entertaining experiences will improve cognitive and learning capacities [3]. Games based on memory and recognition principles can improve motivation, teamwork, and adaptability. Mobile technology integration in language education is quickly progressing, allowing students to participate in mobile-assisted language learning (MALL) with no time or geographical limits. Smartphones, tablets, and laptop computers aid language acquisition by enhancing listening, speaking, reading, and writing abilities (R. Gangaiamaran et al, 2017).

The "EasyMath" software develops an entertaining and instructive system to examine preschoolers' cognitive and physical development. It features simple interfaces, essential materials, and appropriate feedback mechanisms, allowing children to solve problems and use graphical icons effectively [20]. A study developed an app to teach basic English, Spanish, and German to Arabic-speaking children using voice and image recognition (S. Harous et al., 2017). While effective in teaching the alphabet and basic phrases, its limited vocabulary exposure restricts language learning.

The "StoryKit" app allows children to create and share stories using text, illustrations, photos, and sound effects [7]. Despite its popularity, it has limitations in improving pronunciation and interactive content. The "iWrite Words" app helps children practice writing letters, numbers, and sentences using their fingers, focusing on pronunciation and memorization skills [9]. The "Kids Learn to Read" app for Android focuses on pronunciation but lacks memorization techniques and interactivity (R. Gangaiamaran and M. Pasupathi, 2017). The "Starfall App" offers activities to help children learn to read through exploration and inquiry, though it does not assess language development progress [8]. "Duolingo" (M. Shortt et al., 2014) is one of the best preschool language learning applications for 2023. It provides game-based lessons in more than 35 languages and helps children practice speaking, listening, reading, and writing. It provides grammatical explanations and a news feed for additional resources, suitable for children with a solid foundation in

reading and writing. "LingoDeer" [17] offers a customizable language learning experience with flashcards and interactive stories but has limited language options and repetitive content. "Little Chatterbox for Kids" [11] enables children to learn nine languages through vibrant visuals and videos of native speakers. Despite its effectiveness in vocabulary acquisition, the app is expensive and less interactive. The goal of using augmented reality into children's educational applications is to offer engaging and dynamic experiences that will boost students' motivation and level of participation.

B. Integration of Multisensory Learning with Augmented Reality

Combining multisensory learning approaches with AR technology can create a powerful educational tool that enhances early childhood language learning and spelling skills. Teachers can offer a full learning experience that accommodates different learning styles and preferences by utilizing the qualities of both approaches.

Visual and Auditory Integration: AR applications can display 3D models of letters and objects while simultaneously providing audio pronunciation. This integration helps children visually recognize letters and words while reinforcing their understanding through auditory input.

Kinesthetic-Tactile Interaction: AR allows for interactive elements that children can touch and manipulate. For example, children can tap on or drag virtual letters to form words, engaging their kinesthetic-tactile senses and reinforcing learning through physical interaction.

A case study by Yilmaz and Olpak (2020), This study examined the impact of an AR-based spelling application designed for preschool children. The application incorporated visual elements (3D letters and objects), auditory components (pronunciation of letters and words), and kinesthetic activities (interacting with AR elements). The findings revealed that children using the AR application showed significant improvements in their spelling accuracy and language comprehension. The multisensory approach helped maintain their interest and made learning more engaging compared to traditional flashcards and rote memorization techniques.

The researchers [6], investigated an AR application aimed at enhancing vocabulary acquisition in young learners. The application used 3D visual representations of words, audio pronunciations, and interactive touch-based activities to engage multiple senses. The study found that this multisensory engagement led to better retention and recall of vocabulary words. Children using the AR app could understand and spell new words more effectively than those who followed conventional learning methods, which often lack interactive and multisensory elements.

Kucirkova and Flewitt (2019): Focusing on children with dyslexia, this study explored the use of an AR application that provided a multisensory learning environment. The AR app featured visual aids (colorful letters and animations), auditory feedback (correct pronunciation and phonetics), and tactile interactions (manipulating letters on the screen). The study

demonstrated that children with dyslexia showed marked improvement in their ability to recognize, spell, and pronounce words. The AR application helped these children by providing a more engaging and supportive learning experience than traditional, text-heavy methods. Wu et al. (2013). This research analyzed the effectiveness of AR-based educational games in early childhood settings. The games integrated visual (animated characters and letters), auditory (sound effects and spoken words), and kinesthetic (interactive gameplay) elements to create an immersive learning experience. The study found that children who played these AR games were more engaged and showed better learning outcomes in spelling and language acquisition. Compared to traditional educational games, the AR-based games provided a richer, more interactive environment that catered to different learning styles, leading to improved educational achievements.

The literature review highlights the significant potential of combining multisensory learning approaches with AR technology to enhance early childhood education. By engaging multiple senses and providing interactive and immersive experiences, this integrated approach can improve language acquisition and spelling skills, making learning more effective and enjoyable for young children.

III.METHODOLOGY

This approach aims to solve the problem by creating an immersive and interactive augmented reality (AR) application that helps young children memorize word letters and pronounce letters more accurately. Using a mixed-methods approach, this research project combines quantitative and qualitative data. The sample population comprises of fifty Sri Lankan’s parents and preschool teachers who will actively participate in questionnaires and interviews.

A. Requirement Analysis

Researchers have identified two critical areas that require concentrated attention through in-depth interviews and surveys: the present instructional strategies utilized to assist kids in identifying and remembering specific letters inside words, and the kids' desire for interesting and fun learning activities. The feedback from the participants provides valuable insights into the effectiveness of existing teaching strategies and highlights the need for innovative approaches that align with children's interests and preferences.

[1] What strategies have you found useful in teaching children to recognize and memorize specific letters within a word? The question probably has to do with practical strategies for teaching kids to recognize and retain specific letters in words. Their responses to different teaching methods, including as letter-sound association, visual cues, melodies and rhythms, practice and repetition, and flashcards. The respondent draws the conclusion that these methods were applied equitably in light of the data. All of these elements ought to be incorporated into the application's development to guarantee that it teaches kids how to identify and remember certain letters within words. Based on the collected replies, it appears that the majority of children are not participating in the traditional activities meant to teach letters within words. It can be challenging

to maintain students' attention in their courses when parents and teachers worry that their kids will become bored and lose interest rapidly. It appears that just a tiny portion of children favor traditional methods. A fresh and original strategy is required to hold young brains' attention and involve them in the learning process.

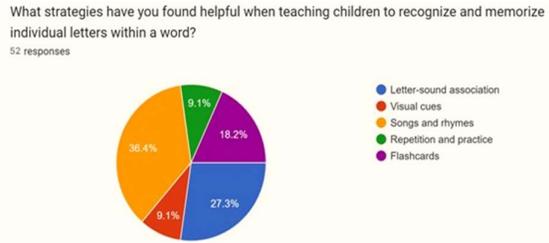


Fig. 1. Responses for question 01

[2] Do you notice that your child is engaged and delighted while participating in activities that teach letters within a word?

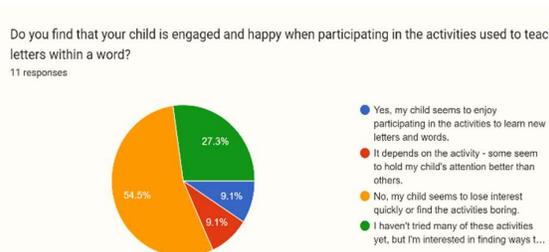


Fig.2. Responses for question 02

B. Application Development

The development of the AR-based mobile application will focus on integrating multisensory learning principles to create an engaging educational tool. The application will feature:

Visual Elements: 3D models of letters and objects to help children visually associate letters with their corresponding sounds and meanings.

Auditory Components: Pronunciation guides and interactive voice feedback to reinforce auditory learning.

Kinesthetic-Tactile Interactions: Interactive activities that allow children to manipulate letters and objects, enhancing their learning through physical interaction.

C. Model specifications

Certain hardware and software components are required for the development of an AR application. The Android SDK, which includes development tools, an emulator, a real Android device, platform tools, the SDK platform, and Google APIs, are essential prerequisites. These elements are essential to developing and evaluating the application. The Sceneform SDK is another useful tool that lets you make dynamic augmented reality apps without having to know how to utilize OpenGL. An Android Studio plugin, a high-level scene graph API, and a physically based renderer are all included in the Sceneform SDK. The scene graph is a data structure that uses transformable nodes to anchor 3D objects within the scene and specify how virtual items interact with one another. A technique called Physically Based Rendering (PBR) makes sure that

every 2D and 3D object on the screen has the right illumination, enabling accurate depictions of a variety of surface types. Furthermore, ARCore is essential to the application since it allows Android smartphones to access AR features without the need for additional sensors by integrating 3D models into the real world with ease via object tracking, light estimation, and environmental awareness.

D. System Design Architecture

As seen in the image below, the suggested solution application is created with a clearly defined system architecture. The diagram depicts the interrelationships between components and how they work together to achieve their desired functionality. The application method is detailed in detail below.

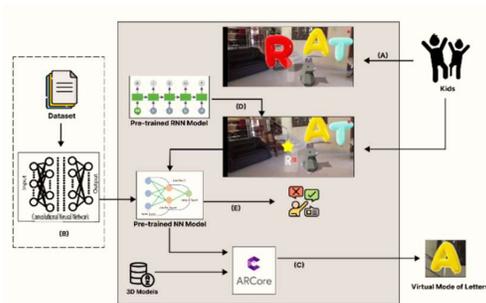


Fig. 3. System Solution Architecture

- Data Processing:** The system processes word datasets using CNNs for feature extraction, forming the foundation for predictive tasks.
- Sequence Validation:** RNNs predict and validate letter sequences, ensuring accuracy in spelling generation.
- Adaptive Optimization:** A pre-trained NN dynamically adjusts difficulty, tailoring the experience to individual learning needs.
- Interactive AR Learning:** ARCore integrates 3D letter models into an immersive learning environment, enabling hands-on interaction.
- Feedback & Evaluation:** Real-time feedback corrects errors, while analytics assess learning outcomes to enhance educational effectiveness.

As an illustration, the application displays the word "DOG" in three dimensions on the ground.

- The three-dimensional letters "D," "O," and "G" can be seen on the device's screen floating in midair.
- It is necessary for the youngster to recognize the proper letter sequence for "DOG" and tap on them in that order.
- Making an item associated with the word visible aids in the child's easier letter memory.
- The application instantly displays whether the selected letters are right or wrong.

This interactive feature engages children in the learning process and helps them visualize how letters form words. Developers leverage Java and ARCore to create sophisticated augmented reality (AR) applications for

Android devices. ARCore uses advanced computer vision techniques to meticulously track the physical environment and accurately position virtual objects within it. For this AR application, developers utilize Sceneform to create 3D models, employing 3D modeling software like Blender to design significant letters and objects, incorporating pre-built 3D animal items and alphabetic letters. Once created, the 3D models are exported in Sceneform-compatible formats such as glTF or OBJ, then imported into the Sceneform Android Studio plugin for customization and accurate positioning within the AR environment. Model generation with Blender, format export, Sceneform integration, environment monitoring by ARCore, and real-time display of AR models—which enable users to interact with virtual items superimposed on their real surroundings—are some of the crucial elements in this process. Additionally, the application integrates visual, auditory, and kinesthetic-tactile modalities to create a comprehensive multisensory learning experience. This meticulous process ensures an immersive AR experience, enhancing the educational potential of the application by engaging multiple senses for a holistic learning approach.

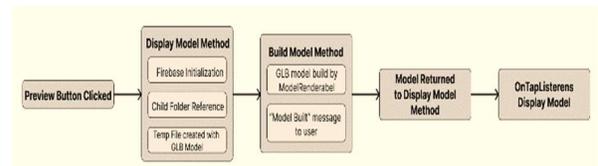


Fig.4. Block diagram to display the AR mode

- To access the AR fragment page, children must first activate the ARMode button and click on the flashcard surface.
- The Firebase database is built up using the display model technique.
- The child node of the scene graph has a 3D model associated to it.
- A temporary file is produced for the download of the model.
- The build model method is used to construct the 3D model at runtime, and it is connected to the scene graph node.
- The model appears on the tapped node in the AR fragment when an on-tap listener is enabled.
- To move and resize models horizontally within the scene graph, utilize a transformable node.
- Quicker CNN generates the most likely alphabetic letter prediction by processing preprocessed pictures of 3D letters.

To minimize the error between predicted output and actual labels, the Faster CNN model undergoes training with a preprocessed dataset divided into training and validation sets, using gradient descent and backpropagation. The validation set evaluates the model to ensure it does not overfit the training data. Once validated, the trained Faster CNN model can instantly identify 3D letters in the AR environment. After receiving

the 3D letter input image, the model guesses the associated letter and presents it for the child to engage with in the augmented reality environment. Additionally, children can tap on a letter to hear its pronunciation, reinforcing spelling skills through auditory feedback.

Because recurrent neural networks (RNNs) can capture the sequential nature of language and voice, they have been effectively used to tap on 3D letters and pronounce words. Recurrent neural networks (RNNs) are a kind of neural network that processes sequential data one input at a time, applying the "memory" of prior inputs to guide the processing of subsequent inputs. The process is here,

- A trained RNN model can predict a letter's or word's pronunciation by tapping on 3D letters repeatedly.
- The input for the model is a series of taps that, in an augmented reality setting, correspond to individual 3D letters.
- The encoded feature vector of every tap includes orientation, size, and position data.
- Through the sequential processing of each feature vector, the RNN updates its internal state.
- A softmax layer is used to provide a probability distribution for the pronunciation prediction of the model's output.
- The RNN model is trained using a labeled dataset of taps and the pronunciations that go along with them.
- Through the use of backpropagation, parameters are gradually changed during training.
- The program provides feedback on spelling accuracy and pronounces words using pre-recorded voice. The software maintains a database with the proper pronunciations of every word.
- The software plays the relevant audio and checks the word construction sequence against the right spelling as users tap letters to form words.
- The software improves learning through interactive aural feedback by providing remedial input when a word is written incorrectly. This feedback takes the form of slower pronunciation or reminders to try again.

IV. IMPLEMENTATION

This illustrates how the application is used in the sections listed below.



Fig.5. Selected Animal (DOG) Fig. 6. Real-time preview

In Figure 6, the set of animals available for selection by the child is displayed. The child enters the AR Mode for the chosen animal by clicking "DOG." The child's succeeding period is depicted in Figure 7. After choosing "DOG," the word "DOG" appears on the screen, and the application shows a "3D virtual DOG" on the ground with

the 3D letters "D," "O," and "G" floating in midair and visible through the screen of the device.

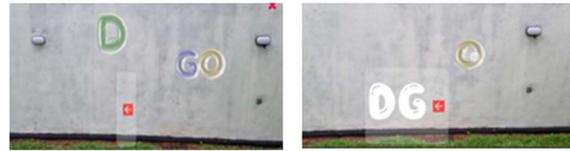


Fig.7. Letters displayed on the surface Fig. 8. List down letters in order

Figure 8 depicts the next phase after showing all of the letters and their connected objects. At this point, kids can click on the letters in the right order after learning the letter sequence for the word "DOG". A youngster can hear a letter's pronunciation spoken aloud by clicking on it. If the letter clicked is in the proper order, it appears in the environment, as seen in Figure 3.

If the selected letter is not in the correct order for the word "DOG," the application will notify you. The youngster must continue to select the correct letters to construct the word, as shown in Figure 9. Upon completing the task, children receive feedback on whether the word was spelled correctly or incorrectly.

Figures 10 and 11 show the feedback notifications.



Fig.10. Correction Feedback



Fig. 11. Wrong Feedback



Fig 12. Words creation in 2D version Fig 13. Feedback

In Figure 12, Kids can see an illustration of the word "DOG" in addition to the letters that make up the word. The youngster can form the word by placing the letters in the right sequence. The feedback alerts that were produced as a result of this activity are shown in Fig 13.

V. RESULTS AND ANALYSIS

This application enhances multisensory learning through augmented reality (AR). To assess teachers' and parents' perceptions and intentions regarding its use by children, a set of 15 statements was evaluated using a 7-point Likert scale. Here are the top seven statements, highlighted. The most highly rated comment was "The child is happy and engaged when participating in the activities used to teach letters within a word". This prompted further exploration among teachers and parents.

TABLE 1: SUMMARIZES THE PERCEPTIONS AND INTENTIONS OF TEACHERS AND PARENTS REGARDING THE EDUCATIONAL GAME

	Statement	Mean (m)	SD
1	The child feels excited and content while engaging in activities designed to teach letters within a word.	6.02	1.14
2	This app helps children remember the words associated with different objects, such as animals.	5.64	1.54
3	This app assists children in memorizing the individual letters that make up a word.	5.01	1.67
4	This app allows children to practice arranging letters to form complete words.	4.96	1.19
5	This app offers feedback to the child to aid in their learning process.	4.35	1.68
6	This game creates an interactive, real-time environment that facilitates word formation.	5.85	1.24
7	The features of this app are compatible with traditional educational methods.	4.98	1.36

Based on these findings, it can be concluded that the app helps young children learn and retain the letters that makeup words and how to associate words with things. Children using the application engage in real-time interactive activities, receive feedback, and exhibit interest and enjoyment. Moreover, the app's functionalities complement traditional learning methods, making it a potentially valuable tool for children in developing literacy skills overall.

The evaluation of teachers' and parents' perceptions regarding the educational app not only highlights its effectiveness in engaging children and supporting fundamental literacy skills but also underscores its impact on multisensory learning. The app's highest-rated statement, with a mean score of 6.02, reflects strong agreement among respondents that it successfully engages and satisfies children during activities focused on learning letters within words. This high level of engagement is particularly significant as it promotes multisensory learning, where children are actively involved through visual, auditory, and tactile interactions facilitated by the app's augmented reality features.

Furthermore, positive perceptions regarding the app's ability to aid memorization of words associated with objects (mean score of 5.64) and letters within words (mean score of 5.01) highlight its role in supporting multisensory learning experiences. By integrating interactive elements that stimulate multiple senses, such as visual recognition of letters, auditory feedback, and tactile manipulation of virtual objects, the app enhances children's cognitive engagement and retention of educational content.

VI.RECOMMENDATIONS

To further leverage the app's impact on multisensory learning, developers should continue enhancing interactive features that cater to different sensory modalities. This includes refining visual interfaces for clarity, optimizing audio feedback for comprehension, and integrating tactile interactions that simulate hands-on learning experiences. By enhancing these multisensory elements, the app can better accommodate diverse learning styles and preferences, thereby maximizing its educational

effectiveness across various educational settings and learning environments.

VII.CONCLUSION

In conclusion, the educational app leveraging augmented reality technology not only excels in engaging children and supporting literacy skills but also significantly enhances multisensory learning experiences. By emphasizing interactive and sensory-rich activities, the app fosters deeper cognitive engagement and holistic learning among young learners. Moving forward, continued enhancements in multisensory features will further solidify the app's role as a valuable educational tool that promotes comprehensive learning and development in early childhood education.

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Design and Implementation of a Web Tool for ISO 22000:2018 Compliance in Sri Lanka's Cake Industry

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Abstract - In response to evolving food safety regulations, Sri Lanka's cake industry faces challenges adhering to ISO 22000:2018 standards, which require a comprehensive food safety management system (FSMS) including hazard analysis, risk management, and traceability. Implementing and maintaining these standards is challenging. Thus, this research aimed to design and implement a specialized web tool to facilitate compliance with these regulations. The newly developed online web tool addresses these hurdles by providing a user-friendly platform guiding businesses through the establishment and maintenance of an ISO 22000:2018-compliant FSMS. Key features of the web tool include pre-configured templates and checklists tailored to the cake industry's specific needs, covering critical aspects of ISO 22000:2018 implementation such as food safety policy development, hazard analysis, control measures, and corrective actions. Interactive guidance and support are integrated, offering step-by-step assistance throughout the implementation process. Furthermore, a centralized document management system allows users to store, organize, and access necessary documentation for ISO 22000:2018 compliance. Evaluation of the web tool's user experience and interface yielded promising results, with significant improvements observed post-evaluation. This signifies the tool's efficacy in enhancing user experience and usability, contributing to higher mean values post-evaluation. Overall, the development of this online web tool represents a substantial leap forward in facilitating ISO 22000:2018 compliance within the cake industry. By providing accessible guidance, resources, and support, the tool empowers businesses to strengthen their food safety practices, mitigate risks, and reinforce consumer trust in the quality and safety of cake products.

Keywords - cake industry, food safety management system, hazard analysis, web tool

I. INTRODUCTION

The cake industry, within the scope of food processing, is notably susceptible to contributing to foodborne illnesses due to inadequate safety practices [2]. The demand for cake products has witnessed a significant surge over the last decade, solidifying its position as a key player in the international food market [6]. Numerous potential hazards loom at different stages of the process lines of the cake products. For instance, the acceptance and storage of raw materials may expose products to contaminants such as birds, rodents, insects, and their waste products [4].

The application of ISO 22000 in the bakery and cake industry facilitates compliance with regulatory requirements, both at the national and international levels (Sîrbu, 2023). As food safety regulations continue to evolve and become more stringent, ISO 22000:2018 provides a proactive and systematic approach to staying ahead of compliance mandates [2]. This is particularly relevant for businesses engaged in the export of bakery and cake products, as adherence to global food safety standards becomes a prerequisite for market access.

The cake industry faces several common challenges, such as a lack of backward linkage with local suppliers, unavailability of raw materials at the right time and place, insufficiently trained human resources, and a deficit of knowledge concerning food safety [4]. These issues underline the pressing need for implementing a Food Safety Management System (FSMS). Although there is awareness of the benefits of ISO 22000:2018 FSMS certification, various obstacles hinder its effectiveness during the implementation process. Notable obstacles include poor employee qualifications, internal resistance to change, FSMS implementation costs, lack of top management commitment, increased workload, time constraints, and misleading consulting services [7].

Therefore, the primary aim of this study is the development of a web tool to enhance the efficiency of the ISO 22000:2018 standard implementation process, with a specific focus on the cake industry. The study centres on a prominent cake chain in Sri Lanka, which is currently in the early stages of implementing ISO 22000:2018 within their organization. The proposed web tool aims to address the unique challenges and obstacles faced during the implementation of food safety standards, particularly ISO 22000:2018, within the cake industry. The resulting web tool has the potential to become a valuable resource for cake companies, unlocking new opportunities, improving operational efficiency, and ensuring long-term compliance with food safety standards.

II. LITERATURE REVIEW

Foodborne illnesses represent a significant threat globally, impacting health and economic development [2]. Ensuring a safe food supply is essential, especially with advancing technologies presenting new food safety challenges [5]. The World Health Organization (WHO) defines food safety as a comprehensive process encompassing food production, handling, storage, and preparation, aiming to prevent contamination and infections in the food production chain [9].

The International Organization for Standardization (ISO) also emphasizes that food safety ensures no harm to consumers when food is prepared or consumed as intended [3].

Increasing consumer awareness and technological progress in food processing have highlighted the importance of food safety. Modern consumers prioritize quality and safety, prompting food producers to adopt various Food Safety Management Standards (FSMS) [6]. These standards are vital for ensuring consistent product quality and minimizing health risks [7]. FSMS, particularly those by ISO, play a crucial role in food safety. The ISO 22000 family of standards, established in 2005 and revised in 2018, offers a systematic approach to managing food safety hazards throughout the supply chain [3]. ISO 22000:2018 is particularly significant in the bakery and cake industry, where complex processes and numerous ingredients necessitate stringent safety measures [1]. By implementing ISO 22000:2018, bakery and cake producers can systematically identify potential hazards, ensuring food safety and quality [4].

The standard addresses unique challenges in this sector, such as ingredient diversity and intricate processing steps, and promotes Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) principles [7]. This comprehensive approach reduces the risk of contamination and foodborne illnesses [1]. ISO 22000:2018 certification also provides a competitive edge, signalling a commitment to high safety standards and fostering consumer trust [4]. It aids compliance with evolving national and international regulatory requirements, crucial for businesses in the global market [8].

III. METHODOLOGY

A. Information Collection

Before the design phase, the requirements of the tool were clearly identified. The information collection was conducted at the production facility of Perera and Sons' Bakers (Private) Limited in Madinnagoda, Rajagiriya, Sri Lanka to collect detailed requirements for the web tool. The focus was on vanilla cake production to maintain a manageable scope and timeline, covering areas such as processing, quality assurance, maintenance, stores, management, and supply chain. The procedure involved interviewing responsible personnel, conducting focused group discussions, and reviewing previous documents. A schedule was prepared to facilitate systematic information collection. Meetings with personnel were arranged based on their availability.

According to ISO 22000:2018, the necessary documents were divided into organizational and operational levels. Organizational information included internal and external issues relevant to the FSMS, latest management review meeting minutes, production meeting minutes, interested parties and their requirements, FSMS scope, process interactions, food safety policy, visitor policy, glass policy, food safety team roles and responsibilities, risks and opportunities, FSMS objectives, external providers, business registration reports, environmental pollution licenses, and payment bills (electricity, water, etc.). This information was gathered by interviewing various management roles such as the General Manager (GM), Quality Assurance Manager (QAM), Production Manager (PM), Human Resource Manager (HRM), Supply Chain Manager (SCM),

Maintenance Engineer (ME), and National Sales Manager (NSM). Focused group discussions provided operational information from quality assurance and production personnel. Key Practices (GMP), Pre-Requisite Programs (PRPs), traceability plan and test reports, product description, characteristics and shelf life, raw material specifications, flow diagram, hazard analysis and identification, verification plan, Hazard Analysis and Critical Control Point (HACCP) plan, Operational Pre-Requisite Program (OPRP) plan, calibration plan and details, food safety procedures, external water analysis reports, food grade certificates, Material Safety Data Sheets (MSDS), medical reports, and pest control monitoring.

B. Development of the Web Tool

The architecture and user interface of the web tool was designed based on the gathered requirements. The home page needed to attract the audience by providing essential information about the services offered. The sidebar was designed to include headers for pages such as About, Home, Process, and Implementation Guide. In the Implementation Guide section, a diagram featuring ten boxes was created to represent the ten clauses of the ISO 22000:2018 standard, with each box containing detailed instructions for implementation. In the Process section, a flow diagram of the vanilla cake production process was included, with each step providing downloadable document templates required for the process. Before writing the code, the project folder was meticulously set up with a proper structure, adhering to the hierarchical order.

The web tool was developed using React and JavaScript, the initial step involved setting up the development environment with Node.js and a code editor such as Visual Studio Code. Subsequently, a new React application was created using Create React App, which facilitates project initialization. Components were organized logically, employing reusable components to enhance maintainability. JavaScript was utilized as the foundation for functionality, particularly through state management with hooks like 'useState' and 'useEffect'. Additionally, libraries such as were integrated for API calls and React Router were used for navigation. For styling, Cascading style sheets (CSS) or frameworks like Tailwind CSS were leveraged to achieve a responsive design. Testing was conducted using tools like Jest and React Testing Library to ensure reliability. Lastly, performance optimization was achieved by analyzing bundle sizes and utilizing lazy loading techniques to enhance user experience.

C. Evaluation of the Web Tool Effectiveness

After the final preparations of the web tool, it was launched as a beta version to test its effectiveness. It was given to the quality assurance department of Perera and Sons' Bakers (Private) Limited which consists of twelve employees, five executives and seven supervisors within it. They were the members of their food safety team proving that the evaluation panel has a prior understanding of the ISO 22000:2018 standard. An unannounced pre-evaluation paper was given to the evaluation panel after one week of web tool handling. Then training was conducted regarding the standard along with a demonstration of the web tool. After that training, an unannounced post-evaluation paper was given to the same panel. Both were multiple answer questions. Thereafter both pre- and post-evaluation marks were analyzed to identify any

significant difference that prevails. When preparing the evaluation papers, each paper bundle was designed accordingly to meet the expected outcomes of the web tool. The pre-evaluation paper questions were at the beginner level while the post-evaluation paper questions were at the medium level. Both paper sets were equipped with fifteen multiple-choice questions allocating thirty minutes each.

D. Evaluation of the Overall Performance of the Web Tool

To evaluate the overall performance of the web tool, specific attributes were determined and incorporated into a ballot paper, which was distributed to a panel after they had one week of experience with the tool. The attributes, which were identified with input from technical experts, included navigation, intuitiveness, reliability, loading time, responsiveness, feature set, compatibility, help resources, clarity, consistency, and engagement. Each attribute was rated on a qualitative scale from one to five. After the evaluation period, the completed ballot papers were collected and analysed to assess the web tool's overall performance.

E. Statistical Analysis

MINITAB version 18 was used to statistically analyse all the results obtained from pre- and post-evaluation papers regarding the web tool's effectiveness. A paired t-test was performed, and the significant difference was defined at $p < 0.05$ for the results of all analyses with both pre- and post-evaluation results. The results obtained were expressed in a box plot of differences. Results of the overall performance were analysed using the Wilcoxon sign rank test.

IV. RESULTS

A. Characteristic Features of The Developed Web Tool

The web tool was developed to provide enough guidance to the industry for ISO 22000:2018 implementation along with hazard analysis details for the vanilla cake production process. The home page describes the importance of adhering to a web tool rather than depending on tangible materials for the ISO 22000:2018 implementation process. The instructions were given with sufficient visual aids aiming a better customer retention. Also, the navigation bar guides users up to the point without any confusion as the home page provides a brief demonstration before handling the tool. Therefore, users enter with enough confidence and try to learn the content "Fig. 1a".

The 'Implementation Guide' page initiates the navigation with attractive visual aids, and it guides the user step by step into every clause of the standard "Fig. 1b". In the introductory content always ask the user to stay and learn while calming down the user at confusing stages through phrases like, 'Don't worry, we got you covered'. In the 'Implementation Guide' page, all ten clauses are displayed in a flow diagram, showing the user the sequence of implementation. According to the user competency, they can access the clause and follow the guidelines for implementation "Fig. 1c". After clicking each box, the user will navigate to a page that provides a detailed description of the clause. On this page, users are asked to read the information carefully and follow the instructions. Also, required document templates are attached in each clause with instructions on how to fill and maintain them. On each page, there are navigations for the previous and upcoming clauses therefore, users can flow easily without confusion "Fig. 1d".

In the 'Process' page, the user can witness the complete flow diagram of the vanilla cake production process. In each box, all the instructions along with templates of checklists and records are included. Before introducing the flow diagram, a brief introduction was included mentioning all the required documents to be maintained to comply with the standardization process of vanilla cake manufacturing.

B. The Web Tool Effectiveness

According to the results of the pre-evaluation and post-evaluation, the mean percentage value of post-evaluation marks was higher than the mean percentage value of pre-evaluation marks. The evaluation papers were designed to justify how effectively the web tool applies to the organization. The questions were prepared based on the clauses of the ISO 22000:2018 standard. Two data sets were compared using statistical analysis and the obtained 'p' value for the test was 0.002 under the 95% confidence interval for the mean. According to the resulting 'p' value, the null hypothesis was rejected, and it confirmed that there is a significant difference between pre- and post-evaluation marks showing that the post-evaluation marks were higher than the pre-evaluation marks. Therefore, the evaluation panel marks showed that there was an 18.6% increase in marks after the web tool handling and it confirmed that the tool effectiveness was at a higher level. The statistical results are given in the box plot "Fig. 2a".

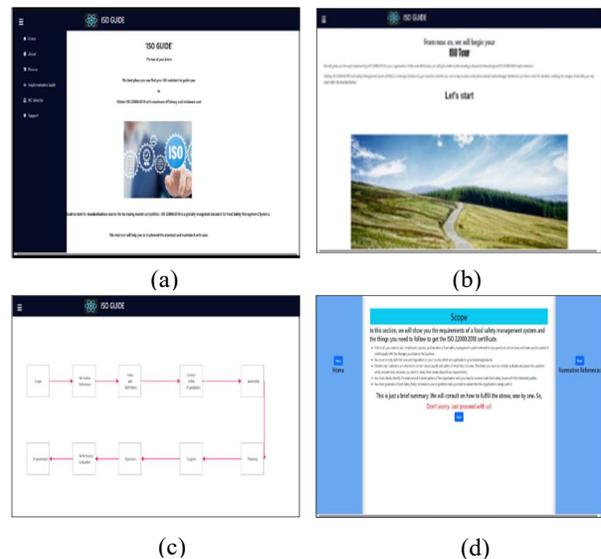


Fig. 1: (a) Home page and navigation bar (b) Interface of the 'Implementation Guide' section (c) Ten clauses in the ISO 22000:2018 standard displayed on the 'Implementation Guide' page (d) Instructions are displayed in each clause and navigations to the next and previous clauses.

C. The Overall Performance of the Web Tool

Overall performance was evaluated through a ballot paper. The ballot paper consisted of eleven important attributes and the rated scores are graphically illustrated in Figure 2b. The ballot paper scores were further analysed statistically for each attribute to check whether they were above the neutral point of the five-point scale. If the 'p' value is below 0.05, it confirms those results are above the average and the overall performance of the web tool is satisfying.

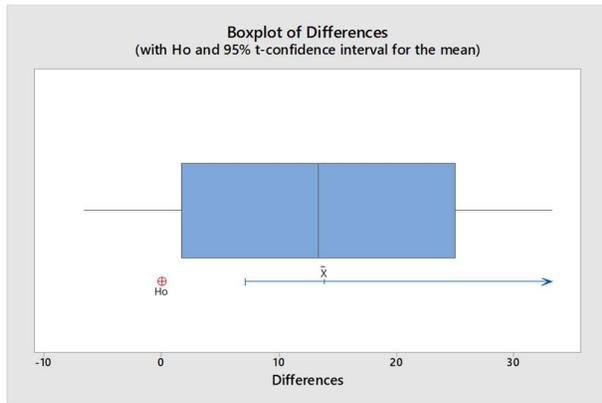


Fig. 2: (a). Box plot of differences between two evaluation papers

All the attributes were below 0.05 except for the ‘feature set’. Therefore, the overall performance of the web tool was tested positive except for the ‘feature set’ attribute. Feature set denotes that the tool offers all the necessary features for its intended purpose. But the resulting ‘p’ value for that attribute was above 0.05 showing that it doesn’t fulfil the intended objectives of the web tool. Reasons for such an outcome might be inadequate testing which can result in bugs, glitches, and other technical issues, and over-engineering issues such as the addition of complex features that lead to a cluttered and overwhelming user experience. Therefore, further improvements should be conducted not only to overcome the existing issues but also to increase the overall performance as well.

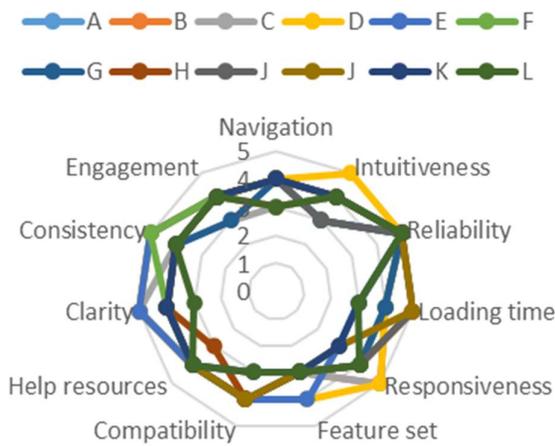


Fig. 2: (b) Radar chart for the scores of different attributes.

V. DISCUSSION

The application of information technologies (IT) in the food processing industry spans various domains, including smart packaging, automation and control technology, standards compliance, and production management. However, efforts to address pressing food safety issues through advanced technologies, particularly artificial intelligence (AI), are still emerging. One notable application is the mobile farming information system, which significantly reduces the complexity of manual traceability data recording for farmers. This system can facilitate both public and private traceability data collection, enhancing consumers’ confidence in healthy

food choices by providing clear food traceability [12]. Similarly, the BioScan mobile application is used to assess food safety levels and manage food safety and quality systems, plant management systems, and Laboratory Information Management Systems (LIMS) [11]. AI technologies are also making significant strides in food safety. Researchers in Singapore developed an AI-driven nose that detects meat freshness by reacting to gaseous compounds produced during spoilage. This innovation can help reduce food waste and ensure safe consumption by verifying the freshness of meat regardless of expiry dates [13].

The expansion of digital Food Safety Management Systems (FSMS) is ongoing, with new Internet of Things (IoT) devices increasingly being integrated into the foodservice industry. As the 5G mobile network expands, these technologies are expected to proliferate. Some foodservice businesses are already experimenting with digital FSMS, such as using IoT cameras with computer vision systems to monitor employees’ food preparation activities for proper safety practices [14]. Several electronic tools are available to food business operators for managing food risks, including tools for hazard identification, characterization, risk monitoring, and emerging risk identification. Platforms like FOODAKAI provide comprehensive solutions for hazard monitoring and risk management, demonstrating the growing capabilities of electronic tools in food safety [15]. Despite the vast amounts of data generated worldwide related to food safety, only a limited number of Big Data tools are currently applied to this field. The potential for Big Data in enhancing food safety management remains largely untapped [16]. However, the development of mobile apps and software for FSMS continues to grow, offering opportunities to design and implement these systems for any business using smartphones.

In Sri Lanka, the application of AI and electronic systems in the food and beverage industry is still developing. This presents a significant opportunity to address the growing needs of companies complying with ISO 22000, including the implementation of electronic Hazard Analysis and Critical Control Points (e-HACCP) systems. The developed web tool for ISO 22000:2018 compliance in Sri Lanka’s cake industry is a pioneering effort in this context, providing a valuable resource to streamline the compliance process. While the current prototype of the web tool has shown effectiveness, it cannot yet be compared with existing literature due to its unique context. Future research should focus on enhancing the tool’s feature set, addressing technical issues, and expanding its functionalities to include real-time hazard monitoring and AI-driven analytics. Incorporating user feedback will be crucial for refining the tool and ensuring it meets the practical needs of its users. By leveraging advanced technologies and addressing these current limitations, future iterations of the web tool can better support the food industry in achieving stringent food safety standards.

VI. CONCLUSIONS

The integration of information technology (IT) in food safety management is advancing, with various applications yielding significant benefits. The developed web tool for ISO 22000:2018 compliance in Sri Lanka’s cake industry demonstrates substantial promise, offering a valuable resource for the food industry to implement these standards effectively. The specific objectives of the web tool were achieved,

providing comprehensive guidance for industries through the ISO 22000:2018 standard implementation process and the Hazard Analysis and Critical Control Points (HACCP) plan for vanilla cake manufacturing. This tool addresses common challenges in the industry, such as staff incompetence, documentation burden, employee resistance to change, and insufficient management commitment. Moreover, it offers potential cost reductions by minimizing the need for external consultation. The effectiveness of the tool was confirmed through statistical analysis, showing a significant improvement in users' understanding and application of the standards. The overall performance was positive across ten attributes, apart from the 'Feature set.' This indicates that while the tool is largely effective, there is room for improvement in minimizing over-engineering and increasing testing frequency to ensure a seamless user experience. In conclusion, the developed web tool serves as a significant step forward for ISO 22000:2018 compliance in Sri Lanka's cake industry. It not only simplifies the implementation process but also helps mitigate common issues faced by the industry. With further improvements and research, this tool has the potential to become an even more robust resource for the food industry, enhancing food safety management and compliance.

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Formulation of Frozen Ginger Puree Cubes Using Ginger in Sri Lanka (*Zingiber officinale*) for the Export Market

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Abstract— Ginger in Sri Lanka, characterized by its small rhizomes and white fibrous flesh, boasts a stronger sensory attribute compared to other varieties such as Chinese and Rangoon ginger. This makes it particularly suitable for producing export-oriented value-added products. Despite its potential, research on using Ginger in Sri Lanka in such applications is limited. This study aimed to develop frozen ginger puree cubes using Ginger in Sri Lanka to enhance their quality, stability, and sensory appeal for the export market. High-quality ginger rhizomes were selected, and five ratios of ginger to water were tested. Xanthan gum was incorporated as a stabilizing agent to address the observed stickiness of the puree cubes. Thawing rate assessments revealed that higher water content led to faster thawing and increased stickiness. Adding xanthan gum (0.5%) effectively mitigated stickiness, with higher concentrations further improving texture and reducing stickiness. pH stability analyses indicated minimal changes post-freezing, preserving the product's flavour profile. Microbial analysis confirmed that microbial counts remained within acceptable thresholds during storage, attributed to the heat treatment of the raw ginger. Based on the sensory evaluations the selection of the most promising formulations were carried out and they are Water 30: Ginger 70, Water 20: Ginger 80, and Water 10: Ginger 90, all with 0.5% xanthan gum. Among these, the formulation with Water 10: Ginger 90 and 0.5% xanthan gum emerged as the most preferred choice, demonstrating superior appearance, aroma, taste, and texture. This research offers practical strategies for producers to improve frozen ginger puree cubes' quality, acceptability, and export success through optimized formulations

Keywords -ginger, frozen puree cubes, xanthan gum, sensory appeal, export market

I. INTRODUCTION

Ginger (*Zingiber officinale*) significant global culinary and medicinal traditions, extensively cultivated in tropical and subtropical regions such as Asia and Africa [1]. Originating from Southern China, Southeast Asia, and India, ginger has become a staple ingredient in various cuisines. Sri Lanka is a notable cultivator of diverse ginger varieties [2]. Historically used in Chinese, Ayurvedic, and Unani medicines, ginger is valued for its therapeutic properties in alleviating pain, inflammation, and gastrointestinal discomfort [1];[3].

Ginger is traditionally esteemed as a spice, so ginger has expanded its use into value-added products. In Sri Lanka and globally, ginger-infused products such as gingerbread, cookies, toffee, cakes, ginger ale, and ginger beer have

become culinary staples, showcasing its versatility [2]; [4]. Its distinct flavor profile, attributed to compounds like bisabolene and its pronounced pungency, contributes to its widespread use as a spice but also in creating value-added products [5]. Beyond culinary applications, ginger is crucial in food preservation and enhancement. Its incorporation into pickles, sauces, and marinades imparts a unique flavor and aids in preserving these culinary creations [6]. With antimicrobial properties, ginger is a natural choice for food preservation aligning with both traditional practices and modern culinary preferences [7]; [8]

Sri Lankan ginger is renowned for its unique sensory attributes, characterized by small rhizomes and white fibrous flesh, which impart a stronger flavor and aroma compared to varieties like Chinese and Rangoon ginger [9];[10]. This robust sensory profile makes Sri Lankan ginger particularly suitable for producing value-added products aimed at the export market [2]. Despite its potential, research on utilizing Sri Lankan ginger in the development of such products is limited. This study aims to bridge this gap by focusing on the formulation of frozen ginger puree cubes to enhance their quality, stability, and sensory appeal for international markets.

The global demand for high-quality ginger products is rising, driven by increasing consumer preference for natural and health-enhancing ingredients. Frozen ginger puree cubes offer a convenient and versatile option for consumers and food manufacturers, providing fresh ginger flavor without the need for peeling and chopping. However, achieving the right balance of quality and sensory appeal in frozen products can be challenging. Key factors include maintaining the ginger's flavor and aroma, ensuring textural stability during freezing and thawing, and preserving the product's overall integrity. This research offers practical strategies for producers to improve frozen ginger puree cubes' quality, acceptability, and export success through optimized formulations.

II. LITERATURE REVIEW

Ginger (*Zingiber officinale*), acclaimed globally for its culinary versatility and medicinal properties, faces intricate challenges in preservation, particularly when processed into puree cubes. The preservation journey begins with the post-harvest handling of ginger, where maintaining optimal moisture levels is crucial to prevent spoilage and preserve its distinct flavour and aroma [11]. Freshly harvested ginger in Sri Lanka typically contains high moisture content (85-90% wet basis), which poses challenges for long-term storage. The

risk of fungal and microbial growth is heightened, necessitating careful management during handling and processing [9]; [10]. To combat these risks, drying ginger emerges as a viable solution. Drying extends shelf life significantly and concentrates ginger's flavour, making it ideal for various culinary applications such as spice blends, teas, and baked goods [12]. The compact nature of dried ginger reduces storage space requirements, enhancing cost-effectiveness for producers and retailers. In contrast, freezing ginger as puree cubes preserve its freshness, aroma, and nutritional integrity more effectively than drying [13]. Puree cubes offer convenience by eliminating the need for peeling and chopping, appealing to commercial kitchens and households seeking efficient preparation options. The frozen form also retains ginger's natural texture, which is crucial for applications where texture plays a pivotal role in culinary creations. However, preserving ginger in the form of puree cubes presents multifaceted challenges. Rapid degradation and nutrient loss during storage are primary concerns, highlighting the importance of stringent temperature and humidity controls throughout the supply [12]. Maintaining temperatures below 12°C mitigates chilling injury, characterized by flesh degradation and discoloration, while low humidity levels prevent shrivelling and excessive moisture curbs Mold formation [14].

Moreover, the preservation process must address ginger's natural decline in pungency over time, attributed to the breakdown of capsaicinoids, essential compounds responsible for its characteristic spiciness [15]. This nuanced challenge underscores the necessity for precise processing techniques and quality control measures to uphold ginger's sensory attributes and nutritional value in puree cube formulations. While drying and freezing as puree cubes offer distinct advantages in ginger preservation, each method requires meticulous attention to moisture balance, temperature regulation, and quality maintenance. Addressing these challenges effectively ensures that ginger retains its sensory appeal and nutritional benefits, meeting consumer demands for high-quality, natural products in the global marketplace.

III. METHODOLOGY

A. Raw Materials

Frozen ginger puree cubes utilized food-grade ingredients to ensure quality and safety. These included fresh local ginger rhizomes, filtered water, citric acid, and Xanthan gum. Additionally, essential instruments such as blenders, ice cube trays, and food-grade polyethylene wraps were employed in the manufacturing process. Xanthan gum was procured from an external supplier, while the remaining ingredients were sourced from Bio Foods Pvt. (Ltd.) organic spice factory premises, Dambulla, Sri Lanka.

B. Process for Preparing Frozen Ginger Puree Cubes

Figure 1 shows the general flow diagram of frozen ginger cube preparation. The preparation of ginger puree begins with selecting the finest rhizomes (8-9 months after planting), which were then thoroughly washed and peeled to remove the tough outer skin. The fresh ginger rhizomes were diced into 4 mm particles using a dicer machine to ensure proper steam transfer during the subsequent heat treatment. The diced

ginger was heat-treated at 78°C for 30 seconds to ensure food safety by inactivating pathogens like *Salmonella* and *E. coli*, and to prevent browning. After heat treatment, the ginger is chopped into smaller pieces to facilitate blending. The ginger pieces were then blended with filtered water and citric acid to create a smooth puree consistency, with Xanthan gum added to enhance texture and stability. Different ratios of ginger and water were used to prepare ginger cubes, each affecting their visual appearance. Ratios ranged from 50% ginger and 50% water to 100% ginger with no water (Figure 2). The puree is poured into ice cube trays and frozen until solid. Once frozen, the cubes were individually wrapped in food-grade polyethylene wraps to prevent freezer burn and maintain freshness, then stored in a freezer until ready for use.

Visual observations assessed appearance, with treatments showing varied textures and structures. Additionally, a sample with removed water (100W:0G*) was included to evaluate changes induced by water extraction.

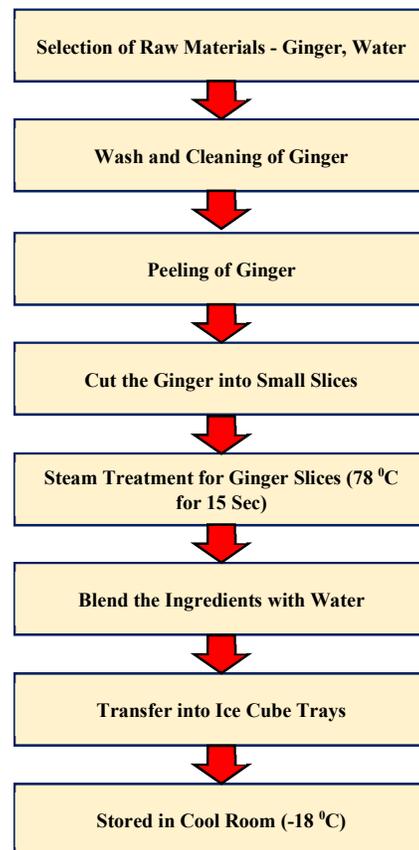


Fig. 1. Flow diagram of frozen ginger cube preparation

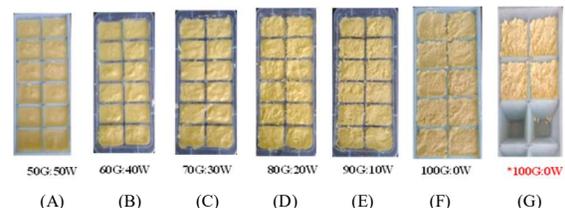


Fig. 2. Diagram of different ratios of ginger and water

TABLE I. TREATMENT COMBINATION OF GINGER AND WATER WITH XANTHAN GUM

Sample Number	Treatment
1	70G:30W:0.1X
2	70G:30W:0.5X
3	70G:30W:1.0X
4	80G:20W:0.1X
5	80G:20W:0.5X
6	80G:20W:1.0X
7	90G:10W:0.1X
8	90G:10W:0.5X
9	90G:10W:1.0X

G: Ginger W: Water X: Xanthan gum

Visual observations were conducted throughout freezing, thawing, and refreezing cycles to evaluate the stickiness of ginger cubes after optimizing different ginger and water ratios. Table 1 summarizes nine treatment combinations, varying in ginger-to-water ratios including Xanthan gum, aimed at enhancing texture in frozen ginger puree cubes.

C. Evaluating Thawing Rate and Stability of Frozen Ginger Puree Cubes

To evaluate the thawing rate of the ginger cubes, their weight change was measured 10 minutes after exposure to room temperature. The cubes were removed from the freezer, allowed to thaw at room temperature, and their weight was recorded at the 10-minute mark. This assessment provided insights into the rate at which the ginger cubes thawed, influencing their sensory characteristics and shelf stability.

D. Determination of pH

pH measurements were conducted at room temperature (25°C) using a pH meter (LAQUA D-17, Yodogawa-ku Osaka, Japan).

E. Determination of Colour Characteristics

Color characteristics were assessed with a colorimeter (CS-10), measuring lightness (L^*), redness/greenness ($\pm a^*$), and yellowness/blueness ($\pm b^*$). These parameters were determined post-preparation of the frozen ginger puree cubes. Chroma (Ch), color difference from the control ($\Delta E1^*$), and total color change ($\Delta E2^*$) were calculated using the respective equations.

F. Determination of Viscosity

Viscosity of frozen ginger puree cubes was measured using a viscometer (TOKIMECINC, Tokyo, Japan) after dissolving in cold water (40C) and hot water (1000C), using specific RPM and spindle size settings.

G. Determination of Moisture

Moisture content of frozen ginger puree cubes was analysed using the oven-dried method, involving drying at 105°C for 24 hours and measuring weight before and after.

H. Microbial Analysis of Frozen Ginger Cubes

The microbial analysis of frozen ginger cube samples involved over 21 days. Samples were retrieved from storage at -18°C. Total plate count assessed viable aerobic microorganisms by diluting and spreading samples on nutrient agar plates. Yeast and Mold tests used selective agar plates. Coliform and *E. coli* tests involved inoculating samples on

selective media to identify faecal contamination indicators and harmful bacteria. These tests ensured the microbiological quality and safety of the ginger cubes, meeting regulatory standards.

I. Sensory Evaluation

To ensure robust results, two sensory evaluations were conducted. Initially, 30 random consumers participated in the first evaluation, focusing on assessing the appearance, colour, aroma, texture, taste, and overall acceptability of frozen ginger puree cube samples labelled as 270 (70G:30W:0.5X), 450 (80G:20W:0.5X), and 774 (90G:10W:0.5X). Using a hedonic 9-point scale, ranging from 1 (least liked) to 9 (most liked), panellists individually evaluated the samples after receiving a briefing on the sensory evaluation procedures. Palate cleansing with water was provided to mitigate any potential inaccuracies in sensory testing.

In the second evaluation, a comparison was made between fresh ginger rhizome, dried ginger powder, and the best ginger cube ratio selected from the initial evaluation. Each sample, consisting of equal amounts (5g) of ginger powder, fresh ginger rhizome, and ginger cube prepared using the selected ratio, was incorporated into separate cups of 20 ml black tea. Panellists, again using a hedonic 9-point scale, assessed attributes such as aroma, flavour, appearance, aftertaste, and overall liking for samples labelled as 200 (dried ginger powder), 425 (ginger puree cube), and 644 (fresh ginger rhizome). As in the first evaluation, panellists received a briefing on sensory evaluation procedures and were provided with water to cleanse their palates between samples to ensure accurate assessments.

J. Statistical Analysis

In the statistical analysis, descriptive statistics including mean, standard deviation, minimum, and maximum values summarized data for pH measurements, viscosity, and moisture content across specified time periods. Analysis of variance (ANOVA) was used to assess differences in pH, viscosity, and moisture among various samples. Sensory data from hedonic scales were analysed with non-parametric Friedman tests due to ordinal data and a small sample size, evaluating consumer scores for appearance, colour, aroma, texture, taste, and overall acceptability across different frozen ginger puree cube samples. Post-hoc Mann-Whitney U tests identified specific pairwise differences when the Friedman test indicated significance.

IV. RESULTS AND DISCUSSION

A. Optimizing Ginger-Water Ratios and Xanthan Gum Concentrations for Quality Frozen Ginger Cubes

In this study, the thawing rate and visual appearance of frozen ginger cubes were evaluated to understand the impact of different ginger and water combinations on these parameters. As depicted in Table 2, the thawing rate, calculated as the change in weight of cubes over time, was analysed for seven treatment combinations, A-G. Treatments A and B, with ratios of 50G:50W and 60G:40W respectively, demonstrated relatively higher thawing rates of 0.040 ± 0.010 g/min and 0.033 ± 0.006 g/min. These higher rates can be attributed to the increased water content facilitating quicker heat transfer during thawing. Treatments C and D (70G:30W

and 80G:20W) exhibited moderate thawing rates of 0.017 ± 0.006 g/min, suggesting a balanced ratio that affected the thawing process less dramatically than higher water content ratios. Treatment E, with the ratio 90G:10W, showed the slowest thawing rate at 0.007 ± 0.006 g/min. This low rate indicates that a higher ginger content relative to water results in slower heat transfer and thus slower thawing. Treatments F and G, where no additional water was added (100G:0W and 100G:0W* respectively), showed thawing rates of 0.020 ± 0.010 g/min and 0.030 ± 0.027 g/min. These treatments had intermediary thawing rates compared to those with added water, highlighting the impact of initial water content and subsequent moisture loss.

Assessing stickiness in frozen ginger cubes after freeze-thaw cycles is critical for evaluating quality. Increased stickiness observed across all treatments (A-G) is attributed to ice crystal formation and moisture release during thawing, affecting texture and usability in various applications, thus influencing consumer satisfaction and product longevity.

TABLE II. THAWING RATE OF DIFFERENT COMBINATIONS OF FROZEN

	Treatment	Mean (g/min)
A	50G: 50W	0.040 ± 0.010^a
B	60G:40W	0.033 ± 0.006^a
C	70G:30W	0.017 ± 0.006^b
D	80G:20W	0.017 ± 0.006^b
E	90G:10W	0.007 ± 0.006^c
F	100G:0W	0.020 ± 0.010^b
G	100G:0W*	0.030 ± 0.027^a

Values are mean \pm SD triplicate analysis- Means with a column superscripted by the same letter are not significantly different at $p < 0.05$, as measured by Turkey's Multiple Comparison tests.

Following initial testing, Treatment C (70G:30W), Treatment D (80G:20W), and Treatment E (90G:10W) were identified as effective ginger-to-water ratios for maintaining optimal texture and appearance while addressing stickiness issues in frozen ginger cubes. Xanthan gum was incorporated at concentrations of 0.1%, 0.5%, and 1% with these selected three ratios to mitigate stickiness. Results indicated that 0.1% Xanthan gum did not effectively reduce stickiness, while 0.5% and 1% concentrations successfully addressed this issue. To align with preferences for minimal additives, concentrations were refined, selecting the following treatments for further analysis:

- Treatment C: Water 30 - Ginger 70 with 0.5% Xanthan Gum
- Treatment D: Water 20 - Ginger 80 with 0.5% Xanthan Gum
- Treatment E: Water 10 - Ginger 90 with 0.5% Xanthan Gum

B. pH Stability in Frozen Ginger Puree Cubes Across Different Water Ratios

The study monitored the moisture content of frozen ginger puree cubes over three weeks of cold storage. Regardless of the selected water, ginger, and Xanthan gum combinations,

moisture content decreased from 85.7% in the first week to 83.2% in the second week, and 81.9% in the third week, indicating a gradual loss that affects texture and quality. The pH levels, measured across various treatment combinations, showed minimal variation and remained close to neutral, similar to raw ginger's natural pH of 5.5 to 6.5 [15]. This stability suggests that different water ratios do not significantly impact acidity, and freezing does not alter the pH, preserving ginger's natural acidity. Consequently, frozen ginger puree cubes can effectively replace fresh ginger in culinary applications, offering a convenient, shelf-stable alternative with extended usability and consistent flavour.

C. Impact of Viscosity on Sensory Characteristics of Frozen Ginger Puree Cubes in Hot and Cold Water

Tables 3 present the viscosity measurements of ginger cubes in cold (4°C) and hot water (100°C), respectively, across three different ginger-to-water ratios with 0.5% xanthan gum. In cold water, the 90G:10W:0.5X sample exhibited the highest viscosity at 125.83 ± 3.82 mPa·s, indicating a thicker consistency, while the 70G:30W:0.5X sample had the lowest viscosity at 77.92 ± 3.15 mPa·s. Similarly, in hot water, the 90G:10W:0.5X sample again showed the highest viscosity at 73.83 ± 1.01 mPa·s, and the 70G:30W:0.5X had the lowest at 64.17 ± 1.44 mPa·s. This demonstrates that higher ginger content leads to higher viscosity, which is more noticeable in cold water.

TABLE III. VISCOSITY OF GINGER CUBES IN COLD WATER (40C) AND HOT WATER (1000C)

Viscosity of ginger cubes in cold water (40C)	
Treatment	Viscosity (mPa·s)
70G:30W:0.5X	77.92 ± 3.15^c
80G:20W:0.5X	114.50 ± 3.46^b
90G:10W:0.5X	125.83 ± 3.82^a
Viscosity of ginger cubes in hot water (1000C)	
70G:30W:0.5X	77.92 ± 3.15^c
80G:20W:0.5X	114.5 ± 3.46^b
90G:10W:0.5X	125.83 ± 3.82^a

Values are mean \pm SD triplicate analysis- Means with a column superscripted by the same letter are not significantly different at $p < 0.05$, as measured by Turkey's Multiple Comparison tests.

D. Colour Variations in Frozen Ginger Puree Cubes

In this study, variations in colour among different ratios of frozen ginger puree cubes were investigated to understand their impact on visual appeal and quality. Results from measurements of lightness (L^*), redness/greenness (a^*), and yellowness/blueness (b^*) revealed distinct differences. The ratio of 90% ginger, 10% water, and 0.5% Xanthan gum exhibited the highest L^* value, indicating a lighter colour, yet showed more intense red and yellow hues (higher a^* and b^* values). Conversely, ratios with higher water content showed lighter colour intensity. These findings underscore how ginger-to-water ratios and additives like Xanthan gum affect colour, crucial for optimizing product aesthetics and meeting consumer expectations.

TABLE IV. COLOR CHARACTERISTICS OF FROZEN GINGER PUREE CUBES

Treatment	'L' value	'a' value	'b' value
70G:30W:0.5X	60.7±1.6 ^a	0.5±0.4 ^b	19.6±0.6 ^b
80G:20W:0.5X	57.7±1.1 ^b	1.1±0.1 ^{ab}	21.9±0.2 ^a
90G:10W:0.5X	56.5±0.6 ^b	1.2±0.0 ^{ab}	23.0±0.6 ^a

Values are mean ±SD triplicate analysis- Means with a column superscripted by the same letter are not significantly different at $p < 0.05$, as measured by Turkey's Multiple Comparison tests.

E. Microbial Safety Assessment of Frozen Ginger Cubes During Storage at -18°C

In this study on frozen ginger cubes, microbial population analysis was conducted to ensure product safety and quality throughout a three-week storage period at -18°C (Table 4). Total plate count results indicated generally stable counts, with a slight increase noted in one sample, possibly due to handling contamination [16]. However, all total plate count values remained within safe limits for frozen foods. Yeast and mold counts showed minimal change or reduction, supported by the inhibitory effect of low temperatures. Importantly, Coliform and *E. coli* were absent in all samples, affirming the efficacy of prior heat treatment in reducing initial microbial loads. These findings collectively confirm the frozen ginger cubes' microbiological safety and quality assurance.

F. Consumer Preference and Sensory Evaluation of Frozen Ginger Cubes

In this study, sensory evaluation was pivotal in assessing the quality and consumer acceptance of frozen ginger cubes. The panelists meticulously evaluated various attributes, including appearance, color, aroma, taste, and texture. Results indicated that samples labeled 450 (80G:20W:0.5X), and 774 (90G:10W:0.5X), which had higher ginger content, exhibited more favorable scores for appearance and color (see Figure 3). After careful consideration, Water 10: Ginger 90 with Xanthan gum 5% emerged as the preferred choice, demonstrating superior attributes in appearance, aroma, taste, and texture.

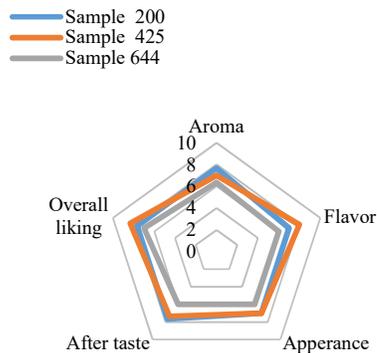


Fig. 3. Sensory Attribute Evaluation of Ginger Puree Cube Sample Combinations Based on Hedonic Test. 270 (70G:30W:0.5X), 450 (80G:20W:0.5X), and 774 (90G:10W:0.5X)

In another phase of sensory evaluation depicted in Figure 4, sample 200 (dried ginger powder) stood out for its strong aroma and aftertaste characteristics. Participants noted that consuming tea with ginger powder resulted in a pronounced flavor that lingered, contrasting with the sensory experiences of 425 (ginger puree cube), and 644 (fresh ginger rhizome) consumption. However, sample 425 (ginger puree cube: 90G:10W:0.5X) received the highest scores across other attributes, indicating broader consumer preference for its overall sensory appeal compared to other samples tested.

TABLE V. MICROBIAL POPULATION ANALYSIS OF FROZEN GINGER

Week	Treatment	TPC/g ($< 10^5$)	Yeast and mold /g ($< 10^4$)	Coliform/g ($< 10^2$)	<i>E. coli</i> /g (Not Detected)
1 st	70G:30W:0.5X	1.6*10 ³	1.3*10 ³	Not Detected	Not Detected
	80G:20W:0.5X	1.6*10 ³	1.2*10 ³	Not Detected	Not Detected
	90G:10W:0.5X	1.9*10 ³	1.2*10 ³	Not Detected	Not Detected
2 nd	70G:30W:0.5X	1.5*10 ³	1.2*10 ³	Not Detected	Not Detected
	80G:20W:0.5X	1.3*10 ³	1.0*10 ³	Not Detected	Not Detected
	90G:10W:0.5X	1.8*10 ³	1.0*10 ³	Not Detected	Not Detected
3 rd	70G:30W:0.5X	1.4*10 ³	1.0*10 ³	Not Detected	Not Detected
	80G:20W:0.5X	1.9*10 ³	1.2*10 ³	Not Detected	Not Detected
	90G:10W:0.5X	1.3*10 ³	9.6*10 ²	Not Detected	Not Detected

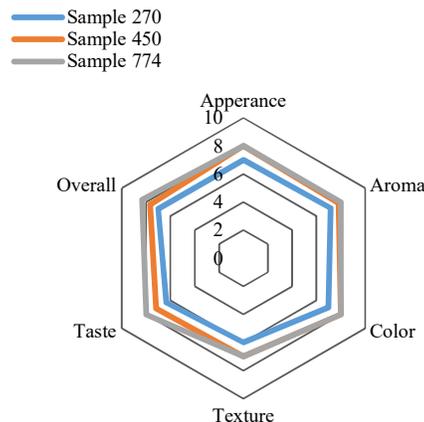


Fig. 4. Sensory Attribute Evaluation of the Final Product with Possible Alternative Products Based on Hedonic Test. 200 (dried ginger powder), 425 (ginger puree cube), and 644 (fresh ginger rhizome)

V. CONCLUSIONS

This study focused on optimizing the production of frozen ginger puree cubes to meet consumer expectations for quality, stability, and sensory appeal. By carefully selecting top-grade ginger rhizomes and incorporating xanthan gum as a stabilizer, significant improvements were achieved in texture and reduced stickiness during thawing. Crucially, adding xanthan gum also preserved the product's natural flavor profile by maintaining stable pH levels post-freezing. Microbial analysis confirmed the product safety throughout storage, underscoring the effectiveness of heat treatment during ginger processing.

Sensory evaluations provided clear guidance on consumer preferences, leading to the selection of optimal formulation ratios that balanced ginger content and water levels with the stabilizing benefits of xanthan gum. Ultimately, the preferred formulation, Water 10: Ginger 90 with Xanthan gum 5%, emerged as a standout choice, excelling in appearance, aroma, taste, and texture. This research offers practical insights and recommendations to producers to enhance the appeal and marketability of frozen ginger puree cubes, ensuring they align with consumer expectations for quality and sensory experience.

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Dyno-Prep: An Efficient and Automated Data Preprocessing Pipeline for Enhanced Machine Learning Performance

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Abstract- The rapid expansion of data across various domains necessitates robust preprocessing techniques to optimize machine learning model performance. This study introduces Dyno-Prep, an automated data preprocessing pipeline designed to adapt to diverse datasets, outperforming existing frameworks dynamically. Dyno-Prep integrates advanced preprocessing steps, including heuristic data type detection, sophisticated imputation methods, hybrid encoding techniques, adaptive scaling, robust feature selection, and dimensionality reduction. Specifically, it employs KNN imputation for numerical data and frequent category imputation for categorical data to handle missing values effectively. The pipeline dynamically selects between OneHotEncoder and OrdinalEncoder based on feature uniqueness and adapts scaling methods to data distribution using RobustScaler and StandardScaler. Feature selection combines ANOVA F-test and mutual information criteria to retain significant features, while dimensionality reduction leverages PCA or UMAP depending on dataset characteristics. The pipeline's performance is validated using Auto-sklearn for automated machine learning tasks and also with traditional algorithms with the best manual preprocessing, demonstrating superior model accuracy and efficiency compared to traditional methods. This dynamic approach significantly enhances dataset readiness for subsequent analytical and machine-learning processes, setting a new benchmark in automated data preprocessing.

Keywords- *automated machine learning, data preprocessing, dynamic data handling, advanced imputation, hybrid encoding*

I. INTRODUCTION

A. Background

The integration of machine learning (ML) models across various domains has surged in recent years, demonstrating remarkable efficacy in solving complex challenges [1]. However, the conventional method of crafting these models heavily relies on manual intervention by specialists, often entailing iterative trial-and-error approaches. Consequently, developing proficient models demands significant time and resources, exacerbating the demand for ML experts [2]. In response, a promising paradigm called automated machine learning (AutoML) has surfaced, intending to optimise the whole machine learning pipeline. AutoML seeks to alleviate the reliance on data scientists, empowering domain specialists to develop ML applications, even without extensive ML expertise autonomously. Core to AutoML is data pre-

processing, feature engineering, model generation, and model evaluation [3].

Data pre-processing stands out as a critical phase within the spectrum of ML processes, often consuming a substantial portion—ranging from 50 to 80 percent—of the analysis time [4]. This underscores the significance of effectively preparing datasets, as the quality of preprocessing significantly impacts model performance [5]. Even the most advanced learning algorithms may yield suboptimal results if applied to inadequately preprocessed data, potentially diminishing accuracy. Recognizing the pivotal role of data preprocessing and the need to democratize its implementation, there is a pressing need for methodologies that streamline this process, making it accessible and efficient.

B. Problem Statement

Automated data preprocessing techniques often lack maturity, requiring significant human intervention. They struggle to determine the most suitable techniques for specific datasets, leading to suboptimal model accuracy. As a result, current automated methods often focus on basic transformations rather than optimizing model performance [6]. Detecting attribute data types in structured datasets is challenging and often relies on manual specification by users [7].

C. Contributions

This research introduces Dyno-Prep, a comprehensive framework for automating and optimizing data preprocessing in ML pipelines. Leveraging automation, Dyno-Prep simplifies dataset preparation for model training. Core features include automatic detection of duplicate rows, data type identification, missing data imputation, categorical encoding, feature reduction, and scaling. Evaluation of ten diverse datasets with Auto-Sklearn reveals that Dyno-Prep not only simplifies preprocessing but also enhances model performance, showcasing its effectiveness in automating these tasks.

Specifically, this paper makes several key contributions:

1. **Automated Data Type Detection:** Implementing a heuristic approach to accurately identify numeric and categorical features within datasets.
2. **Advanced Imputation Methods:** Utilizing KNN imputation for numerical data and frequent category imputation for categorical data to handle missing values effectively.

3. **Hybrid Encoding Techniques:** Dynamically selecting between OneHotEncoder and OrdinalEncoder based on feature uniqueness to optimally encode categorical variables.
4. **Adaptive Scaling:** Adapting scaling methods to data distribution using RobustScaler and StandardScaler to ensure that feature scaling is appropriate for the underlying data characteristics.
5. **Robust Feature Selection:** Combining ANOVA F-test and mutual information criteria to retain the most significant features, enhancing model performance.
6. **Dimensionality Reduction:** Employing PCA or UMAP based on dataset characteristics to reduce dimensionality, thus simplifying models, and improving computational efficiency.
7. **Performance Validation:** Validating the effectiveness of Dyno-Prep using Auto-Sklearn and manual models, demonstrating superior accuracy and efficiency compared to traditional preprocessing methods.

II. LITERATURE REVIEW

The rise of machine learning (ML) in diverse domains highlights its effectiveness in tackling complex challenges. However, real-world data is often unclean [8], impacting learning algorithm performance [9]. Data preprocessing, which includes cleaning, encoding, scaling, and dimensionality reduction, consumes significant analytical time [10]. Automated machine learning (AutoML) has emerged to streamline the ML pipeline, enabling domain specialists to create applications with minimal manual effort.

Data preprocessing is essential, encompassing tasks like handling missing values, inaccurate data types, and duplicate rows. Detecting data types beforehand aids in selecting appropriate preprocessing and encoding methods. Techniques for data type detection range from simple heuristics to complex machine learning models. For example, Messytables, a Python package, predicts data types by testing various conversions for each value and selecting the most successful one [11]. Missing data is common due to manual errors, equipment malfunctions, and intentional omissions, reducing sample sizes and impacting analysis efficiency and precision [9]. Imputation techniques include mean or median imputation, multiple imputation by chained equations (MICE), matrix factorization, and K-Nearest Neighbors (KNN) imputation, with effectiveness varying based on the missing data's nature. ML algorithms require numerical input and output attributes, necessitating the encoding of categorical data. Label encoding assigns a unique number to each category, possibly introducing ordinal relationships [12]. One-hot encoding avoids ordinal relationships but can create a high-dimensional feature space [13]. Techniques like leave-one-out encoding and hash encoding balance computational efficiency and memory usage [14]. Feature scaling is vital for ML models to interpret variables consistently, particularly for distance-based algorithms like KNN and SVM [15]. Common scaling methods include standardization and Min-Max normalization [16] with the choice of method significantly influencing model performance [17]. Dimensionality reduction transforms

high-dimensional data into a lower-dimensional representation, mitigating the "curse of dimensionality," reducing computational costs, and improving data visualization. Techniques include feature selection, which retains relevant features, and feature extraction, which transforms data into a lower-dimensional space. PCA and UMAP are common methods, with UMAP often outperforming for complex datasets [18].

Feature selection enhances model performance by retaining significant features and removing irrelevant ones, improving prediction accuracy, reducing overfitting, and shortening training time. Techniques like ANOVA F-test and mutual information criteria are used to boost model performance [19].

AutoML tools like Auto-WEKA, Auto-Sklearn, TPOT, and H2O AutoML automate the ML pipeline, each with strengths and limitations in preprocessing. Auto-WEKA and Auto-Sklearn offer comprehensive preprocessing within their frameworks [10]. TPOT uses genetic programming for automated pipeline construction, including preprocessing [20]. H2O AutoML includes automated preprocessing like imputation and normalization to minimize manual intervention [21].

Despite advancements, no AutoML tool fully automates data preprocessing, often requiring human intervention for tasks like data type detection and feature engineering. Dyno-Prep addresses these gaps with robust heuristic approaches, advanced imputation, dynamic encoding, adaptive scaling, sophisticated feature selection, and flexible dimensionality reduction. It represents a significant advancement in AutoML, empowering users with enhanced tools for developing effective ML models with minimal manual effort.

In conclusion, while literature underscores the critical role of data preprocessing in the ML pipeline and advancements in AutoML, existing solutions often lack accuracy, flexibility, and full automation. Tools like Dyno-Prep mark a significant step in automating preprocessing, reducing manual efforts, and improving overall ML model development efficiency.

III. METHODOLOGY

The Dyno-Prep pipeline automates and optimizes the data preprocessing stage in the machine learning (ML) pipeline. It dynamically adapts to the characteristics of various datasets to improve the efficiency and effectiveness of ML model training. The pipeline comprises several crucial steps: data type detection, missing value imputation, categorical encoding, feature scaling, feature selection, and dimensionality reduction. Each step employs advanced techniques tailored to enhance the overall preprocessing process. This section offers an in-depth overview of each stage in the Dyno-Prep pipeline.

A. Pipeline Steps

1. Data Type Detection

In the Dyno-Prep pipeline, the initial step involves detecting feature data types, crucial for selecting preprocessing techniques. Dyno-Prep uses a heuristic approach to classify features as numeric or categorical. Numeric features are identified by their ability to be

represented as numerical values, while categorical features are identified based on the presence of non-numeric characters.

2. Missing Value Imputation

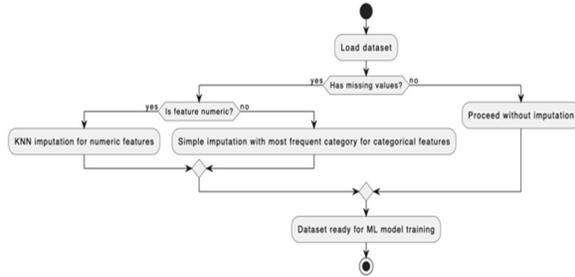


Fig.1 Missing Value Imputation (Source: Authors)

Missing values in datasets can significantly impair the performance of ML models if not handled properly. Dyno-Prep tackles this challenge with two distinct imputation methods. As shown in Fig. 1 KNN (k-Nearest Neighbors) imputation fills missing values based on instance similarity, preserving data distribution and relationships for numeric features. For categorical features, missing values are filled with the most frequent category using simple imputation, maintaining the integrity of categorical distributions.

3. Categorical Encoding

Categorical features need to be encoded into a numerical format for ML algorithms. As shown in Fig. 2 Dyno-Prep uses a hybrid approach for encoding, dynamically choosing between OneHotEncoder and OrdinalEncoder based on feature uniqueness:

OneHotEncoder: Applied to categorical features with a small number of unique values. This method creates a binary column for each category, preventing the imposition of ordinal relationships.

OrdinalEncoder: Used for features with a larger number of unique values. This method encodes categories as integers, which is more memory-efficient and helps avoid the curse of dimensionality.

4. Feature Scaling

Feature scaling is essential to normalize the range of independent variables. As shown in Fig. 3 Dyno-Prep dynamically selects the appropriate scaling method based on data skewness:

StandardScaler: Used for features with a normal distribution, scaling them to have a mean of 0 and a standard deviation of 1.

RobustScaler: Applied to features with a skewed distribution. This method uses the median and interquartile range (IQR) to scale features, making it robust to outliers. By adapting the scaling method to the data distribution, Dyno-Prep ensures features are appropriately normalized, improving ML model performance.

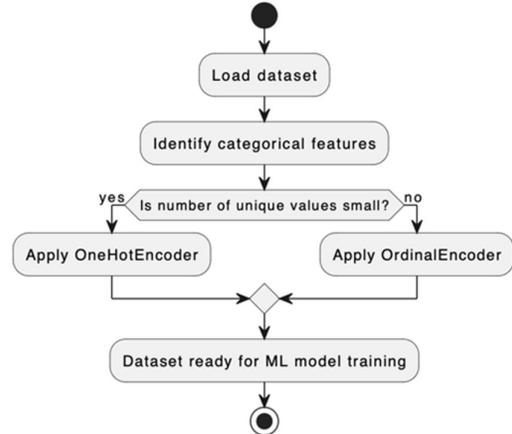


Fig.2 Workflow of categorical encoding (Source: Authors)

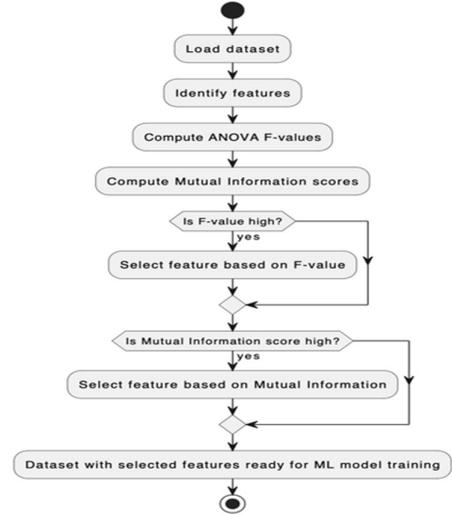


Fig.3 Workflow of Feature Scaling (Source: Authors)

5. Feature Selection

Effective feature selection is crucial for enhancing model performance by reducing the dimensionality of the dataset and eliminating irrelevant features. As shown in Fig. 4 Dyno-Prep employs a combination of ANOVA F-value and mutual information criteria to select significant features:

ANOVA F-value: Measures the dependency between independent and target variables. Features with high F-values are considered significant.

Mutual Information: Evaluates the dependency between features and target variables. Features with high mutual information scores are selected.

This combined approach ensures that only the most relevant features are retained, improving model accuracy and efficiency.

6. Dimensionality Reduction

Dyno-Prep employs dimensionality reduction techniques to optimize datasets, selecting between PCA (Principal Component Analysis) and UMAP (Uniform Manifold Approximation and Projection)

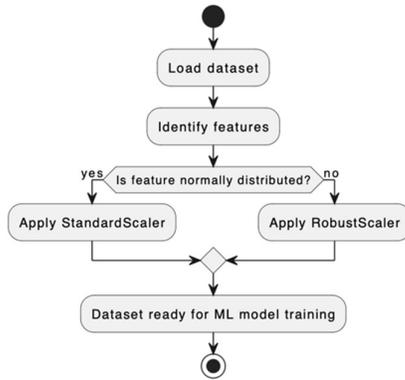


Fig.4 Workflow of feature selection (Source: Authors)

based on dataset characteristics As shown in Fig. 5. PCA is utilized for datasets with many features or to address multicollinearity, transforming them into linearly uncorrelated components through standardization, covariance matrix computation, eigen decomposition, and selection of principal components based on eigenvalues. UMAP, suitable for datasets with fewer features, preserves global structure while reducing dimensionality by constructing a fuzzy topological representation and optimizing the low-dimensional representation by minimizing cross-entropy between high-dimensional and low-dimensional spaces.

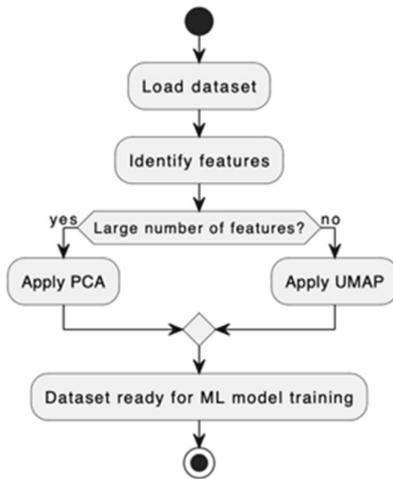


Fig.5 Workflow of dimensionality reduction (Source: Authors)

7. Validation and Performance

The Dyno-Prep pipeline was validated using Auto-Sklearn, an automated machine learning framework, across ten diverse datasets. The results demonstrated superior model accuracy and efficiency compared to traditional preprocessing methods. This validation highlights the effectiveness of Dyno-Prep in automating and optimizing data preprocessing tasks, setting a new standard in automated data preparation for machine learning.

By incorporating these advanced preprocessing steps, Dyno-Prep significantly improves dataset quality and readiness for subsequent ML processes, ultimately enhancing the performance and reliability of ML models.

IV. EVALUATION AND RESULTS

A. Datasets

Our methodology encompasses a comprehensive range of data preparation tasks, leading us to select datasets that cover a wide spectrum of scenarios to rigorously evaluate their effectiveness. We obtained datasets from reputable repositories like the UCI Machine Learning Repository, OpenML, and Kaggle. The selection criteria were carefully crafted to ensure diversity in features, data sizes, and inherent challenges. This strategic selection aims to validate the Auto-preprocessing method under various conditions. Table 1 outlines the key characteristics of the selected datasets.

B. Experimental Setup: Machine Learning Models

The primary objective of our evaluation is to compare the accuracy of models trained with different preprocessing and training methods. Specifically, we aim to compare:

1. Models trained on auto-pre-processed data using Auto-sklearn.
2. Models trained on data without auto-preprocessing using Auto-sklearn.
3. Models trained on auto-preprocessed data using manual training.
4. Models trained on data without auto-preprocessing using manual training.

C. Performance Metrics for Classification

The evaluation of machine learning algorithms in classification tasks relies on several key performance measures. The confusion matrix summarizes performance with true positives, true negatives, false positives, and false negatives. Classification accuracy measures the ratio of correctly predicted instances to the total instances. Recall (sensitivity) is the ratio of correctly predicted positive observations to all actual positives, while precision is the ratio of correctly predicted positive observations to total predicted positives. The F1 score, the harmonic mean of precision and recall, balances these metrics, providing a comprehensive assessment of a model's performance.

D. Evaluation of Dyno-Prep Method on Classification Datasets

The Dyno-Prep method pre-processes four distinct classification datasets (outlined in Table 1), consisting of three binary classification tasks differing in feature size and data quality, and two multiclass classification problems. Table 2 summarizes the pre-processing operations conducted by the Dyno-Prep algorithm on each dataset. Support vector classifiers assess performance on insurance claims, cancer diagnosis, and tic-tac-toe datasets, while support vector machines and random forest classifiers predict wheat-seed and steel-plates datasets, respectively. Each classifier is applied under the following conditions:

1. Models trained on auto-pre-processed data using Auto-Sklearn.
2. Models trained on data without auto-preprocessing using Auto-Sklearn.
3. Models trained on auto-pre-processed data using manual training.
4. Models trained on data without auto-preprocessing using manual training.

TABLE 1: DATASET DETAILS

Dataset Name	Feature Count	Instance Count	ML Task
Cancer Detection	32	569	Binary Classification
Auto Insurance Claims Data	40	1001	Binary Classification
Tic-Tac-Toe Endgame	9	958	Binary Classification
Seeds	7	210	Multinomial Classification
Steel Plates Faults	28	1941	Multinomial Classification
E-commerce Customers	8	501	Regression
Automobile	26	205	Regression

TABLE 2: THE PRE-PROCESSING OPERATIONS PERFORMED BY THE DYNOPREP ALGORITHM ON EACH DATASET ARE SUMMARIZED

Dataset	Total Number of Features	Discrete Numeric Features	Continuous Numeric Features	Quantitative Features	Duplicate Data Available	Numeric of Missing Values	Categorical Missing Values	Missing Value Imputation	Encode Categorical Features	Feature Selection	Feature Scaling	Dimensionality Reduction
Cancer Detection	32	0	31	1	0	0	0	No	Yes	Yes	Yes	Yes
Auto Insurance Claims Data	40	9	11	18	0	1000	881	Yes	Yes	Yes	Yes	Yes
Tic-Tac-Toe	10	1	0	9	0	0	0	No	Yes	No	Yes	No
Wheat-Seeds	8	1	7	0	0	0	0	No	No	Yes	Yes	Yes
Steel Plates Faults	24	4	24	0	8	80	0	Yes	No	Yes	Yes	Yes

TABLE 3: ACCURACY SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual preprocessing and manual model training	Results with Dyno-Prep, manual model training
Cancer Detection	0.958	0.965	0.91	0.951
Auto insurance claims data	0.72	0.764	0.7	0.808
Tic-Tac-Toe	0.983	0.991	0.89	0.983
Wheat Seeds	0.9	0.92	0.95	0.92
Steel Plates Faults	Cannot Train	0.943	0.67	0.91

TABLE 4: PRECISION SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual preprocessing and manual model training	Results with Dyno-Prep, manual model training
Cancer Detection	0.958	0.965	0.947	0.952
Auto insurance claims data	0.518	0.773	0.43	0.806
Tic-Tac-Toe	0.9837	0.9917	0.87	0.983
Wheat Seeds	0.927	0.938	0.95	0.932
Steel Plates Faults	Cannot Train	0.94	0.68	0.91

TABLE 5: RECALL THE SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual pre-processing and manual model training	Results with Dyno-Prep, manual model training
Cancer Detection	0.958	0.965	0.818	0.951
Auto insurance claims data	0.72	0.78	0.56	0.808
Tic-Tac-Toe	0.9833	0.9916	1	0.983
Wheat Seeds	0.9	0.92	0.95	0.92
Steel Plates Faults	Cannot Train	0.943	0.673	0.92

TABLE 6: F1-SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual pre-processing and manual model training	Results with Dyno-Prep, manual model training
Cancer Detection	0.958	0.964	0.87	0.95
Auto insurance claims data	0.602	0.748	0.46	0.807
Tic-Tac-Toe	0.9832	0.9916	0.93	0.9832
Wheat Seeds	0.901	0.921	0.95	0.919
Steel Plates Faults	Cannot Train	0.93	0.675	0.92

E. Performance Metrics for Regression

Regression model evaluation involves several performance criteria, each of which provides a different perspective on how well the model predicts. R-squared is a crucial metric that expresses how much of the variation the model can account for. The mean absolute error, or MAE, measures how much a forecast is off on average. By highlighting bigger errors, the Mean Squared Error (MSE) calculates the average squared difference between the actual and anticipated values. Since RMSE is the square root of MSE, it can be interpreted in the same units as the target variable and is outlier-sensitive. When combined, these indicators aid in evaluating and enhancing regression models.

F. Evaluation of Dyno-Prep Method on Regression Datasets

The Dyno-Prep method preprocesses two distinct regression datasets outlined in Table 2. Subsequently, each regression model is trained under specific experimental conditions:

1. Models trained on auto-pre-processed data using Auto-Sklearn.
2. Models trained on data without auto-preprocessing using Auto-Sklearn.
3. Models trained on auto-preprocessed data using manual training.
4. Models trained on data without auto-pre-processing using manual training

TABLE 7: R2 SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual pre-processing and manual model training	Results with Dyno-Prep, manual model training
E-commerce Customers	-0.002	0.839	0.981	0.989
Automobile	0.856	0.925	0.88	0.898

TABLE 7: MSE SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual pre-processing and manual model training	Results with Dyno-Prep, manual model training
E-commerce Customers	1.101	3544.94	110.1	0.012
Automobile	97339912.45	237.358	9262710.6	321.891

TABLE 8: MAE SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual pre-processing and manual model training	Results with Dyno-Prep, manual model training
E-commerce Customers	0.823	47.5	8.5	0.86
Automobile	2201.71	11.616	2237	14.096

TABLE 9: RMSE SCORE OF CLASSIFIERS

Dataset	Results without Dyno-Prep, Auto-Sklearn	Results with Dyno-Prep, Auto-Sklearn	Results with best manual pre-processing and manual model training	Results with Dyno-Prep, manual model training
E-commerce Customers	1.049	59.53	10.49	0.111
Automobile	3120.88	15.406	3043.47	17.94

V.DISCUSSION

The results unequivocally demonstrate that employing dyno-prep preprocessing consistently augments model performance across diverse datasets. Specifically, integrating automated model training via auto-sklearn

with dynamic preprocessing typically yields superior results compared to traditional manual preprocessing and model training methods. This finding underscores the effectiveness of dynamic preprocessing in managing the complexities inherent in various datasets, thereby enhancing overall model performance.

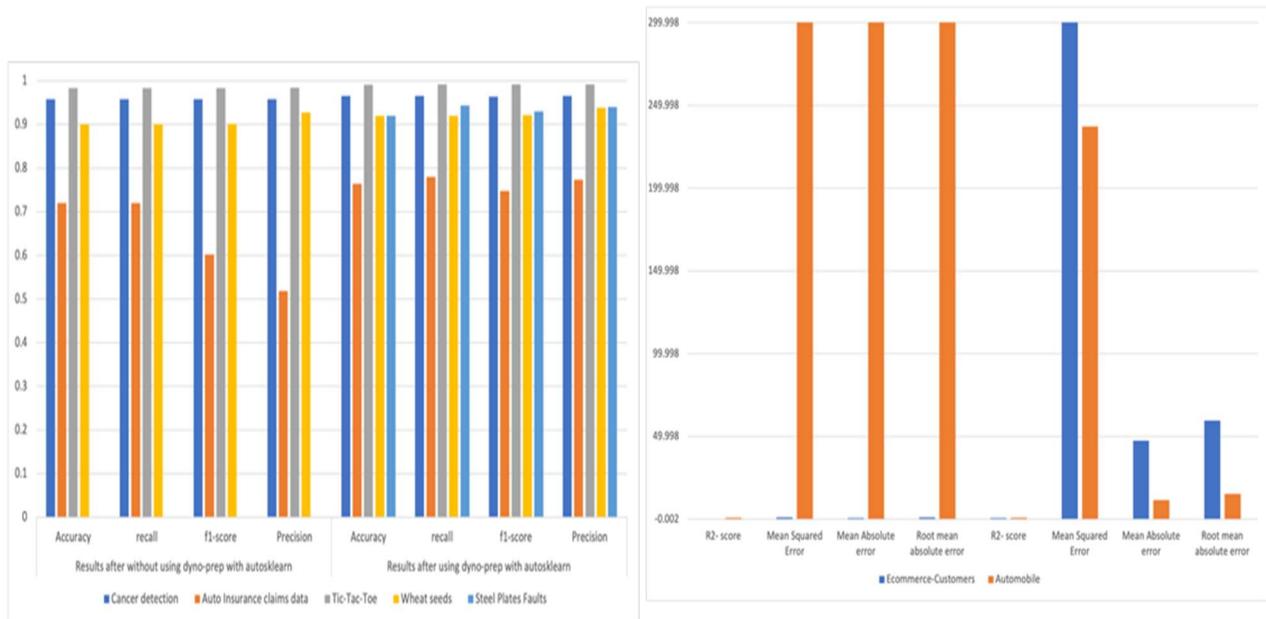


Fig.6. Comparison without Dyno-Prep and with Dyno-Prep using Auto-Sklearn (Source: Authors)

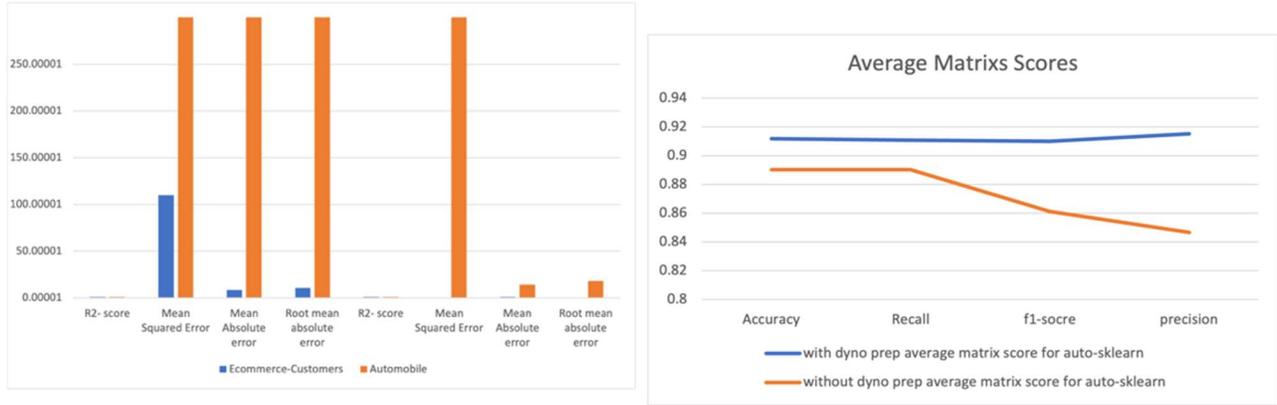


Fig.7 Comparison without Dyno-Prep and with Dyno-Prep using manual training (Source: Authors)

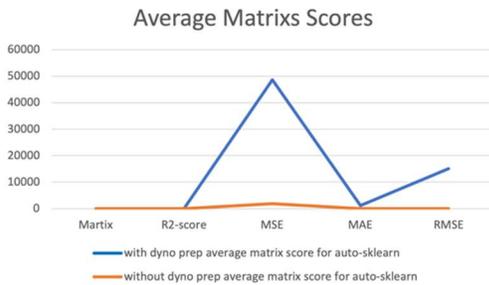


Fig.8 Average matrix scores without Dyno-Prep and with Dyno-Prep using Auto-Sklearn (Source: Authors)

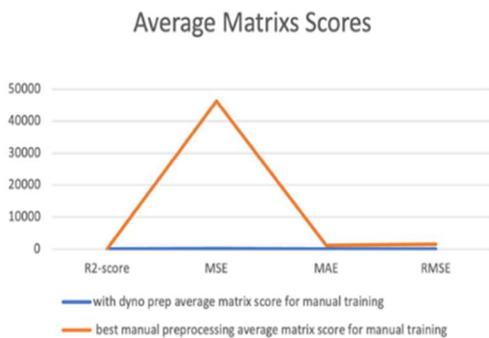


Fig.9 Average matrix scores without Dyno-Prep and with Dyno-Prep using manual training (Source: Authors)

In contrast, manual pre-processing, and model training exhibit less consistent outcomes. While manual techniques occasionally achieve high performance, they generally fall short of the results obtained through the automated dynamic approach. The variability observed in manual preprocessing can be attributed to the inherently subjective nature of manual feature engineering and the challenges associated with optimizing preprocessing steps in the absence of automation. This subjectivity often leads to suboptimal feature selection and transformation, impacting the model's ability to generalize well across different data scenarios. The superiority of automated dynamic preprocessing is further evidenced by its ability to explore a broader range of preprocessing techniques systematically and efficiently. This comprehensive exploration ensures that the most suitable pre-processing strategy is applied to each dataset, optimizing model performance. Additionally, using auto-sklearn's automated hyperparameter tuning and model selection processes minimizes human bias and error, contributing to the robustness and reliability of the resulting models.

VI. CONCLUSION

In conclusion, this research successfully automates data preprocessing tasks, improving efficiency, and addressing common data challenges. Our automated system identifies data flaws and offers recommendations, tailored for machine learning applications. It covers key components like data type detection, missing values imputation, encoding, scaling, feature selection, and dimensionality reduction. Evaluation against Auto-Sklearn and manual models using diverse datasets demonstrates superior accuracy and efficiency. Results indicate significant improvement in model accuracy with Dyno-prep, alleviating preprocessing burdens and enhancing overall model performance. The Auto-Prep method holds promise for future development, emphasizing the importance of automated preprocessing in machine learning and paving the way for further innovations.

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Studying the Risk of Contamination in Chunnakam Aquifer: A Case in Jaffna Peninsula

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Abstract—The main water resource of Chunnakam, Sri Lanka is the groundwater supply of the Chunnakam aquifer, which is used for all drinking, domestic, agricultural, and industrial purposes. However, due to the fuel smell of water, which has been continuously observed in the agro wells near the Chunnakam Power Station (CPS), many researches have been conducted and have witnessed that the wells near the CPS are contaminated and not suitable for usage. This has occurred mainly due to the improper waste discharge of the CPS. This study analyzes the variation of contamination levels of the groundwater in Chunnakam area with the distance to the CPS, concerning time, and according to the type of wells, and further the risk analysis of environmental, economic, and social impact of this contamination. By analyzing the data collected by previous researches, it was observed that, the oil and grease contamination levels decreased with the increase of the distance from CPS, while limiting the contaminated wells within a 1.5 km radius with CPS. The 73% of contaminated wells, in which the oil and grease concentration is more than the standard value of 1.0 mg/l, in 2013/14 has been reduced to 4% in 2016/17, expressing the decreasing pattern of oil and grease contamination level with time. Further, according to the analysis, the type of well does not affect the contamination level significantly. While the Lead, Chromium, and Arsenic concentrations of the groundwater in Chunnakam area are at safe levels, the nitrate-nitrogen concentration and aerobic and anaerobic bacterial counts are higher than the standard values making the water not suitable for usage. Moreover, all these contaminations have created environmental, economic, and social impacts among the residents of Chunnakam area.

Keywords—groundwater, contamination, chunnakam aquifer, risk analysis, oil and grease

I. INTRODUCTION

In human life, groundwater plays a critical role in the world. Groundwater is a crucial factor on a worldwide scale when considering the agricultural sector as well as a source of drinking water. Out of the world's population, two billion people use water aquifers directly as drinking water. Groundwater is directly used for agricultural food production, covering 40% of the world's food requirement. Depending on the human needs' groundwater is crucial to protect due to the rising of day-to-day demand and pollution circumstances [1]. Compared to surface water, pollution of groundwater is invisible to the naked eye, it stays unreported and unrecognized until it reaches the maximum level of pollution [1]. Both natural processes and anthropogenic processes can result the groundwater pollution; industrial waste discharges, agricultural waste runoff, careless waste disposal to the adjacent bare lands, underground storage leakages are

common methods of groundwater pollution which related to human-induced activities. Such pollution lowers the quality of the water supply. Although it is more complex and advanced technologies are required to treat groundwater and it is more difficult to access these sources, it is crucial to assess its quality before use. This ensures safety, eliminates health risks, and reduces living expenses.

This study focuses on the case of contamination of groundwater in Chunnakam, Sri Lanka which has led to socioeconomic difficulties during the last decade. Moreover, this study enhances the exposure condition of the region, contamination-originating places, exploration, and pollution consequences in Chunnakam region. Chunnakam had experienced serious issues with groundwater quality as a result of inadequate waste management practices [2] which proves that the Northern Company (Pvt) Ltd was identified as the main reason for the oil pollution of groundwater in Chunnakam area in 2019, and the contamination of groundwater had been occurred due to improper waste discharge [3]. Reasons for the increased concentration of Nitrate in groundwater in Chunnakam are the enormous daily usage of organic and inorganic Nitrogen-based fertilizers and the heavy rainfall in the wet season, which causes the groundwater level to come up to the surface level and also to pass and dissolve Nitrogen into the groundwater [4].

The case study highlights the necessity of tight legislation, dependable groundwater monitoring systems, and the use of best practices in water management to lessen the risk of pollution. Through focusing on Chunnakam, this study aims to highlight the critical steps needed to protect groundwater and solutions to the more widespread issues related to groundwater pollution [5].

II. LITERATURE REVIEW

A. Geological information

Aquifers in the Jaffna Peninsula are divided into four main categories: Vadamarachchi, Thenmaradchi, Chunnakam, and Kayts [6]. Of these, the Chunnakam aquifer has the highest yield capacity, highest capacity, and the highest demand for water consumption [7], [2]. The key factor is that, including Chunnakam aquifer all those aquifers are being recharged by rainfall [5]. Jaffna Peninsula is positioned in the dry zone of Sri Lanka and consists of Miocene limestone which is important for the storage and discharge of groundwater aquifers [8], [2]. The hydraulic conductivity of Chunnakam aquifer is 13.3 m/day. The limestone of Jaffna Peninsula is a creamy-colored, firmly dense, and partially crystallized rock.

It is flat-layered and has a slender incline to the West [1]. Certain sections of the limestone formation are solid and uniform, while some layers of the formation are highly dense with fossils. As the rock has been eroded or dissolved, creating a considerable number of interconnected cavities and spaces, it resembles the structure of a honeycomb. Due to this structure, the groundwater is stored within these underground cavities [1]. Hence, the limestone of Jaffna Peninsula plays a vital role as a major natural aquifer in storing and transmitting groundwater, while supplying water for drinking and agricultural purposes [1], [9].

B. Historical information

Initially, until the civil wars began in 1973, electricity was supplied to the Northern part of the country from the national grid [7], [10]. In the period of civil war, the Northern part of the country was not connected to the main grid system. In 2008, northern power plant, which is a fossil fuel-based thermal power plant, was built in Valikamam zonal division, Chunnakam, Jaffna Peninsula [11]. Chemical energy for the plant was supplied by fossil fuels. Groundwater pollution from this power station has happened since it started its functions in 2009. However, the public was not aware of what happening inside the power station area which has twenty acres, because during that time the area was under military people who were in the war mind [12]. Sri Lankan government was struggling with war and was not focused on the environmental regulations and legislation before agreeing to the power plant agreement [10].

According to all the local complaints and observations from the local people from Northern region, the identified major sources are the Northern power plant and Uthuru Janani power plant which led to this contamination. It is happening when waste water and waste oil, which emit because of the functions inside the power plant, are dumped into the adjacent bare lands without any proper treatment [11]. Due to this, all the waste reaches the underground aquifer mixing with the water table.

C. Background of the case

Firstly, farmers of the Northern region complained about oil stains and odour in their agro wells to the high officials through the Medical Officer of Health. Since agro wells are deeper and closer to the aquifer than the other wells, they had noticed it first in agro wells. At the beginning, they observed oil stain and odour in their wells. In 2012 oil odour like kerosene was observed in water from Chunnakam Water Supply Scheme intake and in pipe born supply water too [11], [2].

As a result of the spreading of this contaminant more, later other communities also joined hands with them in 2012. They complained about both Northern power plant and Uthuru Janani power station as the main sources to arise this issue. 10,000 families including 20,000 individuals in Valikamam area have been affected by this issue directly [10]. As at December 2014, 3,167 families of Chunnakam Town-South, 1,247 families of Chunnakam Town-East, 3,450 families of Earlalai-South were affected by the oil pollution of groundwater and this number is further increasing [13].

III. RESULTS AND ANALYSIS

The focus of this study is to analyze the impacts of groundwater contamination in the Chunnakam aquifer. There are several impacts that occurred due to contamination such as environmental, economic, social, and cultural, as shown in Figure 1.

Due to the oil wastage contamination of the northern power plant, a major environmental impact has been felt in the quality of the water. Since most people in that area depend on groundwater sources for their drinking and agricultural purposes, it affects the community in different ways, such as economically and socially.

A. Environmental impact

Water pollution is one of the main environmental impacts due to oil and grease contamination. This study aims the facts that affect the quality of water such as oil and grease contamination, heavy metal contamination, change in nitrate-nitrogen concentration, and aerobic and anaerobic bacterial counts in water by analyzing the different data that has been gathered before.

B. Oil and Grease Contamination

According to the data gathered by S. Saravanan [11] an experiment was conducted from November 2013 to August 2014 by using 150 wells within 1.5 km surrounding the power station to observe the higher oil and grease contamination level than the Sri Lankan standard 614(1983) of 1.0 mg/l. The same type of analysis was done from July 2016 to February 2017 by using 160 wells within a 4 km radius centered by the power station [2].

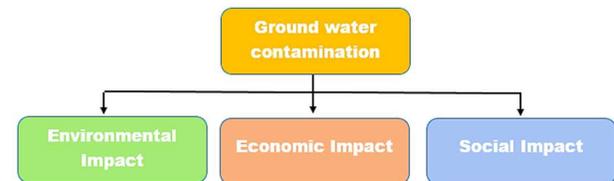


Fig. 1. Impacts of groundwater contamination

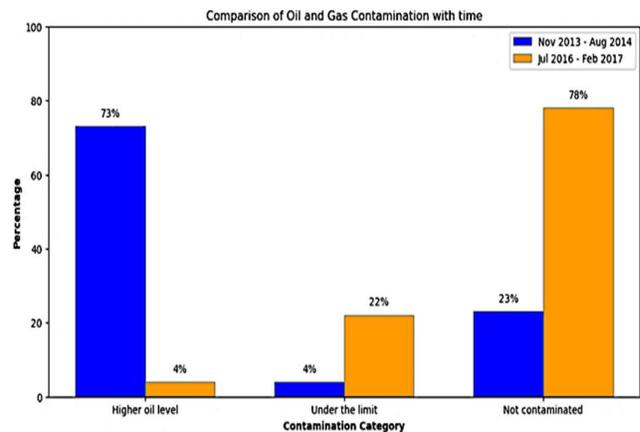


Fig. 2. Comparison of oil and grease contamination in the years of 2013/14 and 2016/17.

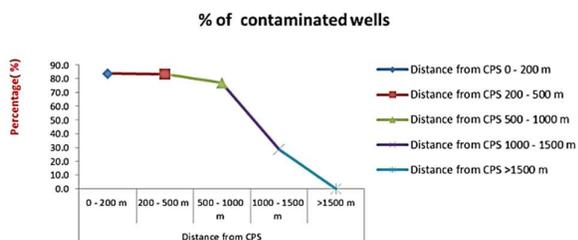


Fig. 3. Oil and grease concentration of wells in the years of 2013/2014 and 2016/2017, with distance.

According to the graph given in Figure 2, 73% of wells had higher oil and grease contamination between 2013 and 2014 and it decreased to 4% between 2016 and 2017. The not contaminated number of wells percentage has increased with time. The highest oil concentration in groundwater was determined as 31.020 mg/l in 2013-2014, and in 2016 – 2017 the maximum oil and grease concentration was identified as 2.3 mg/l. Therefore, based on these results it can be

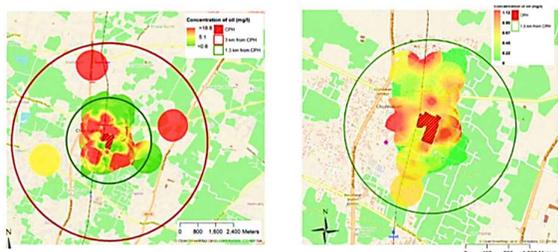


Fig. 4. The change of oil contamination with distance to the CPS.

concluded that the oil and grease concentration has decreased with time. The spatial map in Figure 3, represents the change in the oil concentration from 2013/14 to 2016/17. The graph given in Figure 3, shows that no contaminated wells could be identified beyond 1.0 km from the Chunnakam Power Station (CPS) in 2016/17 [2]. According to the study of S. Saravanan [11] oil contamination level has decreased with distance. Therefore, these studies conclude that oil and grease concentration in groundwater is high near the CPS. Hence, all the identified contaminated wells were located within 1.5 km radius from the center point of CPS premises and the concentration decreased with distance as shown in Figure 4. In Jaffna, most of the people are using groundwater sources for their day-to-day purposes. Therefore, 150 different types of wells such as agricultural/ domestic purpose wells and dug/ tube wells can be analyzed to check the oil and grease concentrations [11]. Graphs in Figure 5 and Figure 6 were drawn to summarize the wells which have higher oil contamination (more than the standard 1.0 mg/l), oil contamination below the limit, and not contaminated with oil.

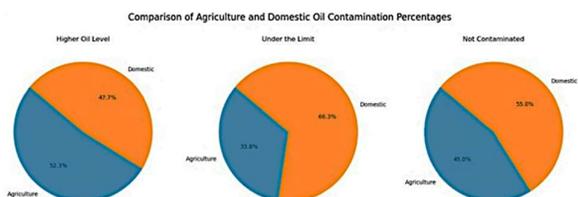


Fig. 5. Oil and grease concentration in agro vs. domestic wells.

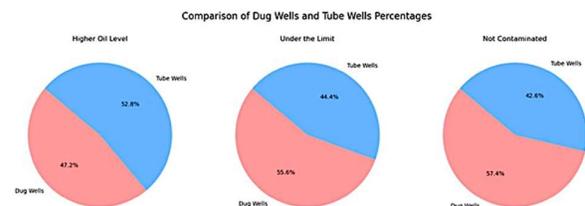


Fig. 6. Oil and grease concentration in dug vs. tube wells.

Figure 5 shows that oil contamination percentages are closely related in agricultural and domestic purpose wells. According to Figure 6, dug wells and tube wells show closely the same oil contamination percentages. Therefore, no significant variation can be observed in contamination according to the type of wells.

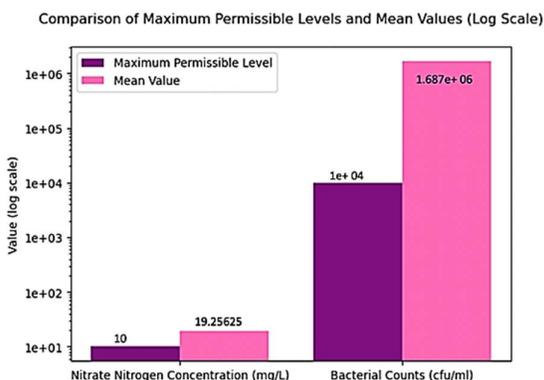


Fig. 7. Maximum permissible level vs mean value of nitrate-nitrogen content and aerobic and anaerobic bacterial counts.

C. Nitrate concentration and bacterial count

An analysis of groundwater quality was done by V. Jeevaratnam [14] in 2017 by analyzing 16 number of samples. There, several criteria were checked such as Chloride content, Phosphate content, total Iron content, PH value, concentration of nitrate-nitrogen, and number of aerobic and anaerobic bacterial counts. Most of the parameters were below the maximum desirable level while some parameters were above the maximum desirable level. The graph of Figure 7 represents the mean value of nitrate-nitrogen content and aerobic and anaerobic bacterial counts in 16 wells with their maximum permissible level.

Based on the above results the mean value of nitrate-nitrogen concentration and aerobic and anaerobic bacterial counts of the selected wells is higher than the recommended level. Therefore, it's clear that the wells are not recommended for drinking. Accordingly, it can be concluded that groundwater quality around Chunnakam Power Station (within 1.5 km radius from the center point of CPS) is affected by oil, grease and heavy metal contamination and nitrate-nitrogen concentration, and bacterial counts are more than the maximum desirable level. Therefore, groundwater quality in that area is not suitable for domestic, agricultural, or manufacturing purposes and it is not dependent on the well type. This polluted water will not only affect humans but also aquatic life such as fish and plants.

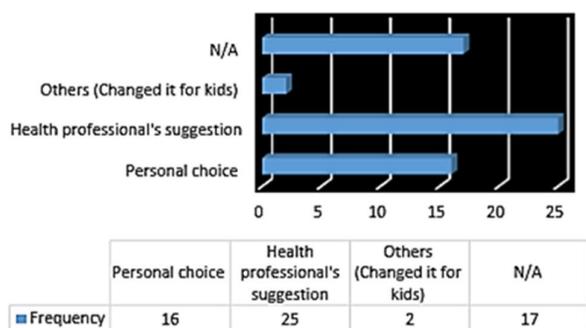


Fig. 8. Reasons to buy water from the shops. Source: [10]

D. Economic Impact

Based on the data gathered by Thirukeswaran [10] from April 1st to May 1st of 2019 by using 60 participants, the people in Chunnakam area using groundwater (dug/ tube wells) for their cooking, farming, domestic activities, and agricultural purposes, most of the people are aware of the oil contamination and some of them are using some purification methods like boiling, filtering with cloth, water dispensers, or using halogen tablets. Out of 60 participants, 72% are buying purified or bottled water from shops due to many reasons, as mentioned in Figure 8. Because of this water contamination, many families in the Chunnakam region are spending more money to buy water or to use some purification methods. This affects the economic status of the families. Oil and grease contamination can cause different health effects from consuming contaminated food or water for a long time which leads to medical expenditure [3]. Oil and grease contamination can impact agricultural water supplies and irrigation systems. This affects the farmers and the people who are engaged in agricultural fields. This will cause less income and economic issues.

E. Social Impact

Oil and grease contamination can cause health hazards. There are many water-borne diseases such as cholera, diarrhea, typhoid, chronic kidney disease, and skin irritations [10]. This type of long-term illness can create stress and anxiety among people and it can affect mental health and family problems. Communities near the Chunnakam Power Station may organize some protests against the government or responsible authorities to address the issue. This will cause a break in the unity among the people.

IV. CONCLUSION

The contamination levels of the wells in Chunnakam area decreases when the distance between the water resource and the CPS, which is the major cause of the contamination, increases. Hence, the contaminated wells were observed within 1.5 km radius with CPS. Further, the oil and grease contamination level of the wells has been reduced with time. The wells with oil and grease contamination levels more than 1.0 mg/l standard level, have been decreased from 73% to 4%, from 2013/14 to 2016/17. The highest oil concentration of 31.020 mg/l observed in 2013/14, has been reduced to 2.1 mg/l in 2016/17. The analysis concludes that there is no significant difference in the contamination level according to the type of wells. When considering the heavy metal contamination, most

of the wells are in safe levels of Pb, Cr, and Arsenic concentrations. But the Nitrate-Nitrogen concentration and aerobic and anaerobic bacterial counts, are observed beyond the recommended value of drinking water. Due to this contamination, environmental, economic, and social impacts have been raised, affecting humans, animals, and plants, health issues, the cost for buying drinking water from shops, and breaks between responsible authorities and the residents in affected area of Chunnakam.

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Incorporation of Natural Inexpensive Filler CNC into Polycarbonate Matrix as a Green Technology Approach to Enhance the Mechanical Properties

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Abstract—Different reinforcement agents have been employed to enhance the mechanical properties of polycarbonate. Cellulose Nano Crystals (CNC) have been identified as promising agents due to their exceptional reinforcing capabilities and eco-friendly nature as green technology. Flexural, hardness, and impact strength of nanocomposite were measured compared to the pristine polycarbonate. The results confirmed an increase of flexural strength by 70.31%, impact strength by 7.26%, and shore D hardness by 6.38%. The results confirm the potential of using CNC as an effective reinforcement agent for polycarbonate with enhanced mechanical properties for sustainable and green technology applications in the polymer industry.

Keywords - cellulose nano crystals (CNC), nanocomposites, polycarbonate (PC), reinforcement agent, sustainable.

I. INTRODUCTION

In the cellulose sources, there are two distinct regions in CNC: crystalline regions with high order and amorphous regions with low order [1]. The arrangement and proportion of these regions vary depending on the cellulose source. Cellulose nanocrystals (CNC) are primarily produced from the crystalline regions extracted from cellulose sources. The extraction process is typically conducted using acid hydrolysis, particularly with sulfuric or hydrochloric acid. Favorable sources for extraction include microcrystalline cellulose, cotton, hardwood pulp, wheat straw, sugar beet, and algae. CNCs possess specific properties such as a high aspect ratio, low weight, high stiffness, large surface area, high mechanical strength, an abundance of surface hydroxyl groups, and a liquid crystalline nature.

The demand for CNC in industry is driven by their advantageous qualities, including low cost, sustainability, eco-friendliness, biodegradability, renewability, and biocompatibility. As a natural reinforcement agent CNC is performing a vital role in the filling industry. A crucial factor influencing the molecular kinetics in the synthesis of these cellulose complexes is the concentration of acid used during the hydrolysis process. Variations in acid type result in the formation of distinct cellulose complexes [2]. Polycarbonate (PC), a prominent polymer in the industry, is expected to benefit from the incorporation of CNC through the enhancement of its mechanical properties. The interaction between CNC and polycarbonate is facilitated by hydrogen

bonding between the abundant hydroxyl groups on CNC and the carbonyl groups in polycarbonate. If CNC successfully improves the mechanical properties of polycarbonate, further surface modification of CNC may not be required. This represents a significant opportunity for industry to enhance polycarbonate's mechanical properties using a natural and inexpensive filler.

II. LITERATURE REVIEW

In the past by varying the cellulose source type, expected dimensions of CNC were changed [2]. In some cases, microcrystalline cellulose was used to synthesize cellulose nano crystals using acid hydrolysis process. The reaction was recorded with the 63.5% of H₂SO₄ w/w ratio in 10% w/v ratio with magnetic stirring in 45 °C for two hours followed by the centrifugation. Volume particle size distribution of cellulose nano crystals in the research recorded between the 0.1 μm – 1 μm range with well dispersed crystals throughout the solution [3]. Industrially, with the benefit of achieving a minimum cost, waste cellulose sources were introduced to the reusing as a cellulose source. S. Thambiraj and D. Ravi Shankaran in 2017 synthesized cellulose micro crystals (CMCs) from industrial waste cottons. The aim was to obtain CNCs with an average width of 10 ± 1 nm and an average length of 180 ± 60 nm. The objectives were successfully achieved using the acid hydrolysis process, yielding the expected results [4].

Narishma. Pandi, Shirish H. Sonawane, K. Anand Kishore conducted research in ultrasonic sonochemistry with synthesis of the cellulose nanocrystals from cotton using ultrasound- assisted acid hydrolysis [5].

III. MATERIALS AND EQUIPMENT

Cotton balls which were purchased from the RRR industry, Sri Lanka. PC pellets were purchased from the OREL cooperation PVT Ltd. The analytical balance (BL-220H) with readability of 0.001 g, Mechanical agitator branded with (IKA EUROSTAR power-b), DAIHAN scientific stirrer hotplate, MSH 20-A, DAIHAN scientific Centrifuge machine, ultra sonic Homogenizer (TF 1000) which were available at the department of chemistry were used. Fourier Transform Infrared (FTIR) spectrometer (Thermo scientific, 4000 cm⁻¹ - 400 cm⁻¹), Dynamic light scattering (DLS) named Malven NanoS90, X ray powder diffractometer (XRD) (“Rigaku-Ultima IV”) was used.

Thermogravimetric analysis (TGA) (TA SDT 650, Controlled by TRIOS software) and Scanning electron microscope (SEM) (Hitachi SU6600 FE-SEM) were used. Hitech, 30-150 Model Internal mixer and MOORE, G314X compression molding hydraulic press were utilized in the Laboratory at Department of Chemical Process and Engineering, University of Moratuwa. From the Department of Polymer science, University of Sri Jayewardenepura, MARX TEST Tensometer was utilized. Hardness tester (Mon Tech Hardness tester model HT 3000), Impact tester (IZOD impact tester) was utilized from the polymer processing laboratory at Department of Material and Mechanical Technology, University of Sri Jayewardenepura.

IV. PROCEDURE

A. Synthesis of Cellulose Nano crystals

Approximately 20 grams of cotton were finely chopped and placed into a container, which then cooled in an ice bath in 0°C for 2 hours. Concurrently, 500 ml of 50 v/v % sulfuric acid solution was prepared and cooled in the ice bath. The cooled sulfuric acid was subsequently added dropwise to the pre-cooled cotton while stirring using a specially prepared glass mechanical stirrer. This stirring process was conducted in a secondary beaker, which was immersed in an ice bath to maintain the reaction temperature at 0°C.

The stirring continued for 6 hours, during which time the mixture gradually transformed into a slurry. After this initial stirring period, the ice bath was replaced with room temperature water, and the stirring was resumed. This time, stirring was maintained for an additional 30 hours at a speed of 250-300 rpm, within a water bath set to 30°C. Upon completion of the stirring process, the resulting slurry was transferred into centrifuge tubes. The samples were then centrifuged at 4500 rpm for almost 1 hour. Following centrifugation, the supernatant was then carefully decanted, and the precipitate was washed three times with distilled water. The washed precipitate was then neutralized to a pH of 6-7 using 3M sodium hydroxide (NaOH) solution. After neutralization, the samples were centrifuged again under the same conditions and subsequently dried in a desiccator for 3 days. The powder was further grinded, weighed and stored.

B. PC/CNC Nanocomposite synthesis

Polycarbonate/CNC nanocomposite sheets were fabricated using internal mixing and compression molding techniques. Initially, polycarbonate pellets were completely melted in an internal mixture. CNCs were then gradually introduced to the molten polycarbonate at a screw rotation speed of 350 rpm and a mixing temperature of 200°C. The homogeneous mixture was subsequently compressed into 2 mm thick sheets using a hydraulic press. The compression molding was performed at 200°C under a pressure of 15 tons, followed by a 5-minute cooling period. Five different ratios of CNC/PC compositions of the nanocomposites were synthesized for this study.

V. CHARACTERIZATION

A. Characterization of CNC

The KBr pellet method was employed to obtain the infrared spectroscopy data for CNC, using a FTIR

Spectrophotometer. The scanning range was from 400 cm⁻¹ to 4000 cm⁻¹. SEM images of synthesized CNC were captured using a Scanning Electron Microscope (SEM) operating at 5.0 kV, Thermogravimetric Analysis (TGA) data of synthesized CNC were gathered using a thermogravimetric Analyzer over a temperature range of 50°C to 800°C, with a nitrogen flow rate of 100 mL/min. XRD data of synthesized CNC were obtained using an X-ray Diffractometer with Cu-K α radiation, 40 kV, 0.020° step size, and a scan speed of 4 degrees per minute, covering a 2 θ range from 5° to 45°. Dynamic Light Scattering (DLS) analysis was performed at 25°C with a count rate of 254.1 kcps, using water as the dispersant. The analysis duration was 50 seconds. The refractive index of the material was 1.59, and the material absorption was 0.010.

B. Characterization of PC

The ATR method was used to obtain FTIR spectroscopy of PC from 400 cm⁻¹ to 4000 cm⁻¹ scanned range.

C. Characterization of PC/CNC composite

Universal testing machine which used to flexural testing was carried out with a 3-point bend fixture. Impact testing and shore D hardness were carried out using an impact tester and Digital shore D durometer.

VI. RESULTS AND DISCUSSION

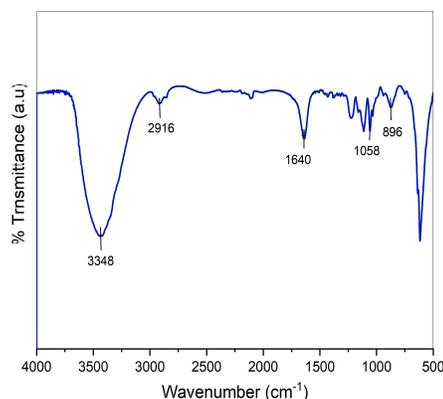


Fig 1: FTIR spectrum of the synthesized CNC

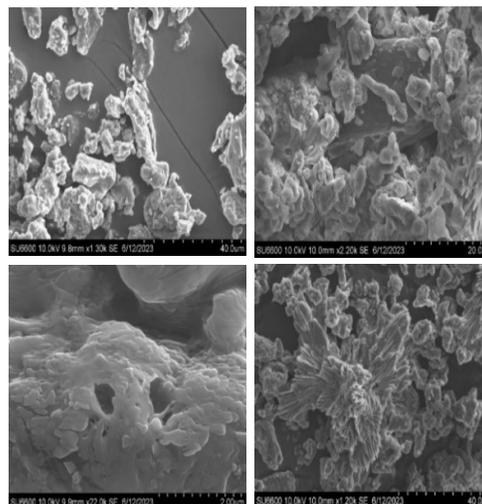


Fig 2: Scanning Electron Micrography images of synthesized CNC

A broad peak observed around 3348 cm^{-1} is attributed to the O-H stretching of the hydrogen bonds in the CNCs. The peak near 2916 cm^{-1} corresponds to the C-H stretching vibration. The peak at 1640 cm^{-1} is due to the O-H bending vibration of adsorbed water, while the C-O-C pyranose ring structure of cellulose shows its stretching vibration at approximately 1058 cm^{-1} . The IR peak around 896 cm^{-1} is associated with the C-H rocking vibrations [6]. These characteristic peaks in the range of 400 cm^{-1} to 4000 cm^{-1} confirm that the acid hydrolysis process has successfully converted native cotton into CNC particles.

The morphology of synthesized cellulose nanocrystals (CNC) was examined using SEM, as shown in Figure 2. The samples possibly contain a mixture of microcrystalline cellulose (MCC) and cellulose nanocrystals.

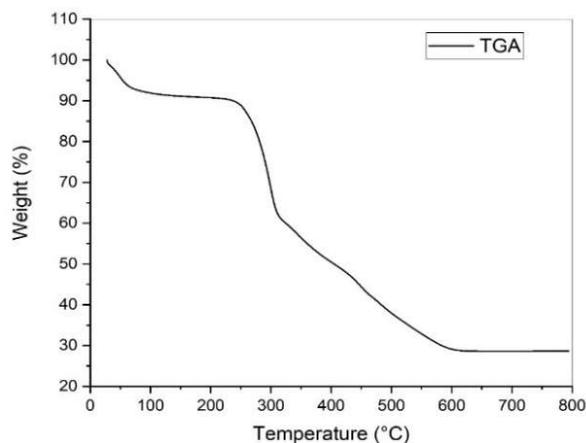


Fig. 3: TGA curve of synthesized CNC

SEM analysis revealed significant agglomeration in the CNC particles, resulting in a large particle size. Various factors, such as incomplete hydrolysis of cellulose microfibrils, storage time, storage conditions, and the presence of hydroxyl groups on CNC, could contribute to this aggregation of CNC.

Thermogravimetric analysis (TGA) for the synthesized CNC, as shown in Figure 3, was conducted over a temperature range of 50°C to 800°C under a nitrogen flow rate of 100 mL/min . This method is used to assess the thermal stability and weight loss of the compound, observe its melting point, and measure its transition temperature.

The results indicate a two-step degradation process. The initial weight loss of 10% below 100°C is attributed to the moisture and volatile compounds in the CNCs. Upon heating the sample to a range of 230°C to 310°C , an additional weight loss of approximately 30% of the sample's total weight was observed. This loss is due to the presence of low molecular weight components and amorphous components in the CNC sample [7]. The primary weight loss is associated with the degradation of the crystalline regions of pure CNC.

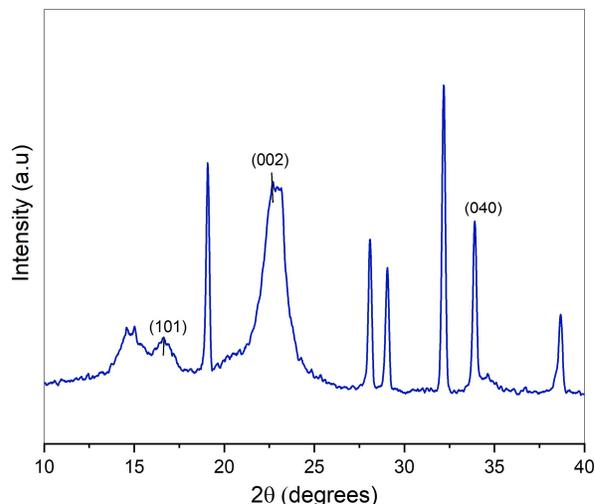


Fig. 4: XRD pattern of synthesized CNC

The crystallinity of the synthesized CNC was determined using XRD analysis. The XRD data exhibited background noise along with distinct peaks corresponding to specific crystallographic planes. In the XRD pattern, three prominent peaks were identified at 2θ values of 14.9° , 22.7° , and 34.2° . An intermediate intensity peak observed at 32.2° corresponds to the 040 crystallographic plane. These peaks are characteristic peaks for the CNC.

The presence of noise peaks in the XRD data suggests the possible formation of sodium sulfate (Na_2SO_4). By comparing the 2θ values of the noise peaks with the XRD peak data for Na_2SO_4 , it is evident that these peaks are indeed due to the formation of Na_2SO_4 . During the neutralization process, 3M NaOH was used, which likely contributed to the substantial formation of this salt. The crystallinity index of the CNC was calculated using the equation which was reported by Segal et al [8].

$$\text{Crystallinity index (CrI)} = \left[\frac{I_{002} - I_{am}}{I_{002}} \right] \times 100$$

I_{002} represents the maximum intensity of the (002) lattice diffraction peak. In the results, the (002) peak appears at a 2θ value of 22.7° . I_{am} in the equation represents the minimum intensity between the (002) and (101) lattice planes, corresponding to the amorphous region of the CNC sample.

$$I_{002} = 551,$$

$$I_{am} = 88,$$

Crystallinity of synthesized CNC = 84.03%
Particle size exhibits variation dependent on the methodological techniques which employed.

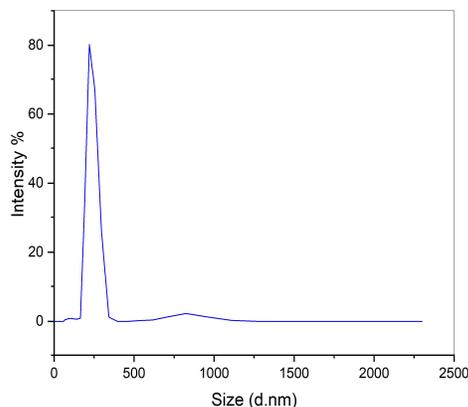


Fig. 5: DLS curve of synthesized CNC

Fig. 6: FTIR spectrum of the pristine PC

Key parameters such as temperature, acid concentration, hydrolysis duration and sonication conditions directly impact the size of cellulose nanocrystals (CNC).

The IR spectrum exhibits signal predominantly in the low wavenumber range, below 2000 cm^{-1} , indicative of characteristic molecular vibrations inherent to the polymer structure. Notably, a prominent peak appears at approximately 1777 cm^{-1} corresponding to the stretching vibration of the carbonyl (C=O) functional group. This feature is consistent with the presence of carbonate linkages within the polycarbonate.

Additionally, a distinct peak at around 1513 cm^{-1} is observed, attributed to the stretching vibrations of the carbon-carbon double bonds (-C=C-) inherent in the aromatic rings of the polymer. This peak serves as a reference point due to the stable confirmation of the aromatic rings within the polymer structure.

A. Characterization of mechanical properties of PC/CNC Nanocomposite

The 3-point bending test, also known as the flexural test, measures the flexural stress, modulus of elasticity in bending, and flexural strain of a material. During this test, specimens are subjected to incremental pressure until they reach the point of failure. The investigation pertains to the flexural strength of pure polycarbonate and its nanocomposite variants with filler concentrations. Notably, the pure polycarbonate demonstrates a minimum flexural strength of 13.81 MPa. As the concentration of filler within the nanocomposites increases, there is a corresponding augmentation in flexural strength by 70.31%. The increment in mechanical properties is primarily attributed to two underlying mechanisms: the enhancement of interfacial interactions between the filler and the polymer matrix, and the improved dispersion of the filler throughout the polymer matrix. The presence of hydrogen bonds between the carbonyl oxygen and -OH groups facilitate the reinforcement of interfacial interactions between the polymer matrix and the filler

Notably, the highest Shore D hardness value was recorded for sample No. 03, which contained a filler concentration of 1.5%. Conversely, the pure polycarbonate sheet demonstrated the lowest value at 75.07. Analysis revealed an increasing

trend in Shore D hardness values by 6.38% with rising filler ratios in nanocomposite samples. However, it is important to note that the homogeneity of filler dispersion throughout the sheet may be compromised. This is attributed to the preparation method involving melt mixing in an internal mixture, which is known to result in non-uniform filler distribution within the matrix. Consequently, this method may not provide entirely accurate composite preparation due to the inherent challenges associated with achieving homogeneous filler dispersion. It is important to acknowledge the possibility of filler agglomeration within the polymer matrix, which may adversely impact the anticipated outcomes [9].

The poor compatibility between most inorganic nanofillers and the polymer matrix often results in filler agglomeration or aggregation, leading to inadequate dispersion of the nanofillers within the polymer matrix.

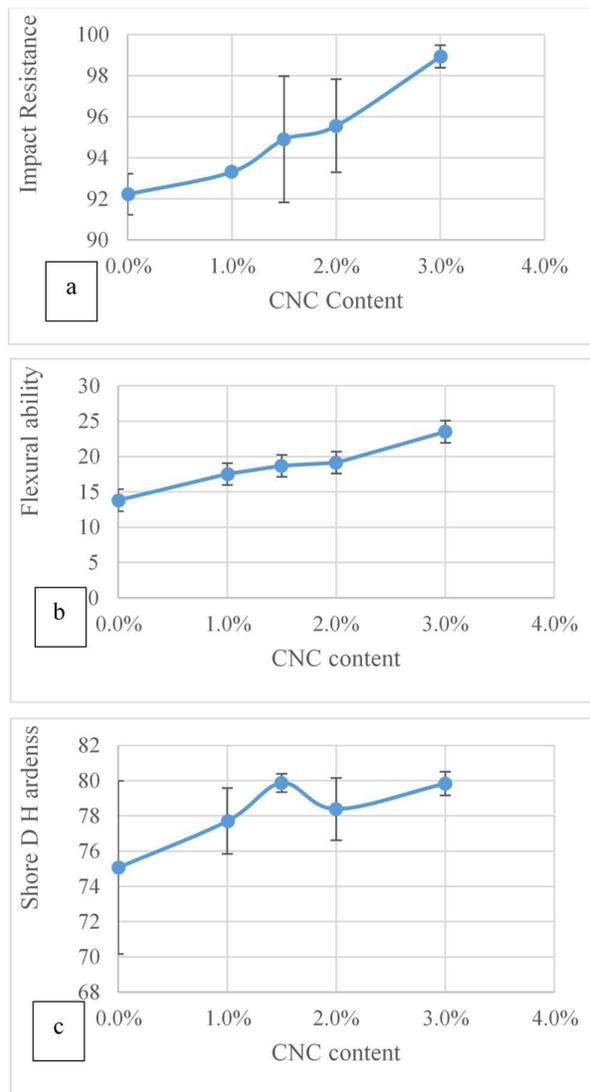


Fig. 7: (a) Variation of Impact Resistance with CNC Content, (b) Variation of Flexural ability with CNC Content, (c) Variation of shore D Hardness with CNC Content

FLEXURAL, IMPACT, AND SHORE D HARDNESS VALUES OF
DIFFERENT CNC RATIO NANOCOMPOSITES

No	CNC Weight (%)	Flexural Results (MPa)	Impact Results (kJ/m)	Shore D Hardness
01	0.0	13.81±0.07	92.23±1.00	75.07±4.91
02	1.0	17.52±0.33	93.33±0.05	77.71±1.87
03	1.5	18.69±0.08	94.90±3.07	79.86±0.52
04	2.0	19.14±0.12	95.56±2.27	78.39±1.77
05	3.0	23.52±0.58	98.93±0.55	79.84±0.67

The impact resistance test measures the energy absorption of a sample during fracture or cracking, providing clear evidence of the material's toughness. The results showed a significant enhancement in the impact resistance of nanocomposites, increasing by 7.26% with higher filler concentrations. The pure polycarbonate sheet exhibited the lowest impact resistance, while the highest impact resistance was observed in the 3% nanocomposite configuration.

The analysis of the FTIR spectra reveals no significant formation or disappearance of peaks. However, a decrease in peak intensity is observed in the nanocomposite spectra compared to those of PC and CNC. Notably, the -OH peaks present in the CNC spectrum are nearly absent in the PC/CNC spectrum. A distinct peak shift at approximately 1760 cm⁻¹ is observed in the spectrum suggesting the potential formation of hydrogen bonds between the carbonyl oxygen of PC and the hydroxyl groups of CNC.

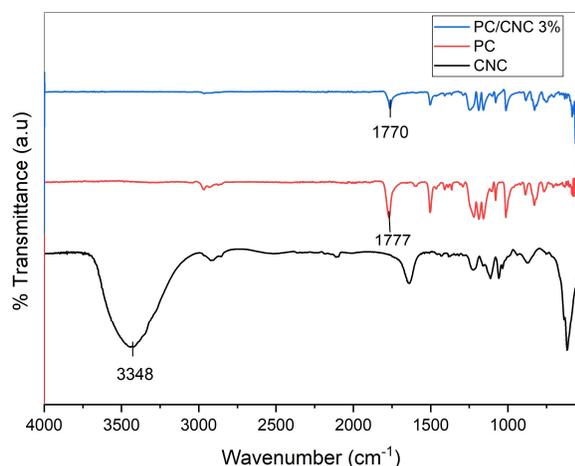


Fig. 8: FTIR spectrum for the synthesized CNC, pristine PC and the 3% nanocomposite

VII. CONCLUSION

The CNC was produced through acid hydrolysis, employing sulfuric acid, of commercially procured cotton balls. The concentration of sulfuric acid was maintained at approximately 50%, while the temperature was sustained at around 30°C throughout the process. Successful completion of the procedure by achieving a percentage recovery of 41%. Characterization of the synthesized particles was performed utilizing various analytical techniques including FTIR, SEM, XRD, TGA, and DLS. These analyses were employed to observe the functionalities, particle morphology, crystalline structure, degradation temperature and particle size distribution. Notably, the utilization of such a low temperature (30°C) for the synthesis of CNC via sulfuric acid hydrolysis with mechanical stirring represents a departure from the conventional practice of conducting similar processes at higher temperatures, thereby contributing to the novelty of this research endeavor. The principal interfacial interaction within this composite system arises from the formation of hydrogen bonds between the -OH groups of the CNC and the carbonyl oxygen of the PC matrix. The FTIR analysis was employed to ascertain the nature of interactions and bonds between the filler and matrix. Mechanical property evaluations encompassed flexural, impact, and hardness tests. The findings demonstrated that the PC/CNC nanocomposite exhibits superior flexural modulus, impact resistance and hardness compared to pure polycarbonate.

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Next-Generation Sequencing in Disease Diagnosis

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Abstract— Next-generation sequencing (NGS) is used to sequence thousands of genes, a whole genome or multiple genomes in a limited time. NGS has a vast range of applications in disease diagnosis. A typical NGS experiment has 5 major steps, which are DNA fragmentation, library preparation, sequencing, analysis, and interpretation. Many applications of NGS is observed in the diagnosis of inherited disorders, infectious diseases, cancers, rare disorders, and pharmacogenomics. At past, the gene that was causing the genetic disorder must be identified prior to the diagnosis. However, with the development of NGS it's no longer a challenge. Due to the development of technologies associated with NGS, such as massively parallel sequencing, it is widely used in precision medicine. Introduction of specific target gene panels to diagnose cancers along with whole genome sequencing, and the use of NGS in diagnosis of infectious disorders has provided a higher efficiency in disease diagnosis. Application of clinical NGS methods for disease diagnosing can be challenging, however, NGS remains cost and time-effective for rapid diagnosis of rare diseases. Currently, methods such as whole exome sequencing can be used for diagnosing rare diseases. This review will focus on long and short-read sequencing technologies and their applications in differential diagnosis. Furthermore, it will focus on NGS applications related to disease diagnosis, advantages, challenges, and future perspectives of NGS. The objective is to provide a brief overview of current NGS technologies, and their availability based on different disease conditions.

Keywords—next-generation sequencing, DNA, whole genome, diagnosis, cancer

I. INTRODUCTION

NGS has revolutionized the biotechnology industry in the last decade. Sanger sequencing known as first-generation sequencing is considered as the path that paved the way for Next Generation sequencing. It was first developed in 1977 by Fred Sanger [1]. First-generation sequencing requires analyzing DNA or RNA fragments individually [2]. Therefore, first-generation sequencing requires a considerable amount of time and read lengths are short. However, with the introduction of second-generation sequencing techniques, sequencing thousands to millions of DNA fragments was possible [2]. Massive parallel sequencing along with high resolution imaging and improvements in microbeads are notable changes in second-generation sequencing [3]. Third-generation sequencing addressed the limitations in previous sequencing techniques and introduced sequencing techniques with long-read sequencing capabilities with the use of much larger DNA fragments [2]. With the third-generation sequencing techniques it is possible to directly sequence single DNA molecules. NGS, which includes second-generation and third-generation sequencing, emerged about three decades later [1]. The name NGS was acquired due to it being a step beyond the first-generation sequencing methods.

There are 4 widely known sequencing methods used in NGS. i.e., pyrosequencing, sequencing by synthesis, sequencing by ligation, and ion semiconductor sequencing belonging to the second-generation [4], [5]. Furthermore, techniques such as, synthetic long-read sequencing, Transposase-Based Sequencing, third-generation sequencing methods such as Single-Molecule Real-Time (SMRT) Sequencing and Nanopore Sequencing are important milestones in NGS. Compared with Third generation sequencing methods, Synthetic Long-Read Sequencing requires very little amount of DNA to sequencing with accurate results [6]. The accuracy of sequencing is based on the readability of the light signals. In pyrosequencing, one base is incorporated at a time and the released pyrophosphates during complimentary base pairing are detected [4]. The released pyrophosphates are then converted into ATP, resulting in luciferin conversion into oxyluciferin, which generates light. This light is captured by a coupled-charge device camera. In sequencing by synthesis method, reversibly fluorescent terminated nucleotides are used [4]. Initiation of this method is done by the binding of DNA polymerase to the primed template [5]. Then DNA polymerase incorporates one fluorescently labelled nucleotide at a time. After the incorporation the unincorporated bases are washed away, and the fluorescent signal is detected [5]. Then the fluorescent label and the terminating group is removed from the incorporated base which allows the repetition of the cycle [5]. The Ligation method uses 16-8mer nucleotide oligomer probes with a specific fluorescent dye to each base and no DNA polymerases, but ligase is used [5]. The ion semiconductor method detects the pH difference when H⁺ ions are released during each complementary binding [4].

Second generation sequencing is known to be a high-throughput DNA sequencing method, with massive parallel sequencing of large amount of DNA. Through this method the sequencing capabilities became faster, accurate and cost effective. The most common second-generation sequencing methods include Roche 454, Ion Torrent, and Illumina, and they differ based on three steps including Nucleic acid extraction, library preparation and sequencing [1]. Though second-generation sequencing is comparatively more cost and time efficient than first-generation sequencing, there are many drawbacks such as short sequence reads in some second-generation sequencing methods, issues related to repetitive regions, PCR artifacts etc. [1]. Therefore, to minimize the drawbacks of these methods and to improve sequencing technologies, third-generation sequencing methods were introduced [7], [1]. These use the single – molecule sequencing based techniques to sequence genomes. The time efficiency of these instruments is comparatively higher and considered the best advantage. However, the error rate is notably high which can be reduced by increasing the depth of sequence. Common examples include Pac Bio Single SMRT

and Oxford nanopore sequencing [1]. PacBio SMRT is a real-time sequencing method with millions of zero mode waveguides on a chip. This method uses hairpin adapters to convert Double-Stranded DNA into circular fragments [1]. The Oxford Nanopore is a real-time sequencing method uses tiny bio pores of a nano diameter which can detect current variation [1].

Fluorescent approaches are present in the Oxford Nanopore method. Different bases that pass through the pore cause different voltage changes allowing the identification of relevant bases. The identification of RNA and proteins is also possible in Oxford Nanopore sequencing. Recently MinION was introduced by Oxford Nanopore Technologies which allows mobile sequencing through laptops [4]. The most recent advancement is the introduction of PromethION, which is a nanopore sequencing method [4]. It is also considered as a high throughput desktop sequencing technique that allows long reads and is also user-friendly sequencing [4]. Currently, NGS is widely used for disease diagnosis and to monitor treatments.

Typical steps of NGS includes, DNA fragmentation, library preparation, sequencing, analysis and interpretation [8]. DNA fragmentation, which is also known as Sample preparation, breaks down DNA into many small segments using methods such as enzymatic digestion or mechanical methods [8]. In library preparation, DNA segments are modified with unique identifiers named as the index,

sequencing adaptors, and sequencing primers [8]. Massive parallel Sequencing is done by using NGS sequencers. Sequencers may include flow cells as in Illumina, or chips as in Ion Torrent [8]. Data analysis is done using bioinformatic methods, where order of nucleotide bases are determined, alignments are read based on the reference genome and the

variations that has the potential to cause health impacts are identified [8]. Interpretation is based on the identification of variants and their significance in causing [8]. Typical steps of NGS includes, DNA fragmentation, library preparation, sequencing, analysis and interpretation [8]. DNA fragmentation, which is also known as Sample preparation, breaks down DNA into many small segments using methods such as enzymatic digestion or mechanical methods [8]. In library preparation, DNA segments are modified with unique identifiers named as the index, sequencing adaptors, and sequencing primers [8]. Massive parallel Sequencing is done by using NGS sequencers. Sequencers may include flow cells as in Illumina, or chips as in Ion Torrent [8]. Data analysis is done using bioinformatic methods, where order of nucleotide bases are determined, alignments are read based on the reference genome and the variations that has the potential to cause health impacts are identified [8]. Interpretation is based on the identification of variants and their significance in causing [8].

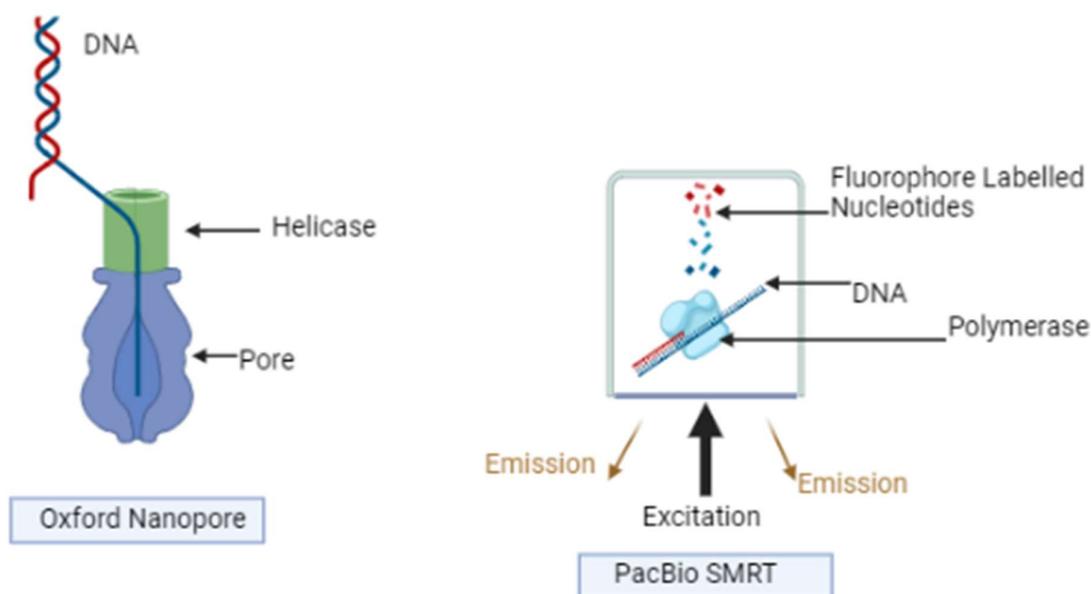


Fig. 1. Third generation sequencing

II. APPLICATIONS OF NGS

NGS is used for the detection of a vast range of constitutional disorders, oncology, infectious diseases, etc. Compared to other genetic detection methods, NGS has a higher diagnostic yield [1]. The diagnostic yield denotes the effectiveness of a diagnosis through a diagnostic test. For instance, In Mendelian disorders the whole exome sequencing

using NGS produces a diagnostic yield of about 25%, while the diagnostic yield of whole genome sequencing in Mendelian disorders has a slightly higher value which is 27% [1]. Depending on different NGS panels the diagnostic yield can differ. The traditional method for detecting genetic mutations are the forward phenotyping method which is also known as the “forward genetics method” [1]. However, NGS was able to introduce reverse phenotyping method which is also known as the “genotype-first” approach.

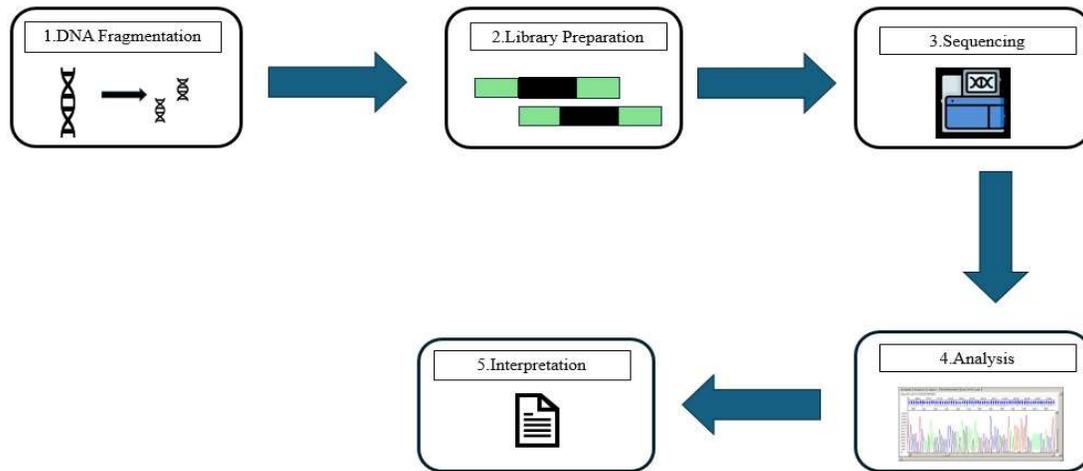


Fig. 2. Typical steps of NGS

Through this method, the genetic variations are identified and then the associated phenotypes are discovered. This method is useful in identifying rare diseases, complex traits, and novel syndromes. NGS has produced target panels, increasing the specificity and sensitivity of genes of interest to a particular disease. If the patient cannot be diagnosed using the target panel, they will be directed to exome or genome sequencing [1]. This will broaden the testing for all known disease-associated genes. For the patients who lack a proper diagnosis, exome sequencing (ES) will provide a molecular diagnosis rate which is around 24% - 52%. Using genome sequencing (GS) before targeted NGS panels can increase the diagnostic yield by 29% [1]. Moreover, target panels can only be used to detect gene variants, making it unsuitable for patients with unknown manifestations. ES and GS both have a higher diagnostic yield, however the cost is also higher.

Cancer plays a significant role in precision medicine, allowing various applications of NGS. NGS can be applied to identify genetic mutations that result in cancers. Even with the presence of ES and GS, targeted gene sequencing is best in use in clinical practice due to its cost efficiency and timeliness. The first application of NGS in cancer was recorded in 2017 in the US against non-small cell lung cancer [1]. Currently it is used in several national reference laboratories. Small NGS panels are being used to detect cancers such as breast cancer and acute myeloid leukemia while larger NGS panels are available to diagnose a wide range of cancers, including

malignancies that are related to hematology and solid tumors [1]. NGS has also been used to diagnose minimal residual disease, which determines the effectiveness of the treatment, re-emergence of the cancer, and diminution of cancer.

Infectious diseases are caused by various pathogens such as bacteria, viruses, and some eukaryotes which accommodate high morbidity and mortality rates. They are diagnosed using three methods: targeted panels, whole genome sequencing, and metagenomic NGS [1]. The sensitivity and specificity of target panels is high, but they have a limited range and cannot identify antibiotic resistance and novel species. Antibiotic resistance can be identified through WGS to determine the first line of drugs. For an example, a transmission of highly resistant strain of *Klebsiella pneumoniae* was explained by using WGS [9]. Low amounts of genetic material of the desired pathogen can be detected by metagenomic NGS (mNGS), which can be missed by other diagnostic methods [1]. For an example, mNGS has been able to identify a scarce amount of genetic material from a bornavirus family in three squirrel breeders who passed away with similar brain-related symptoms [10].

III. NGS IN CANCER DIAGNOSIS

The use of NGS in cancer diagnosis has been a milestone in identifying gene alterations that are the root cause of cancer. NGS can diagnose concomitant genetic mutations simultaneously and provide a faster reporting time.

NGS is applied to detect mutations in solid tumors and hematological cancers. Hereditary breast cancers (HBC) compose about 5 – 10% of total breast cancers [11]. The common mutations associated with breast cancers are *brca1* and *brca2* mutations that accompany 30% of HBCs. Customized NGS panels have been developed to detect these mutations. Quest Sequencing analyzing pipeline (QSAP) has been developed to read large reads of indels and is widely used for breast cancer diagnostics. The combination of MiSeq platform with QSAP alignment has created a NGS method that has a higher sensitivity and specificity [11]. Recent research have been done by using NGS based multi-gene panels to diagnose HBC [12]. 64 genes associated with HBC were included in the multi-gene panel that was used [12].

The recent research denoted that by using multi-gene panel mutation detection rate can be increased from 8.6% to 15.6% [12]. Furthermore, 48 deleterious germline mutations were noted in genes such as *brca1/2*, *cdh1*, *rad51* etc. and novel deleterious mutations related to *brca2* and *mlh1* were detected [12].

The causative mutation for 30 – 70% of melanomas is the *braf* mutation. Very little research is carried out to diagnose melanomas using diagnosing panels [11]. Therefore, there are only a few available clinical applications of melanoma-specific disease panels, such as NGS panel developed by University of Michigan MLabs [13]. Also, a custom panel named AmpliSeq is under research where 11 important full-length genes causing melanoma are used [11]. It has shown higher specificity and sensitivity for diagnosis and is currently under the validation phase. Prostate cancers can also be diagnosed using NGS methods and the studied pathways include RTK–Ras–MAPK, PI3K–PTEN–Akt, and AR–signaling pathways [11]. Thyroid cancers diagnosis also uses a specific panel known as the ThyroSeq which can analyze 12 cancer genes and 284 hotspots [11]. This was later improved to panels - such as ThyroSeq version 2, ThyroSeq version 2.1, and Ion AmpliSeq Hot Spot Cancer Panel version 2 for diagnosing thyroid cancers [11]. The main cause for lung cancers is EGFR mutations [14], [1]. The effect of tyrosine kinase inhibitors towards such mutations can be evaluated by NGS methods, such as Ion AmpliSeq RNA Fusion Lung Cancer Panel and Ion AmpliSeq Colon and Lung Cancer Panel [11].

NGS can also be applied in diagnosing hematological cancers such as multiple myeloma, lymphoma, and minimal residual disease (MRD). A target gene panel was produced by Kortüm et al targeting 47 genes for multiple myeloma [11]. ClonoSEQ is a NGS based method which was approved to diagnose MRD in patients with multiple myeloma and acute lymphoblastic leukemia, by US FDA in 2018 [1]. However, NGS for lymphoma and minimal residual disease are still under development and are rarely applied in clinical practices [11], [1].

NGS revolutionized the field of personalized medicine by detecting driver mutations in cancer [14]. Currently Roche is massively used in personalized medicine because it allows the parallel analysis of 315 cancer related genes [14]. Mutations that can alter the drug response within a patient is known as Pharmacogenomics [14]. In cancer, pharmacogenomics is

important as it can affect both drug metabolism as well as cancerous cells [14]. Several NGS gene panels are developed to detect drug response and metabolism, which lead to the development of PharmGKB database [14].

Highly sensitive NGS techniques have been developed to diagnose cancer by using liquid biopsies which are relatively noninvasive [15]. Components such as circulating tumor DNA (Ct DNA), RNA, Extracellular vesicles, tumor educated platelets etc. can be seen in liquid biopsies [15]. The applications of liquid biopsies are observed in Colorectal cancers, lung cancers, and breast cancers [16]. The most commonly used component for sequencing is circulating tumor DNA [16]. Advantages of sequencing using liquid biopsies includes, overcoming Tumor heterogeneity, Early detection of cancers, predicting adaptations of the tumor to anticancer treatments by repeating the test [15]. However, due to the low levels of Ct DNA in liquid biopsies (blood), and Ct DNA being easily degradable, have caused many challenges in detecting tumor patients while the correlation between Ct DNA with Tumor tissue remains uncertain [16]. Furthermore, the requirement of specific panels with high sensitivity for each mutation is another drawback in liquid biopsies [16].

IV. NGS ON INFECTIOUS DISEASES AND OTHER APPLICATIONS

The determination of the cause of diseases with infectious agents has been fundamentally enhanced by the NGS, a technology that can facilitate rapid recognition, precise character development, and reliable inspection of pathogens [17]. This technique uses extensive sequencing data, which permits comprehensive differentiation and classification of disease-causing microorganisms [18]. This is beneficial in monitoring the propagation of the disease and discovering its epidemiological background. Next-generation sequencing permits assistance with outbreak detection and provenance tracing by analysing the ancestral relationships amongst disease variants through contrasting genetic information. The accessibility of NGS platform in the field of microbiology has expanded. [2].

NGS has been instrumental in identifying and characterizing SARS-CoV-2, the virus responsible for COVID-19, by sequencing its genome from patient samples, thus aiding in the development of diagnostic tests and vaccines. While RT-PCR remains the gold standard for COVID-19 diagnosis, NGS provides a comprehensive alternative by simultaneously detecting SARS-CoV-2 and differentiating it from other respiratory pathogens, which is particularly useful in cases of co-infection [19]. NGS is crucial for variant tracking and surveillance, enabling researchers to monitor viral mutations and the emergence of new variants, thereby informing public health responses and assessing vaccine efficacy. Additionally, NGS helps trace transmission pathways during outbreaks by comparing viral sequences from different cases and identifying infection clusters and sources. It also plays a key role in monitoring vaccine performance through the analysis of breakthrough infections, helping to understand variant-induced vaccine escape. Beyond diagnostics, NGS facilitates extensive research into the virus's structure, function, and interaction with the human host, enhancing our understanding of viral entry, replication, and immune response. The diagnostic workflow for NGS

involves sample collection, RNA extraction, library preparation, sequencing, data analysis, and reporting [20].

NGS offers comprehensive pathogen detection, high throughput, and detailed genetic information, essential for mutation and variant tracking. However, its higher cost, complexity, longer turnaround time compared to RT-PCR, and substantial data management requirements present challenges. Despite these, NGS has become invaluable in combating COVID-19, providing critical insights into the virus and its spread, essential for effective public health strategies and vaccine development [21].

NGS is developing not just in the clinical and medical domains but also in other sectors. Crop plants are subject to mutations that alter their DNA, with individual mutations affecting the function of genes. Understanding the nature, genes, and phenotypic effects of mutations is made possible with the use of NGS technology and processing pipelines to help discover causative mutations. NGS is also applied in SHOREmap, which is a genome sequencing tool used to identify casual mutations in recombinant lines, which follows mapping-by-sequencing principle [22]. NGS-based Human Leukocyte Antigen (HLA) typing offers high-throughput, high-resolution typing results for organ transplant or haematopoietic stem cell transplant, providing information on all HLA loci involved in immune disorders, lung diseases, infectious diseases, and malignancies, generating a population/ancestry-based database [2].

V. CHALLENGES OF NGS

NGS facilitates high throughput analysis of genetic material by producing a large volume of data. Therefore, massive databases and storage of resources are needed to store and maintain the vast quantities of information generated by NGS. Also, NGS inherits technical drawbacks such as elevated rates of errors in comparison to Sanger sequencing and challenges in assembly caused by small read lengths [23]. Preparing the samples for NGS is an intricate procedure that demands delicate handling of samples with exceptional quality to minimise cross-contamination [24]. Furthermore, the need to protect crucial genetic information and govern the authorization, possession of the data, and confidential issues are some associated with NGS. Understanding regulations for therapeutic uses and managing variations in procedures and outcomes are two aspects of regulatory and standardisation challenges in NGS [25].

Moreover, it is necessary to validate the NGS results associated with disease diagnosis by correlating modifications of genes to their phenotypic effects relevant to diagnosis. To tackle these obstacles, continual improvements in technology, sophisticated statistical instrument development, and standardization of procedures and ethical structures to guarantee the conscientious utilization of NGS technologies are necessary [26].

VI. FUTURE PERSPECTIVES OF NGS

The study of genomes has been transformed by NGS, which has many potential applications in the fields of medicine, agriculture, and other disciplines. It is anticipated

that the latest platforms of NGS will provide significantly greater throughput and rapid sequencing capacities in the future, saving time, money, and labour. Errors will be minimized, and complicated genetic domains can be addressed with greater efficiency with the developments in precision and read length [27]. Real-time and on-site sequencing will be improved by introducing more transportable and conveniently available analysing tools, including nanopore sequencers. Prices are anticipated to keep falling as NGS becomes progressively in demand, allowing NGS to be used by a wide range of investigators and industries [28]. Improved automation in data analysis and preparation of samples could further save expenses and labour cost. Enabling personalized medicine based on individual genetic profiles, improving the rapid sequencing of pathogens for vaccine development, and progressing cancer-targeted treatments will be future targets of NGS [29]. It will track the gene expression with spatial context and shed light on the variability of the cells within tissues using single-cell sequencing.

Moreover, a detailed comprehension of biological processes and disorders will be achievable with the combination of multi-omics data and epigenetic sequencing. NGS data analysis will benefit from improved artificial intelligence and machine learning, and cloud computing will facilitate the storage and processing of data. NGS will require security and confidentiality of information as well as regulatory structures due to ethical, legal, and social implications. Biotechnological advancements and precise genome editing will be fuelled by the combination of NGS and CRISPR [30]. In the future, Sri Lanka could implement genome-wide sequencing in diagnosing genetic disorders, cancer, and other diseases, leading to more accurate treatments. Sri Lanka's rich biodiversity can be studied more effectively using NGS. This could support conservation efforts for endangered species and understanding the genetic diversity of ecosystems, particularly in national parks and marine reserves. The Sri Lankan government could play a pivotal role in promoting NGS through national programs aimed at integrating genomics into healthcare and agriculture [31].

VII. CONCLUSION

The field of genomic research and its applications have seen an important development since the introduction of NGS, which has substantially improved various other fields, including medicine, environmental science, biotechnology, bioinformatics, and agriculture. NGS has made personalised treatments, better cancer evaluation, outbreak tracking, and more effective treatments for infectious diseases conceivable by permitting reliable and extensive examination of genetic information. With the incorporation of multi-omics, single cell sequencing methodologies, and sophisticated data processing techniques, the technology promises to yield progressively more profound insights into intricate biological systems as it advances.

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Evolving Technologies for Agriculture: Modernization with Radio Frequency Identification

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Abstract— Current global population of 7.3 billion estimated to increase up to 9.7 by 2050. Food production towards the increasing demand is required. Modern technological aspects of agriculture enhance the productivity, sustainability, and efficiency with specific nurture. Its real-time information overcomes the risk and uncertainty factors of agriculture. Radio Frequency Identification (RFID) as a modern technology is momentous. Its utilization in smart agriculture guarantees accurate traceability from farming sites to the final consumer by linking the “tag” and the “reader”. The paper presents a substantial discussion of the applications and challenges behind the RFID approach in Agriculture. The methodology is qualitative with a content analysis of literature. Environmental, soil, plant growth, and postharvest like aspects are monitored by RFID in agriculture. Enhanced supply chain visibility, precision agriculture and resource optimization, product authentication, supplying of automated data, and quality information are performed by the technology. Traceability enhancement is an important aspect and is provided effectively, accurately, and safely. RFID continues with some challenges called initial investment cost, time and labour requirement, problems with data exchange and integration, high technological requirement, privacy, and security problems of the data, negative influence of harsh conditions on the data, and difficulties in integration of existing agricultural practices etc. RFID approach reaches some advances and continues to address some challenges. Utilization of RFID under maximum technical potential has not yet been reported. Conducting more extensive research and combining of RFID with other technologies will direct to a low-cost sustainable solution in agriculture.

Keywords—advantages, agriculture, challenges, modernization, radio frequency identification

I. INTRODUCTION

As per the United Nations statistical data, there were 1.8 billion people in the world in 1915 and the global population has quadrupled over the last century. Research studies show that present global population of 7.3 billion will be increased up to 9.7 by 2050 [1]. This growth has been continued along with the rising of income in developed countries. The situation is driving up to the creation of improved global food demand with the time. It is predicted that the food demand is increasing in the world between 59% to 98%. Therefore, increasing of overall food production towards the feeding of increasing population is needed [2]. According to the research studies, agricultural food production is basically depended on the application of modern technological aspects aiming to enhancement of productivity, sustainability and efficiency due to its special nurture. Agriculture industry is consisting with

risk and uncertainty aspects and susceptible to many factors. Weather changes, Pest and diseases problems and product decay problems in transits are the identified issues. Therefore, efficient access for the wide range of real time agricultural information directed to an agricultural modernization is worthy [3]. Smart agriculture or precision agriculture is an efficient approach for the suppressing of challenges behind the agricultural production and ensures the food supply from the agricultural industry [4]. It integrates the modern technologies including Internet of Thinking (IoT), Artificial Intelligence (AI), Cloud computing and Wireless communication with agriculture. Radio Frequency Identification (RFID) technology developed in the past two decades is one of the foundations of IoT. The application of RFID technology in modern agricultural practices directs to the covenanting of accurate traceability from the farming sites to the final consumer.

The objective of this study is to review the status-quo of applications and barriers in the implementation of RFID in agricultural industry.

II. LITERATURE REVIEW

A. Radio Frequency Identification (RFID)

RFID is a modern technology with the demand from various sectors to utilize its potential to enhance the collecting of data, tracking of assets and supply chain management [5]. Various types of RFID exist and, the technology can be divided into two categories at higher levels such as active tags, and Passive tags. Active tags can be connected to a power source or used by the energy stored in an integrated battery. Passive RFID tags are not required the batteries or maintenance [6].

Since recent years, RFID technology is being utilized to the agricultural related applications. In here, transition from traditional farming practices to modernized agricultural practices were occurred and farmers were faced some challenges while applying the technology [7].

In RFID technology, electromagnetic field is utilized to automatically identify and the track the objects fixed with RFID tags or transponders. As per the “Fig.1”, Microchip and antenna are included in these tags and which is working with conjunction to transmission of the data to RFID readers when exposing for the radio frequencies. Finally, reader is captured the transmitted data and enabling to the real-time monitoring and data collection without the direct contact or slight visibly line [8].

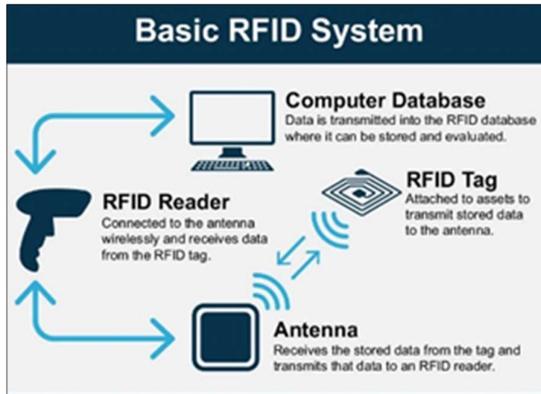


Fig. 1: Basic RFID Systems

B. RFID in Agriculture

Before introducing RFID in the field of agriculture, the barcode system was used by the relevant parties in the industry [9]. In agriculture, RFID offers a pivotal application in the industry such as livestock management, crop monitoring, supply chain optimization, and precision agriculture. In livestock management, each individual animal is fixed with RFID tags for accurate tracking. Apart from that, the technology is applied in the measuring of soil or environmental parameters and making the site-specific decisions regarding the optimum conditions can be reached [10].

Fruit monitoring and orchard task scheduling have been initiated with the RFID technology and the system has been initially utilized for mangoes and testing for other important fruit crops [11]. The RFID can be utilized in smart agricultural practices such as collecting plant growth environment data (Climatic conditions related to the plant growing environment), soil parameters related measurements, growth-related aspects of plants and harvest quality determination etc. Further research on addressing the specific smart agricultural needs with different types of RFID sensors are currently practicing [12].

Traceability control by monitoring of food chains is performed by RFID technology. Exploration of new applications in environmental related sectors, irrigation practices, crop specific factors identification and farm mechanization can be reached by the technology [13].

Spoilage issues faced by agricultural producers can be overcome by the implementation of RFID technology. Temperature monitoring and determination of shelf-life of perishables at every stage in the cold chain are performed by both producers and buyers engaged in the agricultural sector. Competitive pressure in the market, regulatory requirements of the country, condition of the global supply chain and the safety concerns in the agrifood sector are eliminated by the RFID technology [14].

C. Challenges of the RFID Use in Agriculture

Implementation of RFID technology for the agricultural sector faces some problems while approaching to the target groups. RFID technology is consisting with incompatible

standards. It practically applies with the various frequencies, various countries with different radio band allocated to different uses. The standards following by the various parties are differs and many responsible European organizations are working with solving of some problem and, already fulfilled some achievements on standardization. It will stimulate the RFID for the development and extended utilization among people.

Tags, readers and other hardware equipment should be cost effective to the implementation of RFID. Status-quo of the implementation of RFID to the agricultural sector has some drawbacks. Further, costs for the software updating of the management system and following up the system maintenance are comparably high. Agriculture industry is continuing with both risks and uncertainties, and considered as a low-profit industry for some extent. Investment at agricultural industry required too much costs and identified cost reduction strategies are important. Requirement of the key parts of RFID system is reduced with the exploration of semi-conductor manufacturing technology, while considerable reduction of overall implementation cost.

Privacy and security problems of the technology are notable and RFID technology can be attacked by the hackers [15]. Such type of background is emerged due to the transmission of radio frequency signals through the air and easily tracked by the external parties. Privacy of the individual person or business parties can be confronted with some problems on the situation and researchers are currently working hard to explore a reliable trustworthy improved mechanism for RFID system [16].

Apart from the discussed matters, the operation of RFID in rough environments affected by dust particles, dirt, moisture and extreme environmental temperatures, severe mechanical vibrations, peripheral equipment, metal interference, electromagnetic interference, etc. In addition to the discussed Various reasons such that position orientation of RFID reader or antenna, locating and pasting of tags like methods will also affect on the reliability of the RFID implementation approach. It makes some identification problems of the receptors with increased error percentage. The huge data volume is difficult to manage in this approach. Therefore, most of the RFID related applications in agricultural sector can be affected by the environmental factors. Possible damages should be subjected to more continued researches [17].

III. METHODOLOGY & MODEL SPECIFICATIONS

This study is based on the qualitative literature review of RFID utilization in the agricultural industry. Both national and international literature reviewed in this paper to evaluate the context of RFID utilization in the agriculture sector. For the exploration of advantages, barriers and research needs of application of Radio Frequency Identification with the context of modern agriculture was performed by a formal study based on a systematic literature review. Referencing of publications related to the study was comprehensively performed and, utilization of number of search engines towards the confirmation of broad collection of point of views and relevant

data were practiced. Overall quality of the paper was ensured through the referring of scholarly articles on various relevant disciplines, such as, modern agricultural sector in the global context, Radio Frequency Identification and barriers on the technology etc. Literature from various sources such as scholarly articles, various dissertations and theses, books, and responsible conference papers relevant to the study by serving a vast range of creative opinions on the research theme was reviewed.

IV. EMPIRICAL RESULTS

A. Basics of RFID technology and provision for the field of agriculture

As per an article of Jituri, 2020, Conceptually, RFID technology is based on the utilization of radio waves to automatic identification of required people or objects from a specific distance as a measurement of several inches to hundreds of feet [18]. Further, Barcode and Magnetic strips, Integrated Circuit (IC) cards related activities and Optical Character Recognition (OCR) process, Voice Recognition technology, Finger Print and Optical Strip methods are considered as the other identification mechanisms similar to RFID. According to the Profetto et al., 2022 in this review, system efficiency enhancement with the aid of Automatic data capturing system is performed by RFID. Identification purpose is continuing through two parties called “Tag” (RFID tag is storing the relevant code) connected to the physical object and the “Reader”. Object becomes unique and consists with identifiable characteristics after tagging and object transmits code from tag and facilitate to reader to obtain the information on the object [19].

RFID is not labelled as a newest technology but application in various disciplines in modern ways is visible. Agricultural related practices are essential for any society to feed the overall population and play a crucial role in the economical enhancement of any country and its development. Therefore, systematic provision of RFID technology for the global agriculture is justifiable.

B. Applications of RFID Technology in Agriculture

As per the research studies conducted by Rayhana et. al., 2021, environmental, soil, and plant growth like aspects are monitored by the RFID technology in agriculture. There is a positive effect of environmental parameters such as temperature level, humidity condition, light intensity, carbon dioxide and oxygen level etc. on the healthiness level of agricultural crop plants. Accurate monitoring of such parameters can be ensured by RFID technology and, some research studies demonstrated that, monitoring of local climatic conditions surrounding the plant grown environment (Ex: leaves etc.) can be performed by RFID.

Usage of water resources are optimized by the collecting of accurate information such as soil moisture, salinity and pH values from RFID and marked as the essential parameters to ensure the growth of a healthy crop plant compatible with proper irrigation practices. The literature based on the previous works stated that chip based, chip less and add-on sensors explored by the scientists with the objective of

research on the soil monitoring in smart agricultural practices. Also, the measuring activities of soil parameters can be reached by the application of Antenna type RFID sensors.

The plant height, size, lateral spread, number of flowers, fruits and vegetables and further, Lateral plant height, radius, leaf size, size of flowers petals as well as the plant fungal diseases etc. can be measured by RFID tags. Existing literature shows that growth of the roots can be measured by the RFID effectively. RGB (Red, Green & Blue) camera sensors are utilized to the measuring of height, size and the diseases of the plants. All plant growth parameters can be reached through the combining of RFID sensors with some important sensors to detect the required parameters. Plant diseases, weeds, and pest related information like factors can be explored throughout the making of the system equipped with more reliable and robust features so far. Further, quality of the harvest and optimum safety are a significant concern for sellers and consumers in the food chain. Freshness of fruits and vegetables harvested under the handpicked method are determined by the RFID technology due to the short life of perishables. Important information on the highly perishable food supply chain from several parties such as distributors, retailers and consumers etc. are important. Specific awareness on expiry date and remaining shelf-life are mandatory with the incorporation of RFID technology. It will direct to the more RFID investment decision in the highly perishable food supply chain [20].

Greenness is a supportive key parameter to the measuring of freshness of green leafy vegetables. It is measured by the accumulated ammonia gas level. The leafy vegetables are toxicated by ammonia and the toxic accumulation is occurred during the post-harvesting period of the product. Further, wheat, rice, peanuts, mustard, and lentils like grains are tend to be absorbed the moisture under the normal atmospheric temperature in the storage structures. Moisture accumulation makes some fungal problems and caused to the reduction of quality of the grains. It directs to the reduction of the economic values of products influencing for the farmers, sellers and consumers in the marketing chain and quality metrics of the product should be concerned.

Apart from the early discussed matters, industrial application of RFID technology under the field of agriculture is noticeable. As per the Musa and Dabo in 2016, Enhanced Supply Chain Visibility is performed by RFID [21]. Review papers of Sedghy, 2018 describe the RFID as a technology which provides the considerable benefits to enhance the quality control of perishable foods by providing the essential information in supply chain management [22].

When comparing RFID with the traditional bar code recognition lists in Table.1, RFID has some advantages with multi-label collection, fast scanning with high speed, high security of the data and strong repeatability. As per the literature, RFID facilitates in agriculture by automated data collection, traceability enhancement, compliance with regulations, and product authentication. Farmers are empowering with accurate data directing to make informed decisions while optimizing the resource allocations with improved productivity ensuring the sustainable agricultural practices. Automation of precision agriculture process is

performed through the introducing of RFID technology to the agriculture. Quality information of the final products is managed and linkage with the centralized systems is fulfilled with the technology. Supporting for the Sustainable Agriculture is a major role of RFID. It ensures traceability of vegetables and post-harvest losses and analysis is performed in the transport and handling chain. Traceability is a key point to ensure the effectiveness of practices in the global supply chain and guaranteeing the safety of agricultural crops. As per the Gomes et.al., 2023, successful implementation of RFID highlights the potential improvements of various operations, working time reduction, and traceability enhancement in industries [23].

TABLE I. TRADITIONAL BARCODE RECOGNITION VS. RFID

	Traditional Bar Code	RFID
COLLECTION	SINGLE LABEL COLLECTION	MULTI-LABEL COLLECTION
SCANNING SPEED	SLOW	FAST
SCANNING RANGE	SMALL	WIDE
SAFETY	LOW	HIGH
WATER PROOFNESS	NOT WATERPROOF	WATERPROOF
CONTACT	REQUIRES HIGH LIGHT CONTACT	NO NEED FOR LIGHT CONTACT
REPEATABILITY	WEAK	STRONG

C. Challenges for RFID technology in Agriculture

According to the studies conducted by Ruiz-Garcia and Lunadei in 2011, Initial investment cost for RFID in agriculture is not affordable to farmers. Tags, readers and sensors like RFID hardware are relatively expensive for small scale farmers living in the areas with limited resources. Further, communication networks and data storage systems like infrastructure will add to the overall costs. Tagging and maintenance of RFID related equipment is a time and labor-intensive activity. Fixation of the RFID equipment for animals will be challengeable and periodic replacement of tags are needed due to the wear and tear. According to the research articles of Sun et.al., 2019, standardized protocols and compatibility among different RFID systems are influencing on the infinite data exchange and integration [24].

Unified and efficient agricultural ecosystems are reached through the ensuring of interpretability between RFID systems from various manufacturers. Farmers must be equipped with necessary tools and skills to handle and interpret the RFID data effectively. It ensures the effective data management and analysis. As per the Kaur et al., 2022, privacy and the security of the data should be concern towards the gaining the trust of farmers and consumers [25]. RFID tags has a limited read range and interference and moisture like environmental factors and metal objects can affect on the performance and accuracy of RFID systems. According to the Wu, 2024, RFID technology gives many advantages while still meeting with some constraints in practical applications such as label collision and unknown label recognition etc. [26]. These are not only influence on the performance of the

overall system but may also threatable on the actual teaching and management.

In most agricultural practices, exposing of tags for the harsh conditions will affect to the ensuring of reliable data. Integration of RFID with existing agricultural practices and work flows can be uplifted for a complex level. The farmers should need to adopt their new routines and adaptation for the new technologies required some training and special support to ensure the smooth integration. As per an article of Bukova et.al.,2023, European union legislations has been defined the Radio Frequency Identifiers as electronic wastes [27].

D. Research needs for the RFID in Agriculture

Against to the challenges, applicability of RFID for agriculture industry should be improved by the conducting of researches on Supply chain visibility, increased productivity and more sustainable agricultural practices. It can be enhanced by the suppressing of influencing hurdles on the approach.

V. CONCLUSION

Feeding of the rapidly increasing global population was emerged the necessity of the expansion of overall food production in the global arena. Upgrading of the agricultural activities were performed and agricultural enhancement was initiated with the conversion from traditional agriculture to modernized agriculture. Radio Frequency Identification (RFID) has outcome as a modernized technology and it has been started to apply in the agriculture sector by performing with remarkable improvements. Guaranteeing of accurate traceability from the farming sites to final consumer is executed by the utilization of RFID in agriculture. The technology was accomplished with numerous ways by playing the pivotal role in crop establishment activities, harvesting to the yield consumption by relevant parties. Detection of external environmental factors related to the plants, providing the data on water resources, indicating the measurements on plant growth factors and postharvest factors are performed by RFID. All these functions are carried out under efficient and accurate manner and supply chain management, resource optimization, automated data collection and management were also executed. In addition to that, product quality and traceability enhancement, data collection at precision agriculture for a sustainable farming practice were afforded. Apart from the numerous benefits given from the technology, some significant challenges were addressed by the farmers. Cost for infrastructure, maintenance related issues, standardization problems, privacy and some limitations with technological skills can be identified with some potential future research themes. RFID technology is contributing to make some advancements in the field of agriculture. It seems that the maximum technical potential of this new technology has not yet been utilized. Combination of RFID with potential other techniques are required to uplift the agriculture industry through sustainable and cost-effective manner.

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Formulation of a Novel Cane Sugar Product Incorporated with Herbal Ingredients and Evaluation of its Total Phenolic and Flavonoid Contents, DPPH, and ABTS Antioxidant Capacity

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Abstract—Cane sugar is an essential food component in the food industry, added to many foods and beverages as a sweetener. However, a high intake of added sugar raises a health risk as it directly contributes to the onset and progression of type II diabetes. Further, sugar increases the calorie value of a food without adding any nutritional quality to it. Therefore, this study aimed to hinder the glycaemic impact of cane sugar while improving its functionality. A novel sugar was formulated by incorporating *Phyllanthus emblica* and *Zingiber officinale* extracts in minuscule amounts. The glycaemic index of the formulated sugar was evaluated using the standard methodology via a human trial. Further, the Total phenolic and the Total flavonoid content and the DPPH and ABTS antioxidant capacity of novel sugar were assessed against a control. According to the results, the glycaemic index of cane sugar was significantly reduced ($GI=38.45\pm 8.92$) compared to cane sugar ($GI=65$), with a percentage decrease of 40%. Incorporating plant extracts has significantly improved the total phenolic content, total flavonoid content, and antioxidant capacity of sugar. Notably, total phenolic content was increased from 0.31 ± 0.06^b to 8.52 ± 0.16^a and flavonoids were detected in novel sugar (0.12 ± 0.02) while control sugar didn't elicit any activity. DPPH and ABTS radical scavenging activities (%) were improved to 45.01 ± 2.81 and 0.41 ± 0.006 respectively. Thus, it could be concluded that incorporating *Phyllanthus emblica* and *Zingiber officinale* extracts has hindered the glycaemic impact of cane sugar while improving phytochemical contents and antioxidant capacity.

Keywords—cane sugar, glycemic impact, phenolics, antioxidants

I. INTRODUCTION

Sugars are a common food component of our food supply and comprise simple carbohydrates such as monosaccharides and disaccharides. Sugarcane (*Saccharum officinarum*) is one of the most important sugar crops, fulfilling over 76% of the world's sugar requirements. Sugar is utilized in many foods and beverages, mainly as sweeteners. They provide texture and body for food products, increase palatability, and act as preservatives in some foods. Therefore, the role played by sugar in the food and beverage industry and as a household staple is crucial. However, High intake of food and beverages with added sugars directly contributes to the epidemic of diabetes, particularly in South Asia. Sugar per capita consumption and diabetes incidence are positively correlated

when data from 165 countries were considered (Weeratunga et al. 2014).

Glycaemic control is crucial in diabetes management, but 43.2-55.6% of adults do not meet the required glycaemic goals (Thadchanamoorthy et al. 2021). Dietary carbohydrates comprise a major part of the human diet, especially among South Asians. Even with the public awareness of the association, sugar consumption continues to rise. Sharing and enjoying sweets is an integral part of South Asian cultures, and most traditional snacks, desserts, and sweets are prepared with a lot of added sugar (Bhardwaj, O'Keefe, and O'Keefe 2016). The popularity of sugar-sweetened beverages (SSB), including carbonated drinks, flavoured juices, sugar added tea and coffee, sports and energy drinks are also on the rise, which can be considered a main source of added sugar among most populations (Neelakantan et al. 2022).

Even though added sugar contributes to blood glucose spikes and poor glycaemic control, limiting sugar is challenging as it provides texture and flavour to food products. Therefore, an alternative way to reduce the glycaemic impact of sugars has been of interest over time. Various spices and herbs of Asian origin are advantageous in managing diabetes and are considered non-prescription drugs (Bi, Lim, and Henry 2017). Furthermore, they contain abundant functional compounds/ active ingredients such as polyphenols. Phenolic compounds elicit antioxidant, anti-tumoral, anti-allergic, and anti-inflammatory properties and are beneficial to health and facilitate defence mechanisms in the body (Dziki et al. 2014). Thus, incorporating suitable spices and herbs into sugar could suppress the glycaemic impact and increase the phenolic content and antioxidant capacities, elevating it to a functional food.

Spices and herbs such as Indian gooseberry (*Phyllanthus emblica*) and Ginger (*Zingiber officinale*) are well known for rich phytochemistry and are potential candidates to incorporate into sugar without altering the sensory properties. Gooseberry contains a high vitamin C content and aids in lowering blood glucose levels by stimulating the pancreas to secrete insulin (Patel and Goyal 2011). Gooseberry fruit further contains tannins, alkaloids, and phenolic compounds. The main bioactive components are gallic acid, ellagic acid, and emblicanins. Additionally, it includes flavonoids such as quercetin and kaempferol (Baliga and Dsouza 2011).

According to (Bode and Dong 2019), Ginger contains at least 115 known active compounds which have been identified. Ginger is abundant with bioactive compounds, including gingerols, shogaols, zingerone, and paradol (Choudhari and Kareppa 2013). Studies suggest ginger is therapeutic in reducing fasting glucose levels in people suffering from type II diabetes (Andallu, Radhika, and Suryakantham 2003). Thus, incorporating ginger and gooseberry extracts will enhance the nutritional quality of sugar, increasing the bioactive compounds while hindering its glycaemic impact.

II. METHODOLOGY

A. Formulation of sugar

Aqueous extracts of Indian gooseberry fruits and ginger rhizomes were obtained by grinding them with a minimum amount of water. Cane sugar was dissolved in water, and a solution was made. The sugar solution was heated to a crystallizing temperature and cooled down while stirring well. Extracts from Indian gooseberry and ginger were added and mixed while stirring. The mixture was further cooled, and the final crystallized product was dried and packed with airtight packaging.

B. Analysis of glycaemic impact

Before the study commenced, ethical clearance was received from the Faculty of Medicine, University of Sri Jayewardenepura (Ref. no: 13/22).

The method for measuring GI was designed in accordance with WHO/FAO recommendations (FAO/WHO, 1998). Healthy adults (Age: 18 – 45 years, BMI: 18.5-23.5) with normal fasting glucose levels (overnight fast 8 - 12 hours) were selected voluntarily after obtaining written consent. Selected individuals were asked to arrive for each testing session, fasting after 8-12 hours overnight. In the initial session, subjects were given the standard reference food (D (+)-glucose) to consume and the formulated novel product in the next session. The portion size of standard and cane sugar was determined to contain 50g of digestible carbohydrate contents.

The GI of the sugar was calculated using the method outlined by Jenkins (1981). Finger prick blood was obtained at 7 time intervals including 0, 15, 30, 45, 60, 90, and 120 minutes (The start of food intake is time zero). Collected blood samples were centrifuged at 3500 rpm for 10 minutes, and serum was separated. The glucose oxidase peroxidase enzyme kit (Megazyme) was used to determine the blood glucose concentrations of collected samples. The incremental area under blood glucose response (IAUC) for the standard and test product was calculated for each person. Each sample's GI was calculated using the following formula.

$$GI = \frac{IAUC \text{ for the test food}}{IAUC \text{ for the standard (Glucose)}} \times 100$$

The final glycaemic index value for the test food was calculated by averaging the GI values obtained for 12 people.

C. Investigation of phytochemicals: Total Phenolic Content (TPC)

The TPC of sugar was evaluated following a modified Folin-Ciocalteu (FC) assay procedure outlined by

(Maduwanthi and Marapana 2021). To a 96-well microplate, 20 μ L of methanolic extract of samples was added. Then, 110 μ L FC reagent (diluted 10 times) and 70 μ L 10% Na₂CO₃ solution were added and mixed. Absorbance values were recorded at 765 nm after an incubation period of 30 minutes using a microplate reader (Bio-based ELISA) and results were expressed as Gallic acid equivalents.

D. Total Flavonoid Content (TFC)

The TFC of samples was evaluated following the methodology mentioned by (Maduwanthi and Marapana 2021). Samples were extracted using methanol, and 70 μ L of extract was combined with 30 μ L of 5% NaNO₂. After a 5-minute stand, 50 μ L 2% AlCl₃ was added. Next, followed by a 6-minute wait, 50 μ L of 1 M NaOH was added and left to sit at room temperature for 10 minutes. Absorbance values were obtained at 415 nm using the ELISA, and results were calculated as Quercetin (QE) equivalents.

E. DPPH assay

DPPH assay was performed using the methodology outlined by (Verardo et al. 2018) with modifications. DPPH was dissolved in methanol to prepare the DPPH solution, and the absorbance was adjusted to 0.7 (at 517 nm) using methanol. After that, 160 μ L of DPPH/methanol solution was added to 40 μ L extract, and absorbance was read at 517 nm after a 30-minute stand. The findings are presented as Trolox equivalents and as a percentage of radical scavenging activity.

$$\% \text{Radical scavenging activity} = \frac{\text{Absorbance of the control} - \text{Absorbance of the sample}}{\text{Absorbance of the control}} \times 100$$

F. ABTS assay

ABTS radical scavenging ability of formulated sugar was determined using the methodology provided by (Verardo et al. 2018) with slight modifications. Initially, ABTS^{•+} radical was produced by reacting ABTS, and potassium persulfate. Next, distilled water was added to the obtained ABTS^{•+} solution to reach the absorbance value of 0.700 \pm 0.02 at 734nm. After that, 180 μ L ABTS solution was added to 20 μ L methanolic sample extract and let to stand for 10 minutes at room temperature before measuring the absorbance at 734nm using a Bio-based Elisa plate reader. Finally, ABTS radical scavenging activity and antioxidant capacity in Trolox equivalents were calculated.

III. RESULTS AND DISCUSSION

A. Glycaemic impact

The consumption of added sugar along with other refined carbohydrates, contributes to the onset and progression of type II diabetes and cardiovascular diseases in a dose-dependent manner. The World Health Organization warns that added sugar is a silent killer and recommends limiting the daily calorie intake in terms of sugar to less than 5% (Bhardwaj, O'Keefe, and O'Keefe 2016). Since sugar is added to many foods and beverages, limiting its usage was a constant challenge faced by food producers. The most common practice to reduce the calorie contribution of added sugar is the inclusion of natural or artificial sweeteners. However, due to adverse health effects and alterations of organoleptic properties, people still prefer cane sugar. Therefore,

alternative ways of reducing the glycaemic impact of sugar are of paramount importance. During the intervention, minuscule amounts of Gooseberry and ginger aqueous extracts were incorporated into cane sugar syrup, followed by a recrystallization. The GI of novel sugar was calculated by averaging results from 12 volunteers (6 males and 6 females). GI of commercial sugar is around 63-65 (Wolever and Brand Miller 1995). The average GI of novel sugar was 38.45 ± 8.92 , eliciting a percentage decrease of 40.84. The average blood glucose response after ingesting sugar is illustrated in Fig. 1.

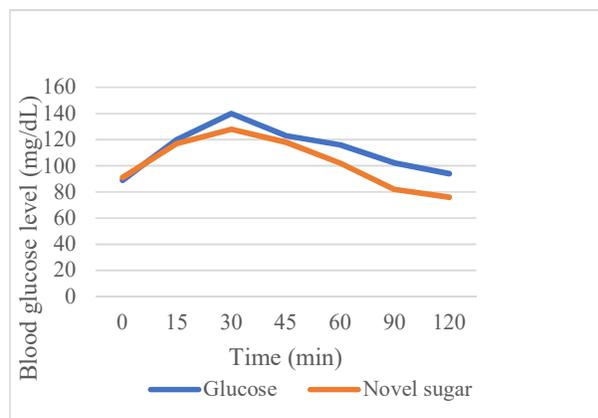


Fig. 1. Average blood glucose variation

The glycaemic impact of cane sugar has significantly reduced with the inclusion of ginger and gooseberry extracts. Studies evaluating the efficacy of incorporating Indian gooseberry and ginger extracts into food products and diets are limited. However, direct supplementation in humans has proven their anti-diabetic and hypoglycaemic properties (Akhtar et al. 2011)(Andallu, Radhika, and Suryakantham 2003). Ginger contains gingerols and shogaols, potent bioactive compounds inhibiting both α -amylase and α -glucosidase enzymes, limiting glucose absorption. Ginger is proven to assist insulin release leading to improved insulin sensitivity (Li et al. 2012). Further, a substantial amount of vitamin C is found in Indian gooseberry, stimulating the pancreas and facilitating insulin secretion, thus lowering blood sugar levels to normal (Patel and Goyal 2011).

B. Phytochemical analysis: Total phenolic and total flavonoid content

As illustrated in Table 1, the Total phenolic content of sugar was significantly improved with the addition of plant extracts. The percentage increase of TPC is 96.35%, which is remarkable. The total flavonoid content followed a similar trend, where TFC significantly increased compared to control sugar.

TABLE 1: TPC AND TFC OF SUGAR

Sample	TPC (mgGAE/g dry extract)	TFC (mgQE/g dry extract)
Cane sugar(control)	0.31 ± 0.06^b	N.D ^b
Novel sugar	8.52 ± 0.16^a	0.12 ± 0.02^a

(N.D: not detected. Means that do not share a letter are significantly different at a 95% confidence level)

Phenolic compounds are grouped into phenolic acids, flavonoids, and tannins. Phenolics have many health benefits, including antioxidant, anti-inflammatory, and anticarcinogenic properties. Flavonoids are a type of phenolic compounds that are responsible for plant colours and exert health-promoting activities by acting as radical scavengers (Tanvir et al. 2017). It is apparent that the incorporation of Gooseberry and Ginger extracts contributed to the improvement in TPC and TFC contents. Gooseberry fruit possesses antioxidant, anti-inflammatory, and anticancer properties due to its complex combination of bioactive compounds. It has a high concentration of tannins such as Ellagic acid, Corilagin, Pyrogallol, Chebulagic acid, and Gallic acid. Quercetin, a potent antioxidant, is the main flavonoid found there (Zhao et al. 2015). Ginger is widely recognized for its nutraceutical value, attributed to the range of bioactive compounds. Ginger contains several groups of bio-actives including Gingerols, Shogaols, Paradols, and Zingerone. Gingerols, the main bioactive in ginger, are a group of phenolic compounds and are of prime importance for its rich phytochemistry (Butt and Sultan 2011)(Semwal et al. 2015). Since cane sugar has zero value as a functional food, its utility could be elevated to a new level by this improvement in phytochemicals.

C. Antioxidant activity

The antioxidant activity of novel sugar was assessed using DPPH and ABTS assays along with the control and results are illustrated in Table 2. Both DPPH and ABTS antioxidant capacities improved significantly with the inclusion of Gooseberry and Ginger extracts.

TABLE 2: ANTIOXIDANT ACTIVITY OF SUGAR

Sample	DPPH assay		ABTS assay	
	RSA (%)	Antioxidant capacity (mgTE/g dry extract)	RSA (%)	Antioxidant capacity (mgTE/g dry extract)
Sugar (Control)	N.D ^b	N.D ^b	N.D ^b	N.D ^b
Novel sugar	45.01 ± 2.81^a	8.14 ± 0.59^a	0.41 ± 0.007^a	0.025 ± 0.002^a

(N.D: Not detected, RSA: Radical scavenging activity, TE: Trolox equivalent. Means that do not share a letter are significantly different at a 95% confidence level)

A food's antioxidant and radical scavenging activity are closely related to the availability of phenolic components. Many studies suggest that antioxidant activity is positively correlated with phenolic contents, and the results obtained from the experiment agree with that observation. The antioxidant action is exhibited by polyphenolic components of an extract as they can trap free radicals by donating hydrogen atoms or electrons (Stoilova et al. 2007). Reasonably, neither DPPH nor ABTS assays detected any antioxidant activity in cane sugar. However, the novel sugar elicited a strong antioxidant capacity, particularly in DPPH analysis. When considered individually, ginger exhibits a strong inhibition effect against DPPH, reaching up to 90.1% at a concentration of 20 μ g/ml (Stoilova et al. 2007). The methanolic extract of Indian gooseberry fruits also yields a high percentage inhibition against DPPH, 83.33% at a concentration of 1mg/ml (Middha et al. 2015). Thus, both extracts might have

contributed to the increased antioxidant activity of novel sugar. Overall, the study suggests that the inclusion of Indian gooseberry and ginger extracts has significantly increased the phenolic content and antioxidant activity of cane sugar. It can be considered that the elevated levels of phenolic compounds and antioxidant activity contributed to the low glycaemic status of cane sugar, converting it into a functional food.

IV.CONCLUSION

The incorporation of *Phyllanthus emblica* and *Zingiber officinale* extracts has significantly improved the phenolic content and antioxidant capacity of cane sugar. The inclusion of the plant extracts has hindered the glycaemic impact of cane sugar, significantly reducing its glycaemic index. This intervention introduces an alternative way to lower the glycaemic impact of sugar-added food products while improving their nutritional quality.

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Development of a Half-Fat Cooking Cream by Blending Dairy and Coconut Fats

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Abstract—Hybrid food trend has grasped the attention of the industries as an emerging technology that caused for the upliftment of the nutritional profile of pasteurized dairy cooking cream products alongside the beneficial health aspects and improved cost-efficiency. Utilization of coconut cream as the non-dairy source has paved the way to achieve the efficacy of this recently evolved food trend. This study is focused on the development of a commercially viable and consumer-acceptable hybridized half-fat cooking cream by bridging the gap between traditional dairy-based and plant-based culinary solutions. Sample combinations with coconut fat to milk fat ratios; 1:0, 2:1, 1:1, 1:2, 0:1 were developed and subjected to physicochemical and sensory analysis in order to determine the optimal blend. Sensory evaluation was performed utilizing the ranking test and the optimal blend was obtained through the preferences of the panelists. Final product was manufactured using this optimal blend and a physicochemical analysis was conducted with regards to the significant parameters of the product. Sensory evaluation to decide the most applicable food range was executed using a 9-point Hedonic scale test. Based on the results, 1:1 blend was selected as the optimal blend and the final product exhibits 80.98 ± 0.04 % moisture, 19.02 ± 0.04 % total solids, 15 ± 0.01 % total fat, 4.02 ± 0.04 % solids non-fat, a pH of 4.64 ± 0.02 , $1.62 \times 10^{-5} \pm 0.08$ moldm⁻³ titratable acidity, 0.09 ± 0.08 % overrun, 301.7 ± 0.12 cP viscosity, 1.0313 ± 0.09 gcm⁻³ density, PANTONE 7527 U colour, and 4.7° brix as total soluble solids. The profit gained from the product when using coconuts from the local market is 31.73%. Eventually, incorporating coconut cream in milk-based cooking creams has proven to emphasize significant physicochemical and sensory properties. Overall, the coconut fat integrated half-fat cooking cream can be utilized as an alternative for milk or milk cream-based products.

Keywords- coconut fat, hybridized cooking cream, half-fat, profit gained

I. INTRODUCTION

Cooking cream, a milk fat emulsion, consists of fat globules enveloped by a lipoprotein membrane, creating a unique oil-in-water emulsion [1]. Typically, cooking cream contains about 30-40% fat and is designed primarily for whipping into foam [16], [14]. However, it is also commonly used unwhipped in various culinary applications, such as desserts and cooking. To meet consumer expectations, cooking cream must not only taste

good and have a long shelf life but also possess excellent whipping ability, producing a stable foam with significant volume [14].

In recent years, there has been a growing interest in plant-based foods, driven by health and sustainability concerns [7]. Coconut milk, which is high in calories and fat, offers a potential alternative to dairy milk [7], [23]. Unlike animal-based saturated fats, the plant-based saturated fats in coconut milk may offer unique health benefits. Coconut milk is noted for its positive effects on gastrointestinal health due to its antibacterial properties and antihyperlipidemic characteristics. It is a rich source of lauric acid, a medium-chain saturated fat that can increase high-density lipoprotein cholesterol levels in the blood [12].

The increasing popularity of plant-based diets and the need for sustainable food products have paved the way for innovative hybrid food items that combine plant and animal-derived ingredients [7],[14]. Coconut, known for its nutritional value and sustainability, is an excellent candidate for such products [23]. In many developing countries, the high cost of milk makes coconut a more affordable alternative, enhancing the accessibility and nutritional value of food products [12],[18]. Additionally, for individuals with lactose intolerance, coconut milk can serve as a suitable substitute, reducing product costs and broadening consumer options [14].

Blending coconut milk with dairy milk, up to 30%, can produce a nutritious and flavorful product with desirable sensory qualities [14],[18]. This study aims to develop a commercially viable and consumer-acceptable half-fat cooking cream, combining traditional dairy and plant-based ingredients. By adhering to dietary guidelines and health-conscious trends, the research seeks to create a cooking cream that meets half-fat standards (15 % w/w) while maintaining the creaminess and functionality of conventional cooking creams.

II. LITERATURE REVIEW

Cream is a concentrated emulsion of milk fat globules, resulting from the physical separation of the low-density lipid phase in skimmed milk [1]. This versatile dairy product is widely used in both sweet and savoury dishes, ranging from desserts and fresh fruits to soups, ice cream,

and cakes, and serves as a critical raw material in butter and butter oil production [16]. The characteristic "creaminess" of cream is due to the fine dispersion of fat globules in a continuous hydrophilic phase, which is closely related to the cream's fat content [1],[16]. Creams are classified based on fat content and processing methods, including light coffee cream, single cream, double cream, pasteurized cream, frozen cream, and cultured or sour cream [24].

Traditionally, cooking cream is derived from dairy sources, particularly milk. However, non-dairy alternatives such as coconut milk, avocado, soybeans, groundnut, and oat are increasingly being incorporated to enhance nutritional quality and modify fat composition [16]. Coconut milk, an oil-in-water emulsion made from fresh coconut flesh (*Cocos nucifera* L.), is celebrated for its nutty flavor and high nutritional value [19]. Its composition, which includes moisture, fat, protein, ash, and carbohydrates, varies with water content [14]. Key nutrients in coconut milk include sugars (mainly sucrose and starch), minerals (phosphorous, calcium, potassium), and small amounts of vitamins B and C [7],[12]. The fat content significantly influences coconut milk's appearance and sensory properties, affecting the food products it is added to [23]. Proteins in coconut milk, primarily albumins, globulins, and phospholipids, serve as natural emulsifiers, stabilizing the emulsion and preventing cream separation [4],[19].

Coconut cream, a concentrated emulsion extracted from coconut kernels, is rich in total solids, fat, and non-fat solids [14],[19]. It is widely used in food applications such as chocolate products, gouda cheese, and ice creams. Various extraction methods, including the cold method, cream separator method, and centrifugation, are employed, with emulsifiers and stabilizers often added to maintain stability during storage [4].

Modern diets, predominantly based on animal products, have been linked to health issues like obesity, high blood pressure, and cardiovascular diseases [22]. As a result, there is a growing push towards more sustainable and healthier food systems, emphasizing plant-based alternatives. Blending animal-based and plant-based ingredients, particularly coconut cream, is a promising approach that combines nutritional benefits with sustainability [14]. This hybridization could potentially address health concerns while promoting more sustainable dietary practices.

III. METHODOLOGY

A. Raw Materials

Coconuts used for coconut cream extraction were sourced from local retail shops in the Gampaha district of Sri Lanka. Fresh dairy cream and additional ingredients, including sodium polyphosphate, microcrystalline cellulose, modified starch, and mono- and diglycerides of fatty acids, were provided by Fonterra Brands Lanka (Pvt) Ltd, located in Biyagama, Sri Lanka.

B. Extraction of Coconut Milk and Cream Separation

Mature coconuts were selected, de-husked, and deshelled. The testa around the kernel was removed to eliminate any dark hue and off-flavors. The white coconut kernel was grated using a traditional grating machine. Two parts of water was added to one part of grated coconut and the mixture was ground thoroughly using an electric grinder (BL380B, China). The resulting mixture was manually squeezed and filtered through a fine mesh to separate any grated coconut particles from the coconut milk. The coconut milk was stored in a transparent plastic container and refrigerated at 4 ± 1 °C for 15 hours to facilitate cream separation. After 15 hours of refrigeration, the coconut cream layer was separated from the skimmed coconut milk layer and stored at 4 ± 1 °C until further use. Milk cream was separated from raw milk using a cream separator (MSA 130-01-076, Germany). Tested and approved coconut and milk cream by Fonterra Brands Lanka (Pvt) Ltd company were utilized as raw materials to ensure the quality and safety.

C. Half-fat Cream Preparation

Five sample formulations were prepared by blending raw materials in specific proportions to maintain a constant fat content and meet half-fat standards. Stabilizers, thickeners, and emulsifiers were added in recommended proportions within acceptable limits to ensure mixture stability. The sample compositions were as follows:

- S1: 15% coconut fat, 0% milk fat, stabilizers, and water
- S2: 10% coconut fat, 5% milk fat, stabilizers, and water
- S3: 7.5% coconut fat, 7.5% milk fat, stabilizers, and water
- S4: 5% coconut fat, 10% milk fat, stabilizers, and water
- S5: 0% coconut fat, 15% milk fat, stabilizers, and water

For each sample combination, three replicates were prepared. The samples were mixed using a laboratory-scale mixer (L5M-A, United States) at speeds ranging from 30-40 rpm to facilitate homogenization. The mixed samples were homogenized at 40 bar pressure and 25 °C using a laboratory-scale homogenizer (APV 2000, Poland) to break down and disperse fat globules throughout the mixture. Homogenized samples underwent heat treatment at 105 °C for 1 minute using an autoclave (HV-25, Japan). After cooling, the heat-treated samples were packaged in HDPE bottles and stored at 4 ± 1 °C until further use.

D. Sample Range Analysis

Microbiological analysis: Samples (S1, S2, S3, S4, S5) were tested for coliforms to verify microbial quality before the sensory evaluation.

Sensory evaluation: Sensory evaluation was performed using a ranking test and a 9-point Hedonic scale test. The

optimal blend was selected based on the results from an untrained panel of 27 participants. Samples (S1, S2, S3, S4, S5) were introduced to the panellists in a random order and appearance, aroma, overall taste, colour, mouthfeel and overall acceptability were evaluated as parameters.

Evaluation of physicochemical parameters: Moisture content (MC) of each sample was initially determined using a moisture analyzer (MB 90, United States). Total solids content was also analyzed with the same moisture analyzer and further calculated using the AOAC, 2005 [3] method by subtracting the moisture content from 100, enhancing the accuracy of the results. Fat content was measured using the Gerber method as per AOAC, 2005 [3] guidelines. Solid Non-Fat (SNF) content was calculated by subtracting the sum of the moisture and fat contents from 100, following the AOAC, 2005 [3] method.

pH of the samples was measured using a pH meter (Mettler-Toledo, Switzerland). Titratable acidity was assessed based on the method described by [20]. Viscosity measurements were taken using a viscometer (DV-E, United States), with samples placed in separate beakers, and the S61 spindle immersed in each sample. The viscometer was operated at 100 rpm for 1 minute at room temperature (25°C). Density was determined using the AOAC, 2005 [3] method. The appearance of the samples was evaluated after 24 hours of refrigeration at $4 \pm 1^\circ\text{C}$ using an optical microscope (B-350, Italy). This allowed for the observation of fat globule shapes and the emulsion's diversity due to compositional changes. Color analysis was performed manually with a Color formula guide (PANTONE, United States) as per [15]. Based on the physicochemical analysis results and the research objectives, the optimal blend was chosen and compared among the prepared sample range. This optimal blend was then utilized in developing the final product, following the same procedures.

E. Final Product Analysis

The optimal blend was subjected to physicochemical and microbiological testing which includes analyses of overrun and Total Soluble Solids (TSS), as detailed above. Its shelf-life stability was assessed over seven days under ambient (25 °C) and chilled ($4 \pm 1^\circ\text{C}$) conditions. Oxidative rancidity was evaluated by measuring Free Fatty Acid (FFA) content and Peroxide Value (PV) using standard AOAC, 2005 [3] guidelines. Microbiological stability was ensured through coliform, aerobic plate count, and Yeast and Mold tests. A sensory evaluation employing a 9-point hedonic scale was conducted to determine the product's applicability as an alternative to milk-based (pasta) or coconut-based (milk rice) products. Panellists were presented with samples in random order and rated them on appearance, aroma, overall taste, colour, mouthfeel, and overall acceptability. Both samples (pasta, milk rice) were prepared using controlled conditions (Temperature, Time, Humidity) to avoid any external effect to the sensory properties of the samples.

F. Statistical Analysis

Parametric data were analysed in triplicate using one-way ANOVA and Tukey's Multiple Range Test at a 95% confidence interval ($p < 0.05$) with Minitab 21.2 software. The sensory evaluation data for the five sample combinations were analyzed statistically using descriptive statistics, one-way ANOVA, post-hoc Tukey's HSD, and non-parametric tests. These analyses identified significant differences in sensory attributes and determined the most preferred sample combination.

IV. RESULTS AND DISCUSSION

A. Compositional Characteristics in Coconut and Milk Fat Blends

Compositional characteristics gained from the sample range analysis are elaborated in the Table 1. The total fat content of the five samples was adjusted to 15% to comply with half-fat standards, which range from 10-18% according to [8]. Significant differences ($p < 0.05$) were found among the samples across various characteristics at a 95% confidence interval. The moisture content ranged from $81.71 \pm 0.04\%$ in sample S5 to $82.58 \pm 0.04\%$ in sample S1. The total solids content also showed significant variation ($p < 0.05$), ranging from $17.42 \pm 0.04\%$ in S1 to $18.28 \pm 0.04\%$ in S5. S1, with 15% coconut fat, had the lowest total solids, while S5, with 15% milk fat, had the highest. The increase in total solids content with the incorporation of coconut cream is attributed to the higher solid content in coconut milk compared to milk cream [13].

The solid-not-fat (SNF) content ranged from $2.42 \pm 0.04\%$ in S1 to $3.48 \pm 0.04\%$ in S5, with a significant difference ($p < 0.05$). The SNF content increased with the milk composition, indicating that higher dairy cream levels contribute to higher protein content, a key parameter in SNF [9]. The pH values of the samples varied significantly ($p < 0.05$) from 4.43 ± 0.02 in S1 to 6.50 ± 0.03 in S5. S1, containing only coconut fat, had the lowest pH, while S5, with only milk fat, had the highest. This shift in pH towards acidity in coconut fat samples is due to the acidic nature of coconut cream [17]. Titratable acidity (TA) also showed significant variation, ranging from $5.0 \times 10^{-6} \pm 0.04$ mol/dm³ in S5 to $2.2 \times 10^{-5} \pm 0.16$ mol/dm³ in S1. Higher TA values were found in samples with increased coconut milk content, further confirming the influence of coconut milk on acidity levels [6].

B. Microbiological Safety Confirmation for Sensory Evaluation of Fat Blends

The sample combinations (S1, S2, S3, S4, S5) underwent a coliform test before sensory evaluation, resulting in < 1 CFU/g for all samples. This indicates no colony-forming units were detected, confirming a negative coliform test. Consequently, the samples were deemed suitable for sensory evaluation [10].

TABLE I: COMPOSITION AND CHEMICAL CHARACTERISTICS OF COCONUT AND MILK FAT BLENDS

Sample range	Moisture (%)	Total solids (%)	SNF (%)	Total fat (%)	pH	TA (moldm ⁻³)
S1	82.58±0.04 ^a	17.42±0.04 ^a	2.42±0.04 ^a	15	4.43±0.02 ^a	0.000022±0.16 ^a
S2	82.32±0.03 ^b	17.67±0.03 ^b	2.67±0.03 ^b	15	4.62±0.02 ^b	0.000018±0.09 ^b
S3	82.12±0.03 ^c	17.87±0.03 ^c	2.87±0.03 ^c	15	4.87±0.01 ^c	0.000011±0.13 ^c
S4	81.99±0.04 ^d	18.00±0.04 ^d	3.00±0.04 ^d	15	5.53±0.02 ^d	0.000009±0.13 ^d
S5	81.71±0.04 ^e	18.28±0.04 ^e	3.28±0.04 ^e	15	6.50±0.03 ^e	0.000005±0.04 ^e

Mean ± Standard deviation values with different superscripts in each column are significantly different ($p < 0.05$) from each other. SNF = Solid Non-Fat, TA = Titratable Acidity, S1 = Coconut fat 15% + Milk fat 0%, S2 = Coconut fat 10% + Milk fat 5%, S3 = Coconut fat 7.5% + Milk fat 7.5%, S4 = Coconut fat 5% + Milk fat 10%, S5 = Coconut fat 0% + Milk fat 15%

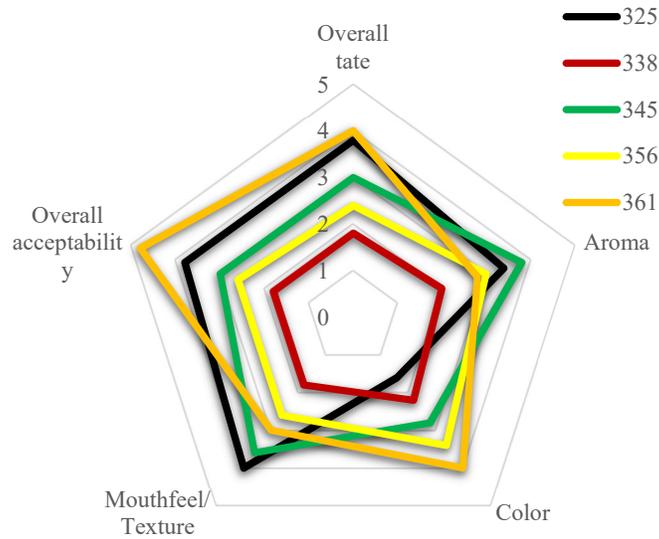


Fig. 1: Sensory Attribute Evaluation of Coconut and Milk Fat Sample Combinations Based on Preference Ranking Test. 325 = Coconut fat 15% + Milk fat 0%, 345 = Coconut fat 10% + Milk fat 5%, 338 = Coconut fat 7.5% + Milk fat 7.5%, 356 = Coconut fat 5% + Milk fat 10%, 361 = Coconut fat 0% + Milk fat 15%

C. Sensory Evaluation of Coconut and Milk Fat Blends

The radar chart Figure 1 presents the sensory attributes of five different sample combinations of coconut and milk fat based on a preference ranking test. The data highlighted that sample 338 (Coconut fat 7.5% + Milk fat 7.5%) was the most preferred, especially in terms of aroma, texture, and acceptability. Conversely, sample 361 (Coconut fat 0% + Milk fat 15%) was the least preferred across most attributes.

D. Physicochemical Characteristics of the selected Coconut and Milk Fat Blend

Physicochemical analysis of the selected blend, S3, which consisted of 7.5% coconut fat and 7.5% milk fat, demonstrated that it meets essential physicochemical parameters crucial for product acceptance (Table 2). Even

with a moisture content of $80.98 \pm 0.04\%$ and total solids of $19.02 \pm 0.04\%$, the product's characteristics including pH, Titratable acidity, Viscosity and Density also align within acceptable limits. However, it's noted that the milk fat content of 7.5% falls short of the CODEX STAN 288 standards, which mandate a minimum of 10% milk fat in cream products. This deviation is deliberate to conform to a half-fat standard, influencing both the composition and sensory attributes of the product. The resultant low overrun of $9.98 \times 10^{-2} \pm 0.08\%$ and a moderate TSS (Total Soluble Solids) of 4.7° brix reflect adjustments made to meet this specification. While blend S3 satisfies several critical parameters necessary for product quality and acceptance, its adherence to a reduced fat content standard necessitates careful consideration of its implications on both regulatory compliance and consumer expectations.

TABLE II: PHYSICO-CHEMICAL PARAMETERS OF THE SELECTED BLEND

Physicochemical parameters	Results
Moisture (%)	80.98
Total solids (%)	19.02
SNF (%)	4.02
Total fat (%)	15
pH	4.64
Titratable acidity (moldm ⁻³)	1.62×10^{-5}
Overrun (%)	0.0998 %
Viscosity (cP)	301.7
Density (gcm ⁻³)	1.0313
Color	PANTONE 7527 U
TSS° Brix	4.7

SNF = Solid Non-Fat, TSS = Total Soluble Solids

The optical microscope evaluation conducted at production time (pre-chilling) revealed a clear microscopic view of the sample, showing no significant agglomerations. The microscopic view distinctly displayed the final emulsion formed by blending coconut and milk fat. The stability of this emulsion was evident, as depicted in Figure 2.

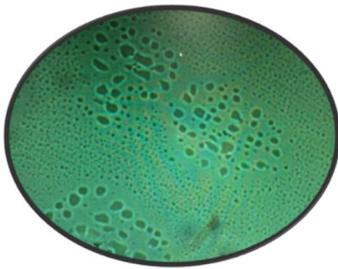


Fig.2: Microscopic view of the final product evaluated at 25 °C.

E. Sensory Evaluation of Coconut Half-Fat Cooking Cream: Milk Rice vs. Pasta Applications

Results of the sensory evaluation conducted to assess the suitability of a coconut integrated half-fat cooking cream in two food applications—milk rice (123) and pasta (456) - highlight several key findings. The panellists did not perceive a significant difference in aroma between the two food applications, indicating consistency in this sensory attribute across both samples. However, significant variations were observed in all other sensory attributes evaluated between the milk rice and pasta samples. Notably, pasta (456) received higher ratings on the 9-point hedonic scale for overall acceptability compared to milk

rice (123). This preference underscores the potential of the coconut integrated half-fat cooking cream as a viable alternative to traditional dairy-based products in culinary applications. The detailed sensory attribute scores are presented in Figure 3, providing a comprehensive overview of how each attribute influenced the panellists' perceptions. These findings suggest promising market potential and consumer acceptance for the product, particularly in pasta-based dishes, aligning with contemporary dietary preferences and trends.

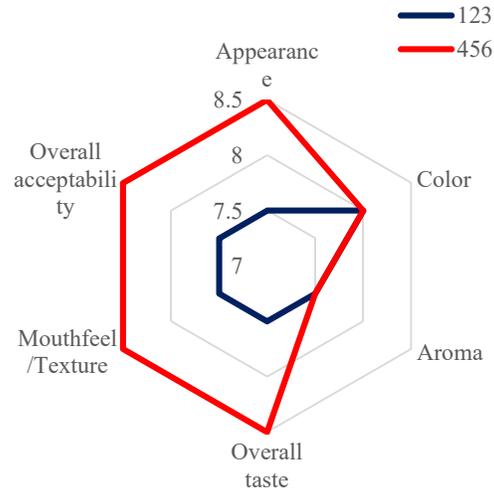


Fig.3: Sensory Attributes Evaluation of the Final Coconut and Milk Fat Combination concerning two food applications, 123 = Milk rice (Coconut milk alternative), 456 = Pasta (Milk or milk cream alternative)

F. Determination of Storage Stability

The storage stability of the final product was evaluated under two storage conditions: ambient (25°C) and chilled (4 ± 1°C). Microbiological analyses were conducted at two-day intervals over a week, and the results are summarized in Table 3. According to [5], the generally accepted Aerobic Plate Count (APC) limit for ready-to-eat foods is 10^5 CFU/unit, though this critical limit can vary depending on the food product and country of origin. A commonly utilized limit is 1000 CFU/ml. In this study, the APC count of the sample stored under ambient conditions exceeded this limit by the 5th day, whereas the chilled sample remained within the acceptable range until the 7th day of storage. Maximum permitted limit of Yeast and Mold counts for food products is 100 CFU/ml. The sample stored under ambient conditions exceeded this limit at the onset of the 5th day, while the sample stored under chilled conditions remained within the acceptable range even after 7 days of storage. Based on these findings, it is recommended that the product should be stored under chilled conditions to maintain quality and safety for culinary use. The average shelf-life of the product is 5 days when stored at 4 ± 1°C, whereas, at ambient temperature (25°C), it's only 3 days.

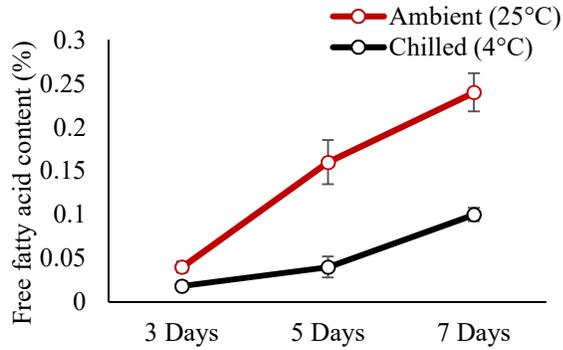


Fig. 4: FFA content variation over days in ambient (25 °C) and chilled (4 °C) storage conditions for a week.

TABLE III: MICROBIOLOGICAL ANALYSIS RESULTS OF PRODUCT SAMPLES STORED UNDER AMBIENT (25°C) AND CHILLED (4 ± 1°C) CONDITIONS OVER ONE WEEK

Day	Ambient		Chilled	
	APC (CFU/ml)	Yeast and Mold (CFU/ml)	APC (CFU/ml)	Yeast and Mold (CFU/ml)
1	240	3	240	3
3	860	66	372	11
5	1840	112	840	21
7	2650	164	1140	44

CFU = Colony Forming Units, APC = Aerobic Plate Count

G. Analysis of Oxidative Rancidity under Ambient and Chilled Storage Conditions

Oxidative rancidity of two samples stored in ambient (25°C) and chilled (4°C) conditions was analysed over a week. The results for Free Fatty Acid (FFA) content and Peroxide Value (PV) are detailed in Figures 4 and 5, respectively. From day 1 to day 7, the FFA values in the ambient conditions showed a significant increase, with mean values rising from 0 to 0.24%. This trend is consistent with the findings of [21], who reported a significant increase in FFA content in coconut oil during storage. The increase in FFA content under ambient conditions is attributed to greater exposure to atmospheric oxygen and microbial activity. In contrast, samples stored in chilled conditions exhibited a lower increase in FFA due to limited oxygen exposure and reduced microbial activity. Based on [4], the author found that coconut cream stored in frozen conditions developed only a small amount of FFA over two months.

The PV, an indicator of primary oxidation in fats and oils, also showed significant differences between the two storage conditions. From day 1 to day 7, PV in the ambient conditions increased from 0 to 14 meq/kg, while under chilled conditions, the increase was more gradual, from 0 to 8.5 meq/kg. According to [2], the rancidity limit for PV is 35.5 meq of O₂ per kg fat, with the freshness limit set at 10 meq of O₂ per kg fat. The sample stored in ambient

conditions exceeded the freshness limit within a week, whereas the sample in chilled conditions did not. The reduced peroxide formation in chilled conditions suggests that storing the product at lower temperatures helps maintain its quality. According to [4], the author also observed lower PV in coconut cream stored in frozen conditions over two months, indicating that freezing (-18°C) can further limit peroxide formation. Based on these results, it is recommended to store the product in chilled or frozen conditions to retain its quality and freshness.

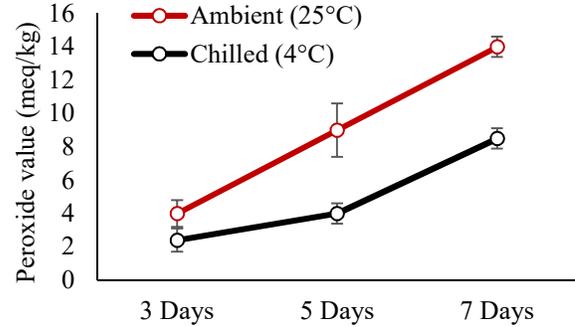


Fig.5: Peroxide value content variation over days in ambient (25 °C) and chilled (4 °C) storage conditions for a week.

H. Analysing the profit gained

When utilizing coconut milk from the market to separate and extract coconut cream, the total cost of the product is Rs. 663.45. According to the cost of the existing product; Rs. 743.01, produced using the same conditions, the profit gained through the hybridized cooking cream is 10.70%. When using coconuts from the market, the total cost of the hybridized cooking cream is Rs. 507.20 while the cost of the existing dairy cream under same conditions is Rs. 743.01. The profit gained is 31.73%. This emphasizes the fact that utilizing either of the two raw materials; coconut milk or coconuts, has given a significant profit while using coconuts provide more revenue compared to coconut milk from the market.

V. CONCLUSIONS

Hybridizing coconut cream with milk cream in a 1:1 ratio has resulted in favorable physicochemical and sensory properties for the coconut fat-integrated cooking cream, outperforming other blended ratios of 1:0, 2:1, 1:2, and 0:1. Sensory evaluation, conducted through a ranking test with a trained panel, confirmed that the optimal 1:1 blend exhibits desirable characteristics in terms of appearance, overall taste, aroma, color, mouthfeel/texture, and overall acceptability. Additionally, adjusting the fat content to 15% to meet half-fat standards has enhanced the product's profit margin while improving its health benefits, particularly those associated with coconut cream. Consequently, coconut cream in specific ratios can serve as a significant dairy cream alternative, facilitating the development of a commercially viable and consumer-

acceptable product compared to traditional dairy-based cooking creams.

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Enhancing Lung Cancer Diagnosis with Custom-Designed Convolutional Neural Network

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Abstract - Lung cancer is a major cause of cancer deaths globally, which highlights the importance of early detection to improve survival rates. This study focuses on creating and testing a custom Convolutional Neural Network (CNN) designed for accurate lung cancer detection based on Computed Tomography (CT) Scan images of the lungs. To evaluate its effectiveness, the proposed custom CNN architecture is compared with two established pre-trained models, ResNet50 and VGG16. The research utilized datasets from the Kaggle website and Teaching Hospital Anuradhapura Sri Lanka, with images which are preprocessed to a size of 256x256 pixels. Techniques such as SMOTE were employed for class balancing and data augmentation to boost model performance. The custom CNN, which includes multiple Conv2D layers, MaxPooling2D layers, dropout, and batch normalization, achieved an impressive accuracy of 98.55%. This performance surpassed that of ResNet50, which achieved 97.67%, and VGG16, which recorded 66.15%. The models were trained and evaluated using cross-validation, measuring performance through metrics like precision, recall, and F1-score. Despite the promising results, limitations exist due to reliance on a specific dataset and the necessity for further clinical validation. This research indicates that custom CNN performs better than pre-trained models in detecting lung cancer.

Keywords - convolutional neural network, lung cancer detection, machine learning

I. INTRODUCTION

Lung cancer remains one of the deadliest forms of cancer globally [1]. At the same time, technologies such as MRI and CT scans are commonly used for identifying lung cancer, early-stage detection remains a challenging task that heavily relies on the expertise of radiologists [2]. Convolutional Neural Networks (CNNs), a type of machine learning, are gaining popularity in the analysis of medical images [3]. CNN could learn and identify patterns of images, making patterns particularly useful for tasks like cancer detection. With access to large datasets and advanced computing capabilities, CNNs can provide accurate diagnoses and serve as valuable support tools for radiologists.

The objective of this study is to examine the effectiveness of different CNN architectures for lung cancer detection. This study compares custom CNN with two well-established models, ResNet50 and VGG16. The custom CNN is designed to balance complexity and efficiency, incorporating insights from existing models and related studies to enhance accuracy.

ResNet50 employs "residual learning" to construct intense networks without compromising performance [4]. VGG16 demonstrates the advantages of using numerous small filters

in a simple, consistent design [5]. These insights informed the development of the custom CNN, intending to achieve high performance in lung cancer detection.

This approach's potential impact extends to enhancing the accuracy, and by focusing on lung cancer detection, this study seeks to contribute to earlier diagnosis and improved patient outcomes.

II. LITERATURE REVIEW

Patel and Ganatra [6] proposed an innovative system integrating Internet of Things (IoT) and deep learning for early breast cancer detection in institutional settings. The study suggests using thermal imaging cameras combined with convolutional neural networks (CNNs) to automate breast cancer screening. The authors developed a two-factor framework for cancer detection involving initial thermal image collection and subsequent targeted scanning. The proposed system aims to improve early detection rates, particularly in underserved communities, by enabling continuous health monitoring and automated screening in institutional environments.

Bushara A. R. and Vinod Kumar R. S. [7] explore deep learning-based lung cancer classification using augmented Convolutional Neural Networks (CNNs). This study utilizes data augmentation techniques on CT images to enhance classification accuracy, specifically employing scaling, rotation, and contrast modification transformations. The Lung Imaging Database Consortium-Image Database Resource Initiative (LIDC-IDRI) was used for evaluation. The proposed system demonstrated a high accuracy of 95% with precision, recall, and F1-score for benign and malignant test data around 0.93 to 0.96, showcasing significant improvements over other state-of-the-art methods. The authors emphasize the critical role of early detection in improving survival rates. Thus, their work supports the development of more efficient Computer-Aided Diagnostic (CAD) systems for early lung cancer identification, potentially saving lives by facilitating earlier treatment interventions.

Atsushi Teramoto, Tetsuya Tsukamoto, Yuka Kiriyama, and Hiroshi Fujita developed an automated classification system for differentiating lung cancer types—adenocarcinoma, squamous cell carcinoma, and small cell carcinoma—using deep convolutional neural networks (DCNNs) applied to cytological images [8]. The DCNN model, composed of three convolutional layers, three pooling layers, and two fully connected layers, processed images preprocessed to a uniform resolution of 256x256 pixels. This utilized data augmentation techniques like rotation, flipping,

and filtering to combat overfitting. The system achieved an accuracy rate of approximately 71%, comparable to the diagnostic accuracy of cytotechnologists and pathologists, demonstrating the potential of DCNNs to support and enhance the precision of lung cancer diagnosis through cytological evaluation.

Sathyakumar et al. [9] focused on evaluating the efficacy of Artificial Intelligence (AI) in the automated detection of lung cancer through Deep Convolutional Neural Networks (DCNNs). This study analyzed various AI models and compared their performance to human physicians and radiologists in detecting lung nodules. The models reviewed primarily used chest CT scans for detection, with a specific age focus of 18-65 years old, excluding any studies using PET scans, chest X-rays, or genomic data. The performance of the AI systems was gauged through metrics such as sensitivity, specificity, accuracy, ROC curve, and AUC, demonstrating the high accuracy and low false-positive rates of these advanced technologies. This narrative review emphasizes the potential of AI-assisted systems in reducing the workload of physicians, thereby mitigating the risk of burnout and improving the quality of patient care. Integrating AI in lung cancer screening enhances diagnostic accuracy and preserves the invaluable doctor-patient relationship by allowing doctors more time for direct patient interaction.

The research paper by Wadood Abdul discusses an Automatic Lung Cancer Detection and Classification (ALCDC) system utilizing a Convolutional Neural Network (CNN) to analyze CT scan images for lung cancer detection [10]. The system distinguishes between malignant and benign tumors with a reported accuracy of 97.2%, considered superior to existing systems. This study, which taps into the Lung Image Database Consortium (LIDC) and Image Database Resource Initiative (IDRI), emphasizes the potential of deep learning techniques in medical diagnostics to improve accuracy and efficiency in lung cancer detection. The CNN model benefits from automated feature extraction that bypasses the need for hand-engineered methods, thereby enhancing the robustness and reliability of the diagnostic process.

Dewan Ziaul Karim focused on detecting lung cancer from histopathological images using a Convolution Neural Network (CNN) [11]. Their study employed a CNN model to classify three types of lung tissues: Benign tissue, Adenocarcinoma, and Squamous cell carcinoma. The model was trained with a dataset of 15,000 images, divided into training, validation, and testing groups. Notably, their CNN model achieved a training accuracy of 98.15% and a validation accuracy of 98.07%, demonstrating its high efficiency in classifying lung cancer types from histopathological images. This work highlights the potential of deep learning models to assist pathologists in diagnosing lung cancer accurately and efficiently, contributing to better patient management and treatment outcomes.

Adarsh Pradhan, Bhaskarjyoti Sarma, and Bhiman Kr Dey have developed a 3D Convolutional Neural Network (CNN) approach for detecting lung cancer from CT scans [12]. Utilizing the SPIE-AAPM Lung CT Challenge dataset, this implemented morphological preprocessing techniques to enhance the visibility of lung nodules, such as converting

images to Hounsfield Units and applying lung nodule masks. Their method involves cropping, resizing, and rescaling DICOM image slices, then training a 3D CNN model. This approach yielded impressive results, with their model achieving a training accuracy of 83.33%, a testing accuracy of 100%, and perfect scores in precision, recall, kappa-score, and F-score, highlighting its potential effectiveness in lung cancer detection. Susmita Das and Swanirbhar Majumder's paper compares traditional Computer Aided Diagnosis (CAD) schemes with those based on deep learning techniques for the detection of pulmonary cancer [13]. This comparative analysis highlights that Convolutional Neural Networks (CNNs) are predominantly used due to their effectiveness in feature learning and pattern recognition within pulmonary cancer detection applications. This emphasizes the advantages of deep learning CAD systems in automatically recognizing lung nodules with high accuracy and efficiency, potentially reducing the radiologist's workload significantly. The study points out several challenges in implementing these systems, such as computational demands and the need for extensive training datasets, but also notes the superior performance of deep learning models over traditional methods. The authors conclude that deep learning enhances the diagnostic processes by handling large-scale image data more effectively, leading to better detection rates of pulmonary nodules.

Bijaya Kumar Hatuwal and Himal Chand Thapa conducted a study on lung cancer detection using Convolutional Neural Networks (CNNs) on histopathological images [14]. This research focuses on classifying histopathological images into three types: benign tissue, adenocarcinoma, and squamous cell carcinoma. The CNN model developed achieved training and validation accuracies of 96.11% and 97.2%, respectively, indicating high effectiveness in classifying lung cancer types from biopsied tissue images. This approach enhances the speed and accuracy of diagnosing lung cancer, which is crucial for early treatment and improving patient survival rates. Their study demonstrates the potential of deep learning in medical image analysis, offering a more reliable tool for pathologists and enhancing diagnostic outcomes.

Chao Zhang et al., titled "Toward an Expert Level of Lung Cancer Detection and Classification Using a Deep Convolutional Neural Network," demonstrates the use of a three-dimensional convolutional neural network (CNN) to enhance the detection and classification of pulmonary nodules from CT scans [15]. This deep learning approach was trained and validated using a large dataset from multiple clinical centers, achieving a sensitivity of 84.4% and a specificity of 83.0%. The CNN model showed superior performance over manual assessments by radiologists, suggesting its potential to significantly improve the efficiency and accuracy of lung cancer screening.

III. METHODOLOGY

A. Dataset

The dataset, gathered from Kegalle website [16], includes CT scan images divided into three categories: benign, malignant, and normal. Additionally, the dataset was gathered from the teaching hospital Anuradhapura, which was used for secondary texturing.

B. Model Architecture

According to Figure 1, a custom CNN model for lung cancer detection features an input layer accepting $256 \times 256 \times 1$ grayscale images, followed by two convolutional layers (Conv_1 and Conv_2). Each is paired with max pooling. These layers progressively reduce spatial dimensions while extracting features.

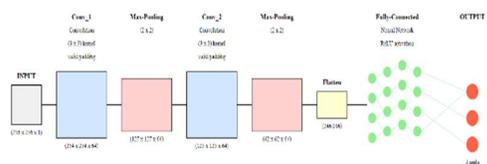


Fig. 1. Model Architecture

The flattened output of 246,016 units feeds into a fully connected layer of 16 units with ReLU activation. The model concludes with an output layer of 3 units using softmax activation to classify images such as Benign, Malignant, or Normal.

This custom cnn model has a simpler design with fewer parameters, which leads to faster training and quicker predictions. Further, it reduces the chance of overfitting, especially when using smaller datasets. Additionally, the model is specifically designed for CT scan images, allowing it to focus on important features that help tell the difference between benign, malignant, and normal cases, which can improve accuracy. Moreover, its simpler design makes it easier to understand and use in settings with limited resources, allowing faster adjustments in tuning and optimizing the model.

C. Data Preprocess

Grayscale CT scan images are loaded and resized to 256×256 pixels in the preprocessing stage. The pixel values are normalized by dividing them by 255.0 to bring them into the range of 0 to 1. Optionally, Gaussian blur is applied to reduce noise. Finally, the images are reshaped to (256, 256, 1) to prepare them for the neural network input.

D. Key Components of the Model

Input Layer: This layer sets the input shape to ($256 \times 256 \times 1$) for grayscale images, where each image has 256×256 pixels with 1 channel (grayscale). The pixel values are normalized by dividing 255.0, bringing them into the range [0, 1], which helps in faster convergence during training.

Conv_1 Layer: This layer applies 64 filters of size (3x3) to the image. Each filter detects specific patterns (such as edges or textures) in different parts of the image. The ReLU activation function is used here to introduce non-linearity, allowing the network to capture more complex features. The convolution operation slightly reduces the size from 256×256 to 254×254 due to the kernel size, while the depth becomes 64 (one channel per filter).

MaxPool Layer: This layer performs down-sampling by reducing the spatial dimensions from 254×254 to 127×127 . It does this by selecting the maximum value from each (2x2) patch of the image, helping to reduce the amount of data and

computation while preserving important features. The depth (64 channels) remains unchanged.

Conv_2 Layer: Like Conv_1, this layer applies 64 additional filters with a (3x3) kernel to the down-sampled image, looking for more complex patterns that combine the features from Conv_1. The ReLU activation is again used to add non-linearity. The output size is reduced to 125×125 , and the image still has 64 channels.

MaxPool Layer: Like the previous MaxPooling layer, this layer further reduces the image size from 125×125 to 62×62 , again retaining the strongest features while reducing computational load. The number of channels remains at 64.

Flatten Layer: This layer flattens the 3D output from the previous layer (shape $(62 \times 62 \times 64)$) into a 1D array (246,016 elements).

Fully Connected Layer: This layer has 16 neurons. It takes all 246,016 values from the flattened layer and connects them to each of these neurons. The ReLU activation function is applied here, enabling the model to capture complex relationships between the features extracted by the convolutional layers.

Output Layer: The final layer has 3 neurons, each representing one of the possible diagnoses: Benign, Malignant, and Normal. The softmax activation function is used, which converts the outputs of the neurons into probabilities for each class.

Model Compilation: The model is compiled with `sparse_categorical_crossentropy` as the loss function, which is suitable for multi-class classification problems where the target labels are integer-encoded. The adam optimizer is used to update the model weights efficiently during training. The model is trained for 10 epochs with a size of 8 batch, meaning that it processes 8 images at a time, adjusting the weight after each batch.

TABLE I. CNN ARCHITECTURE

Layer Type	Output Shape	Number of Parameters
Input	(256, 256, 1)	0
Conv2D	(254, 254, 64)	640
MaxPooling2D	(127, 127, 64)	0
Conv2D	(125, 125, 64)	36,928
MaxPooling2D	(62, 62, 64)	0
Flatten	(246016)	0
Dense	(16)	3,936,272
Dense (Output)	(3)	51

According to Table I, the layers with 0 parameters (Input, MaxPooling2D, and Flatten) are often called "fixed function" layers. These layers perform a specific operation that didn't adjust during the training process. This is why those layers have 0 parameters. The total parameters (3,973,891) represent all the weights and biases that the network can adjust during training. The original 256×256 grayscale lung CT scan image enters the network and is immediately analyzed for basic features by the first convolutional layer, resulting in 64 feature

maps of size 254x254. These feature maps are then condensed by the first max pooling layer, keeping only the strongest signals and reducing the size to 127x127. The second convolutional layer further analyzes these condensed features for more complex patterns, producing 64 new feature maps of size 125x125. Another max pooling layer then condenses these complex feature maps to 62x62. The flattened layer stretches this 62x62x64 data cube into a single line of 246,016 numbers. These numbers are fed into a fully connected layer, which calculates 16 high-level features. Finally, the output layer uses these 16 high-level features to determine the final diagnosis probabilities for the three possible outcomes (Benign, Malignant, Normal). This entire process transforms the original image into a set of probabilities, indicating how likely the image belongs to each of the three categories, effectively turning a complex visual input into a simple, interpretable medical diagnosis.

E. Data Training

1. Data Augmentation and Balancing

- Data Augmentation: Gaussian Blur were applied to increase the diversity of training data.
- Balancing Class with SMOTE: SMOTE was used to generate synthetic samples for minority classes and ensure equal representation.

2. Model Compiling

- Compiling Model: The custom CNN model was compiled using the Adam optimizer along with sparse categorical cross-entropy as the loss function.
- Training Model: The training utilized a balanced dataset with a batch size of 8 over 10 epochs. This approach helped ensure that the model learned effectively from each class without bias towards any category.

3. Model Evaluation

Dataset Utilization

- The evaluation was conducted using a dataset obtained from Kaggle, specifically tailored for lung cancer detection.

Model Performance

- Custom CNN Model: The custom model demonstrated high accuracy in predictions. This model was specifically designed and trained on the dataset, allowing it to adapt better to the unique characteristics of the images.

IV. RESULTS

The performance of the custom CNN model is evaluated and compared with the pre-trained ResNet50 and VGG16 models. The custom CNN model achieved an accuracy of 98.55%, demonstrating its effectiveness in lung cancer detection. It provided competitive results with a precision of 98.90%, recall of 97.33%, and F1-score of 98.11%. The pre-trained ResNet50 model, leveraging its deep architecture and residual learning capabilities, attained an accuracy of 97.67%, with a precision of 98.00%, recall of 93.67%, and F1-score of 95.80%.

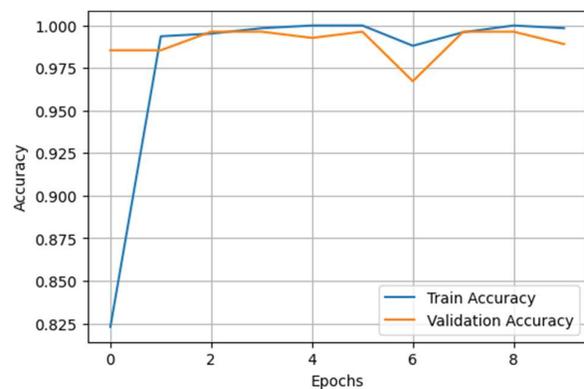


Fig. 2. Model Accuracy

The fine-tuned VGG16 model, known for its simplicity and effectiveness, reached an accuracy of 66.15%. These results highlight that the custom CNN, despite its simpler architecture, can perform with sophisticated pre-trained models. The enhancements such as data augmentation, handling class imbalance with SMOTE, and optimization strategies like early stopping and learning rate reduction contributed significantly to the custom model's high accuracy and robustness. This comparative analysis underscores the potential of the custom CNN model to deliver efficient and accurate solutions for medical image analysis, particularly in lung cancer detection. The accuracy graph (fig. 2) shows the accuracy over the training epochs for both training and validation sets. A consistently high validation accuracy indicates that the model performs well for unseen data. The loss graph (fig.3) shows the loss over the training epochs for both training and validation sets. A decreasing loss indicates the model is improving for the predictions. This study proves that carefully designed custom CNNs can be powerful tools for helping doctors find lung cancer in medical images, potentially leading to earlier detection and better patient care.

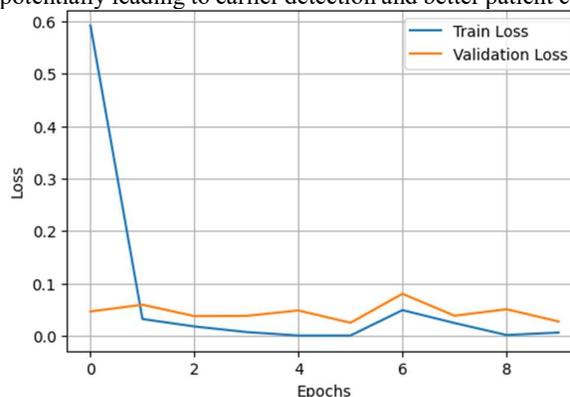


Fig. 3. Model Loss

V. CONCLUSION

This study demonstrates the effectiveness of a custom CNN model for lung cancer detection based on CT-Scan images of lungs, achieving superior performance (98.55% accuracy) compared to well-established pre-trained models like

ResNet50 (97.67%) and VGG16 (66.15%). The custom model, incorporating multiple Conv2D layers, MaxPooling2D layers, dropout, batch normalization, and advanced techniques such as SMOTE and data augmentation, proved highly effective in classifying lung cancer images. These results highlight that carefully tailored CNN architectures can match or exceed the performance of complex pre-trained models in specific medical imaging tasks, offering a more efficient and potentially more accurate solution for lung cancer detection. The study confirms that a custom CNN can outperform established models in lung cancer image classification, underscoring the importance of task-specific architecture design in medical image analysis. However, limitations include the use of a specific dataset, necessitating further validation of diverse datasets from multiple institutions, and the need for evaluation in clinical settings. Future research should explore advanced optimization techniques, extend this approach to other medical imaging tasks, investigate the integration of additional data sources like patient history or gene.

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An Approach to Make Data-driven Decisions on User Experience of Digital Products

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Abstract— In today’s era, with digital transformations and technological advancements, the needs of modern consumers have become more complex and advanced. To address these demands effectively, enterprises are expanding boundaries to deliver more customer-centric and optimized digital products like web and mobile applications. While providing these products, user experience has become a crucial concern in the industry due to the critical facts behind it. A positive user experience with useful, usable, and enjoyable interactions between the consumer and the product provides the best customer journey and ensures the product’s success. Despite the criticality of the user experience of digital products being acknowledged, it is very challenging to define it due to its subjective nature and dependency on user context and usage patterns. Ordinary and manual usability testing cannot provide successful impacts with undefined UX. To address this context, this paper explores the importance of user experience (UX) in digital product development. It introduces a comprehensive Business Intelligence (BI) approach as a novel solution that contains facilities to track digital user behavior and analyze both quantitative and qualitative analytics to enhance User Experience. With user experience and data science concepts such as behavioral analytics, attitudinal metrics, A/B testing, onsite surveys, and error tracking, the approach leads to real-time iterative agile UX development. It provides businesses with a holistic view like CCTV (Closed-Circuit Television) for digital products, facilitating informed decision-making and continuous improvement.

Keywords— agile UX, human-computer-interaction, usability testing, user-experience, user-interface

I. INTRODUCTION

A. Background

Modernized consumer needs are growing and sophisticated in today’s era of rapid technological advancements and digital transformation [1]. To fulfil these novel user expectations, businesses are evolving and expanding their limits to provide more optimized, customer-centric, and optimal digital innovations such as web applications, mobile applications, etc., to cater competitively to their target audience’s demands[2,3].

When developing digital products to address consumer needs and problems, usability, usefulness, and ease of use are well examined [4]. These factors are considered under the umbrella of user experience. User experience, often called UX, is how users interact with a product, service, or system. It is a design process to develop products that provide a relevant user experience [5]. It involves the entire product

development design process of acquiring and integrating the product, including aspects of branding, design, usability, and function [6]. UX extends beyond functionalities, aiming to make meaningful connections between users and the products [2]. In addition, a meaningful user experience allows the developers to define the customer journey on the product, which ensures the business’s success and brand reputation [7]. Considering product or sales conversion optimization, knowing how users interact with products while competing with competitors is significant. UX directly affects user engagement, sales, credibility, brand presence, conversion, retention, loyalty, revenue generation, and market value of a product or service [6]. Moreover, in the modern commercialized society, People look for features in the products that they use or intend to use, such as “cool”, “attractive”, “sleek”, “handy” etc, to go with the basic functionality needs [2]. Although widely spread and given significant importance, it lacks consensus in its unified definition [2]. Here, defining user experience means identifying metrics, analytical methods, or insights to evaluate it using a standard format, such as a usability testing method framework. However, UX cannot be measured by only examining them because the user experience depends on the user, emotions, literacy, context, product usage, etc.[7]

To address these issues, as a novel approach to solving user experience bottlenecks, a Business Intelligence (BI) platform can emerge. The approach can offer comprehensive dashboards that track user engagement, quantitative analytics, and qualitative insights, empowering commercial goals to gain advanced insights about user interactions and preferences using advanced techniques such as behavioral analytics, attitudinal metrics, A/B testing, user review scores, onsite surveys and defined UX metrics. The platforms lead to iterative product development in real-time grounded in Agile and Lean UX methodologies. It can be made to see all infographics on where the user navigates, how far they visit, what they ignore, and their interactions. Many infographics are collected under the hood, and it’s like CCTV for your product (web, mobile, etc.). You can replay visitor behavior afterwards.

B. Problem Statement

The industry pays more attention to the user experience of the products it builds. However, many identified and unidentified issues have been raised regarding UX [8]. One of the primary challenges is the need for a clear definition of UX that will lead to consistency in its interpretation [2]. This

issue complicates establishing clear benchmarks and best UX design and evaluation practices.

In application development, follow a non-data-driven approach based on assumptions, hunches, and guessing without collecting data from real-world settings and determining stakeholders' needs for personas and materials. The UX and testing teams build digital experiences for the products based on the above-collected data. This non-data-driven approach leads to frustrations such as non-user-centric products, inappropriate CTA placements, searchability/readability issues, design hierarchies, and incorrect typography. Depending on these, the outcome misleads system implementations by not completing the conversations, product funnel failures, etc.

Traditional usability testing methods cannot provide comprehensive insights from consumers regarding UX. This inability to accurately observe real-world user engagement and behavior limits the opportunity to see how users interact with the developed product, how they are frustrated, and efforts to identify pain points and opportunities for improvement in digital products and services. They often rely on static feedback mechanisms and do not provide deep insights into evolving user preferences and behaviors.

User engagement manifests in how people choose to get value from the user experience, as enabled by the application (e.g., social network) and device (e.g., smartphone) they elect to use [9]. It can be used to identify if the product's user interface can solve the user's problem and how successful the product will be [7].

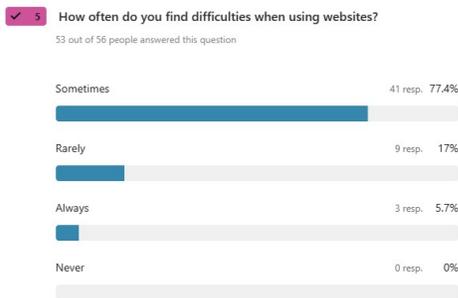


Fig. 1. Research Survey Question for website users (Source: Author's conducted survey)

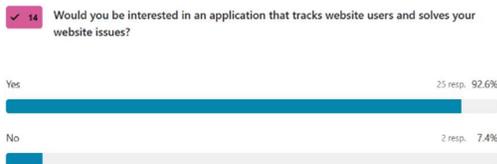


Fig. 2. Research Survey Question for website owners or managers (Source: Author's conducted survey)

The survey conducted for this research for an open audience, considering two social groups as web application users and owners or managers, which got 56 submissions proves the above problems. Figure 1 and Figure 2. International surveys and benchmarks conducted by organizations like Mixpanel, ProProfs, Spiralytics, Forrester

Research, Salesforce, etc., prove these issues using population samples [10].

II. LITERATURE REVIEW

The concept of data-driven user experience (UX) evaluation has been extensively researched in recent years. Several studies have highlighted the importance of Business Intelligence (BI) platforms, which provide comprehensive dashboards that track users. This research helps to facilitate informed decision-making for application development. UISim, UI experience analysis framework presented by Mohommad [11] discusses the importance and difficulties of Human-Computer Interaction (HCI) and provides a framework for measuring user engagement using users' activities and emotions in real time. Specific activity detectors, activity analyzers, and data structures were used.

A/B Testing is a popular technique for evaluating modification of the application user interface. Puneet [12] describes the A/B testing approach and utilization in application development. Narendren [13] presents an approach to implementing agile methodology in UX development in South Africa. It is a grounded theory, and integration is revealed practically to prove it is suitable for qualitative methods.

A systems development life cycle model that can be used to integrate UX-related practices is discussed by Azi [14] This method has shown success in several areas, such as agility, separation of concerns, and the perceived level of user experience.

The user-centered design (UCD) model for e-commerce small and medium enterprises (SMEs) was presented in a paper by Maulana [15], and it reveals a model that can be used in different contexts with different user points of view. As the result shows, a low-fidelity platform could be used. The approach specifies the context of use and requirements, evaluates designs, and determines solutions.

Apart from this literature, some existing platforms like Google Analytics, Mixpanel, Hotjar, and MouseFlow, which depend on user behaviors or quantitative analytics, often in isolation with few metrics, are considered sales or marketing, which follows the data-driven decision-making approach for digital UX.

Predictive analytics is essential to making data-driven business decisions, as described in the paper by Nazhath [16]. According to the proposed sales analysis, the collected data can lead to business decisions.

III. OBJECTIVES

A. Data-driven UX development

The proposed approach collects and utilizes data to make data-driven decisions and enhances the UI/UX of digital products. It involves analyzing several metrics gathered by consumers' behavior to make data-driven decisions. A platform that implements this approach can observe user engagements via proposed metrics like heatmaps, behavioral metrics (bounce rate, user session time, time on task), attitudinal metrics (daily/monthly active users, daily/monthly user sessions), and user reviews score with

advanced data science[14]. This approach intends to create data-driven UIs that align with the real world without depending on hatches or assumptions. The data collected throughout a certain period can lead to different analytical calculations and make predictions to perform this approach more productively [16].

B. Determination of optimum UI from A/B Testing and Agile UX:

A/B testing can follow a recursive approach combined with Agile UX until the product achieves optimal user satisfaction with the most appropriate UI component, depending on the requirement or context[17].

C. Collective and Insightful user feedback:

Implementing live onsite user feedback and UX interaction polls directly enhances the user experience by gathering real-time insights from users. From the user perspective, onsite surveys offer a direct avenue to feedback on the pain points related to the products while engaging. The system can gather a complete product overview through error-driven event tracking and session recordings. Fluctuations, pain points, etc. can be gathered with this approach. The data collected through UX polls could align with metrics like Net Promoter Score (NPS), System Usability Scale, and conversion rate to generate more detailed and comprehensive insights about the product's UX[18]. Further discussion on these details can be found in the 'Metrics and UX Principles' section. Reducing identified pain points and minimizing obstacles or friction points that impede the user journey towards completing a sales funnel increase sales funnel and conversions through the seamless feedback initiative, ultimately, increasing revenue [16].

D. Reduction of UX testers' labor and cost

With the proposed approach, the usability testing process can be optimized and automated. It leads to improved accuracy, efficiency and productivity and reduces labor costs. The approach is proposed especially to beta testers or insight testers. The beta test is the last test run prior to commercial release done by non-paid stakeholders outside the company with real-world exposure from a diverse user base. E.g.: Microsoft Insights [19].

IV. METHODOLOGY

A. Approach

This paper proposes a novel, systematic approach to making data-driven decisions on UX. It is essential to incorporate this approach with a standard product development approach. For the requirement, suggest developing an SDK (Software Development Kit) as a Software-as-a-Service (SaaS) solution, complemented by event triggers implemented in the client application of the product that is to be tracked and a comprehensive dashboard with quantitative and qualitative insights for real-time metrics with predictive analytics as shown in Figure 3. The robust SDK tracks user interactions as a SaaS within the product that needs to be tracked.

The SDK will be instrumented with a sophisticated event trigger mechanism to capture user engagement effectively. This involves using DOM (Document Object Model) event listeners to monitor and log interactions with UI elements like buttons and forms. Additionally, advanced user behavior-tracking methodologies can be integrated to provide in-depth insights through techniques such as heatmaps, error tracking and session recordings.

A separate dashboard suggests visualizing metrics, analytics and insights in real time. The data collected through SDK is sent to a database via RESTful API (Representational State Transfer Application Programming Interface) or GraphQL and the dashboard retrieves data from it. The data should be presented in a mannered way using visualization libraries. The system should incorporate a predictive analytics model to proactively anticipate future user behaviours and enhance UX. Historical interaction data will be analyzed using the developed machine-learning models like regression, decision trees, and clustering. Based on all these metrics, insights, and predictions, the dashboard users can follow a data-driven approach in decision-making on the user experience of the products, not being limited to just assumptions or hatches.

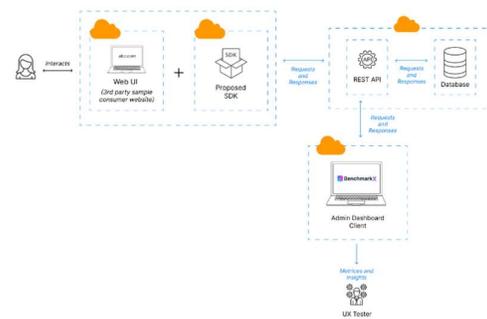


Fig.3: High-level architecture (Source: Author's compilation)

B. Metrics and UX Principles

A/B Testing with Agile UX: A/B Testing is used to evaluate applications' user interface modifications. Users are randomly divided into two or more groups and exposed to different UI variants to compare their performance based on metrics like revenue per unit (RPU) and determine the optimal variant. A/B Testing determines the optimal UI of variants and tracks their performances separately[12]. According to the UX context, the number of call-to-action (CTA) clicks, bounce rate ratios, and conversion rates can be calculated.

Agile methodology breaks the development into phases, allows continuous improvement and concentrates on the instant delivery of products. It is a recursive approach that can align with UX methodology. Implementing Agile UX methodology can facilitate getting the most optimal UI after certain recursions [13].

C. Mouse click and movement mapping using heatmaps:

A heat map is a strategy for revealing users' flow on the platform and determining which elements capture the most attention. Heatmaps overlay hot and cold spots directly onto

the application to make user activity easy to understand. Heatmaps provide evidence of the need to make data-informed decisions about user engagement patterns. If there are any place users engage more strategically, that way, they're more likely to get clicked and engaged[9].

D. Behavioural and Attitudinal Metrics:

Behavioural metrics are quantitative data analysis types based on concrete, measurable actions like time spent on the page, task success, average session, and error rate, which measure the users' interaction with digital products. This provides numerical measurements of user behaviours and provides analytics into user engagement patterns and their preferences.

Bounce rate measures from the percentage of visitors who leave an application or website without interacting beyond the first page. A high bounce rate indicates that visitors may not find the content insightful or engaging enough to explore further.

E. User Review Score:

User review score is a type of aggregated rating given to a product based on users' feedback or reviews. This provides the general idea of the user satisfaction out of 5 or 10.

F. Net Promoter Score (NPS):

Net Promoter Score (NPS) is a metric that measures customer satisfaction and loyalty and how the company promotes the product to the next customer. It depends on a single question: "How likely are you to recommend our website to a friend or colleague?" The survey participants can rate on a scale of 0 to 10. The users' responses classify values as Promoters, Passives and Detractors. Values between 9 and 10 are considered promoters, highly satisfied users or customers who will recommend a product or service to others. Detractors, the visitors' value from a score of 0-6 are not promoting the application to someone else with the impression they are having. The visitors who put scores between 7 and 8 are customers who are satisfied but not enthusiastic. Their promotion is not confident enough. In the calculation of NPS, the percentage of detractors is subtracted from the percentage of promoters, and the score ranges from -100 to +100. NPS provides more actionable insights and helps people get an idea of the product they are providing. It can be used as the KPI (Key Performance Indicator) for CXP (customer experience) management [18].

G. Conversion rate:

Conversion rate is defined as the percentage of application visitors who followed or clicked CTA to complete a specific task like Register, Buy, Subscribe or Download [20].

$$\text{Conversion Rate} = \left(\frac{\text{Number of Conversions}}{\text{Number of Visits}} \right) \times 100$$

A higher conversion rate indicates that a high number of visitors have gone through the process (lead generation) by taking the desired action, which can be considered a positive outcome. The reason may be the high quality of the user experience a good impression of the user interface or the quality of the service/product may be high.

H. Onsite Surveys and UX interaction polls:

Real-time live on-site surveys and UX interaction widgets are the optimal and most actionable ways to collect and listen to users' voices. Through UX interaction widgets, visitors open the feedback tab and provide feedback. These allow for an informative interpretation of the user engagements and user thoughts about the product. Page by page, event by event, these data can be collected Eg: user satisfaction [21].

V.CONCLUSION

This report offers an approach to making data-driven decisions on the user experience of digital products. It discusses the crucial essentiality of a user experience evaluation platform complemented by qualitative insights and quantitative analytics to enhance user experiences of digital products. The approach could deliver a comprehensive dashboard by integrating robust predictive analytics techniques. This approach empowers the executive administration of businesses to make more data-driven decisions to optimize their retention and reputation and improve customer satisfaction. As for future works, the development of a software development kit and dashboard with an appropriate technical stack would take place with the integration of more comprehensive analytics and insights in combination with powerful demographics. Continue the user experience tracking up to the user emotions like facial expression, emotions could be considered as inputs and processes to make data-driven decisions. Overall, this paper marked a significant step in the field of user experience and quality assurance of digital products by providing business value with actionable data analytics and data-driven and finally delivering enhanced value to their customers in business.

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Smart Agriculture System Leveraging Machine Learning Technology for Price Forecasting and Crop Recommendation

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Abstract- The agriculture industry in Sri Lanka faces numerous challenges including climate variability, market unpredictability, and inefficient supply chains. This research investigates the application of Machine Learning (ML) technique to forecast crop prices and recommend optimal crops in Sri Lanka. It provides future price forecasting for crops and offers crop recommendations based on key features such as rainfall and soil conditions. The platform's user-friendly interface, combined with data from various sources and a thorough review of existing literature, aims to make advanced agricultural forecasting and recommendation tools accessible and affordable for all farmers in Sri Lanka. This initiative aligns with global trends in agricultural innovation, promoting data transparency and positioning Sri Lankan agriculture to benefit from latest technologies. The research successfully integrates sophisticated technology with the practical needs of the farming community and promotes sustainable growth and adaptability in the agricultural sector. By enabling precise crop price forecasting and tailored crop recommendations.

Keywords - agriculture, crop-price-forecasting, crop-recommendation, machine-learning, smart-agriculture-system

I. INTRODUCTION

Agriculture is a critical sector in Sri Lanka, contributing approximately 7% to the national GDP. Covering over 30% of the country's land area, or around 2.8 million hectares, the agricultural industry plays a vital role in food security and economic stability. A significant portion of this agricultural land is managed by small-scale farmers who cultivate less than 2 hectares each, collectively accounting for nearly 80% of the country's annual crop output [1, 2, 3].

However, traditional farming methods are often challenged by climate variability, lack of timely market information, and inefficiencies in the supply chain. As the demands for food security and sustainable practices grow, it becomes increasingly critical to integrate innovative technologies into traditional farming methods. This research focuses on the application of Machine Learning (ML) to enhance decision-making processes in agriculture, particularly in forecasting crop prices and recommending suitable crops for planting.

Machine Learning technology offers transformative potential by allowing data-driven insights that improve productivity and economic stability in farming. However, the adoption of these technologies in agriculture often encounters many barriers, including the complexity of model

implementation and the availability of relevant data. This study addresses these challenges by developing a comprehensive suite of predictive models designed to help farmers in making informed decisions about crop selection and agriculture market price forecasting.

The objective of this study is to create robust, user-friendly models that can be easily utilized by farmers and agricultural stakeholders. By focusing on model accuracy, accessibility, and practical applicability, this present study aims to fill the gap between complex technological advancements and everyday farming needs.

The contributions of this paper include an in-depth review of several predictive models, their methodological underpinnings, and the incorporation of these models into an integrated framework for improving agriculture. This study offers insightful analysis and useful resources that can be modified and implemented in comparable situations across the globe by tackling the particular difficulties that the agriculture industry in Sri Lanka faces.

II. LITERATURE REVIEW

As demonstrated by the Sadiq A. Mulla and S. A. Quadri's, introduces a supervised machine learning approach to enhance agricultural productivity and economic forecasting [4]. The study employs the Decision Tree algorithm to predict crop yields and market prices for crops like paddy, arhar, and bajra by analyzing historical data on rainfall, temperature, market prices, and previous yields. The model provides a twelve-month time series analysis, offering valuable insights into future crop prices and potential gains. This innovative model underscores the potential of machine learning to revolutionize agricultural practices and economic forecasting for farmers.

As for the Changxia, Menghao, and Haiping Si addresses the challenge of significant prediction errors in agricultural product prices due to substantial fluctuations and non-linear features [5]. The authors propose a hybrid forecasting model named VMD-EEMD-LSTM, which integrates Ensemble Empirical Mode Decomposition (EEMD), Variational Mode Decomposition (VMD), and Long Short-Term Memory networks (LSTM). The residual component is further decomposed using EEMD. These decomposed components are then input into an LSTM model for training, and the resultant predictions are linearly combined to generate the final price forecast. Empirical analyses conducted using weekly price data for various commodities including pork,

Chinese chives, shiitake mushrooms, and cauliflower sourced from China's wholesale agricultural markets demonstrate the improved accuracy of this composite model, marking it as a major advancement in agricultural commodity price forecasting.

According to the paper by Gastli M, Nassar L, Karray F explores the utilization of satellite imagery and advanced deep learning models for predicting crop yields and forecasting agricultural prices [6]. The study leverages high-resolution satellite images, which are processed into histograms representing pixel frequencies, to train various neural network models. The authors highlight the advantages of the CNN-LSTM ensemble model, particularly when enhanced with a Gaussian Process, demonstrating its superior performance in predicting soybean yields and forecasting strawberry prices with a significant improvement in RMSE by 31%. This innovative approach not only addresses the complexities of agricultural data but also provides a scalable solution for reliable yield and price predictions, thereby contributing to global food security and market stability.

According to the paper by Ganesh. K and Prabhakar R. addresses the significant challenges faced by farmers due to fluctuating crop prices and a lack of awareness about suitable crops and soil conditions [7]. The study introduces a machine learning-based system designed to forecast crop prices for the next twelve months using Decision Tree Regression techniques. The system utilizes various parameters such as historical prices, rainfall data, and soil conditions to predict future prices and suggest optimal crops for cultivation. The proposed system aims to minimize financial losses and increase profits for farmers by providing accurate and reliable crop price forecasts, thereby enhancing their decision-making capabilities and improving overall agricultural planning and economic development. The results are presented in an accessible web application to ensure that even farmers with limited technical skills can benefit from this innovative tool.

III.DATASET

The prices history dataset utilized in this project is derived from the Department of Census and Statistics Sri Lanka. It encompasses detailed retail price data spanning back to 7 years, focusing on 122 unique retail products available in the open marketplace. From this extensive dataset, four products were selected based on their significant price fluctuations and seasonal variations like green chilies, leeks, beetroot, and carrots. These products were chosen to assess the model's ability to predict prices amidst varying external factors. The dataset provides a comprehensive view of price dynamics influenced by market conditions, seasonal trends, and economic factors, offering insights into how machine learning models can effectively predict price fluctuations and aid in strategic decision-making for stakeholders in the agricultural sector.

The crop recommendation dataset utilized in this study originates from the Kaggle website and it is designed to optimize agricultural practices through AI-driven insights. It includes data on various crops grown in the region, augmented with detailed environmental parameters such as temperature, humidity, pH levels, and rainfall patterns. Specifically, the

dataset covers 22 unique vegetables cultivated in India, with each vegetable category consisting of 100 samples.

Rainfall data from the Department of Meteorology, encompassing records from 2017 to 2022 for three key districts that have most impact on the crop prices such as Anuradhapura, Jaffna, and Nuwara Eliya were integrated into the analysis. This additional dataset provides crucial insights into how rainfall patterns impact crop prices and recommendations, allowing the models to account for climatic variations and improve their predictive accuracy.

IV.MODEL ARCHITECTURE

The price forecasting model integrates machine learning regressors to analyze historical data and forecast future. The model architecture includes implementations of SARIMAX, and ensemble methods like XGBoost Regressor, Random Forest Regressor, and CatBoost Regressor to harness their respective strengths in handling nonlinear relationships and optimizing predictive accuracy.

The crop recommendation model integrates machine learning classifiers tailored to analyze agricultural parameters crucial for crop suitability. The model architecture includes implementations of classifiers like LGBM, CatBoost, Decision Tree, and Random Forest, each selected for its ability to handle complex feature interactions and optimize crop classification based on soil and climatic conditions.

V.DATA PREPROCESSING AND TRAINING

The preprocessing stage is crucial for ensuring the robustness and accuracy of the models. In this research, multiple datasets were integrated from diverse sources such as rainfall data, soil nutrient content, climate conditions, and historical price trends. The integration process involved standardizing different formats and units to ensure compatibility across datasets. Additionally, inconsistencies such as duplicate entries and outliers were identified and addressed using z-score analysis and IQR (Interquartile Range) methods. This preprocessing step ensured that the final dataset was clean and consistent.

To handle missing values in the dataset, systematic imputation techniques were applied. For continuous variables, such as soil nutrient levels or historical prices, missing values were imputed using the mean or median values depending on the distribution of the data (e.g., median imputation for skewed distributions). For categorical variables, the mode was used. A more sophisticated approach, such as k-nearest neighbors (KNN) imputation, was considered for filling gaps in climate and soil data, as it leverages the proximity of similar data points to make better-informed estimates. To improve the diversity of the dataset and ensure generalization, data normalization techniques were employed. Variables like temperature, humidity, and nutrient levels were normalized using min-max scaling, ensuring that all features contributed equally to the model's performance. Additionally, data augmentation was used to increase the diversity of the training data, especially in cases where imbalances existed in certain crops or weather conditions. Techniques like adding small random noise to environmental data and generating synthetic data using SMOTE (Synthetic Minority Over-sampling

Technique) ensured the model trained effectively on diverse scenarios without overfitting to specific conditions.

To capture complex historical patterns in crop prices, feature engineering played a critical role in this research. Key features like lag features (e.g., previous week's price) and rolling averages (e.g., 3-week rolling average for price) were employed to model the temporal dependencies in price fluctuations. Lag features help in predicting trends by considering past price behaviors, while rolling averages help mitigate short-term fluctuations and noise in price data.

To evaluate model performance and ensure generalization, the dataset was divided into training and testing subsets. A 70/30 split was used to ensure that the model was trained on a sufficiently large portion of the data while retaining enough test data for robust evaluation. For the Crop Recommendations this split was done randomly to prevent any temporal or spatial bias and for the Price Forecasting this split was done using Time Series Splitting. The training process involved optimizing the models using a combination of advanced optimization techniques and early stopping mechanisms. To prevent overfitting, techniques like L2 regularization and dropout were implemented. Early stopping was utilized by monitoring validation loss, halting training once the model's performance plateaued to avoid overfitting to the training data. Cross-validation, specifically k-fold cross-validation, was employed to further enhance generalization. This ensured that the models were not reliant on any single partition of the data for high performance, improving reliability across diverse datasets. Evaluation metrics such as Root Mean Squared Error (RMSE) and R-squared score were used to assess model performance. RMSE was selected because it effectively penalizes larger errors, which is critical in ensuring that the price prediction model handles both small fluctuations and large price surges. Additionally, for classification models like crop recommendation, Log Loss was employed to measure the uncertainty of predictions, penalizing not just incorrect classifications but the confidence in those predictions. The use of both metrics ensured that the models were not only accurate but also robust in handling real-world data with inherent variability.

To further enhance the model's generalization capabilities, ensemble methods were used. Techniques such as bagging and boosting (implemented through Random Forest and CatBoost models) were employed to combine the strengths of multiple weaker models into a more robust and accurate prediction model. These ensemble techniques were critical in handling non-linear relationships between features and improving predictive performance.

VI.RESULTS

Evaluation of price forecasting model performance reveals varying strengths across different algorithms. The Cat Boost Regressor is identified as the optimal model, demonstrating superior predictive accuracy with the lowest RMSE of 42.4 and the highest score of 82.26 among evaluated models. These metrics highlight Cat Boost's robust performance in capturing complex patterns and dynamics in agricultural price fluctuations, making it an essential tool for stakeholders in making informed decisions in agricultural markets.

Despite the overall success, the accuracy of the price forecasting model was significantly impacted by the abnormal growth in price trends observed in late 2023. As shown in "Fig. 1", the model struggled to adapt to this sudden price surge.

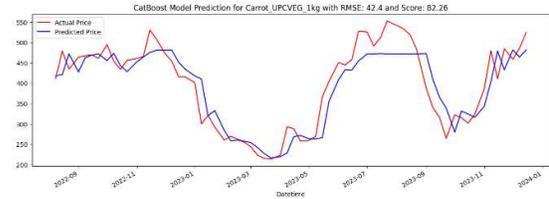


Fig. 1. Catboost Model Prediction result. Y-axis show price of the carrot per kilogram and X-axis show the time.

This growth was closely linked to increased operating expenses in agriculture, driven by rising fuel and fertilizer prices, higher taxes, and fluctuations in the dollar exchange rate. These factors introduced substantial price volatility into the market, complicating the task of accurate forecasting and impacting the performance of the models.

Data collected from the website of Department of Census and Statistics and the Ceylon Petroleum Corporation underscore the significant impact of external factors such as rainfall patterns and fuel prices on agricultural prices. As illustrated in "Fig. 2", these external variables contribute substantially to price fluctuations, complicating accurate forecasting. Rainfall data reveals the influence of climatic conditions on crop yield and pricing, while fluctuations in fuel prices, depicted in the corresponding figure, highlight their direct impact on the cost of agricultural production and transportation.

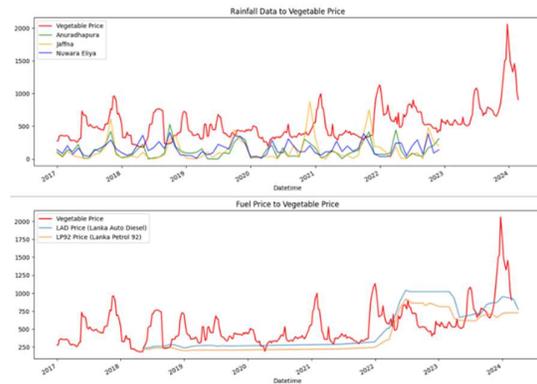


Fig. 2. Impact of external factors to vegetable price. First chart shows impact of the rainfall to vegetable price and second chart shows impact of fuel price to vegetable price.

As shown in "Fig. 3", the Random Forest Classifier acquired a high accuracy score of 99.7%, indicating its effectiveness in correctly predicting crop suitability. The model's Log Loss is 0.061, demonstrating its proficiency in minimizing the uncertainty of predictions and penalizing incorrect classifications. Confusion matrix provides a detailed analysis of the model's reliability in various agricultural scenarios.

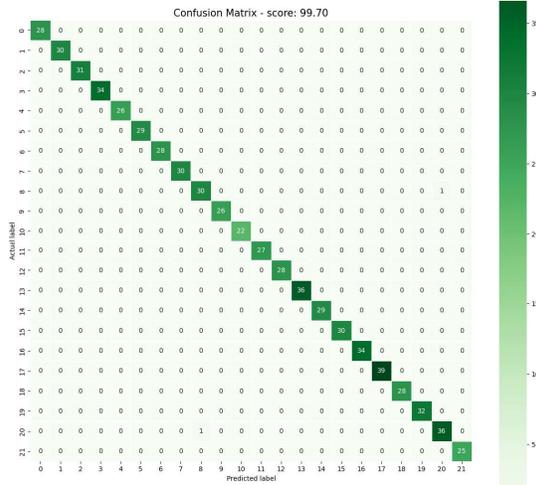


Fig. 3. Confusion matrix for random forest. Y-axis shows actual label and X-axis shows model predicted label

VII.FUNCTIONALITIES

The system development involves creating a comprehensive web platform that enables farmers to optimize their farming practices by providing tools for crop selection and market price forecasting. The system diagram in Figure 5 showcases the architectural framework of this platform, detailing the integration of various components and services. It streamlines agriculture management by integrating machine learning technology to offer personalized crop recommendations based on soil and climate data. The web platform is meticulously designed to ensure that all users, including those with lower literacy levels, can effectively engage with its functionalities and derive maximum benefit without encountering usability barriers. As illustrated in Figure 6, the user interface (UI) for accessing price forecasting details is intuitively designed, enabling easy navigation and understanding. Similarly, Figure 7 highlights the UI for obtaining crop recommendations, demonstrating a user-centric approach that prioritizes clear and actionable insights. This approach is based on usability practices and UI/UX (User Interface/User Experience) principles, which prioritize intuitive design and accessibility.

The project leverages modern technologies to develop a comprehensive smart agriculture platform aimed at revolutionizing farming practices in Sri Lanka. The frontend of the platform is built using React.js, employing interactive UI elements that facilitate ease of use and accessibility. Using the Restful API ensure seamless data flow between the frontend and backend.

On the backend, Node.js and Express.js form the core framework for server-side operations, integrating seamlessly with MongoDB for robust and scalable data management. Additionally, specialized services such as the Recommendation service and Price Prediction service are implemented using Flask and Python. Also using containerization techniques ensures each component is encapsulated for scalability and ease of deployment using Docker.

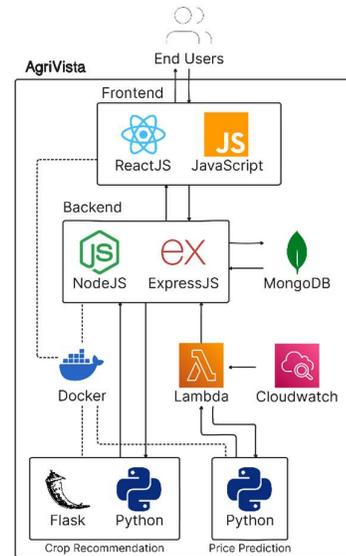


Fig. 4. System Diagram of the proposed system.

Furthermore, the platform includes a user-friendly and mobile-responsive frontend, designed to cater specifically to farmers with varying levels of technical expertise and literacy. With the help of the Google Translation feature enables accessing the platform using Sinhala language as well. This accessibility feature enables seamless interaction with the system's functionalities, empowering farmers to make informed decisions based on real-time data and insights provided by the platform.

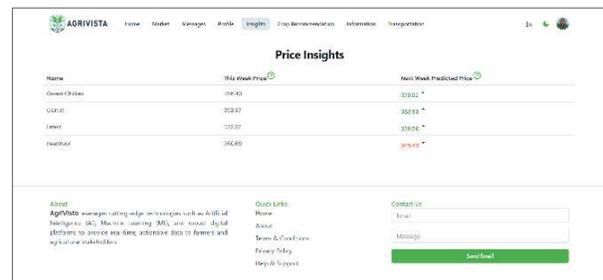


Fig. 5. Proposed User Interface for accessing price forecasting details.

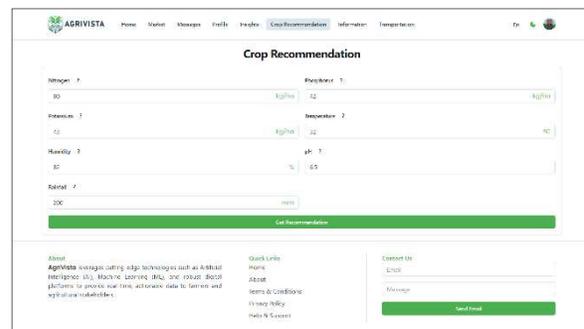


Fig. 6. Proposed User Interface for Crop Recommendations form.

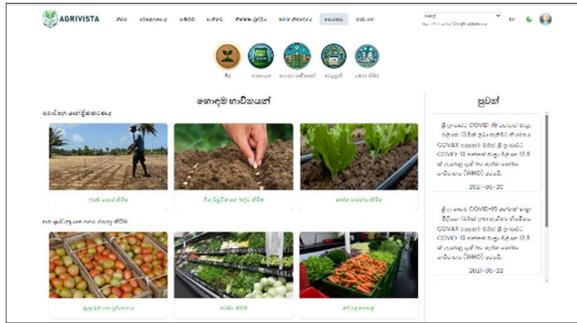


Fig. 7. Proposed User Interface in Sinhala Language.

VIII. FUTURE IMPLEMENTATION

This research acknowledges certain limitations that pave the way for future enhancements and developments. Key challenges include the availability of localized data for the crop recommendation in the Sri Lankan context and the complete integration of predictive models. To address these, future efforts should concentrate on expanding data collection efforts, refining predictive models through continuous learning methodologies, and incorporating more detailed local conditions to increase accuracy.

Moreover, expanding the system's capabilities to include a mobile application accessible to users with low literacy rates and incorporating push notifications would significantly enhance user engagement and facilitate timely updates. Such enhancements would empower farmers by providing easier access to critical information and updates directly on their mobile devices.

Integrating advanced neural networks represents a crucial step towards improving price forecasting accuracy. Neural networks possess the capability to discern complex market patterns that may otherwise remain undetected by traditional models. This integration would increase the system's forecasting capabilities, thereby offering farmers more reliable insights for informed decision-making.

IX. CONCLUSION

This research advances the application of Machine Learning (ML) technologies to enhance agricultural practices in Sri Lanka, with a primary focus on crop price forecasting and crop recommendation. By integrating sophisticated models, the study addresses key challenges in the local agricultural sector, such as market unpredictability, climate variability, and soil conditions. The developed platform bridges the gap between technological innovation and practical farming needs by providing farmers with accessible tools for data-driven decision-making.

The CatBoost Regressor demonstrated superior performance in forecasting agricultural prices, achieving an RMSE of 42.4 and a predictive score of 82.26. This highlights the model's ability to capture complex, non-linear price fluctuations, providing farmers with valuable insights to mitigate financial risk caused by market volatility. Similarly, the Random Forest algorithm proved highly effective in crop recommendation, achieving an accuracy score of 99.7% and a

Log Loss of 0.061. These metrics showcase the model's precision in recommending crops based on soil nutrients, climatic conditions, and economic viability, offering actionable insights for sustainable farming practices.

However, a limitation of this research is the use of a dataset from India due to the lack of comprehensive, localized data specific to Sri Lanka. While agronomic and climatic similarities between the two countries justify this approach, future work will focus on utilizing transfer learning to adapt models trained on Indian data for more effective use in the Sri Lankan context. Transfer learning fine-tunes pre-trained models using smaller, region-specific datasets as they become available, improving accuracy without needing large volumes of local data. Additionally, collaborating with local authorities and agricultural institutions for data collection will further refine the models, ensuring they are tailored to Sri Lankan agricultural needs.

In conclusion, this research provides a valuable contribution to sustainable agriculture by equipping farmers with advanced tools for price forecasting and crop recommendation. The platform paves the way for future advancements in smart agriculture, promoting sustainability, profitability, and resilience in Sri Lanka's agriculture sector. By continuously refining the models with localized data and improving the platform's usability, this initiative has the potential to significantly enhance the decision-making capabilities of Sri Lankan farmers, helping them navigate the challenges posed by climate change and market unpredictability.

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Development of an Agile-driven Project Management Information System for Research and Development Companies in Sri Lanka

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Abstract— The primary goal of this study is to create and evaluate the impact of an Agile-driven Project Management Information System (PMIS) on Research and Development (R&D) organizations, with a particular emphasis on agricultural robotics and food technological companies in Sri Lanka. This study has conducted in a quantitative approach by gathering data from CAFT employees, and it highlights the necessity for an effective PMIS to solve inefficiencies in knowledge exchange, resource allocation, data integrity, project tracking, scalability, and regulatory compliance in R&D projects. The proposed PMIS uses Kanban methodology, and it integrates blockchain technology with Hyperledger fabric technology to improve transparency, security, and operational efficiency. The results show that the project management procedures, effectiveness of R&D enterprises can be improved by using an Agile-driven PMIS and ultimately can contribute to Sri Lanka's overall economic development. According to the report conducted based on the results of conducting user acceptance testing, establishing an Agile-driven PMIS system with Blockchain methodology can significantly improve the agriculture industry, fostering innovation and growth. Future advances in artificial intelligence are also discussed, with a focus on the possibility of greatly increasing the system's capabilities.

Keywords—*agile methodologies, blockchain, project management information system, hyperledger fabric, framework*

I. INTRODUCTION

Research and Development (R&D) is crucial which helps to solve challenges by coming up with cutting-edge innovations for product or service improvements and helps to maintain economic and technological competitiveness. In the area of research and development, numerous projects are being handled in diversified areas mainly as state-owned projects and commercial projects due to its high complexity in several stakeholders involved, diversity of skills, and uncertainty involved, require precise information to flow within the project progress and management involvement between diverse participants leading to efficient knowledge sharing needs to early addressed [1]. R&D is a very expensive process as it requires a significant investment in materials and equipment. At present the total global R&D expenditures amount to 2.48 trillion U.S. dollars in 2022 [2]. The United States is the leading country to spend on R&D, and the company that spends most on R&D is Amazon. However, when expenditure is considered as a share of overall gross

domestic product, smaller countries with tech-heavy economies invest larger shares of their GDPs into R&D [2]. Although innovation through R&D is a major competitive advantage for a country, Sri Lanka has a very lower-level situation for R&D. In 2020, a total of Rs. 18,174.60 million has been spent on R&D in Sri Lanka [2]. Currently, research and developments have been done by the government, higher education sectors, business enterprises, and private non-profit organizations in Sri Lanka under Engineering and Technology, Natural Sciences, Medical sciences, Agricultural Sciences, Social Sciences, and Humanities [3] CAFT (Ceylon Agro-food Technologies), IFS Colombo 2, National Engineering Research and Development Centre of Sri Lanka – NERDC, and Market Research Company are companies existing in Sri Lanka following many research and development projects in Sri Lanka. In practice, R&D in the agri-food industry has been given priority and it has now become the world's most dynamic economic sector for R&D projects to conduct [4, 5].

Each company or industry may have its unique business research processes, but, in a research and development process, there are some basic steps followed; foster ideas, focus ideas, develop ideas, prototypes and trials, regulatory activities, marketing and product development activities. Ceylon Agro-food Technologies (Pvt) Ltd (CAFT), [6] is a leading Research and Development company, which explores synergies between advanced agricultural robotics and food product development [5] to demonstrate its commitment to innovation in agricultural technologies. Furthermore, on the engineering front, they have emphasized mechanical engineering, mechatronics engineering, and the development of drones.

All the manual business process steps that are already done in R&D companies can be smoothly done using the current technology by developing a Project Management Information System (PMIS). A PMIS can help an organization to; streamline project workflows, enhance communication, and ensure that projects are executed on time and within the budget [7]. Project Management Information Systems have been already developed for different technologies, but their development in Agri and Food technology has a lower rate. Agile projects get timely data through daily updates during an iteration. These updates can be included in timesheets, emails

to the project manager, or as daily updates on cards on a Kanban board, by having an agile-driven PMIS [8]. As a PMIS can be developed also for Agri and food technology, the development of an agile-driven PMIS to run a smooth business process by using the agile framework 'Kanban', in R&D companies will be studied during this research study with regards to the R&D projects.

In the current context of R&D companies in Sri Lanka, they have been handling their projects in a complex manner by facing many challenges for project management in streamlining the process of handling the project and giving out the best solution in an accurate manner to the senior level management. Most companies are now addressing this by considering the involvement of cutting-edge technologies and project Management Information System development in managing their projects with clear understanding, and accessibility, and building up a user-friendly environment for the users and management to make better decisions and enhance the business capacity. In addition, the use of blockchain technology and use of agile methodologies to make the process smooth in working and secure the traceability of projects and authentication and connecting the business process in the value chain of R&D projects is essential. This makes the pathway for the development of an Agile-driven PMIS system using blockchain technology for the Agriculture Robotics and Food sector, as there has been a lack of developing systems for project management and is lacking with the use of mering technologies. This study aims to identify the crucial business process ongoing in the projects of Agri & food related R&D projects and make the project management by developing a PMIS using agile methods and blockchain technologies [9].

As per the previous studies conducted there has been notified different challenges are being faced such as inefficiencies in resource allocation and progress tracking in ongoing research and development projects, coordination and communication among the peers, and identification of bottlenecks in the ongoing research and development projects is lacking due to its complexity in high revenues R&D companies, Complex regulatory process and the patent process is being complex the regular updating is required in the ongoing processes, projects needs to be streamlined and optimized to its optimum level in getting the maximum efficiency and accurate decision marking purposes.

II. LITERATURE REVIEW

A. Applications of Project Management Information Systems

Project management information system (PMIS) is an integrated management tool or application which facilitates implementation, project planning, execution, monitoring, knowledge management, decision making, information collection, and dissemination [10]. PMIS helps organizations to successfully plan and implement their projects. Compared to the establishment of modern project management, the concept of information systems is new. PMIS acts as a bridge among the stakeholders to communicate and helps to obtain the correct information to

the right people at the right time to take corrective measures [10].

In the context of Agile methodologies, it helps project management to be flexible and adaptable to the changing requirements in various industries. Agile methodology is an iterative approach that allows for continuous feedback and adaptation and helps to reduce risks to meet the project objectives [11]. According to [12] have shown that projects implementing Agile methodologies have higher success rates, by having a reduced number of failures. Therefore, among various agile methodologies, Scrum, Kanban, and Extreme Programming (XP) are some most prominent agile methodologies in use [11]. Among them, Kanban is an agile method first implemented in Toyota's manufacturing process, and afterwards spreads across various industries and academic fields. It focuses on project and process improvements and highlight a team's ability to improve the efficiency of everyday activities by implementing the core practices like, limiting work-in-progress, visualizing workflow, and managing flow [13]. The article 'Kanban based information management in organization', states that the applications of Kanban can already be seen in several fields - from its origins to its present expansion to many different domains. A Project [14] Kanban Wall, which illustrates the developments in project flows rather than task flows, along with the use of Scrum as a software development tool, has been implemented for the field of software development [15]. Similarly, the Kanban method can be used in R&D companies to have a higher succession rate.

B. Blockchain Technology

Cutting edge technologies Artificial Intelligence (AI), Internet of Things (IoT), and Blockchain help industries to transform into a different aspect [16]. Among them, Blockchain is a technology that acts as a digital ledger containing the records of transactions of a certain business and stores data across a network of computers (nodes).

Transparency is a must to have in an organization as it helps the management to make better decisions. Therefore, blockchain is implemented to have a transparent PMIS. Blockchain is already available in the food and construction sectors and also can be implemented in the R&D sectors. A private blockchain with a Hyperledger Fabric system is selected to carry out this study, as it is very secure as a third party cannot access the data. Although there are fewer resources to implement this system, implementing it will create greater benefits. Several nodes can be connected with this Hyperledger fabric system. The same copy of data with different encryption codes will be there in each block, and if any change is made in any copy, it can be detected by the system. So, by having a blockchain system, it can ensure the security of data. A blockchain system can be implemented for data like project IDs, estimated budgets, and intellectual property numbers, in R&D, food sectors, etc. Therefore, organizations consider the prospects of adopting blockchain as a central database to store data.

When it comes to the agricultural sector, implementing blockchain technology in project management information

systems is beneficial and it can improve the efficiency and integrity of agricultural applications. Provenance traceability and food authentication which can be regarded as a use of blockchain, contain all necessary data related to the product origin and its movements [17]. As a result, it is the most capable way to improve food safety and decrease fraud and food scandals. Blockchain also helps with trade finance in supply chain management, smart farming data management, and other information management systems [17].

The case study “Blockchain Technology in Current Agricultural Systems: From Techniques to Applications”, has identified the major technological challenges like scalability issues when integrating with data-intensive technologies, integration with existing legacy systems, and security and privacy challenges. According to the study, the mixture and links of blockchain with storage systems, such as IPFS, provide a more scalable and sustainable way to deal with the exponential increase of data. The demand of high throughput data storage requirements can be solved while maintaining data integrity with the use of hybrid architecture. The study believes the use of cloud services could solve the issue of integration with the existing legacy systems. To further improve blockchain privacy and security, they have identified that an infrastructure-level solution will be more appropriate [17].

Blockchain can be there as a public/permissionless system or as a private/permission system. Private blockchain is a usual blockchain system with numerous nodes which do not fully trust each other [18]. Some nodes have a complex behavior while the majority are honest. The nodes perform transactions modifying the states while maintaining a set of shared, global states [18]. The security, performance, and scalability of private blockchains are much better and information sharing can be controlled very well than in public blockchains [19] Quorum, Hyperledger Sawtooth, R3 Corda, Ripple, Multichain, and Hyperledger Fabric, are some private blockchain systems that can be used. Hyperledger fabric is being used by many vendors as it helps to build up numerous solutions for the related necessary areas [19].

III.METHODOLOGY

A. Study period and sample

The methodology is composed of structured ways or methods [20] to do a certain thing to gain knowledge related to a certain study. This study aims to implement an agile-driven PMIS to ease the project management of agriculture-related R&D companies in Sri Lanka [5]. This study applied quantitative research on a long-term basis by collecting quantitative data via questionnaire through convenient sampling selecting a sample of 32 employees from the R&D organization on agricultural robotics and food technologies at Ceylon Agro Food Technologies Pvt Ltd (CAFT) in Sri Lanka. The sample size was determined with a minimum sample of 24 employees by getting the results of the confidence level as 85%, margin of error as 15%, and population proportion as 50% through calculations [21]. The quantitative analysis is performed after the collection of data related to Logistics and transportation, patent information, drone monitoring and operators’ information, engineering sub

division information and food technologies related information, project progress details.

B. System Design Methodology

System tools like; Figma to develop the prototype with wireframe was used to create this PMIS, by selecting the Data Base Management System (DBMS) as a Relational Database Management System (RDBMS) for further development. The system consists of a variety of features; analytical dashboard features for top level managers, R&D Project Management & Progress tracking, Project Management meeting notes & weekly progress report generate features, Patent application progress monitoring features, Logistics detail monitoring features, etc.

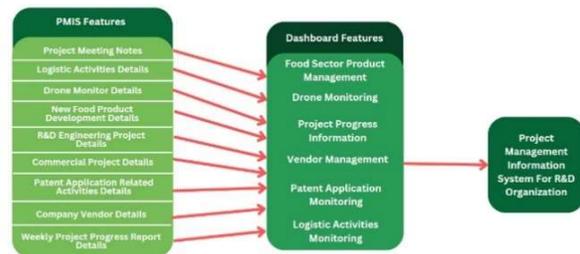


Fig. 1: Agile-Driven Project Management System Framework.

The above framework is created in order to ease the first stage of designing the PMIS, and according to it, the outcome, which is the PMIS for R&D organization, consists PMIS features. The PMIS features like, project meeting notes, logistics activities details, etc. will help to achieve dashboard features like, food sector product management, vendor management, etc.

IV.RESULTS

A. System Architecture

An automated PMIS system can be implemented in a company instead of a traditional PMIS as it helps to manage all the information easily and helps the management of the company to run their work smoothly. So, this study has focused on creating an agile-driven PMIS in R&D companies, especially in the Agricultural sector of Sri Lanka, to have a change in their environments and to work effectively and efficiently. A PMIS should be developed according to the company and should contain different functions to help the management of the company, at different levels of the project. Accordingly in this study, a PMIS which is suitable for an agricultural R&D company is developed by using a blockchain system with a Hyperledger fabric facility. Hyperledger fabric blockchain helps the organization to have a more secure PMIS within the organization by identifying all the data modifications and preventing any unwanted third-party data modifications.

Agile Project Management helps to manage projects, incremental progress, adaptability, and emphasize collaboration in a flexible and iterative approach. In Ceylon Agro Food Technologies (Pvt) Ltd, the system architecture is composed of the following key elements;

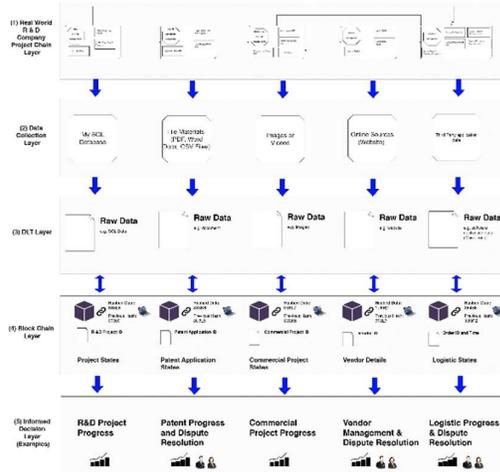


Fig. 2. Agile-Driven Project Management Information System Architecture

1. Iterative Development – A project is divided into small, manageable sub-sections. Each sub-section act for a portion of the overall project. It helps to get feedback and helps for the continuous development.

2. Cross-Functional Teams - Having members from various engineering sectors (mechatronic, mechanical, electronic, automation) and food sector leads can promote the relationships, variety of skills, and the cooperative ownership of project outcomes.

3. Customer-Centric Approach - Stakeholder (including investors and end-users) needs, are central to decision-making. The feedback loops and regular engagements make sure that the project remains positioned with the expectations of the customer and process is streamlined aligning with the main agile methodology for the top-level management in making accurate decisions.

4. Systematic & dynamic Planning – Dynamic plans help to evolve the project progresses. According to the requirement changes, management will be able to do further adjustments to ensure that the resources are allocated efficiently.

5. Daily Scrums and Stand-Up Meetings – The team members can share their daily updates, plan their daily tasks, and discuss the challenges with these short and focused meetings. This improves the transparency within the project team and keeps everyone notified about the progress.

6. Visual Tools (e.g., Kanban Boards) - Workload management, identification of bottlenecks, and maintenance of a clear overview of the project's status can be done by visualizing the tasks and progress on a board.

7. Empowered Teams - Team members are encouraged to get collective decisions, and to take ownership of their work, in order to adapt them to changes and to drive the project forward.

Well-maintained and accurate meeting notes, records of progress, and updates are necessary for accountability and successful communication with stakeholders. This study aims to leverage the benefits of collaboration, agility, and adaptability in R&D activities, by adopting this Agile Project Management conceptual framework. Below framework provides a structured and a flexible approach to manage

projects, by lining up with the dynamic nature of research and development in the agricultural and food sectors [5, 22].

In this study, the agile-driven PMIS for R&D companies is created using a Kanban board instead of using any other agile framework like Scrum mainly due to the transparency facility provided by the Kanban board. AI can be used to develop this system further. Agricultural managers and farmers can increase efficiency and enhance their decision-making capabilities by adopting Agile and AI [22]. PMIS with all these facilities is created as a result of this study by targeting the R&D companies in the Agricultural sector. This agile-driven PMIS can be implemented instead of the traditional PMIS of a company by having step by step progress planning with a suitable team by considering all the needs of the company [22].

V. IMPLEMENTATION

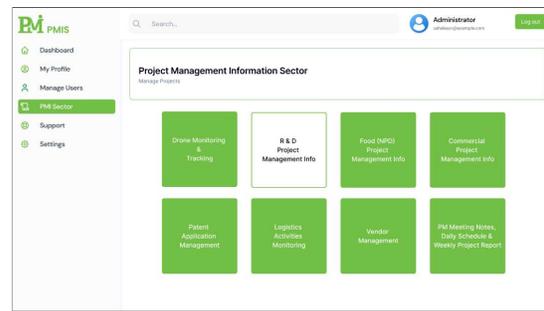


Fig. 3. UI Design of Project Management System Main Interface

The business process ongoing in the projects of Agri & food related R&D projects and managing the projects, can be smoothly done with the use of this PMIS system. This system helps to; track the resource allocation and the progress efficiently, coordinate and communicate efficiently, finish up the regulatory and patent processes, and also to streamline and optimize the processes to take it towards maximum efficiency.

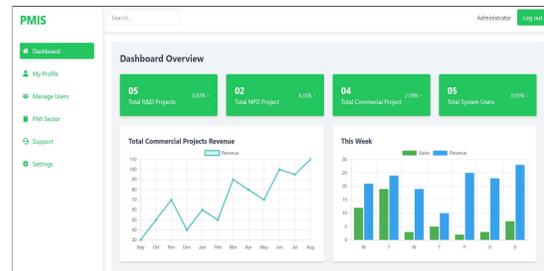


Fig. 4. UI design of project management system analysis dashboard design

This system will help the top management to take data-driven decisions by providing an analytical view. The following Project Management Information system related to drone monitoring, R&D project management, food project management, commercial project management, patent application management, logistics activities, vendor management, and project management meeting notes, daily schedules and weekly project reports.

VI. USER ACCEPTANCE TESTING

As this study aims on developing an Agile driven PMIS, there is a need of performing a pilot testing before finalizing. Therefore, this research has conducted a User Acceptance testing by providing an output of the proposed system to some of the employees like project managers, to get their feedbacks.

Accordingly, 87.50% of the employees opinion is that the system is easy to use, and no one has reviewed that the usability of the system is difficult.

TABLE I. SUMMARY OF THE STUDY

Ease of Usability of the System Status	This percentage (%) based on different roles in the organization
Easy	87.50%
Neutral	12.50%
Difficult	0%

VII. CONCLUSION

This study has considered every aspect of developing and implementing a PMIS in an organization. During the study, it was identified that a PMIS can have a huge impact on R&D companies, especially on the company’s management. It has been identified that there is a lower consideration for developing a PMIS for the Agricultural R&D companies in Sri Lanka. The agriculture sector is one of the major economies in Sri Lanka. Therefore, by implementing a PMIS in these R&D companies of this sector, can have a huge impact on the country’s economy and development. Therefore, this study has come up with an ‘Agile driven Project Management Information System’ by using the Kanban board as the Agile framework. With consideration in all the aspects, the system was created using a private blockchain system namely Hyperledger fabric blockchain to have a transparent and more secure system. The system can be further developed by using AI. Agricultural managers and farmers can increase efficiency and enhance their decision-making capabilities by adopting Agile and AI [22]. Under drone monitoring in PMIS, a machine learning part has also been implemented with algorithm, as it has been identified as the most accurate among the four algorithms; after ongoing several tests from each algorithm. Drone pilots can get the weather predictions for the needed date through this system. Overall, this study suggests that a PMIS like an Agile-driven PMIS, for the R&D organizations in the field of Agriculture, can improve the effectiveness of the organization and meanwhile, it can help for the development of Research & Development sector in Sri Lanka.

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Impact of Dietary Factors on Colon Cancer Development: A Review

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Abstract— Colon cancer is the third most common diagnosed cancer worldwide. Scientific evidence emphasizes that diet, nutrition, and lifestyle modulatory factors influence colon cancer development. This report reviews the published research to date indicating the current evidence related to dietary factors and colon cancer. An extensive search of nutrition for potential interaction between dietary factors and colon cancer using different electronic databases, including PubMed, Google Scholar, and Science Direct. This study aimed to examine the latest information available about the nutritional components of the diet-colon cancer interaction. Colon cancer risk has been increased by considerable intake of red meat and/or processed meat. In contrast, fish, rich in vitamin D and omega-3 fatty acids, and fiber from fruits, vegetables, whole grains, and cereals help lower the risk of developing colon cancer. Meanwhile, colon cancer is preventable by modifying risk factors mainly diet and physical activity. It is essential to adhere to a healthy dietary pattern consisting of nutritional factors that reduce the risk of colon cancer.

Keywords— carcinogenic, colon cancer, diet, risk factor

I. INTRODUCTION

Cancer is a major health problem that affects patients and their families. Among them, age-standardised incidence rates of colon cancer have become the third most commonly diagnosed cancer in Sri Lanka and worldwide [1, 2, 3, 4]. The following figure represents (figure 1) colorectum cancer as the third most prevalent cancer in Sri Lanka in 2019 according to the Sri Lanka Cancer Registry, Cancer Incidence & Mortality Data in Sri Lanka [5]. Increasing colon cancer incidence is highly influenced by dietary factors and lifestyle. Among many considerable factors that affect the development of colon cancer nutrition is an important factor that affects the development of colon cancer, nutrition is an essential factor as it is preventable [6].

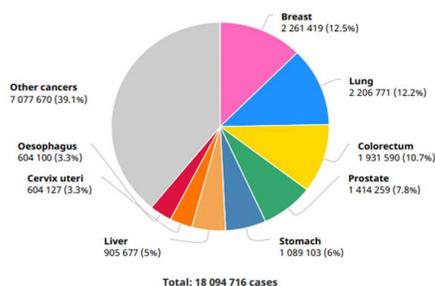


Fig. 1: Cancer Incidence & Mortality Data Sri Lanka 2019; Sri Lanka Cancer Registry. (Source: Globocan 2020 WHO)

Thus, nutrition plays a major role in the development of colon cancer [7, 8]. The relationships among cancer prevention, survivorship, and nutrition have been emphasized through many research studies, mainly in summarized published research by The World Cancer Research Fund International (WCRF)/American Institute for Cancer Research (AICR) [8, 9, 10].

As carcinogenic factors have begun to be recognized in food and beverages, diet has become more critical in cancer causation than other factors. Meanwhile, certain aspects of lifestyle, mainly dietary factors, were associated with colon carcinogenesis [11]. However, in Sri Lanka, much research has shown the wide availability of processed and unhealthy foods due to the nutrition transition that adversely affects the development of colon cancer. Meanwhile, in both urban and rural parts of Sri Lanka average dietary habits have changed considerably during the past decades [14, 15, 16].

According to The World Cancer Research Fund (WCRF)'s assumption, approximately 30% of cancers can be prevented through adopting a healthy diet. [11, 17, 18].

II. METHODOLOGY

As several epidemiological studies provide discoveries regarding diet-associated risk factors for colon cancer, this review is mainly focused on publications conducted between 2023-2004 years. This literature search was conducted in PubMed, Google Scholar, and Science Direct to prepare this review. The search included using terms related to colorectal cancer following keywords: carcinogenic, colon cancer, diet, and risk factors.

III. RESULTS

Recent studies emphasize that the transition from a healthy dietary pattern, high intake of fruits and vegetables, fish, and white meats to a modern modified dietary pattern, high intake of red meat and/or processed meat, and fast food adversely affects increasing colon cancer [8, 11, 19, 20]. The risk of colon cancer increased due to the enhancement of dietary risk factors such as increased consumption of processed meat and decreased consumption of dietary fiber, and lifestyle factors such as obesity, high energy intake, low physical activity, poor sleep patterns, smoking, and high alcohol intake [21].

A. Red and processed meat consumption

Despite the importance of substances in meat components that are essential for human nutrition (Selenium, zinc, omega-3 fatty acids, vitamins B6, B12, D and folic acid), high meat consumption is considered associated with developing colon

cancer, based on a considerable number of studies [18, 22, 23]. There are many mechanistic hypotheses that describe red meat and processed meat can increase the risk of developing colorectal cancer. Excess fat, excess protein, excess iron, or heat-induced mutagens are suspected as pro-cancer factors in red meat. Other than these factors, adding salt and nitrite during the processing of meat may be a pro – cancer factor. Likewise, increased meat intake causes increased fat intake that facilitates carcinogenesis through increase in insulin resistance and higher production of secondary bile acids [8], [24].

Thus, dietary fat raises the secretion of bile acids inside the gut, and they act as aggressive surfactants for the mucosa that leads to cell loss and proliferation. Fatty diets lead to obesity that increases insulin resistance. It is associated with changes in blood values (high glucose, free fatty acids, insulin, and IGF1): these factors increase proliferation and decrease apoptosis (cell suicide) of pre - cancerous cells, and promoting tumor growth [25]. Subsequently, toxic products like phenols and H₂S are produced in colon due to fermentation of excess proteins that have carcinogenic effect on the mucosa [26, 27].

Processed meats are preserved with chemicals like nitrates and nitrites that effect as pro – cancer factor. While meat undergoes the cooking process, nitrates and nitrites are converted to genotoxic substances such as Heterocyclic aromatic amine (HAA), Polycyclic aromatic hydrocarbons (PAH), N-nitroso compounds (NOc). Those carcinogenic dietary factors may initiate the carcinogenesis process for colon cancer [8, 26].

Research studies have emphasised that consumption of about 100 g/day of red meat or 50 g/day of processed meat increases the risk of colon cancer by approximately 15–20%. Likewise, the French National Cancer Institute recommends: Limit intake of red meat to less than 500 g per week and limit intake of cured meats [8, 29]. When blended with cereal proteins, pulses offer an alternative source for nutritional and functional proteins, and also fibre rich food. Thus, pulses and cereals in combination can be used alternatively for red meat that improve the health of the digestive system [30, 31].

B. Fish consumption

As it is high in vitamin D and omega-3 fatty acids, fish consumption has a positive impact on reducing the risk of development of colon cancer. Incidence of colon tumours was reduced considerably in animals fed with diets high in omega-3 and omega-6 fatty acids as observed in recent studies. Those findings can be emphasized as below. Findings among Mediterranean and Eskimo populations whose main source of fat is olive oil (monounsaturated fatty acid) and fish oil (containing omega-3) are supporting these findings that are the low incidence rates of colon cancer [32]. Due to the nutritional value and relationship with the onset of certain types of cancers, essential fatty acids of the omega-3 family (alpha-linolenic acid, eicosapentaenoic acid [EPA], and docosahexaenoic acid [DHA]) and omega-6 family (linoleic acid and arachidonic acid) were subjected to many studies [33, 34].

According to the studies, omega-3 fatty acids anti-inflammatory affect colonic tissue. Likewise, it increases gut bacterial diversity and makes a healthy environment inside the

colon [35, 36, 37]. According to animal studies, the reduction of colon polyps on the colon lining and, hence, suppression of colon cancer could be done with the help of fatty acids. Likewise, current scientific evidence shows that fish consumption may reduce colon cancer risk [8, 23].

C. Fibre consumption

Several protective mechanisms of dietary fibre are found against carcinogenesis in the colon. According to that, increased faecal bulk and decreased faecal transit time are more simplistic hypotheses. By increasing faecal bulk and diluting concentrations of carcinogens in the faecal matter, Thus, due to dilution and a shorter period of mucosal contact, decreased faecal transit time in the colon allow less chance for faecal mutagens to interact with the colon epithelium and altering rates of cell proliferation [8], [38] .

High faecal bile- acid concentration is a risk factor for colon carcinogenesis. Bile acids are thought to promote cell proliferation, thus allowing an increased opportunity for mutations and the increased replication of abnormal cells. Fibre is for binding or diluting bile acids of faecal materials. Likewise, another mechanism has been emphasised as through the binding of carcinogens and removing them from the body, fibre protects the colon against carcinogenesis. [38, 39].

Thus, the protective effect of fibre is mainly associated with reducing the risk of developing colon cancer [40, 41]. Fibre requirement that is needed for the body is provided by the consumption of fruit, vegetable, and whole grain cereals. [7, 42]. A meta-analysis regarding whole grain consumption consistently shows that the intake of whole grains (30 g/day) was associated with a ~7% lower risk of total cancer mortality including colon cancer [19].

IV. DISCUSSION

Colon cancer is considered as the world's third most deadly cancer [23, 43, 44]. Furthermore, countries with a higher development index, such as China, Japan, and Korea, have reported increased incidence of colon cancer. Due to changes in lifestyle, South Asians who migrated to Western countries also reported a high incidence of colon cancer [45]. Meanwhile, Sri Lanka has increased the risk significantly in recent years. It is indicated that colorectal cancer is ranked as the third most common cancer in the country [2].

The relationship between red meat consumption and increased risk of colon cancer has been emphasized by considerable research [8, 46]. The impact on colon cancer risk depends on both the amount of ingested meat and the frequency of meat consumption. Fish is high in vitamin D and omega-3 fatty acids, which has a positive impact that reduces the risk of developing colon cancer [36, 43, 47]. Likewise, fibre that is enriched in fruits, vegetables, whole grains and cereals reduces the risk of colon cancer [8, 24, 43].

Though colon cancer is a leading cause of morbidity and mortality worldwide, it is preventable. Some risk factors are modifiable such as nutritional factors and lifestyle related risk factors. Thus, in the form of healthy dietary patterns, minimally processed foods, diets rich in fruits and vegetables, and low intake of red/processed meats can be practiced. The WCRF/AICR suggests that 50% of colon cancer could be

prevented by the adoption of lifestyle recommendations to minimise the risk; decreasing red meat intake, maintaining healthy body weight, etc. [24, 26, 41, 48]

V. CONCLUSION

In conclusion, this updated review provides additional important evidence of the interrelation between colon cancer and nutritional compounds. Diet can be considered an important risk factor for colon cancer development, as it is a modifiable factor. Thus, a healthy dietary pattern reduces the risk of colon cancer.

This review suggests the promotion of healthy dietary patterns among the general public, especially those who are prone to getting cancer. A better understanding of nutrition and the risk of cancer development has a major public health impact. It is important to conduct further studies that consider factors on healthy diet and cancer risk. Meanwhile, healthcare policy planners need to be alert to these trends of increasing the burden of colon cancer effectively.

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Seamless Software Integration with an Application Programming Interface Enabled Software as a Service Recommendation Engine

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Abstract—In this data-driven era, systems powered by AI/ML (artificial intelligence and machine learning) algorithms play a significant role in different domains. When considering the entertainment, e-commerce, finance, healthcare, and education sectors, recommendation engines become essential tools for enhancing user experience and satisfaction by suggesting more user-personalized outputs using their end user's inputs or behaviour in real time. Businesses can generate more revenue from enhanced engagement with end users by suggesting that users may like outputs on a personal level. However, developing, integrating, and maintaining a system like that from the initial steps also takes a lot of resources and time. As a solution to that, this research explores the development of a SaaS (Software as a Service) dynamic context-aware recommendation engine powered by a state-of-the-art algorithm that can be developed and provided to third parties as an efficient, flexible and scalable RESTful API (Representational State Transfer Applicational Programmable Interface) that can easily integrate with their systems despite their system developed technology with cross-platform compatibility. Moreover, can develop systems like that across different domains, enabling interested third parties to cost-effectively integrate with their systems without developing a recommendation engine from the beginning and without worrying about operational and development costs and with the ease of integration ability using minimal technical knowledge.

Keywords—API development, machine learning, recommendation engine, software as a service, user experience

I. BACKGROUND STUDY

In this constantly evolving data-driven era, recommendation engines are utilized across various fields to enhance the user experience by providing user-personalized outputs based on their inputs or behaviors, which will help users save time and discover new interests [1]. The history of recommendation systems goes back to the early 1900s, and in 1992, the first automated recommendation system for Usenet articles was developed by the GroupLens project [4]. After considering the evaluation, it developed large pre-trained models with self-supervised learning and novel pre-trained methods [1]. There are two main types of recommendation engines: content-based filtering and collaborative filtering algorithm approaches. Other than that, there are hybrid algorithm approaches, which combine content-based and collaborative filtering algorithm approaches and deep learning approaches. Nowadays, recommendation engines have

become one of the essential systems to enhance user experience in many prominent platforms like Amazon, Netflix and LinkedIn by user-interested outputs based on their behaviour and inputs [1].

II. PROBLEM STATEMENT

Recommendation systems help users efficiently enhance their user experience by providing personalized suggestions based on their behaviour or user inputs. From the business aspect, this will increase revenue by increasing user engagement by suggesting products or services that users may like. However, developing such a system from scratch and maintaining is a tedious and challenging task due to various factors like time and resource constraints. When considering those facts, to develop such a system from scratch and need resources like large amounts of rich datasets to feed into the recommendation engines and train them, which takes a significant amount of time, budget for operational and infrastructure for deployment and maintenance as well [6]. Depending on the use case, one needs to select the appropriate algorithm approach, and each algorithm has its pros and cons. Some algorithms have cold-start issues, which is a significant disadvantage in collaborative filtering approach algorithms [3] and recommendation engines, that type of algorithm-based models will take some time to adjust with the user behaviour and suggest user likeable products or services based on users' past behaviour or inputs and content-based filtering algorithm approach-based recommendations engines only can suggest based on user inputs as well. Moreover, existing recommendation systems that serve as software services need more scalability and flexibility. This may lead to less customizability according to user requirements and integration problems due to incompatible developed technologies, lack of documentation, and high cost. Moreover, small and medium-scale businesses may find it challenging to develop and sustain systems like that due to cost, which will cause them difficulty competing with large enterprises.

III. PROPOSED SOLUTION

To solve the above-mentioned challenges, can develop a scalable, flexible, and easy-to-integrate Software as a Service recommendation engine powered by a hybrid algorithm approach that can serve as a RESTful API (Representational State Transfer Applicational Programmable Interface) for third parties. This solution helps to connect with a convenient

context-aware recommendation engine. It can give user-personalized suggestions efficiently and securely without bearing many burdens like infrastructure management and operational and development costs. Additionally, it solves the technology incompatibility issue by offering technology-independent systems for third parties regardless of whether the application is web, mobile or desktop. It also offers a cost-effective approach using the pay-as-you-go concept in cloud computing services. Moreover, giving the recommendation engine as a RESTful API makes it easy to integrate with any application and with less technical knowledge.

IV. PROJECT OBJECTIVE

Using this proposed concept for the project objectives by fulfilling those objectives aim to deliver a system with the following features. An efficient and intelligent recommendation engine powered by a hybrid algorithm approach to suggest user-personalized outputs based on user input details and behaviour. A well-documented RESTful API gives away an easily integrative, flexible and scalable recommendation engine as software as a Service for third parties, which is a system that can be compatible with any application, whether web, mobile or desktop, regardless of the application-developed technology with less technical knowledge can develop secure API that adheres to privacy policies and security protocols in API development like authentication and authorization and API endpoint data validations.

V. LITERATURE REVIEW

This section reviews existing SaaS recommendation engines, their drawbacks, and how this proposed concept can solve those issues. When considering existing recommendation engines there are a lot of in-house recommendation engines which are developed using sophisticated tailored algorithms to achieve their goals. Prominent companies like Netflix and Amazon use recommendation engines like that. However, the major problem is that building a system like that is a complex task and requires so many data resources, and pre-processing those data and model training needs expertise, knowledge, resources and time. The next issue is the scalability issue, which is when handling a large number of user requests needs proper infrastructures that can handle concurrent users with load balancing capability and whether developing a system like that will consume high cost to maintain it as well and small and medium scale companies may find it challenging to develop and maintain their systems due to those factors mentioned above [9]. Another type of existing system is the open-source recommendation engines that offer a framework for building recommendation engines using various open-source customizable algorithms. Apache Mahout and Surprise are examples of that. However, the major drawbacks in these types of existing systems are that even though they are cost-effective, they need the technical expertise to integrate and maintain due to a lack of documentation and the complexity of the application [10]. The last type of recommendation engine in the current context is commercial recommendation systems, and the main drawback is the need for more flexibility in those systems. Small and medium-scale businesses may find it expensive, and in the future, they might face migration issues as well. Some existing solutions can

integrate only with the CMS (content management system), and Recombee, Rumo, and Fulcrum are examples of existing systems like that in the current context [5].

VI. DATA AND VARIABLES

To identify issues in SaaS recommendation engines and validate the need for solutions for those problems, conducted a survey of external parties who engage with recommendation engines in their business context and interested parties looking forward to integrating a system like that, and got 43 responses using that survey. These survey results represent the necessity for a system like that in the current context. Below are the two main questions and responses for the survey that indicate the essence of a system like that. According to the results, figure 1 represents the type of recommendation engine they are currently using or planning to use. The majority of them use commercial products, and the least use their in-house recommendation engine. Moreover, Figure 2 represents their primary challenges when interacting with those systems. Most of them faced integration difficulties with their existing system, scalability and flexibility issues, and high development and maintenance costs. Considering those facts, a recommendation engine that can give a RESTful API on the pay-as-you-go concept is the most suitable approach in the current context.

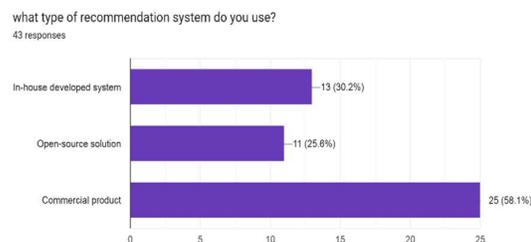


Fig. 1- Research Survey Question (Source: Author's conducted survey)

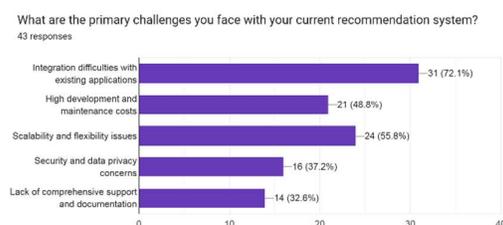


Fig 2- Research Survey Question (Source: Author's conducted survey)

VII. METHODOLOGY

This section showcases the implementation steps for this proposed concept. The initial step to developing software as a service recommendation engine is to gather requirements and analyze and define them through proper methods. In this stage, conducting interviews and surveys with stakeholders helps to broaden perspectives and requirements, and the survey mentioned above helps to prove there is a pressing need for a system like that, and it helps to identify common features and areas for improvements in the existing systems. After that, from the development perspective, a feasibility study is to ensure technical feasibility to assess the tools and technologies requirements needed for development,

operational feasibility to ease deployment and maintenance, and financial feasibility to develop and maintain a system like that. As for the defining stage solidifying the project scope, tools, and technologies using identified project requirements in the first phase according to project requirements. In the design phase, according to the identified project requirements, API design helps identify API endpoints and their HTTP (Hypertext Transfer Protocol) requests and responses. As in Figure 2, system architecture diagram design helps get an idea about the overall system, how the system components interact with each other, and what processes happen inside each component. It also helps the development process in the later part.

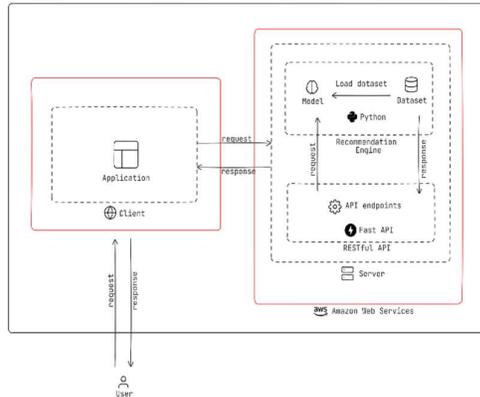


Fig 3- High-level architecture (Source: Author's compilation)

When it comes to the development phase, the recommendation engine can be developed using Python and Scikit learn library using a hybrid algorithm approach by calculating cosine similarity using TF-IDF (Term Frequency – Inverse Document Frequency) vectoriser for the content-based filtering approach and for the collaborative filter approach can use k-nearest neighbour and by combining those two algorithm approach can develop a hybrid algorithm which can recommend products or services according to user behaviour and user inputs in a real-time by mitigating their algorithm limitations. For API development, can use Fast API, which is a Python-based modern web framework for building APIs. Defining API endpoints and using HTTP requests can connect with the recommendation engine, and using HTTP responses can give away relevant suggestions as an output. Finally, testing needs to ensure the system fulfils the project requirements and works defect-free. As for the recommendation engine testing can calculate the precision which is the ratio of relevant items recommended to the total items recommended, and recall, which is the ratio of relevant items recommended to the total relevant items available by following equations. Finally, for the system deployment, a cloud service provider like AWS (Amazon Web Services) can deploy the scalable RESTful API, maintain the application, and use that to make the system more reliable for end users.

$$precision = \frac{Total\ number\ of\ items\ recommended}{Number\ of\ relevant\ items\ recommended}$$

$$recall = \frac{Number\ of\ relevant\ items\ recommended}{Total\ number\ of\ relevant\ items}$$

VIII. CONCLUSION

This research paper focuses on the concept of developing SaaS hybrid algorithm approach-based context-aware recommendation engines which can give as efficient, scalable and easy-to-integrate Recommendation Engines as a RESTful API for third-party users without depending on the development cost or technology and platform type, whether Web, Mobile or Desktop and without the burden of infrastructure management in a cost-effective way. Moreover, this concept will impact recommendation engine development to the next level by combining software development and machine learning domains. Throughout the conducted research, one of the main limitations encountered was the survey because it was focused on businesses that were currently using recommendation systems or planning to use them, resulting in only limited responses. As for future implementations, can go for approaches like the deep learning algorithm approach such as neural collaborative filtering with rich, extensive datasets for better results.

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The Influence of Colour Psychology in Creating a Healing Environment in Palliative Care Units

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Abstract— This study explores how color psychology can be used in palliative care facilities to create a more calming and supportive environment for patients. It is important to understand how colors can affect emotions and well-being, as patients in these units need compassionate care as they approach the end of their lives. The study reviews existing research on color psychology, emotional responses, and therapeutic environments. It aims to understand the psychological effects of different colors, identify colors that promote healing and emotional support, and evaluate the effectiveness of using color interventions in palliative care settings. The study uses a mixed-method approach, including case studies to assess emotional responses and color preferences, as well as focus groups and questionnaire surveys with patients, family members, and healthcare professionals. Participants' consent and privacy are protected while upholding ethical principles. Data analysis includes both statistical and thematic analysis techniques to identify patterns and trends in the data. The results of the study can be used to improve the comfort and well-being of patients and their families in palliative care facilities. Patients in palliative care units had different preferences for colors that they found comforting than those that were considered soothing in their environment. Palliative care patients preferred colors that reminded them of home, indicating a desire for familiar and comforting surroundings. A familiar and emotionally resonant environment can improve the mental and physical well-being of palliative care patients, helping them to cope with their medical challenges. It is challenging to create a fixed color scheme for palliative care patients, as their preferences can change based on their mental state. For example, choosing black might indicate hidden emotional distress. Integrating color psychology principles into the design and decoration of palliative care facilities can improve the quality of life for patients and their families.

Keywords— *palliative care unit, healing environment, color psychology*

I. INTRODUCTION

This The Palliative Care Centre is a facility created to offer comfort and healing to terminally ill patients and their families. It can be demonstrated how useful this is for healthcare. Palliative care aims at early detection and prevention of their suffering in order to improve the quality of life for patients and diseases that endanger the lives of their families. Because the patient's mind is paralyzed, serious illnesses are stressful. Here, it helps to foster positive thinking and enhance the patient's and their family's quality of life. Doctors, nurses, and a professional team with specialized training work in the ICU wards. It can be made available for people of any age and at any stage of serious illness. as in other nations, increased life expectancy, a growing elderly population, rising rates of cancer and other incurable diseases

are all contributing to a greater need for palliative care centers in Sri Lanka. Teaching Hospital Karapitiya Sri Lanka is providing this service in light of the increase, the need for it, and as part of its efforts to provide palliative care. This facility is the only comprehensive palliative care center in Sri Lanka. The goal of this study is to comprehend how colour psychology might help palliative care facilities foster a healing environment [1]. Health is influenced by environmental, psychological, social, and emotional factors, impacting both visitors and patients. Palliative care facilities face significant insecurity, dread, and uncertainty. Hospitalization is a defining experience, and patients and doctors view healthcare institutions differently. Color in healthcare facilities should consider physical and psychological factors [2]. considering patient health. Careful color schemes, including daylight hues and strong reflected lighting, are essential. Patients' perspectives on fear and stress change upon entering a hospital, and palliative care centers should consider users' emotional states when designing décor [3].

II. RESEARCH PROBLEM AND METHODOLOGY

A. Research Question

What kind of influence does color psychology have on the health and well-being of palliative care unit users by being in a healing environment?

Aims and objectives

1. To analyse the potential effects of different colors on the emotional state, comfort, and overall well-being of patients and their families in palliative care units.
2. To analyse the potential effects of different colors on the emotional state, comfort, and overall well-being of patients and their families in palliative care units.
3. To evaluate the perceptions and experiences of patients, families, and healthcare providers regarding the influence of color psychology in creating healing environments in palliative care units.
4. To provide recommendations and practical strategies for implementing color psychology principles effectively in palliative care unit design to enhance the well-being and comfort of patients and their families.

This research aims to explore the impact of color psychological combination on the wellbeing of palliative care patients and to establish a comfortable environment. The study will employ a mixed-methods approach, involving literature review, qualitative interviews with healthcare personnel, patients, and relatives, and quantitative data collection through surveys to explore the psychological

impacts of colors in palliative care and their relationship with healing outcomes. The research methodology involves qualitative information, case studies, and surveys with palliative care units' patients, doctors, and visitors to understand the influence of color psychology on creating a healing environment. Data was collected during site visits, data collection, and photography. Literature Survey, Case Studies, Questionnaire.

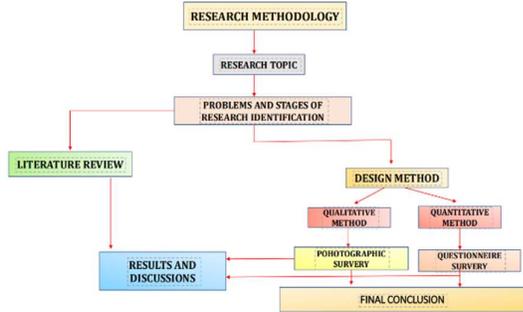


Fig. 1. Research methodology design by author

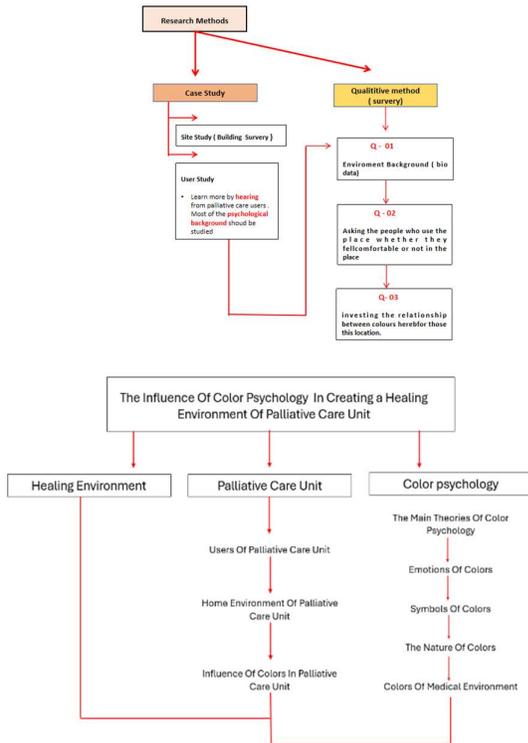


Fig. 2. Sample from each palliative unit's design by author

A. Research design

This study employs a mixed-method research approach to examine color psychology's role in creating a healing atmosphere in palliative care units, aiming to provide evidence for its integration in end-of-life care design.

B. Case Study & Photographic Survey

The case study focuses on patient and staff comfort, color relationships, and palliative care unit comfort. 13 patients from Mahar agama Cancer Hospital and 10 from Teaching Hospital Karapitiya were treated, with 26 staff members and 20 patients from both hospitals.

- Teaching Hospital, Karapitiya
- Apeksha Hospital, Maharagama

III. LITERATURE REVIEW

A. Healing Environment

Research suggests that healing, a psychologically beneficial outcome, can be applied to landscape and architectural design, particularly in the healing garden, and suggests future studies on its benefits [4]. Nature can be integrated into environmental design through immersion or visual access. Windows provide outdoor scenery and indoor gardens, while features like bird feeders and accessible patios enhance patient experience. This approach enhances patient satisfaction and satisfaction in institutional settings[5]. Participants rated a healing environment based on physical characteristics, emotions, familiarity, connection to nature, spiritual importance, and attentive staff, describing a peaceful, comforting atmosphere [6]. The concept of a homely setting, resembling family members and familiar spaces, was emphasized as a therapeutic environment with natural views. Participants described porch swings, backyard porches, and windows with forest views as healing spaces [7]. Participants linked healing places with spiritual connections, enjoying talking to the Lord, serving God, and receiving spiritual care. places for well-being enhancement [8]. Hospital settings are being transformed into therapeutic environments, focusing on emotions, sensations, and physical features, but some find the current settings impersonal and lacking connection [9]. Hospital staff's professionalism, family visits, and home-like atmosphere improved patient recovery. Relaxation, sleep, and comforting thoughts were key, with TV channels promoting these aspects [10].

B. Hospitalized patients Experience of the Healing Space

The study surveyed hospitalized patients about their healing experiences, focusing on the pathogenesis perspective. Participants transitioned from sickness to wellness, with some believing hospital staff needed to solve issues. However, few articulated healings beyond sickness settings from a spiritual or autogenic perspective, as per the SI [11].



Fig. 3. Healing Courtyard - Dominican Hospital Foundation



Fig. 4. Healing Courtyard - Dominican Hospital foundation



Fig. 5. Healing Through of Architecture in Health Care

C. Healing through architecture in health care by author

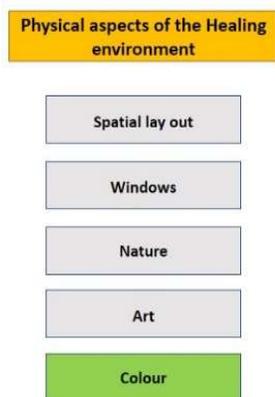


Fig. 6. Healing Through Architecture in Healthcare by Author

The "ambiance" of a place affects the individuals who use it. In order to lower stress and anxiety, boost patient happiness, and encourage health and recovery, healthcare environment design has started incorporating aesthetic improvements in recent years [12]. Proponents most frequently claim that the natural environment is naturally therapeutic or health-promoting. From just harmless to safe (physically and psychologically), to "providing a positive context" to actively, we propose a hierarchy of impacts of environmental factors [13]. For the purpose of developing design guidelines for the physical components of an ideal healing environment, the majority of pertinent research has focused on a small number of settings and is insufficient. There are chances to contribute significantly in this field, which is expected to have a big effect on people's health outcomes [14]. Healing environments create a sense of home for participants, allowing them to feel connected in unexpected settings. Patients often associate a healing environment with their own house, while others see it as impersonal and functional [15]. Patients perceive healing

environments as promoting cognitive, physical, and spiritual well-being through visual associations, soothing distractions, and social relationships, suggesting a need for focus on social cohesion and healing relationships [16].

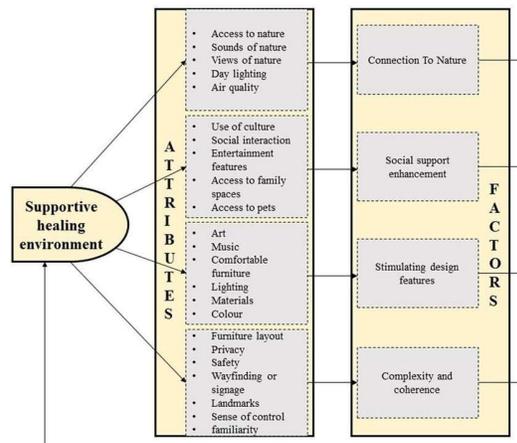


Fig. 7. Conceptual model of a supportive healing environment with the four attributes from Ulrich's and Dilani's theories.

A holistic approach to healing environments considers both physical and social factors, focusing on the interconnectedness of physical, psychological, spiritual, and behavioral components. An ideal environment supports healing and wholeness, with environmental factors impacting cognitive and emotional components, such as plant-based environments reducing anxiety [17]. The text explains various physical elements such as spatial layout, lighting, scent, nature, art, color, acoustic comfort, aesthetics, and ambient conditions.

D. Spatial Layout

Single-patient rooms offer patients safety, cleanliness, and reduced medical errors due to fewer individuals, fewer patients, family members, and staff. They also provide greater patient satisfaction by ensuring voice and visual privacy and confidentiality [18].

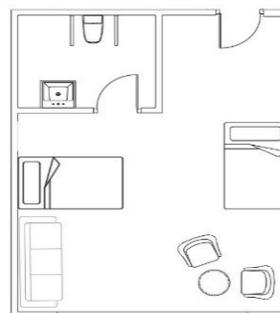


Fig. 8. Patients room Lay out design by author

E. Windows

Windows serve as ornaments for patients, allowing them to escape crowded or uncomfortable areas. Large windows with low parapets help patients look out onto sunny natural areas, reducing suffering and distracting their attention, thus reducing depression [19].

F. Nature

Nature significantly contributes to a healing environment, and its use in hospitals can improve patient satisfaction. Utilizing natural colors, materials, and views through windows, projections, and technology can enhance the impact of nature on patient well-being [20].

TABLE I. OPTIMAL HEALING ENVIROMENTS

Internal	Interpersonal	Behavioral	External
Healing	Healing	Healthy	Healing
Intention	relationships	Lifestyle	Spaces
Personal	Healing	Integrative	Ecological
Wholeness	Organizations	Care	Resilience

Palliative care aims to lessen pain, prolong life, enhance quality of life, and support patients with terminal illnesses and their families. Doctors, nurses, social workers, spiritual counselors, and other necessary specialists provide integrated palliative care. After sick patients leave [21], palliative care will continue. Specifically, by emphasizing the provision of assistance to the families left behind Seven categories of palliative care activities are listed in the Palliative Care Policy: nurse care, pain management, treatment of other medical complaints, social support, psychological support, cultural and spiritual support, and assistance before and during times of loss [22]. Patient care and treatment units in palliative care institutions should cater to their individual, social, physical, and psychological needs. They require a balanced diet, comfortable bed, cleaning, care, love, and attention, as they may experience sadness and separation from families [23].

Palliative care is a form of responsive care that addresses the psychological, social, and spiritual issues of patients and their families, aiming to provide the best quality of life from diagnosis to end, focusing on pain relief, symptom reduction, and overall well-being.



Fig. 9. Palliative care concepts

G. Color psychology

Color plays a crucial role in human senses, biochemistry, and psychology, impacting community environment design. Understanding color psychology is essential for community health settings. However, there is limited scientific advice for color design in community environments, and a comprehensive color system is still in its infancy [24]. Color expresses diverse human emotions and observable phenomena, influencing psyche, physiology, and imagination through eye contact and influenced by psychological and physical situations [25].



Fig. 10. The effects you're paint colure has on you're mental and physical wellbeing

1. The main theories of color phycology

Colour theory explains that hues' meanings vary based on environment, society, age, and other factors, with approximately 7 million visible colours starting with fundamental building elements [26]. Red, Blue, and Yellow are the foundation colors for tones, while black is created by mixing these colors in an exact ratio. Secondary colors, such as violet, lime, lavender, purple, amber, and turquoise, are hues created by combining two main colors [27].

2. Emotions of colors

Color psychology research has provided a scientific basis for evaluating and producing colors in community health environments. Colors can convey visual information and emotions, allowing individuals to express various emotions and make impactful visual statements. This research has aroused imagination and memory, intensifying emotional resonance [28].

COLOUR PSYCHOLOGY	
WHITE	+ LIGHT, GOODNESS, PURITY, SAFETY , COOLNESS, CLEANLINESS , WHOLENESS - ASSOCIATED WITH HOSPITALS, MEDICINE, DOCTORS
RED	+ LOVE , PASSION , ENERGY , ACTION , AMBITION , DETERMINATION - WAR , DANGER , SEXUALITY , IRRITABLE , ANGER
PURPLE	+ ROYALTY, POWER , NOBILITY , LUXURY , AMBITION , WISDOM - IMMATURE , IMPRACTICAL , SAD FEELING , FRUSTRATION
BLUE	+ TRUST, LOYALTY, KNOWLEDGE , POWER, PEACEFUL, QUITE - WITHDRAWN , CONSERVATISM, DEPRESSIVE , FRIGIDITY
GREEN	+ CALM, BALANCE, GROWTH, HARMONEY, FRESHNESS, PEACE, FERTILITY - AMBITION, GREED, JEALOUSLY, SICKNESS, FEELING TRAPPED
GRAY	+ COMPROMISE, NEUTRAL, INDEPENDENT - RIGID, DETACHED, INDECISIVE, UNEMOTIONAL
YELLOW	+ OPTIMISTIC, HAPPY , BRIGHT, CHEERFUL , ALERT - IMPATIENCE, FEARFUL, CRITICISM

Fig. 11. Emotional effect of colors by author

3. Symbols of colors

The sign of color represents the conceptual spectrum of color, referring to the association between a color and associated objects. People from different backgrounds attribute symbolic meanings to colors, suggesting color symbolism is not just a historical and cultural form, but a symbolic form in society [29].

Colour	Emotional Effects of colour	
	Calmness, tranquility, trust	Linked to feelings of relaxation and stability.
	Growth, harmony, nature	Symbolizes renewal and balance found in the natural world.
	Creativity, luxury, spirituality	Represents a mix of calming blue and vibrant red.
	Earthiness, reliability, comfort	Evokes a sense of stability and connection to the earth.

Fig. 12. Symbolic meaning of colors by author.

4. Relationships between color and the mind

Pantone's article "How Does Color Affect Us?" highlights that color is light and energy, and exposure to certain colors can trigger physiological changes, stimulate, excite, depress, tranquilize, increase appetite, and create warmth or coolness [30]. John Gage's book *Color, and Meaning: Art, Science, and Symbolism* provides valuable insights into color associations and their connotations, despite the limited number of studies on color therapy and interaction [31].

H. Colors of medical environment

Research on colour use in hospital settings is contradictory, but consensus exists that hospitals should be welcoming, therapeutic, and support healing. Designers must consider functional and perceptual requirements for various user groups[32]. Research on color's physiological and psychological impacts in healthcare settings is often limited due to limited sample sizes and repeated studies, with some studies promoting green as a beneficial color for eyes [33].

I. Influence of colors in palliative care unit

Color, a significant natural element, can influence human behavior, either positively or negatively, depending on the amount of light and darkness. The color scheme in the waiting room enhances stress reduction and creates a visually relaxing atmosphere. Furniture, color, and lighting contribute to creating a friendly atmosphere, utilizing color in architecture in various ways. Color in public spaces should consider emotional and psychological factors, aiming to create a warm [34].

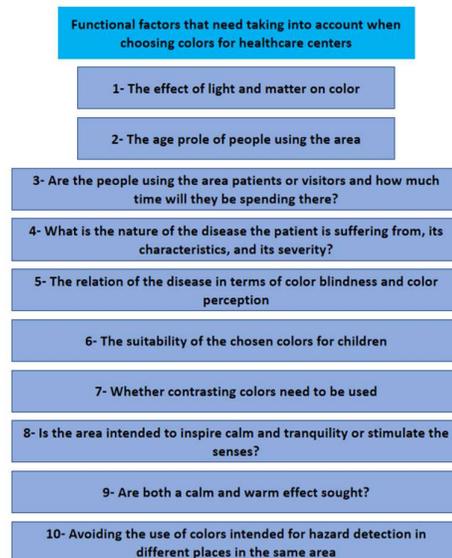


Fig. 13. Choosing colors for health care centers by author design

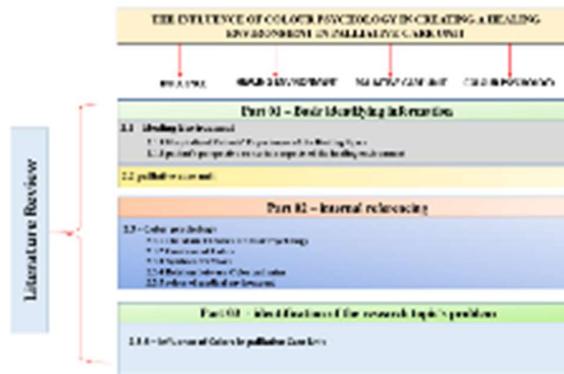


Fig. 14. Conclusion of the literature review

NAME	TEACHINH HOSPITAL KARAPITTYA	APEKSHA HOSPITAL MAHARAGAMA
PICTURE		
LOCATION	Karapitya , Galle - Sri lanaka	Maharagama - Sri lanaka
DESCRIPTION	A follow-up to a March 2020 item on the construction of the karapitya Palliative Care Centre has been sent to us. On June 13, 2020, Karapitya Teaching Hospital's first palliative care center in Sri Lanka was inaugurated by consultant oncologist Dr. Krishantha Perera	The leading facility for cancer treatment in Sri Lanka is the National Cancer Institute (Apeksha Hospital).

Fig. 15. Case study basic information's by author

IV. DATA ANALYSIS AND DISCUSSIONS

A. Case study I: Apeksha Hospital Maharagama Palliative care unit



Fig. 16. Apeksha Hospital Maharagama - palliative care unit by author



Fig. 17. Apeksha Hospital Maharagama - palliative care unit by author

A	Using for larger window Using for larger windows in palliative care units allows for more natural light to enter the space , creating a brighter and uplifting environment for patient . The increased access to natural light can positively impact patients moods . Reduce feelings of isolation , and promote a sense of connection with the outside world . Additionally , larger windows offer better views of the surroundings , which can be comforting and therapeutic for patients facing end of life care .
B	Natural sunlight and natural ventilation .
C	Lite color curtains – using white color curtains in palliative units creates a serene and peaceful environment , promoting a sense of tranquility and comfort for patients their families during their difficult journey . The purity and simplicity of white can also enhance the overall brightness of the space , contributing to a welcoming and soothing atmosphere .

Fig. 18. Apeksha Hospital Maharagama - palliative care unit by author

A	Using the white color in walls – In palliative care facilities, using white for the walls promotes calmness and serenity, fostering a relaxing environment that can be comforting for patients receiving end-of-life care .
B	using for some indoor plants – Indoor plants in palliative care nursing units improve well-being, reduce stress, and enhance indoor air quality for patients and families.
C	White color finishing furniture - Patients benefit from the relaxing environment created by furniture with a white color finish in Apeksha Hospital Maharagama palliative care units. White represents purity, tranquility, and peace, which helps create a quiet environment that can reduce stress and anxiety in patients receiving end-of-life care. White furniture can also create a feeling of openness and space, which benefits patients and their families during difficult times.
D	natural ventilation and sun light
E	comfortable seating arrangement, Gray and white colure furniture using Using a gray and white color combination for furniture in palliative care units creates a harmonious and soothing aesthetic that promotes a serene and calming atmosphere for patients and their families. The blend of these neutral colors can provide a sense of comfort and tranquility during challenging times, helping to improve the overall well-being of those in care

Fig. 19. Case study description by author

B. Case Study II: Teaching hospital Karapitiya - Palliative care unit



Fig. 20. Teaching hospital Karapitiya - palliative care unit by Author

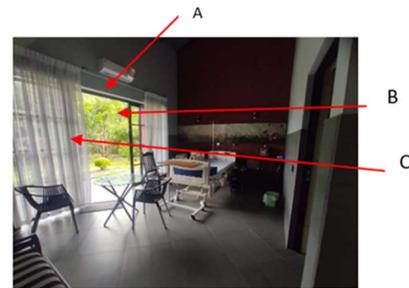


Fig. 21. Case study description by author



Fig. 22. Apeksha Hospital Maharagama - palliative care unit by author

C. Questioner Survey: Case 01 - Apeksha hospital Maharagama

A survey was conducted at Apeksha Hospital Maharagama and Teaching Hospital Karapitiya to analyze patient responses to palliative care, considering factors like gender, age, duration of use, unit name, and occupation. The palliative care unit at Apeksha Hospital Maharagama has been mostly used for at least 2-6 years. These estimates will vary from year to year depending on the available data.

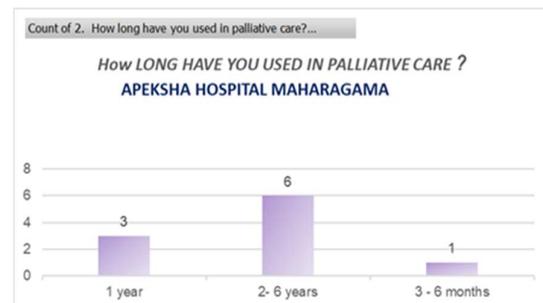


Fig. 23. Teaching hospital Karapitiya - palliative care unit by author

The demographic table shows that most patients at Apeksha hospital Maharagama are married, with no distinction between married and unmarried individuals admitted to palliative care programs. The study explores the impact of environment on patients' perceptions of the palliative care unit at Maharagama Hospital, finding that 8 patients preferred both noise and ambient light.

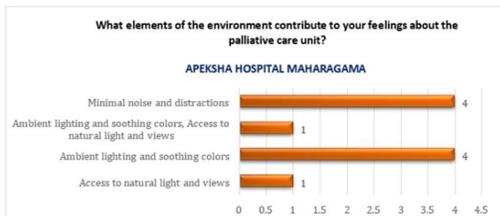


Fig. 24. Teaching hospital Karapitiya - palliative care unit By Author

What elements of the environment contribute to your feelings about the palliative care unit	Count
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1
Access to natural light and views	1

Fig. 25. What elements of the environment contribute to your feelings about the palliative care unit by author

D. Relationship Between Colors in the Palliative Care Unit using for patients

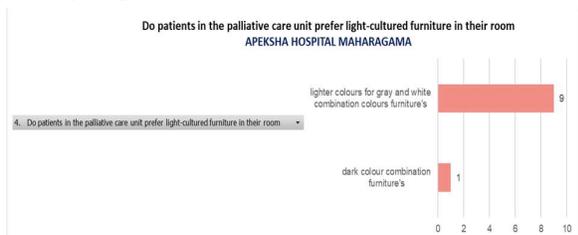


Fig. 26. Case study description by author

Patients in Apeksha Hospital Maharagama palliative care unit prefer slightly lighter colours, such as white and Gray, with a preference of 9.

E. Case 02: Teaching Hospital Karapitiya

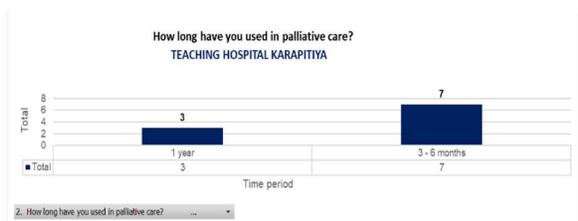


Fig. 27. How long have you used in palliative care unit by author

The palliative care unit at Teaching hospital Karapitiya has been mostly used for at least 3- 6 months. These estimates will vary from year to year depending on the available data.

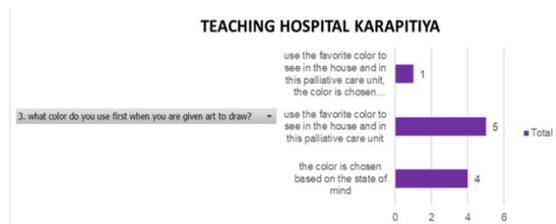


Fig. 28. How long have you used in palliative care unit by author

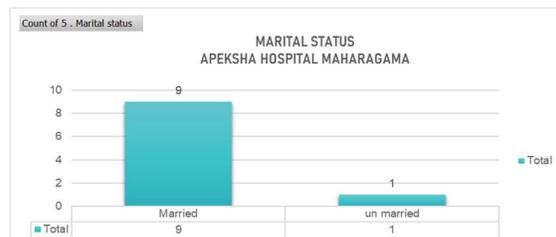


Fig. 29. What color do you use first when you are given art to draw by author

Patients at Teaching Hospital Karapitiya are asked to draw a picture using their home colours and mental levels, with 05 patients choosing their preferred colours and 04 patients choosing colours based on their mental level. Similarly, a questionnaire survey has been prepared for the medical staff.

COMPARISON CHART	
Case study 01	Case study 02
<p>Apeksha hospital maharagama</p> <ul style="list-style-type: none"> Completely this questionnaire survey will evaluate the user presentation When examining the use of colors in this palliative care unit, it will be clear from the study that the palliative care unit of the hospital has been created with a combination of gray and white. When investigating the comforts of this palliative care unit, it became clear that further facilities should be developed. Although the number of patients is high, it will be clear that the number of facilities available here is low. 	<p>Teaching hospital karapitiya</p> <ul style="list-style-type: none"> Completely this questionnaire survey will evaluate the user presentation When examining the use of colors in this palliative care unit, it will be clear from the study that the palliative care unit of Karapitiya Teaching Hospital has been created with a combination of dark colors. When investigating the comforts of this palliative care unit, it became clear that it is at a very high level. It is clear that the unit has been designed so that the staff can attend to all of the patient's needs.

Fig. 30. Compression chart for case studies by author

V.CONCLUSION

The survey of palliative care patients revealed that they prefer colours that bring peace and comfort, improving their physical and mental conditions. However, a specific color scheme is not possible for patients of colour, as their mental levels change over time. For example, a patient with cancer may choose the first colour due to emotional distress, making it impossible to formulate a specific colour scheme for these patients.

A. Findings

- Patients in palliative care unit s favored different comforting colors than those deemed soothing in their environment.

- Palliative care patients preferred colors reminiscent of home, indicating a desire for familiar and comforting surroundings.
- A similar, emotionally resonant environment enhances mental and physical well – being for palliative care patients , addressing medical challenges .
- Creating fixed color scheme for palliative care patients is challenging due to their shifting preference based on mental Staes.
- Choosing black might signify hidden emotional distress, emphasizing difficulty in creating standardized color schemes for palliative care.

B. Recommendations

- Patient rooms in palliative care units need privacy, cheerful interiors, minimal furniture, and bedside placement near large windows for comfort and tranquility.
- Palliative care should employ light colors to uplift the mind, caution must be taken with darker hues impacts on emotions.

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Psychological Stress Detection Through Speech Using Machine Learning

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Abstract—This Research focuses on identifying individuals' psychological or mental stress based on their speech signals using machine learning. The speech signals are restricted to the Sinhala Language hence, to utilize in the training and testing of machine learning models, a new dataset has been created with 144 speech files. Two machine learning models were developed with the intention of stress identification and classification using Support Vector Machine (SVM) and Artificial Neural Networks (ANN). Speech signals were converted into frequency domain with Fast Fourier Transform (FFT) and the Mel Frequency Cepstral Coefficients (MFCC) were generated as feature vectors for the machine learning models. The experiments were conducted with both machine learning models where SVM provided 59% accuracy and ANN provided 63% accuracy in identifying psychological stress from speech signals.

Keywords—artificial neural networks, fast fourier transform, psychological stress detection, speech signal analysis, support vector machine

I. INTRODUCTION

Speech is the verbal way of exchanging ideas among humans which is claimed to be derived about 50000 years ago in the Upper Paleolithic age. This form of communication is absent in other closely related species including Neanderthals and earlier humans. Vocal folds of the larynx are mainly responsible for generating voice signals. Nonetheless, the motor cortex, basal ganglia, arcuate fasciculus, Wernicke's area, Broca's area, and auditory cortex are all linked to a complex neurological process. [1]. Therefore, the emotional state of the brain has a direct correlation with speech and it could be reflected in the speech signals [2][3].

Mental stress is a physiological response to perceived challenges in the external or internal environment. In those situations, hormones such as cortisol and adrenaline are released, and hence, sugar levels in the blood are increased. Also, blood flows to the lungs and muscles are raised and heart rate is boosted. This process is usually considered as a positive reaction that prepares the person physically and mentally to confront a threat. These responses died out as the challenging circumstances disappeared. However, there are cases that they do not switch off which could lead to more serious and long-term negative effects [4][5].

People in modern society with complicated lifestyles are frequently confronted with competitive situations that could trigger stress, and hence suffer from prolonged stress-related problems. When a person is mentally stressed, physical and emotional changes could affect the voice of the person and it

could be detected in the speech [6][7]. For effective communication with people especially when it is taken place via voice media such as telephone or online voice chat, it is essential to detect the emotional status of the other parties. If an appropriate mechanism can be generated for detecting persons' condition of stress using speech signals, there are many applications in various domains. Also, several studies have been conducted in this area to address the same problem, and reasonable outcomes have been achieved.

This study specifically focuses on the detecting psychological stress in speech signals of the Sinhala Language, using machine learning. However, a dataset of speech related to stress is not available for Sinhala Language, hence, a dataset of 144 audio files was created in the early stage of the research. This dataset includes recorded speech files of different people in stressful and non-stressful situations.

Speech signals originally in the time domain are transformed into the frequency domain using Fast Fourier Transform (FFT) and Mel Frequency Cepstral Coefficients (MFCC). These features are then utilized as the input vector for stress detection models. According to the previous experiments that have been conducted, Support Vector Machines (SVM) and Artificial Neural Networks (ANN) have been frequently utilized for detecting stress in speech signals. Hence, those two machine learning techniques were tested and compared with the created dataset and the details of the experiments and the analysis of the results are presented in the later sections.

II. LITERATURE REVIEW

Speech-based stress detection has become a substantial field of exploration in recent years. In this section, the literature on stress detection using speech is presented. Dhole and Kale have used machine learning (ML) models and artificial intelligence (AI) together with MFCC feature extraction methods to develop an algorithm for stress detection and classification [13]. In the study, SVM has achieved 97.52% of accuracy among various classification models such as SVM, Recurrent Neural Networks (RNN), Radial Basis Functions (RBF), Multilayer Perceptron (MLP), Adaptive Neuro Fuzzy Inference System (ANFIS), Feed-Forward Back Propagation Neural Networks (FFBP NN) where the features are extracted using the MFCC [13], [14]. Also, this model is capable of real-time speech detection and it is language and word-independent [13]. A speech analysis has been done to detect candidates' psychological stress while

passing through them in HR (Human Resources) screening interviews with the help of Machine learning. For this experiment, they have used few classification features such as mean energy, mean intensity, and Mel-Frequency Cepstral Coefficients (MFCCs) to detect stress in speech which have been completed on three different datasets: i) EmoDB (German), ii) KeioESD (Japanese) and iii) RAVDESS (English) [14]. Both ANN and SVM algorithms have shown satisfactory results, however, with ANNs have provided slightly better accuracies than SVMs. Hyewon and Han et al, have proposed a deep learning-based algorithm for psychological stress detection using speech signals. For the detection of the stressed condition of speech signals, audio clips have been collected by running through a specific process with three steps and established stress-detection models using deep learning algorithms with long short-term memory (LSTM) [15]. The condition of psychological stress (i.e., stress vs. unstressed) was detected as a binary classification task, and a 66.4% of accuracy has been obtained. A study conducted by Firoz Shah et al focuses on automatic recognition of stress from spoken words in the Malayalam language. It explores stress detection from speech to assess the exact stress level of human voice signals with the aid of various machine learning algorithms [21].

III. METHODOLOGY

One of the initial steps of our methodology is extracting the MFCC features from the voice signals. Each step of the MFCC feature extraction process is carefully executed. Following this, the machine learning model training is initiated using the generated datasets. Those steps are detailed below.

A. Feature Extraction

In human speech, various types of features can be identified. However, in alignment with the primary objective of the study, only the most relevant features of the voice signals are concerned. With the careful analysis of previous research on stress detection in speech signals, MFCC was selected as the most suitable set of features. At initial stage of performing feature extraction, the data pre-processing was performed and followed the steps of the MFCC feature extraction method.

B. Pre-processing with MFCC: Mel-frequency Cepstral Coefficients (MFCC) can be considered the standard method for feature extraction in speech recognition. [14]

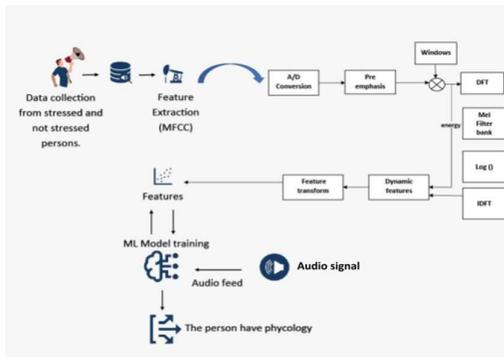


Fig. 1: The overall architecture of the proposed methodology

This method consists of several steps such as pre-emphasizing, framing, windowing, converting the signal into frequency domain using the Fast Fourier Transform (FFT), and passing through the Mel Filter Banks and Discrete Cosine Transform.

Pre-emphasis: This is the first step of the MFCC feature extraction. Here, a single word sample is passed through a high-pass filter which emphasizes higher frequencies by boosting the energy of the signal at those frequencies. This step assist to retain critical informations in the higher frequency components.

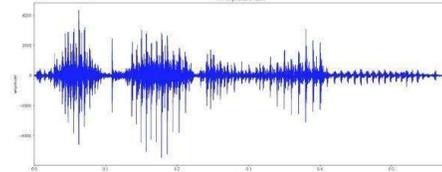


Fig. 2: Result of the Pre-emphasis step for amplifying the high-frequency components of a signal.

Framing: In framing, the pre-emphasized speech signal is divided into small consistent blocks known as frames, typically duration of 20ms, with in the range of 5ms to 50ms. In this research, a speech signal is segmented into 25ms frames with an overlap of 20ms.

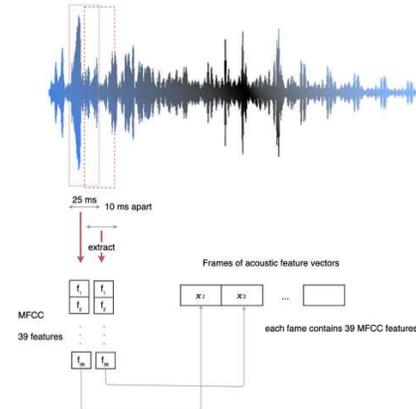


Fig. 3: The signal is segmented into Frames

Windowing: After segmenting the signal into frames, the Hamming window is applied on each frame as a windowing function. In this process, for maintaining the continuity of the first and last points in each frame, they should be multiplied with a window function. Hamming window, used in this process, acts as a smoothing function for the signal and it reduces spectral leakage ensuring a more accurate representation of the frequency components.

Fast Fourier Transform: Fast Fourier Transformation (FFT) is performed to convert each frame which consists of N samples from the time domain into the frequency domain. After applying FFT, the frequency content of the signal can be visualized and analysed.

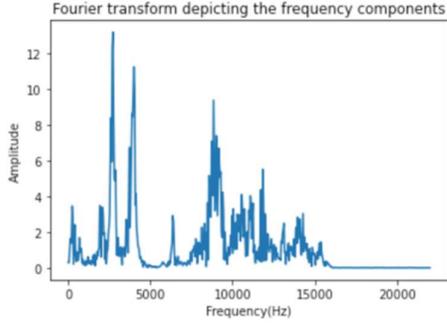


Fig. 4: The frequency spectrum of a frame generated using the Fast Fourier Transform (FFT)

Mel Filter Banks: This can be considered the final step of the feature extraction process. Mel can be defined as the unit of measuring actual frequency for human ear perception of sound. In Mel-filter banks, a set of triangular filters are utilized, typically the number of filters ranges from 20-to 40 can be seen. However, in this study, 13 band-pass filters were adopted to pass the Fourier-transformed signal. Here, the filters are placed based on Mel-scale are applied to each frame. The main objective of using a Mel-filter bank is, to extract frequency bands by converting the Mel-scale into a power spectrum.

The conversion is done by using the following equations,

$$10 \log \left(\frac{f}{700} \right) \quad (1)$$

Equation (1) shows the way of converting to Mel-scale where f is the frequency in Hertz and m is for Mel scale,

$$f = 700 \left(10^{\frac{m}{2595}} - 1 \right) \quad (2)$$

Equation (2) shows the way of converting to the Frequency Spectrum.

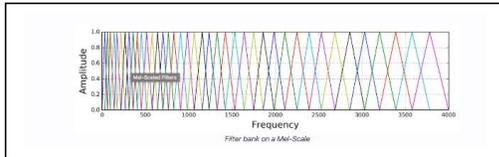


Fig. 5: Mel Filter Banks

For experimental purposes, the datasets were generated for 15ms, 25ms, and 35ms window sizes separately. Inside of a single feature vector, there were 13 parameters such as `sample_rate`, `win_length`, `win_step`, `nfft`, `low_freq`, `high_freq`, etc.

C. Dataset

In the domain of mental stress analysis in Sinhala speech, one of the main challenges was to find a standard dataset to be utilized as the benchmark. Since the lack of availability of a public dataset, it was essential to create a dataset with speech recordings in Sinhala Language. For speech recordings, 24 people were utilized and each subject was asked to speak three emotional-neural sentences.

The dataset should include speech recordings when the subjects are in stressful conditions as well as when they are in a relaxed state. To record speech in stressful conditions, two types of environments were used. voice clips from the students on the day before the GCE (Advanced Level) Examination and voice recordings from the people who are playing an intense video game were recorded. For unstressed conditions, the same group of people was utilized when they were free and in a comfortable mode. Before recording, a piece of relaxed music was played in the background.

1. ඒක අරගන්න (Eeka Araganna). (Get it)
2. මෙතනින් ඉඳ ගන්න. (Methanin Inda Ganna) (Sit here)
3. මේ වැඩේ ඉවර කරන්න. (Mee wede iwara karanna) (Finish this job)

Also, when voice clips were recorded, the subjects' blood pressures were measured using a digital blood pressure monitor to verify the stress levels. In general, the heart rate is increased based on the person's psychological stress level. The main reason for that is, that the ventricles in the heart contract more forcefully, causing an increase in blood pressure [12].

Six (06) numbers of separate and differentiated datasets were generated based on the differentiation of window sizes in two conditions of stress. In the first version, 34 samples of voice clips were taken by impelling to read three sentences under both conditions for 15ms, 25ms, and 35ms. In the second version, the dataset had been increased to 144 samples of voice clips, with the same sentences differentiating window sizes as 15ms, 25ms, and 35ms. Those were taken under both stressed and non-stressed conditions.

Also, the duration of these audio files varies from 2 to 4 seconds. These sentences were kept short to make the audio files short in length.

D. Model Training Process

In the model training process, three machine learning models were used with the dataset, Support Vector Machine (SVM), and Artificial Neural Network (ANN). SVM and ANN were selected and tested initially.

E. Support Vector Machine (SVM)

SVMs belong to supervised learning algorithms commonly used to deliver classification and regression tasks. [20] SVM's main objective is to divide the datasets having any number of features into groups to find the maximum marginal hyperplane (MMH) that uniquely classifies the data points. First, SVM will iteratively generate hyperplanes with the best isolation of the groups. Then it will choose the hyperplane that correctly divides the groups. [19] Since the SVM works in a high-dimensional feature space, kernel functions are included to perform computations without mapping the data point more explicitly. The kernel types such as linear, polynomial, and radial basis function (RBF) can be considered as general types.

The basic mathematical theory behind SVM is to find the hyperplane which helps to maximize the margin between different classes. Given a dataset with features, label x_i and label y_i , where $i = 1, 2, 3, 4, \dots, n$. and y can be -1 or 1.

$$w^T \cdot x + b = 0 \quad (3)$$

where in the equation (3) the weight vector is denoted by w , and the bias term is denoted by b . The decision rule for classifying a new data point.

$$\min 1/2 \|w\|^2 \quad (4)$$

Here, the weights are denoted by w , b is the bias term, and $\|w\|$ denotes the Euclidean norm of as equation (4).

F. Artificial Neural Network (ANN):

Models of computing based on the architecture and operation of the human brain are called artificial neural networks (ANNs). [21] A specialized cell that is an essential component of the nervous system is the biological neuron. Information transmission and processing are carried out via neurons. Neurons facilitate communication through electrical and chemical signals. The architecture of an ANN consists of a vast amount of artificial neurons, which are considered nodes and are made up of interconnected nodes grouped into layers such as input, hidden, and output. The fundamental unit of an ANN is the neuron, which determines a weighted sum of all its inputs and an activation function is applied to produce an output. With the last number of neurons, this type of model can handle more than one task simultaneously. ANNs are capable of performing tasks including classification, regression, and pattern recognition. Here the output of a neuron is denoted from O_j where in a single neuron, For papers with more than six authors: Add author names horizontally, moving to a third row if needed for more than 8 authors.

$$O_j = f \left(\sum_{i=1}^n w_{ij} \cdot a_i + b_j \right) \quad (5)$$

Here in equation (5), x_i represents the input to the neuron j , w_{ij} is the weight associated sum of the input i with respect to the neuron j , b_j denotes the bias term and f denotes the activation function in this equation.

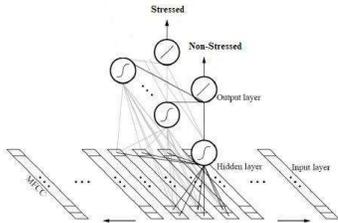


Fig. 6: Abstract view of the ANN model

IV. EXPERIMENTAL OVERVIEW

According to the observations in this study, data were collected two times transforming those into the dataset setting three different window sizes and two versions. As mentioned in the above methodology part, six types of datasets were generated under three different kernels in SVM. In data acquisition, three environments were designed. One is for neutral condition and the other is both for stressed condition. With the help of MFCC, features of voices were extracted for all the combinations of datasets in both versions. Here our own dataset was used for the model training process.

Mainly, for the training process of models the Support Vector Machine (SVM) and Artificial Neural Network (ANN) were used. In SVM, support vectors that are the nearest to the hyperplane utilizing Vectors-Data Points, which can be considered as one of the most essential concepts. With the aid of these data points, the separation line or hyperplane can be easily initiated. SVM's main objective is to divide the datasets into groups and find a maximum marginal hyperplane in between them. In training the SVM model different kernels were utilized within the SVC functions like polynomial, Radial Basis Function (RBF), linear, and sigmoid.

Artificial Neural Networks are capable of handling issues with the use of self-learning and self-organizing where they are distinguished by their topologies, activation functions, and weight vectors, which are occupied in their hidden and output layers for processing with the help of basic mathematical operations.

Further during the study, an Artificial Neural Network sequential model was built using Keras for the training of Neural Networks. During the stage of model building, a fully connected network structure (Dense) with three layers was used. Moreover, the ReLu activation function was applied on the first two layers, and in the output layer, the sigmoid activation function was applied.

V. RESULTS AND EVALUATIONS

In line with the experiments on both SVM and ANN, all the models have gained over 50% as mentioned in tables I and II. In this case, the window sizes are represented by each column as 15 ms, 25 ms, and 35 ms and for the kernel functions polynomial, radial basis function, and sigmoid are indicated in each row.

To evaluate the performance of the SVM and ANN models more hypothetically, confusion matrices were constructed using the resulting positive and negative counts of the results in actual and predicted ways. For the calculation of accuracy (6), precision (7) and recall (8) following equations were used.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (6)$$

$$Precision = \frac{TP}{TP+FP} \quad (7)$$

$$Recall = \frac{TP}{TP+FN} \quad (8)$$

According to the derived outcomes, among both SVM and ANN, an ANN model with a 35ms Window size and a second version dataset performed well for our dataset which displayed 63% accuracy.

Both models have their limitations. The ANN model's reliance on substantial computational resources makes it less practical for real-time applications on devices with limited hardware capabilities. Additionally, ANN requires significant expertise in selecting appropriate architectures and hyperparameters, which could introduce variability in results. On the other hand, the SVM model's inability to adapt dynamically to varying temporal patterns limits its effectiveness in handling data with high variability.

TABLE I. RESULTS OF SVM

Window size	0.015s		0.025s		0.035s	
	Initial	Second	Initial	Second	Initial	Second
Polynomial	57%	57%	54%	58%	56%	58%
Radial basis Function	57%	57%	55%	58%	59%	59%
Sigmoid	50%	50%	50%	51%	55%	51%

TABLE II. RESULTS OF ANN

Window size	0.015s		0.025s		0.035s	
	Initial	Second	Initial	Second	Initial	Second
Epoch – 150 Batch size- 10	59%	58%	60%	58%	61%	63%

Furthermore, SVM's performance heavily depends on the choice of kernel and hyperparameters, and improper tuning can lead to suboptimal results.

VI. CONCLUSION AND FUTURE WORK

To detect mental stress in individuals based on speech in the Sinhala language, this research applied Support Vector Machines (SVM) and Artificial Neural Networks (ANN), achieving accuracies of 59% and 63%, respectively. One of the major contributions of this research was to introduce the Sinhala speech audio dataset which consists of voice clips recorded in stressful and non-stressful situations which has been a gap in the domain. The accuracies are concerned, the SVM displayed slightly higher accuracy than ANN since the SVM is robust to the size of the dataset. The maximum number of data here is 144 which could be the reason for the lower accuracy in ANN. Expanding the dataset may increase the accuracy of ANN. Also, the longer audio recordings would provide more data for training.

Future research is conducted based on the dataset expansion, and the model enhancements. Also, it is desired to utilize Deep Learning models such as Recurrent Neural Networks with LSTM. Deep Learning methods tend to demand larger datasets. Based on the enhancements, this stress detection model has potential applications in the areas of virtual interactions, customer care, health care, and others. In addition to that, a complete solution for biofeedback therapy utilizing a multimodal approach will be proposed that contains facial and emotional recognition with voice analysis.

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Anthracene and Pyrene Degradation Potential of Soil Inhabit Bacteria in Waste Disposal Sites: Bioremediation Approach for a Clean Earth

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Abstract—Polycyclic aromatic hydrocarbons (PAHs) are organic molecules composed of interconnected benzene rings, consisting solely of hydrogen and carbon atoms. Recognized as environmental contaminants, these compounds are highly carcinogenic and mutagenic, posing significant risks to human health and other living organisms. Among the various PAHs, pyrene, and anthracene are frequently present in the environment. Although physical and chemical methods can neutralize PAHs, they often have harmful environmental side effects. Therefore, bioremediation emerges as the most eco-friendly and cost-effective solution. This study aims to evaluate the concentrations of PAHs in the environment and to identify soil bacteria capable of degrading PAHs like pyrene and anthracene. Bacterial strains degrading PAHs were identified through plate assays, and their degradation efficiencies were assessed using spectrophotometric analysis. The results indicated that the bacterial strains MW-1-2, MW-1-1, MW-10-4, MJ-5-4, DP2, DG1, and DJ2 degrade anthracene by more than 80%. Additionally, the strains MJ-5-1 and MJ-5-2 degraded pyrene by over 80%, while the strains MJ-5-4 and MG-5-1 degraded pyrene by more than 50%. The HPLC environmental analysis test results showed that the soil samples contained pyrene concentrations ranging from 35 ppm to 45 ppm and anthracene concentrations ranging from 50 ppm to 60 ppm. In conclusion, the selected PAH-degrading soil bacteria demonstrate potential as effective biological agents for degrading PAHs, specifically pyrene and anthracene.

Keywords—polycyclic aromatic hydrocarbons, anthracene, pyrene, bioremediation, degradation percentage

I. INTRODUCTION

Soil pollution has become a severe problem due to its formation from both natural and anthropogenic sources that includes both industrial and agricultural activities. This can further compromise the strength of the upper soil layers, diminishing fertility and negatively impacting the soil's biological activity [1]. Soil pollution is regarded as the contamination of soil with toxic substances, and chemicals that can affect the soils fertility and its quality [2]. Contaminated soil further affects the quality of ground water as these pollutants can leach down with time, thus affecting both humans and the ecosystem [3].

Polycyclic aromatic hydrocarbons (PAHs) broadly found in aquatic and [4], composed of more than two fused benzene rings and is formed due to the incomplete combustion of fossil fuels, coal and crude oil. Overexposure to these Polycyclic

aromatic hydrocarbons can lead to kidney damage, liver damages, and cataracts [5]. Certain polycyclic aromatic hydrocarbons are suspected carcinogenic and prolonged exposure can lead to adverse health effects including cancers and reproductive disorders [6]. Polycyclic aromatic hydrocarbons are degraded by different types of bacteria by secreting enzymes such as peroxidases and oxygenases [7]. *Spingomonas* and *Rhodococcus* are two types of bacteria capable of degrading PAHs and are responsible for the production of biosurfactants. Biosurfactants can reduce surface tension and entrap PAHs on the water surface making it available for bacterial degradation.

Bioremediation refers to a technological approach employing microorganisms, including bacteria, archaea, fungi, or algae, to diminish, confine, or alter the target compound, with the ultimate goal of mitigating the possible harmful outcomes. Bacteria, as inherent scavengers, with multiple mechanisms to adapt have undergone evolutionary processes, to actively break down organic pollutants and derive energy from contaminated sites over time. Leveraging their natural remediation capabilities, bacteria have been harnessed as a biotechnological tool for addressing environmental pollution. Notably, the degradation of naphthalene and phenanthrene has been a focal point, with various bacteria recognized for their ability to break down polycyclic aromatic hydrocarbons. Leveraging their natural remediation capabilities, bacteria have been harnessed as a biotechnological tool for addressing environmental pollution. Notably, the degradation of naphthalene and phenanthrene has been a focal point, with various bacteria recognized for their ability to break down PAHs [8].

II. METHODOLOGY

All required safety protocols were meticulously followed, and aseptic conditions were strictly maintained throughout the study to ensure the integrity and reliability of the results.

A. Sample Collection

Soil samples were collected from various garbage dumping sites and fuel stations across four distinct districts in Sri Lanka: Gampaha (Gampaha District), Karainagar (Jaffna District), Wadduwa (Kalutara District), and Peliyagoda (Colombo District). Approximately 100 g of each contaminated sample were gathered and securely sealed in sterile zip-lock bags. Each sample was meticulously labeled with its corresponding location.

Geographical coordinates of sample collection site:

Jaffna - 9° 44' 0" N, 79° 52' 0" E

Ampara - 7° 13' 0" N, 81° 51' 0" E

Colombo - 6° 52' 28.76" N, 79° 51' 37.74" E

Gampaha - 7.0840° N, 80.0098° E

B. Isolation of Soil Bacteria

The soil samples were subjected to serial dilution up to a 10^{-10} factor, 5 grams of each soil sample were weighed and transferred into appropriately labeled conical flasks. To each flask, 50 ml of autoclaved distilled water was added, and the mixture was thoroughly swirled for 5 minutes. Then, 1 ml of this sample solution was transferred to a test tube containing 9 ml of autoclaved distilled water to achieve a 10^{-1} dilution. This process was repeated sequentially 10^{-10} , fold dilution was achieved.

C. Spread Plate Technique

Each sample, 0.1 ml of the 10^{-5} to 10^{-10} dilutions were placed at the center of a nutrient agar plate, appropriately labeled to evenly distribute the bacterial sample across the agar surface until the spreader encountered resistance. After preparing all the spread plates, they were incubated at room temperature for 24 hours.

D. Streak Plate Technique

Morphologically distinct bacterial colonies were selected from the spread plates and labeled with unique identification codes. These colonies were then isolated using streaking.

E. Bacterial Starvation in Bacto-Bushnell Hass (BBH) plates

Solidified BBH agar (MgSO_4 , CaCl_2 , KH_2PO_4 , K_2HPO_4 , NH_4NO_3 , and FeCl_3) plates were inverted, and 25 equal squares were drawn on each plate and labeled. Single colonies from nutrient agar plates were inoculated on BBH plates and was cultured at room temperature for 72 hours.

F. Preparation of Anthracene/Pyrene spiked BBH agar plates

A 100 ppm solution of anthracene and pyrene in acetone was prepared. Subsequently, 500 μL of the anthracene/pyrene solution was added to the solidified BBH agar plates. The solution was evenly distributed across each plate using a cotton swab, and the plates were left partially open for a few seconds to allow the acetone to evaporate.

All bacterial colonies grown on the BBH agar plates were transferred to anthracene and pyrene spiked BBH plates and incubated for 24 hours at room temperature.

G. Spectrophotometric analysis

The test tubes were filled with a 2% methylene blue solution. Using an inoculation loop, the respective bacterial colony was added to the medium for both anthracene and pyrene, resulting in a total of 20 test tubes. Each tube was appropriately labeled. For the analysis, 1000 μL of each sample was transferred to a cuvette and placed in the spectrophotometer. Prior to sample analysis, a blank sample was measured to ensure accurate baseline readings. Three measurements were taken for each sample, and the average was calculated. This procedure was repeated for all 20 test

tubes, and readings were recorded for both pyrene and anthracene samples [9].

III. RESULTS AND DISCUSSION

A. Sample Collection

Soil samples were collected from the sites where a diverse emission of PAHs could take place including fuel stations where PAHs are emitted at a higher rate due to oil spills and garbage dumping sites where PAHs are introduced to the environment due to incomplete combustions. The reasons as to why soil samples were collected from Colombo, Ampara, Jaffna, and Gampaha was that it represents the foremost corners of the island making it possible to observe how certain environmental conditions could affect soil bacteria.

B. Spread Plate Technique

The method of distributing bacteria uniformly on the surface of an agar plate is known as the spread plate method. Using the spread method, a small amount of bacterial dilution prepared using serial dilution was uniformly speeded on the surface of the agar plate using a sterilized spreader. When determining colony-forming units (CFUs), plates comprising 20 to 300 CFUs were used to calculate the number of CFUs/ml of the original sample. And using the obtained results the bacterial colony with the best population density was identified [10].

C. Streak Plate

The streak plate method is a microbial technique to isolate pure cultures of bacteria colonies from a mixed population. It is a very simple aseptic technique that uses cotton swabs, or an inoculating loop to dilute and spread the specimen over the surface of pre-sterilized specific solid agar media [11]. Isolated colonies represent a clone of cells, being derived from a single precursor cell. Which represents different characteristics unique to each of the isolated bacterial colony that help identification of the bacteria [12].

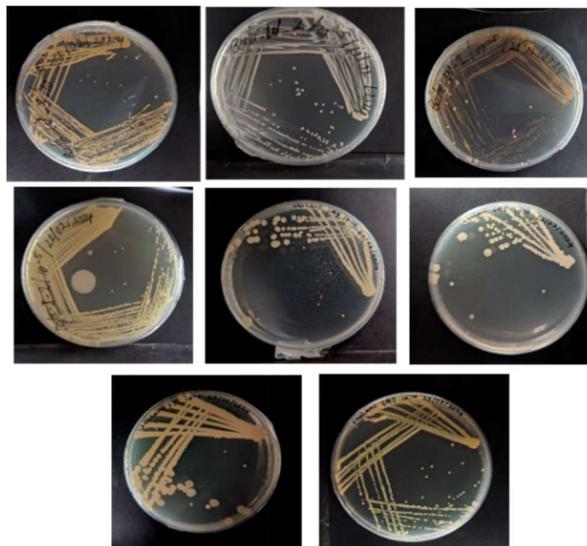


Fig. 1. Streak Plate results.

D. Population density

Population density (CFU/mL) = (Number of isolated colonies) × 1ml (Amount of diluted sample used in spread plate × dilution factor) (1)

TABLE 1: POPULATION DENSITY CALCULATION

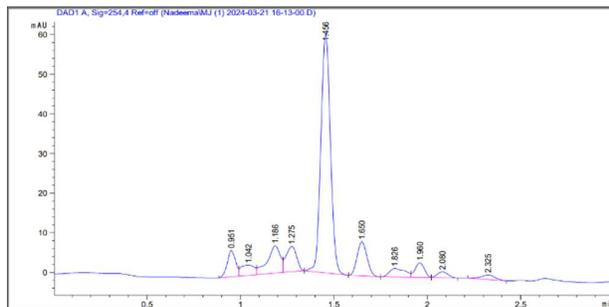
Colony samples	Number of Isolated Colonies in the sample	Dilution Factors	Population Density (CFU/mL)
MW – 1 – 1	1	10 ⁻¹	100
MW – 1 – 2	1	10 ⁻⁵	1 x 10 ⁶
MW – 10 – 4	3	10 ⁻⁵	3 x 10 ⁶
DG1 10 ⁻¹⁰	212	10 ⁻¹⁰	2.12 X10 ¹¹
DP2 10 ⁻¹⁰	2	10 ⁻¹⁰	2X10 ¹¹
DJ2 10 ⁻¹⁰	6	10 ⁻¹⁰	6 X10 ¹¹
DG3 10 ⁻⁵	1	10 ⁻⁵	1 X10 ⁶

E. Primary Screening using Plate Assay

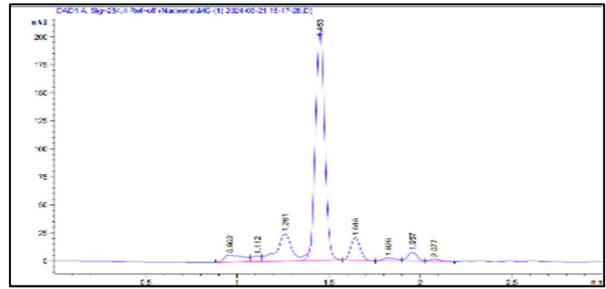
TABLE 2: PLATE ASSAY SCREENING OF BACTERIA

Bacterial sample	Number of colonies present in Pyrene spiked plates	Number of colonies present in Anthracene spiked plates
MW – 1 – 1	25/25	25/25
MW – 1 – 2	0/25	0/25
MW – 10 – 4	0/25	25/25
DG1 10 ⁻¹⁰	25/25	16/25
DP2 10 ⁻¹⁰	2/25	25/25
DJ2 10 ⁻¹⁰	5/25	19/25
DG3 10 ⁻⁵	20/25	25/25

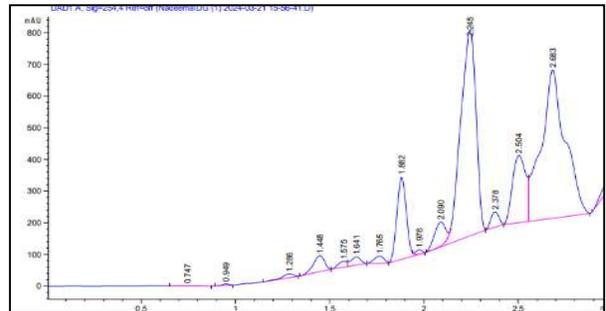
F. Environmental analysis of collected soil samples using High-Performance Liquid Chromatography (HPLC)



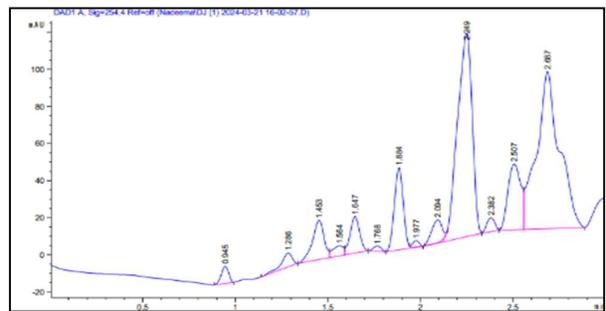
(a)



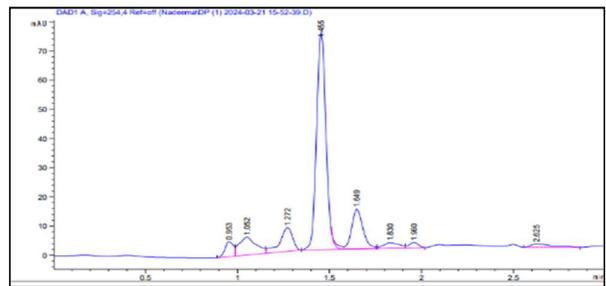
(b)



(c)



(d)



(e)

Fig.2: HPLC results of Waste dumping sites and petroleum sites of each of the collected soil samples namely: a) MJ (Jaffna), b) MG (Gampaha), c) DG (Gampaha), d) DJ (Jaffna) and e) DP (Peliyagoda).

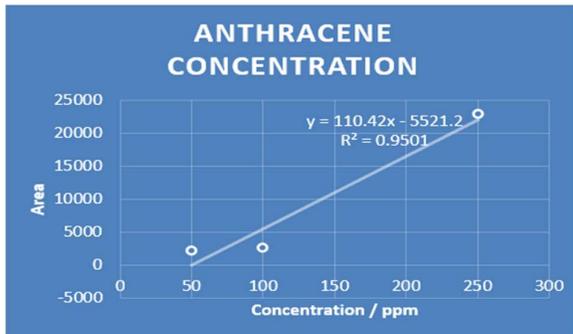
The above figure depicts the histograms obtained from the HPLC analysis. This was done to identify the concentration of the PAHs present in the soil samples that were collected from each of the specified locations used in testing.

For the above results, the retention time for each PAH is given below:

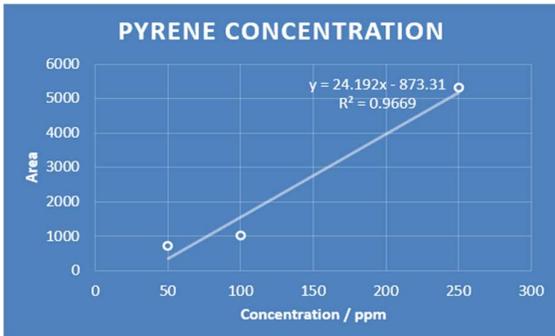
TABLE 3: RETENTION TIME OF EACH PAH

PAH	Retention time
Anthracene	1.875 - 2.1 min
Pyrene	2.3 - 2.5 min

Using the retention time for each PAH a standard curve was plotted as shown below and this standard plot was used to find the concentration of each PAH in the isolated soil samples.



(a)



(b)

Fig.3: Standard plot for the PAHs Anthracene and Pyrene: a) standard plot for anthracene and b) Standard plot for Pyrene

TABLE 4: PAH CONCENTRATION IN COLLECTED SOIL SAMPLES

Bacterial strain	MG	MJ	MW
PAH			
Pyrene/ppm	0	39.36	39.37
Anthracene/ppm	57.1	57.06	57.05

G. Spectrometric analysis to identify the percentage degradation of PAH using isolated bacterial samples

The below bars graphs show the data obtained using spectrometric analysis to calculate the percentage degradation of PAHs using each bacteria. This was calculated to find out the bacteria capable of the highest degradation. The below

equation shows how the percentage degradation was calculated.

PAH degradation percentage =

$$\frac{\text{Initial absorbance} - \text{Final absorbance}}{\text{Initial absorbance}} \times 100$$

Equa.2: PAH percentage degradation [13].

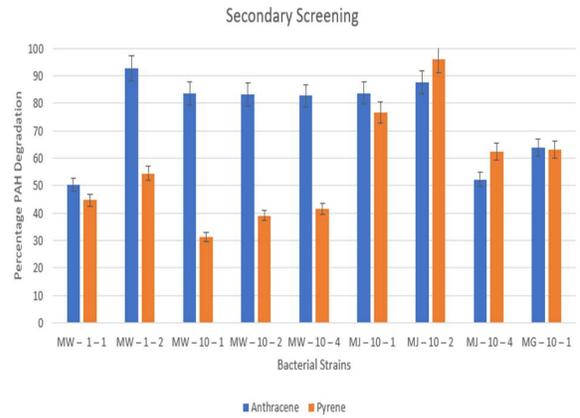


Fig.4: Percentage degradation of Bacterial colonies isolated from waste disposal sites

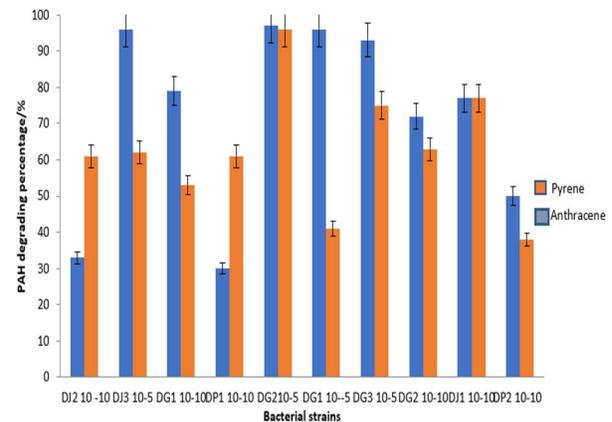


Fig.5: Percentage degradation of Bacteria isolated from petroleum stations.

IV. CONCLUSION

The study effectively isolated and identified several bacterial colonies with the capability to degrade polycyclic aromatic hydrocarbons (PAHs). Through primary and secondary screenings, the efficiency of these isolates in PAH degradation was demonstrated. These bacterial strains show potential for integration into compost media, offering a sustainable bioremediation approach for PAH-contaminated environments. This presents a promising solution for combating soil pollution caused by industrial and agricultural activities, as well as mitigating the harmful effects of these pollutants on ecosystems and human health.

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Diversity and Adaptive Mechanisms of Oil-Degrading Bacteria in Varied Environments: A Comprehensive Review

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Abstract— Oil spills are significant environmental hazards with profound impacts on ecosystems, economies, and public health. This review explores various cleanup methods, emphasizing bioremediation as an eco-friendly and affordable way to remediate oil-contaminated environments. Bioremediation harnesses the natural degradation abilities of oil-degrading bacteria to metabolize toxic hydrocarbons into less harmful forms. Optimization of environmental factors and growth conditions enhances bioremediation productivity. Oil-degrading bacteria exhibit diverse genetic and structural adaptations, and their metabolic pathways are tailored for efficient hydrocarbon breakdown in toxic environments. Current research focuses on advancing bioremediation through genetically modified microorganisms, assessing environmental and economic impacts, and proposing innovative cleanup strategies. High-throughput technologies like Next-Generation Sequencing facilitate an understanding of microbial communities and their functional potential. Novel approaches, including surfactant utilization, aim to further enhance oil spill cleanup efficiency. Future research aims to address current limitations, improving the efficiency and effectiveness of oil-degrading bacteria for advanced bioremediation practices.

Keywords— *bacteria, bioremediation, genetic adaptations, oil-degrading, oil spills*

I. INTRODUCTION

Oil pollution is a major issue affecting ecosystems globally, impacting marine, terrestrial, and forest environments. Oil spills cause severe damage to plants, animals, and entire ecosystems. Notable historical spills include the Deepwater Horizon spill situated in the Gulf of Mexico, which polluted underwater ecosystem [1], and the Exxon Valdez spill in Alaska in 1989, emitting 40.8 million Litres of crude oil [2]. Recently, in Sri Lanka, the 2021 MV X-Press Pearl spill was the country's biggest maritime environmental disaster [3]. Clean-up processes often take years, with only 14% of the spilled oil removed after 11 years from the Valdez spill [2].

Oil spills cause immediate and long-term effects on marine life, such as inhalation and ingestion of oil, leading to fatalities among bald eagles, sea birds, harbour seals, sea otters and killer whales [2]. A past study found that Coral colonies suffer from tissue loss and excess mucus production as side effects of oil spills [4]. Oil contamination in soil affects fertility, inhibits plant growth, and contaminates water resources, impacting ecosystem health and function [2]. People living in

coastal regions are also affected due to the economic reliance on marine environments. Long-term impacts include reduced immune defence mechanism in adult herring and embryo-harming effects on cardiorespiratory performance [5]. According to [6], the direct skin contact with oncogenic oil substances could induce neurological complications.

This review aims to explore the diversity and adaptive mechanisms of oil-degrading bacteria in various environments. Understanding these bacteria's roles, capabilities, and effectiveness in biodegradation can enhance bioremediation strategies. By examining the types of bacteria, their environmental adaptations, and the properties of different oils, the review targets to provide insights into optimizing microbial approaches for oil spill clean-up and environmental restoration.

II. OIL-DEGRADING BACTERIA IN SOIL

Bacteria can ferment complex organic matter into less harmful substances, playing a crucial part in the bioremediation of oil spills and industrial waste. These bacteria degrade petroleum hydrocarbons into simple molecules [7], utilizing enzymatic systems that break down oil for energy and carbon emissions [8].

Soil is a life-supporting layer of earth, housing organisms like bacteria, fungi, protozoa, algae, actinomycetes, and nematodes. These microbes maintain soil parameters and soil health [9], and participate in biochemical cycles such as carbon, nitrogen, phosphorus, and water cycles [10]. Soil degradation affects these cycles due to human-induced activities [11].

Soil microorganisms decompose complex molecules into simple ones using extracellular enzymes, which vary based on soil conditions and litter quality [9]. Bacteria primarily decompose biotic matter, as fungi form mutualistic interactions with plants [12]. Actinomycetes also decompose organic content, protozoa aid in nutrient turnover, and algae fix nitrogen and recycle nutrients [13].

Bacteria and fungi are crucial for degrading oil-contaminated soil, with bacteria being more efficient [14]. Optimal conditions for degradation include temperatures of 30-40 °C, oxygen requiring conditions, and nutrients like nitrogen, phosphorus, and iron, with neutralized pH [8]. Bacterial species like *Marinococcus albus*, *Methylobacterium mesophilicum*, and *Nocardia otitidisoviarum* [15], and

terrestrial bacterial genera like *Rhodococcus*, *Arthrobacter*, *Corynebacterium*, and *Bacillus* [16] are effective oil degraders.

Historically, bacterial cultures like *Bacillus*, *Micrococcus*, and *Pseudomonas* were used to clean up oil spills. However, these bacteria are less efficient compared to *Coryneform* bacteria, which provide higher efficiency in cleaning oil spills by degrading oil field waste and eliminating residues [17].

III. OIL-DEGRADING PROCEDURE AND ENVIRONMENTAL ASPECTS

Oil is composed of biotic matter, and the accumulation of biotic compounds can disrupt ecological balance. Microorganisms play a crucial role in maintaining this balance by decomposing organic materials and forming symbiotic interactions with plants [18]. The decomposition of oil involves numerous routes influenced by environmental aspects such as temperature, oxygen, nutrients (nitrogen, phosphorus, iron), pH, and moisture [19]. The oil degradation paths include physical disintegration, chemical weathering, biodegradation, and volatilization.

A. Oil degradation process

The oil degradation process begins with physical weathering, where photooxidation breaks oil contaminants into fine particles using sunbeam. Chemical weathering involves oxygen engaging with oil, requiring elevated temperatures. Biodegradation is carried out by microbes that utilize oil as a carbon source, producing enzymes to break down hydrocarbons [20]. Chemical dispersants, containing surfactants, minimize the surface tension within oil and water [21]. Volatilization causes volatile substances in oil to transform into vapour in warm conditions. Biologically, plants and microbial catabolism of hydrocarbons further aid in oil degradation [19].

When observing contaminated soil samples using scanning electron microscopy, soil particles typically average 50 micrometres in size and are coat by crude oil. Hydrogen bonds and weak van der Waals forces bind the oil to the soil, creating a densely packed, flake-like pattern [14]. This contamination results in blocked soil pores, reduced aeration, and decreased soil permeability [8].

B. Parameters required for oil degradation

Several parameters regulate and elevate the productivity of hydrocarbon degradation, including temperature, pH, oxygen, nutrients, and salinity [22]. Additionally, bioavailability, the quality and quantity of pollutants, beside play a role [23].

Temperature is a significant controlling factor in oil degradation, with a span from $-40\text{ }^{\circ}\text{C}$ to $+130\text{ }^{\circ}\text{C}$ [22]. Bacteria able of growing at cool temperatures, such as $-1.5\text{ }^{\circ}\text{C}$, can clean up oil spills in arctic soils [24]. For instance, *Sphingomonas* sp. AR-OL41 illustrates genetic mechanisms to decompose hydrocarbons in reduced temperatures. As temperature amplifies, the rate and capability of hydrocarbon volatilization also increase [19]. Thermophiles and thermotrophs are engaged in higher temperature degradation, with thermophiles not growing below $50\text{ }^{\circ}\text{C}$ and thermotrophs having a range between $20\text{-}30\text{ }^{\circ}\text{C}$ [22].

Oxygen is essential for aerobic oil-degrading bacteria, which cannot survive in anaerobic conditions. Notable

examples of these bacteria include *Rhodococcus*, *Pseudomonas*, *Arthrobacter*, *Corynebacterium*, *Bacillus*, *Dietzia*, and *Gordonia* [11, 16].

Oil-degrading bacteria produce enzymes using carbon sources, and require additional nutrients such as nitrogen, phosphorus, and iron [8]. In low-nutrient environments like deserts and permafrost soils, the growth rate of bacteria is lower. Conversely, marine environments with high nutrient diversity support higher bacterial growth [22].

IV. ADAPTIVE MECHANISM OF OIL-DEGRADING BACTERIA

Oil-degrading bacteria exhibit diverse adaptive mechanisms, metabolic pathways, genetic variations, and responses to environmental conditions, facilitating efficient hydrocarbon degradation in contaminated sites.

A. Metabolic pathways

Bacteria utilize various metabolic pathways to degrade hydrocarbons present in crude oil, which is a complex mixture containing over 170,000 chemical compounds including aliphatic, aromatic, linear, branched hydrocarbons, and cyclohexenes, with approximately 230 different hydrocarbons [25]. These pathways vary depending on the type of oil, its chemical composition, and the length of the hydrocarbon chains. The primary pathways for hydrocarbon degradation are aerobic and anaerobic pathways [26].

B. Aerobic pathways

Aerobic degradation is characterized by enzymatic reactions that occur under oxygen-rich conditions, renowned for their efficiency in breaking down hydrocarbons. For aliphatic hydrocarbons, the process begins with monooxygenases by cleaving the hydrocarbon backbones into alcohol, and the β -oxidation of alcohol results in carboxylic acid. [19]. In the case of aromatic hydrocarbons, different types of oxygenases involve in the catalysing the cleavage of aromatic rings. This leads to the formation of carboxylic acids through both ortho and meta cleavage processes [27].

C. Anaerobic pathways

In anaerobic degradation processes, bacteria utilize alternative electron acceptors like nitrate and sulfate when oxygen is scarce. This metabolic strategy involves various mechanisms such as fumarate addition, intra-aerobic hydroxylation, hydration carboxylation, and reverse methanogenesis [28]. The anaerobic bacteria adapt to these conditions through specialized metabolic pathways, which enable them to degrade complex hydrocarbons into simpler compounds. This contributes significantly to the biogeochemical cycling of carbon in environments with limited oxygen availability [29].

D. Enzymatic processes

In aerobic degradation pathways, enzymes play crucial roles in breaking down hydrocarbons. The key enzyme, monooxygenase, initiates the process by catalysing the oxidation of hydrocarbons, essential for their breakdown. Additionally, alkane dehydrogenase contributes significantly, particularly in the metabolism of aliphatic hydrocarbons. These enzymes can be classified into several groups depending on the length of hydrocarbon chains they degrade: hydrolases for short-chain hydrocarbons, hydroxylases for medium-chain hydrocarbons, and enzymes specialized in

longer alkanes. In the degradation of aromatic hydrocarbons, cytochrome monooxygenase, including the P450 system, plays a critical role by facilitating alternative pathways. These enzymes, including monooxygenases and dioxygenases, are pivotal in cleaving aromatic rings and transforming them into intermediary products during aerobic degradation [30,31].

E. Genetic adaptations

Genetic adaptations in hydrocarbon-degrading bacteria are essential to adapt to toxic nature of oil contaminants sites and ensure their survival, enabling the encoding of enzymes that convert hydrocarbon residues into less toxic forms. These genes are primarily located on chromosomal plasmids and DNA. Two key genes, *alkB* and *nah*, play pivotal roles in this process. *alkB* is responsible for alkane degradation by encoding the monooxygenase enzyme crucial for initiating aerobic breakdown. The abundance of *nah* genes differ based on various factors such as salinity and the type of hydrocarbon present. Alkane hydroxylases categorized into three groups; AlkB-related hydrolases, cytochrome P450 monooxygenases, and soluble di-iron monooxygenases, and they are the dominant enzymes facilitating the degradation of different alkane chain lengths. Some bacteria also possess *phenN* genes for phenol degradation and *cyp153A* for medium-chain hydrocarbon breakdown, contributing to their ability to degrade a wide range of substrates. For instance, *Marinobacter* species express multiple genes like *alkB*, *cyp153A*, and *almL*, which collectively enhance their capacity to degrade wide range of hydrocarbons [32, 33].

Genetic and structural adaptations of oil degrading bacteria are essential for their acclimatization to toxic compounds present in oil-contaminated sites. When exposed to these conditions, bacteria undergo genetic variations and structural changes that enhance their survival capabilities. Horizontal gene transfer plays a significant role in this adaptation process, facilitating the acquisition of genes that confer resistance to toxicity [32]. These adaptations also involve increasing the number of catabolizing genes and altering the density of bacterial communities, which collectively contribute to improved degradation efficiency [34]. Structural changes in bacterial cells, crucial for effective hydrocarbon degradation, are facilitated by interactions between the bacteria and hydrocarbons present in the environment [33].

F. Biosurfactant production

Biosurfactant production is another vital adaptation strategy employed by bacteria for oil degradation. These surface-active compounds, known as bio surfactants, alters the cell membrane properties of oil degrading bacteria, enhancing their relationship with hydrophobic oil compounds. This alteration increases the bioavailability of hydrocarbons to bacteria, thereby accelerating the degradation process under unfavourable environmental conditions [35].

V. INVESTIGATING OIL DEGRADING BACTERIA IN SOIL

Research on oil-degrading bacteria has utilized rigorous sampling and analysis methods to ensure accurate results. Across diverse environments, samples were collected using sterile techniques to minimize contamination, and preservatives were added to maintain integrity during transportation in temperature-controlled (6 °C) ice boxes to laboratories [15, 23].

For example, a study conducted in India collected seawater samples from the Alang coast in Gujarat, a region heavily polluted due to ship-breaking activities. These samples were stored in sterilized glass bottles and transported within 6 hours for analysis [23]. Similarly, sediment samples rich in methane gas from the Haima cold seep in South China, covered with mussels, were collected in sterilized centrifuge tubes and stored at 4 °C until laboratory processing [15]. In Nigeria, enriched soil samples from oil-polluted sites in Kegbara Dere were collected for further investigation [8].

In Iraq, researchers collected crude oil-contaminated soil samples from storage tank sites in Wasit province near the Tigris River and the Karadiya forest area, transporting these specimens in polythene bags to preserve sample quality [16, 36]. Additional studies focused on soil from mechanic workshop sites contaminated with gasoline and diesel, which were transported under cool conditions for laboratory analysis [11].

A. Isolation and culture

Following sample collection, researchers employed serial dilution and plating techniques to isolate bacterial cultures [36]. Identifying bacterial strains capable of degrading pollutants is a critical step toward developing advanced bioremediation approaches and environmental monitoring strategies.

A variety of culture media has been utilized in these studies, including enrichment media with crude oil as a carbon source, Luria Bertani (LB) medium, Mineral Salt Medium (MSM), Marine Mineral Medium (MMC), and Nutrient Agar, all designed to support the growth and activity of oil-degrading bacteria [8, 15, 37].

B. Experimental techniques

Bioaugmentation strategies involved introducing laboratory-grown microorganisms to enhance degradation capabilities in environments where native microbiota may be insufficient [11]. Biodegradation pot experiments were conducted under controlled conditions to assess degradation rates over 60 days, with adjustments made to soil pH and nutrient levels to optimize bacterial activity [8].

Metagenomic analysis, utilizing DNA sequencing and bioinformatics tools, was employed to assess the functional potential of microbial communities in degraded environments [11]. Bacterial consortia were developed by culturing selected colonies to enhance resilience and stability, followed by biodegradability testing [20].

Analytical techniques such as CHN analysis measured hydrocarbon presence based on carbon and nitrogen percentages, while Energy-dispersive X-ray spectroscopy and Fourier-transform infrared (FT-IR) spectroscopy analysed soil composition and elemental content in crude oil-contaminated soils [8].

C. Optimization and assesment

Central Composite Design was used to optimize bioremediation conditions, incorporating factors like pH and nutrient ratios to enhance oil degradation efficiency [38]. These methodologies collectively provided insights into the variations and adaptations of oil-degrading bacteria across

various environments, facilitating the development of effective bioremediation strategies.

VI. LIMITATIONS IN OIL DEGRADATION RESEARCH

The speed of growth and productivity of oil-degrading bacteria depend heavily on environmental parameters such as temperature, salinity, pH, nutrients, and moisture, making it challenging to manage these variables in laboratory settings [19]. Accurate sample collection is crucial, particularly in restricted or remote areas like deep seas, where obtaining permissions and ensuring proper handling of hazardous substances are significant challenges [8]. Strict protocols for cleaning and sterilizing sampling equipment and containers before use are essential to prevent cross-contamination during laboratory testing.

Transporting samples to laboratories without contamination is critical for obtaining accurate results. Delays in transportation, especially from remote areas, can affect sample integrity despite the use of preservatives [15]. Proper handling and preservation techniques are essential to minimize errors caused by sample degradation during transit [8].

VII. IMPLEMENTATION OF OIL-DEGRADING BACTERIA

Hydrocarbon-degrading bacteria are pivotal in treating polluted sites, wastewater treatment, and biodegradation procedures. These bacteria and their enzymes are utilized in bioplastic production from used transformer oil, where they convert waste into biodegradable plastics like polyhydroxyalkanoates (PHA) [39]. In oil spill remediation, microorganisms effectively metabolize oil compounds, aiding in marine and terrestrial ecosystem restoration [20]. Additionally, oil-degrading bacteria significantly involve in enhancing oil recovery processes in the oil industry, facilitating the breakdown of heavy hydrocarbons to improve extraction efficiency [40].

A. Enhancing oil recovery

Oil-degrading bacteria are instrumental in enhanced oil recovery processes within the oil industry. By breaking down heavy hydrocarbons in reservoirs, these bacteria enhance oil flow and extraction efficiency, contributing to sustainable oil recovery practices [40].

VIII. FUTURE DIRECTIONS

Oil spills remain a significant source of environmental pollution, necessitating effective cleanup methods like bioremediation. Future research aims to leverage advancements in technology and genetic engineering to enhance the productivity of oil-degrading bacteria in mitigating the impacts of these spills.

A. Technological advancements

Recent developments in high-throughput techniques such as Next-Generation Sequencing (NGS) offer unprecedented capabilities to discover novel hydrocarbon-degrading bacteria. NGS facilitates the identification of bacteria with enhanced enzymatic capabilities and adaptations to extreme environmental conditions, such as high salinity [41].

Meta genomic approaches provide valuable awareness into the functional diversity of bacterial species involved in bioremediation. By understanding gene functions across

diverse taxa, researchers can optimize bioremediation strategies for different environmental contaminants [42].

B. Genetic engineering approaches

Genetic engineering holds promise for developing genetically modified organisms (GMOs) with tailored metabolic pathways and enhanced oil-degrading capabilities. GMOs engineered to efficiently degrade persistent hydrocarbons can be strategically deployed through bioaugmentation to accelerate cleanup efforts in contaminated sites [43].

However, the widespread application of GMOs faces regulatory challenges and environmental concerns, including the potential for gene transfer to native microbial communities. In future, attention should be paid on mitigating limitations related to risks where can assuring the safety and effective deployment of genetically engineered solutions [41].

C. Development of novel solutions

Introducing biosurfactants represents a promising strategy to improve bacteria-hydrocarbon interactions in bioremediation. Biosurfactants enhance the bioavailability of hydrophobic compounds, facilitating their uptake and degradation by oil-degrading bacteria in contaminated environments [44].

Innovative approaches are needed to address current limitations in bioremediation. These include refining genetic modification techniques to minimize environmental risks and developing robust bacterial consortia capable of degrading a wide range of hydrocarbons under diverse environmental conditions.

Future research directions should integrate remote sensing technologies like Synthetic Aperture Radar (SAR) imagery for real-time oil spill identification and conduct comprehensive in-situ assessments to evaluate the long-term ecological impacts of bioremediation efforts [3, 45]. Understanding the resilience mechanisms of microbial communities to oil contamination will be crucial for developing sustainable and effective strategies for environmental management.

IX. CONCLUSION

Oil-degrading bacteria are highly effective in breaking down hydrocarbon residues due to their versatile capabilities. This makes bioremediation a preferred and successful method for cleaning up oil spills in diverse environments, particularly noted after incidents like the Exxon Valdez spill. Over 79 bacterial genera, including dominant species like *Alcanivorax*, *Marinobacter*, *Pseudomonas*, and *Acinetobacter*, utilize hydrocarbon residues for energy and growth. They exhibit varying degrading rates depended on parameters such as oil type, chemical composition, spill location, and environmental conditions. These bacteria possess genetic and structural adaptations that enable them to thrive in toxic environments and employ diverse metabolic pathways to convert hydrocarbons into non-toxic compounds.

Understanding these bacteria is crucial for developing effective bioremediation strategies, leveraging techniques like biostimulation and bioaugmentation. However, bioremediation faces challenges such as environmental variability, toxicity adaptation, hydrocarbon resistance, legal considerations for bioaugmentation, and spill-specific

impacts. Current research aims to overcome these limitations by exploring genetically modified organisms and advanced technologies such as next-generation sequencing and metagenomics. Novel approaches like bio surfactants also show promise for enhancing bioremediation efficacy in eliminating a broader range of toxic hydrocarbons from oil spills.

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Evaluate the Effective Design Elements in an Interior Photograph which Impact on Decision-Making

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Abstract— This study investigates the design elements that enhance the appeal of interior photographs on social media and influence viewers' decisions to visit any places they find attractive through a photograph. By a qualitative analysis, surveys, and case studies, key factors such as colour schemes, lighting, space arrangements, texture, line, and patterns that contribute to the visual impact of these spaces were identified. The findings reveal what combination of these elements evoke emotional responses and shapes viewer perceptions, providing valuable insights for interior designers, photographers, and digital marketers. The study highlights the importance of creating visually compelling interiors that not only attract online engagement but also convert viewers into visitors. While the focus on Colombo's commercial interiors may limit generalizability, the results offer practical guidelines for enhancing the marketability of interior spaces through strategic design and photography.

Keywords - interior design, design elements, interior photography, user perspective, user preference

I. INTRODUCTION

In the digital age, the role of visual media in shaping user behavior has become increasingly significant. Social media platforms like Instagram, Pinterest, and Facebook are flooded with images that capture the essence of spaces, experiences, and lifestyles. Among these, interior photography stands out as a powerful tool for influencing viewer perceptions and decisions. Whether it's a restaurant, a luxurious hotel, or a cozy home, the way interiors are photographed and presented online can make a lasting impression on potential visitors. This research aims to explore the design elements that enhance the appeal of interiors when viewed through photographs on social media and the internet and to understand how these elements influence the decision-making process of viewers.

Interior design is an art that combines aesthetics and functionality to create spaces that are both beautiful and liveable. When captured in a photograph, the design elements of an interior can convey countless no. of messages and evoke a range of emotions. Elements such as colour schemes, lighting, furniture arrangements, and decorative accessories, contribute to the overall visual impact.

The start of social media has transformed how people discover and engage with spaces. A single photograph can

inspire a viewer to visit a location, share it with friends, or even plan a trip. This shows the importance for designers, photographers, and marketers to understand which design elements are most effective in photographs and how they can be used to attract and engage viewers. Due to the growing importance of this situation, there is limited research on specific design elements that enhance an interior's appeal in photographs and their influence on viewers' decisions.

This research investigates how various design elements within interior photographs impact an individual's decision-making process. The study aims to identify specific elements such as colour schemes, lighting, furniture arrangement, space layout, and textures that enhance the visual appeal of interior spaces, by understanding how these elements affect viewer perceptions and choices.

The main question for this research would be, what design element/s in an interior photograph influence in the decision-making process of an individual?

Therefore, the following objectives will be considered when conducting the research.

1. To identify design elements of an aesthetically visualized interior space.
2. To investigate the connectivity and the role of interior design elements in shaping the visual narrative and aesthetic quality of interior photography.
3. To analyse and identify the contribution levels of each design element in highlighting a better photograph.
4. To analyse the viewer's preference and their perspective on design elements.

II. LITERATURE REVIEW

A. Basics of Design Elements and their impact on Interior Ambience

Professional interior designers will usually follow a set of informal "rules", based on specific interior design principles and elements. These interior design elements include space, line, forms, light, colour, texture and pattern; and keeping them balanced is the key to creating an aesthetically pleasing interior.

In addition to enhancing the appearance of a room, getting these elements to work together in harmony will also bring increased functionality. To start, an interior designer will assess the room according to these interior design elements, and then use them to disguise or enhance the various features and flaws of the space. As a minimum, the following seven elements should always be considered in the creation of any interior. (“The Interior Design Academy - Blog” 2019)

TABLE 1: ABOUT DESIGN ELEMENTS

Design Elements	Description
Space	The physical boundaries and area in which design occurs
Line	The visual guide created by edges or contours in space
Form	The shape and structure of objects within a given space
Light	The illumination that affects visibility and mood within spaces
Colour	The hues and shades that create aesthetic and emotional effects
Texture	The surface quality that can be seen or felt physically
Pattern	The repetitive design elements that add interest and cohesion

B. Ambience of restaurant interiors

The ambience of restaurant interiors is meticulously curated through the strategic use of design elements to establish a welcoming and immersive dining experience. Elements such as colour schemes, interior decor, lighting, furniture quality, and overall aesthetic impression play a pivotal role in shaping the atmosphere of a restaurant (Han & Ryu, 2009). By thoughtfully integrating these design elements, restaurant owners can create a unique and appealing ambience that resonates with customers, enhances their dining experience, and fosters customer loyalty.

C. Hotel interior ambience

In the context of hotel interior ambience, design elements are employed to craft a luxurious, comfortable, and inviting environment for guests. Factors such as facility aesthetics, architectural design, interior decor, lighting, and spatial layout contribute to the overall ambience of a hotel (Ryu & Jang, 2007).

By paying attention to these design elements, hoteliers can establish a distinctive atmosphere that reflects the brand identity, enhances guest satisfaction, and promotes positive guest experiences, ultimately leading to customer loyalty and positive reviews.

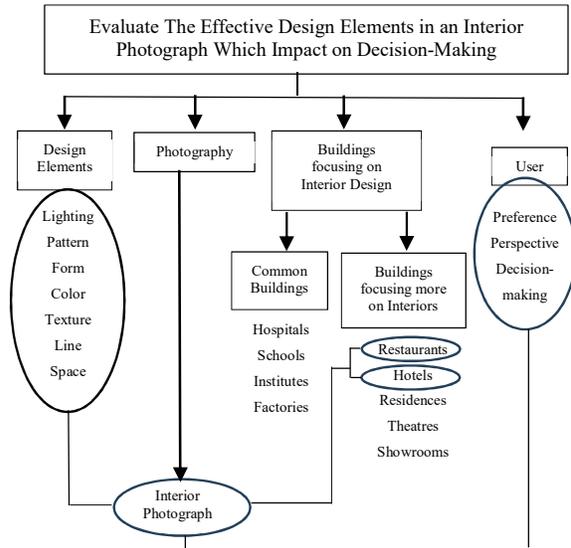
D. Importance of interior photography

In architecture and design, interior photography is essential not only for documenting spaces but also for influencing perceptions of architectural designs. (De Silva & Hettiarachchi, 2021) highlight the importance of photography in the design process for architects, enabling them to assess and refine their creations visually.

Additionally, interior photography plays a crucial role in the commercial marketing of architectural designs, allowing designers to showcase their work to potential clients and the public, thereby influencing their perception of the space.

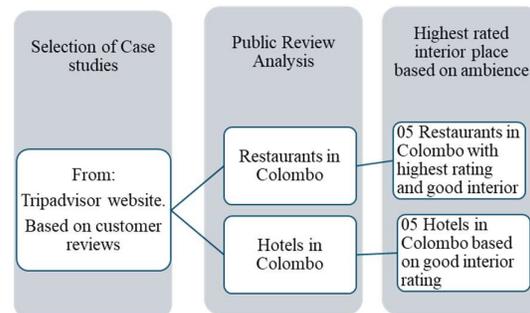
This underscores the significance of high-quality interior photography in effectively communicating the essence and appeal of architectural designs.

III. THE ORETICAL FRAMEWORK



IV. METHODOLOGY

A. Research Strategy



Data Collection: A Questionnaire Survey through Google sheet via online was conducted among students, designers, and the common public to analyze their preferences on design elements and interior ambience.

B. Limitations

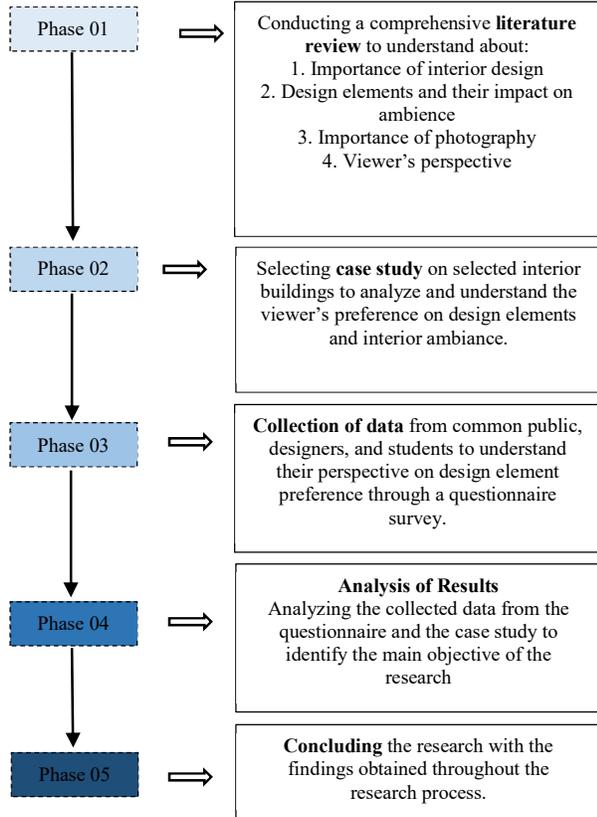
This research is based on identifying the design elements that attract the common public to visit a place through an interior photograph. To analyze this factor, out of all buildings, the focus is placed on restaurant and hotel interiors. For this purpose, some of the restaurants and Hotels within the Colombo region are selected based on the rating system obtained from the Tripadvisor website, as the case study to proceed with the survey.

V. CASE STUDY

A. Stage 01- Selection of Website

The best review site is selected out of the review sites used by the public to select restaurants and hotels for visiting. As per the analysis on Jan 2023 and Oct 2023 in websites called

Podium and Mini Hotel, Tripadvisor ranks in the no.1 position. Also, Tripadvisor website provides reviews of both hotels and restaurants along with price comparison features.



B. Stage 02 – Selection of Restaurants and Hotels

Based on the Tripadvisor website reviews and rankings, 5 restaurants and 5 hotels were selected to do the photography observational study to analyze the design elements that are highlighted through the photographs published.

TABLE 1: SELECTED RESTAURANTS AND HOTELS

	Restaurants	Hotels
1	Sapphyr Lounge Shangri-La	Marino Beach Colombo
2	Vertele by Jetwing	Taj Samudra Colombo
3	Minori Japanese Restaurant	Cinnamon Lakeside Colombo
4	Central Restaurant Shangri-La	Residence by Uga Escapes
5	The Dining Room by Cinnamon Lakeside	Paradise Road Tintagel Colombo

The overall rating given by the Tripadvisor website, and the rating for the atmosphere of the restaurant along with total number of reviews for each restaurant given by the customers and the number of reviews mentioned about the atmosphere are classified in this table.

The overall rating given by the Tripadvisor website and the total number of reviews by the customer and the number of reviews filtered specified on the rooms are expressed through this table.

TABLE 2: SELECTED RESTAURANTS

Selected Restaurant	Sapphyr Lounge Shangri-La	Vertele by Jetwing	Minori Japanese Restaurant	Central Restaurant Shangri-La	The Dining Room by Cinnamon Lakeside
Rating	5/5	5/5	4.5/5	5/5	4.5/5
Rating for atmosphere	5/5	5/5	5/5	5/5	4/5
Total no. of Reviews	945	387	157	1090	457
No. of Reviews on Ambience	153	79	17	111	26

TABLE 3: SELECTED HOTELS

Selected Hotels	Marino Beach Colombo	Taj Samudra Colombo	Cinnamon Lakeside Colombo	Residence by Uga Escapes	Paradise Road Tintagel Colombo
Rating	4.5/5	4.5/5	4.5/5	4.5/5	4.5/5
Total no. of Reviews	1451	5467	8004	597	798
No. of Reviews about Room Interior	500+	1000+	1000+	300+	300+

VI. RESULTS AND DISCUSSION



A. Photographic Observational Study on Restaurants

B. Sapphyr Lounge, Shangri-La Colombo

Fig 1: Interior of Sapphyr Lounge

The interior of this restaurant highlights patterns, lighting, and colour through the photographs.

1. The intricate geometric patterns found on the screens, wall panels, and ceiling designs add a touch of sophistication and elegance to the space. These detailed patterns not only attract the viewer but also add a layer of refinement and charm, enhancing the overall ambience of the lounge.
2. Large floor-to-ceiling windows allow an abundance of natural light to flood the space, creating a bright and inviting atmosphere. And along with the combination of patterned screens, the shadows created gives more elegance and photogenic feel to the interior. The windows also provide stunning views of the surrounding area, enhancing the overall experience. The usage of neutral colour palette to the overall interior including furniture gives a luxurious finish to the place and increase its attractiveness.
3. Also, Decorative lightings are used to highlight and enhance the space giving an elegant, luxurious look to the interior and through the photograph.

C. *Virticle by Jetwing*



Fig 2: Interior of Virticle By Jetwing

The photographs of this restaurant highlight lines, lighting, space and colour in the interior.

1. Usage of curved lines in the pathway enhances the pathway and gives a photogenic feel and add a sense of flow and continuity to the interior.
2. Using accent lighting in those curved pathways and shelves highlights the way enhancing the usage of curved lines and shelves, attracting viewers to its' uniqueness.
3. Capturing from an angle highlighting the vertical lines of the place makes the interior feel large and deep.
4. Large glass windows incorporated in the space allow the natural light to enter the interior enhancing the aesthetic of the restaurant.

A proper space arrangement with suitable furniture also enhances the elegance of the interior. The overall warm colour tone used in the space creates an inviting cozy atmosphere.

D. *Minori Japanese Restaurant*



Fig 3: Interior of Minori Japanese Restaurant

1. The vertical and horizontal lines captured in the photograph enhances the space and gives an aligned finish to the interior. The angle at which the photograph is captured adds depth to the interior making it feel larger and highlighting.
2. Texture highlighted through the flooring and furniture adds a natural touch to the interior giving a comfortable and cozy feeling. The balance between the natural and ambient lighting of the interior is also enhancing the interior space through the photograph. Also, the space utilization and arrangement are enhanced in the photograph making viewers visit and enjoy the view.

E. *Central Restaurant, Shangri-La*



Fig 4: Interior of Central Restaurant

In the photograph, it is prominent that the usage of colours enhances the interior giving a vibrant feel to the atmosphere.

1. Patterns are highlighted through the decorations used in the interior.
2. Even the usage of lights isn't interfering with the overall ambience. It merges with the other elements highlighting other elements as a support.
3. The photograph enhances the patterns that is used in the flooring giving an aesthetic look to the interior.

The space arrangement and usage of forms in furniture are also highlighted in the photograph. An overall vibrant inviting atmosphere is visualized through the photographs.

F. *The Dining Room, Cinnamon Lakeside, Colombo*



Fig 5: Interior of The Dining Room

3. The pattern used in the ceiling is highlighted through the photograph.
4. Accent lighting to enhance the glass pillars to create a sophisticated aesthetically pleasing interior ambience.

Overall furniture arrangement highlights the positive space that is incorporated as another design element in the interior. Usage of vertical columns highlighting the lines along with the ambient lighting enhances the pathway of the entrance expressing a welcoming interior ambience.

G. *Ratings of Restaurants based on Design Elements*

Based on the design elements that can be seen through the photographs of each restaurant, a point is given for each design element and an overall rating out of 7 is given for each restaurant selected.

H. Photographic Observational Study on Hotels



Fig 6: Marino Beach Hotel interior

TABLE 4: DESIGN ELEMENT RATING OF RESTAURANTS

Restaurant	Rating
Sapphyr Loung Shangri-La	4
Virticle By Jetwing	4
Minori Japanese Restaurant	3
Central Restaurant Shangri-La	5
The Dining Room Cinnamon Lakeside	3

The spacious layout is prominently highlighted. The arrangement of furniture allows for easy movement and contributes to an open, uncluttered feel. This use of space makes the room appear larger and more inviting. The use of both natural and artificial light stands out. Large windows allow ample natural light to flood the room, creating a bright and airy atmosphere. This is complemented by strategically placed artificial lighting, such as bedside lamps and ceiling lights, which add warmth and enhance the room's ambience.

A. Taj Samudra, Colombo



Fig 7: Taj Samudra, interior

Both natural and artificial ambient lighting is balanced in the overall interior enhancing the room's warmth and creating an inviting ambience.

Forms are highlighted in the incorporation of furniture styles used in the interior giving a traditional feel to the user. A proper space layout enhances openness and allows easy movement is also highlighted in the photograph.

I. Cinnamon Lakeside Colombo



Fig 8: Cinnamon Lakeside interior

The usage of Patterns in the floor carpets, and bed head creates a visual interest to the user and the viewer. The balance between natural and artificial lighting creates a welcoming and comfortable atmosphere evoking the user's interests. A proper arrangement of space is noticeable throughout the photograph which makes the viewer attracted to the place giving a spacious feel.

J. Residence by Uga Escapes



Fig 9: Interior of Residence by Uga Escapes

Texture is highlighted in the interior through the flooring, fabric and walls giving a rustic look and adding more interest to the place. Adequate lighting without disturbing the aesthetic also is highlighted in the photograph. The overall lighting and the colour give a warm and cozy feeling to the interior.

K. Paradise Road Tintagel, Colombo



Fig 10: Interior of Paradise Road, Tintagel

The texture, space, colour and lighting are highlighted in this interior photograph. Dark colour tones give an antique feel to the interior attracting the viewer. Along with the lighting used in the interior a warm feel is created for the viewer. A variety of textures is also highlighted in the photograph enhancing the visual appeal of the interior.

L. Ratings of Hotels based on Design Elements

Based on the design elements that can be seen through the photographs of each hotel, a point is given for each design element and an overall rating out of 7 is given for each hotel selected.

TABLE 5: DESIGN ELEMENT RATING OF HOTELS

Hotels	Rating
Marino Beach Colombo	3
Taj Samudra Colombo	4
Cinnamon Lakeside Colombo	3
Residence by Uga Escapes	4
Paradise Road Tintagel, Colombo	3

VII. RESULTS OF THE QUESTIONNAIRE SURVEY

Based on the answers received in the questionnaire survey conducted among 60 participants who are common public where most of them are students and undergraduates of age 20 - 25 years, the following analysis were made.

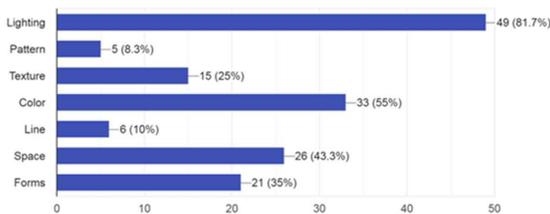


Chart 1: The most important design element analysis obtained from the questionnaire survey

According to the preferred design elements of the participants, they mostly assume that the lighting is more important when it comes to interior ambience. And then the next important element will be colour followed by space. The rest of the design elements are preferred as important by some participants. Based on the interior photographs of the restaurants selected for photographic study, majority of the participants have selected Central Restaurant at Shangri-La to be the appealing interior space.

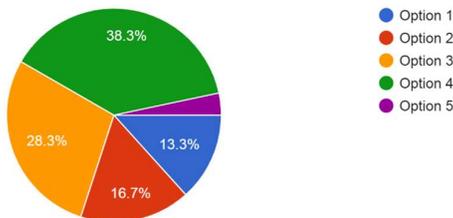


Chart 2: Most selected restaurant option out of the given selected case study photographs

Option 4 - Central Restaurant at Shangri-La



And the design element which attracted the participants of the survey most in the selected photograph would be, Lighting, Colour and Space in order.

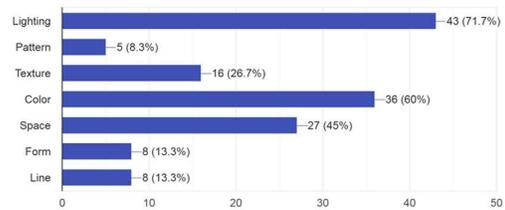


Chart 3: Design elements attracted the viewers through the photograph

The responses for the selection of interiors of the hotels have closer values. Yet Residence by Uga Escapes is preferred by most participants. All other interiors are also preferred quiet equally by the members.

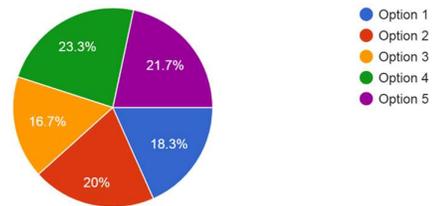


Chart 4: Most preferred hotels out of the given hotel photographs

Option 4: Residence by Uga Escapes



Based on the interior selections highlighted design elements are ordered as Lighting and colour on the same level followed by Space and then texture. These elements seemed

to be highlighted in the interior photographs displayed for choice.

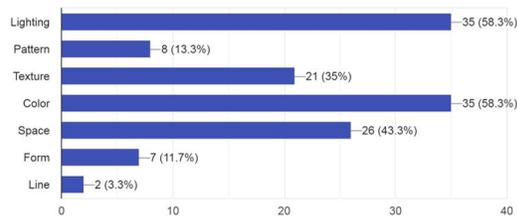


Chart 5: Design elements seen by the viewers through the photograph

VIII. CONCLUSION

This research explored the interiors of selected restaurants and hotels through a photographic study based on the website. A questionnaire survey was also conducted to analyse the viewer perception on specific attraction towards design elements to make decision over the interior photograph.

Based on the questions on design elements it was clear that whatever design elements are used in an interior, lighting becomes a main part of it. Especially the usage of natural light has a significance of enhancing the ambience of the interior.

The questionnaire related to the case studies and the photographic study stated that no matter whether a place is seen by the naked eye, a proper interior photograph too can influence the decision-making of an individual. For example, even though a place is visited or not a visually pleasing image can attract the viewer and can evoke the interest of visiting the place seen through the photograph. Also, the main findings of this research are, Lighting is the key element for a better interior design. Especially the usage of proper and adequate

natural lighting is required for a good ambience. Highlighting other elements such as texture, patterns and lines can be done using proper accent lighting to enhance the ambience. A good colour scheme for an interior is admired and attracted by viewers. The feel and the mood created in the interior is enhanced by the usage of colour. Space arrangement in an interior also affects the viewer. Especially a proper balance of positive and negative space is expected to make the interior more comfortable and welcoming. An interior focused on the lighting, colour, and space mainly, and with other elements preferred as per the concept of the designer is considered to be the most liked interior by the viewers.

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Assessing the Resilience and Adaptability of Sri Lankan Interior Design and Build Companies Amidst and Post the COVID-19 Pandemic

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Abstract— This study investigates how Colombo, Sri Lanka-based interior design and construction companies responded to the unusual problems posed by the COVID-19 pandemic, which had a negative impact on supply chains, site visits, Design process changing, and client relationships. The study looks at how ordinary design processes have changed and how that has directly impacted operations, earnings, and customer interactions, focusing on six severely impacted organizations. It looks at tactics including online discussions, improved digital project management tools, and stringent health and safety regulations on construction sites. These tactics' efficacy in preserving revenue stability, business continuity, and customer happiness are evaluated. The study intends to provide insightful information about the adaptability and resilience of interior design and build companies by offering a thorough examination of these responses and adaptations.

Keywords— *resilience, adaptability, interior design and build companies, covid 19 pandemic*

I. INTRODUCTION

The COVID-19 pandemic caused significant disruptions for interior design companies in Colombo, Sri Lanka, affecting operations, earnings, and clientele due to lockdowns, travel restrictions, and broken supply chains. This study examines the resilience and adaptability of six Colombo-based companies, focusing on how they maintained business continuity through innovative strategies and adaptations in design processes and material selection during and after the pandemic. The research highlights the challenges faced and the creative solutions implemented to navigate the crisis. This study focuses on six interior design and build companies in Colombo, Sri Lanka, that have been significantly impacted by the COVID-19 pandemic. The industry, which relies heavily on client relationships, site visits, and a stable supply chain, faced unprecedented challenges due to the pandemic. These businesses had to quickly adapt to new circumstances, finding innovative ways to continue their operations and meet client needs despite various restrictions and health concerns. The pandemic disrupted key aspects of the interior design process, such as client meetings, site visits, material procurement, and project execution. Lockdowns and social distancing made in-person meetings difficult, pushing companies to use online tools like Zoom and Microsoft Teams for client interactions. Initial site assessments were halted and later conducted under strict health guidelines. The global supply chain disruptions caused delays and increased costs, prompting companies to turn to local suppliers for materials. Additionally, workforce limitations and lockdowns affected on-site operations, necessitating new health and safety protocols. The immediate

impacts of the pandemic on Colombo's interior design industry included operational disruptions, revenue declines, and changes in client demands. Projects were delayed or halted, and companies had to navigate new regulations and procedures. The economic uncertainty led to a decrease in revenue, and businesses had to find ways to cut costs while maintaining quality. Additionally, there was a shift in client priorities, with increased demand for home offices, health-oriented spaces, and multifunctional living areas. Companies had to quickly adapt their offerings to meet these new demands, demonstrating their ability to innovate and remain relevant in a changing market.

II. LITERATURE REVIEW

A. Definition of Interior Design

Good interior design adds a new dimension to a space. It can increase our efficiency in the way we go about our daily lives, and it adds depth, understanding, and meaning to the built environment. Thoughtful and well-crafted design makes a space easier to understand, and experiencing such a space lifts the spirit, too. It is, therefore, not just about the aesthetic; it is a practical and philosophical discipline. Beautiful spaces show a logical and rational questioning of the status quo and can be an honest attempt to find new and exciting ways to lead our lives. In some areas of design, such as hospitality design (the design of bars, restaurants, hotels, etc.), the designer's work can play a large part in creating a successful business for the owners. The stock returns in China. From these studies, it is reasonably apparent that large ownership holdings have a mixed effect on stock performance, which diverges from country to country.

B. Introduction to Interior Design Companies

Companies that specialize in designing aesthetically beautiful and practical interior environments for a range of settings, including residential, commercial, institutional, and hospitality settings, are known as interior design companies. These businesses use talented individuals to work together to realize their clients' design concepts, including project managers, interior designers, architects, and decorators. A variety of services are provided by interior design companies, such as project management, furniture selection, colour coordination, lighting design, and space planning. They frequently collaborate closely with clients to fully grasp their requirements, preferences, and financial limitations before adjusting their design solutions. Construction, interior design, and international promotion companies make a major contribution to providing construction and interior design

services. Construction activities are the complete or a part of a sequence of making plans or implementation activities along with supervision that consists of work, architectural, civil, electrical, and environmental.

C. Conventional Design Process

According to (Jones et al. 2018), interior design often adheres to a predetermined procedure that includes several sequential steps, such as ideation, space planning, material selection, and implementation. Designers can methodically create and execute their ideas thanks to this organized process. The significance of client collaboration is underscored by (Smith and Johnson 2019), who point out that face-to-face meetings and site visits help designers and clients communicate effectively and gain a better grasp of the client's preferences and project requirements (Johnson, 2019).

D. Project management (PM) process framework in interior design projects

Clevenger and Haymaker (2011) define design process as "implementation of a strategy to a challenge resulting in an exploration" ideally made of three (Adapted from: RIBA, 2020) elements namely, challenge, strategy, and exploration. The Council for Interior Design Qualification, CIDQ (2019) defined the widely accepted phases of the interior design process as Programming, Schematic Design, Design Development, Contract Documentation and Contract Administration. The council further lists the tasks that the practice and management of an interior design project may involve. These include: (Adapted from: RIBA, 2020) Project management; (Adapted from: RIBA, 2020) Project goals which involves the understanding and documentation of the client's and stakeholders' goals and objectives with reference to the project (project scope management); (Adapted from: RIBA, 2020) Data collection in order to maximize design outcomes and stakeholder satisfaction, evaluation and assessment of existing site conditions; (Adapted from: RIBA, 2020) Design conceptualization; Selection of materials, furniture, fitting and equipment (FF&E); Documentation that involves contracts and permits as well as documentation of design by phases of schematic, design development as well as construction drawings and specifications;

Coordination of other consultants such architects, engineers and other specialty consultants; Contract administration that involves the tasks of distribution and bid analysis, the administration of construction, review and payouts of contractors, assessment of shop drawings and other relevant documents and drawings, site visits and work progress reports and lastly, project close out; and Pre-Design and Post-Design Services which are used to measure the success of the project with reference to client or stakeholder's expectations and goals. Therefore, (RIBA, 2020) (Adapted from: RIBA, 2020) of stock market and export dip, which deteriorated its corporate financial health. Prior to the crisis, Indian market and economy have shown a growth and a positive trend. The economic and market performance of pre-crisis is better than the post-crisis phase in India, which specifies that pre-crisis period was a growth phase and post-crisis was a sluggish phase. Hence, consideration of these two periods would furnish the fluctuations that occurred in investors' sentiment, equity investments and stock performances during these phases.

E. The factors influence in covid 19 pandemic

1. Features of the Virus

SARS-CoV-2 is a new coronavirus with distinct features that influence its severity, ability to avoid immune responses, and transmission. Over time, variations in the virus may arise, resulting in modifications to the degree of disease severity, vaccine efficacy, and transmissibility.

2. Public Health Measures

The transmission of COVID-19 is greatly impacted by the adoption and observance of public health measures such mask use, social distance, hand cleanliness, and immunization. These policies' efficacy varies according to community involvement, enforcement, and compliance.

3. Government Reactions

A major factor in preventing the spread of COVID-19 is government policies and actions related to the pandemic, such as travel bans, lockdowns, testing plans, and immunization efforts. The efficacy, timeliness, and strictness of these regulations differ throughout nations and areas.

4. Healthcare Capacity

Factors like hospitalizations, mortality rates, and access to care are all impacted by the ability of healthcare systems to respond to the COVID-19 pandemic. Healthcare staff capacity, hospital bed availability, ventilator availability, and medical supply availability are all factors that impact healthcare capacity.

F. Introduction of the construction industry and interior design and build companies in Sri Lanka

The COVID-19 pandemic has been one of the most significant health emergencies in recent history, leading to deep recessions and disruptions in global value chains. (Tumwesigye et al.2020) highlights the severity of the economic downturn, comparable to the Great Depression, affecting over 216 nations and territories. The impact has been profound, with millions of confirmed cases and deaths worldwide (World Health Organization, 2021). Lockdowns, travel bans, and labour mobility restrictions have caused a slowdown in economic activities globally, affecting businesses and supply chains (Shafi et al., 2020). The construction industry, a crucial sector in many economies, has experienced unprecedented challenges, including project delays, disruptions, and financial difficulties (Fairlie, 2020).

The effects of the pandemic on the construction industry in Sri Lanka have been significant, with almost every construction project being delayed or disrupted (Fernando, 2020) note the cancellation of projects and financial difficulties faced by construction companies due to a shortage of funds and building supplies. The Central Bank of Sri Lanka (CBSL) acknowledges the pandemic's adverse impact on the country's economic and social infrastructure, including public transportation and the ports sector (Central Bank of Sri Lanka, 2020). Despite initial signs of recovery, the construction industry contracted again with the third wave of the pandemic, leading to a decrease in GDP from the construction sector (Department of Census and Statistics, Sri Lanka, 2021).

Certain firm-specific factors based on previous studies are considered to control their effect on the stock return. This

study includes firm size, firm age, firm risk, profitability, leverage, current ratio, and dividend pay-out to gauge the effect.

G. Intract of the Resilience and COVID 19 Pandemic

The document "Responsive Interior Tactics for Adaptation and Resilience" from Interiority (2022) discusses the importance of resilience and adaptability in design disciplines, particularly in response to the rapid changes and complex issues brought on by contemporary challenges such as the COVID-19 pandemic. The pandemic has highlighted the need for the design field to strengthen its capacity to adapt and predict future changes, moving away from fixed and permanent architectural solutions that quickly become obsolete.

H. Intract of the Adaptability and COVID 19 Pandemic

The COVID-19 epidemic has brought to light how vital flexibility is to every aspect of society. As the virus expanded around the world, people, companies, and institutions had to quickly adapt to hitherto unheard-of difficulties. The quick adoption of new technology, the shift to remote employment, and the modification of daily routines and social conventions all served as examples of this flexibility. Adaptability in the healthcare industry was defined by the quick creation and implementation of telemedicine services, the restructuring of hospital staffing, and the acceleration of vaccine development and delivery. With the transition of educational institutions to online learning environments, teachers and students have to adapt to new pedagogical approaches. The epidemic also made clear how crucial emotional resilience is for assisting individuals in navigating the stress and uncertainty of a world that is changing quickly. Bruno F. Abrantes.

I. Data Collection Methods

Owners, executives, and staff members of interior design and building companies make up the target group. Quantitative Methods Surveys using questionnaires sent via Google Forms to 10 members from each of the 6 selected interior design companies, totalling 60 respondents.

J. Structure of the Questionnaire

General Questions Age range, position within the organization, size of the business, number of years of operation, and overall COVID-19 impact. Resilience includes strategies for adaptation, retrofitting initiatives, modifications to designs, the effect of changes in material prices, and the use of substitute materials. Adaptability Online platform use, tactical response effectiveness, flexibility in design processes, use of hybrid design approaches, and online platform constraints. The COVID-19 pandemic has had an impact on various aspects of life, including the design process, supply chain disruption, financial management, and alternative financial solutions.

III.METHODOLOGY

This study employs data collection approaches strategy that combines quantitative techniques. With this method, a thorough grasp of the adaptability and resilience of Sri Lankan interior design and build companies will be possible.

A. Research Design

Quantitative research that uses structured questionnaires to get quantifiable data.

B. Sample and Population

Population Sri Lankan interior design and build in Colombo. Sample 60 responses from 6 interior design and build companies, each with 10 members.

C. Instrument for Gathering Data

25 questions in a structured questionnaire with sections covering general inquiries, COVID-19 impact, resilience and adaptation outcomes, and resilience and adaptability parameters.



Fig. 1. Research key words and research topic

D. Data Gathering Methodology

Google Forms will be used to distribute the questionnaire via email to facilitate and expedite the gathering of responses.

E. Methods of Data Analysis

Using descriptive statistics, the data will be compiled.

Regression analysis is used inferential statistics used to analyze the correlations between variables and make inferences about the adaptability and resilience of the businesses. 3.5 Research Strategy.

F. Selection

This study will be conducted on the highly effected area to the covid 19 pandemic, focused on 06 interior design and build companies in Colombo Sri Lanka.

1. Leema Creations (Pvt) Ltd Colombo 06.
2. B Creations (Pvt) Ltd Kohuwala Colombo 06.
3. Monara Creation (Pvt) Ltd Nugegoda Colombo 07.
4. Widac Commercial Interiors (Pvt) Ltd Colombo 07.
5. A Design Studio (Pvt) Ltd Colombo 5.
6. SJ Interiors (Pvt) Ltd Kottawa.

IV. DATA ANALYSIS

A sizable portion of businesses (41%) frequently employed hybrid design techniques, suggesting Adaptability Hybrid Design strong propensity for adaptable and flexible procedures. Adopted: A reasonable percentage (42.6%) occasionally used hybrid techniques, demonstrating a moderate degree of adaptability. This chapter examines the relationship between the dependent variable (the resilience and adaptability of internal design and built companies) and the independent variables (variables such as the impact of COVID-19, adaptation techniques and changes to design processes). Interior design and construction businesses in Colombo, Sri Lanka are the subject of this study. The study examines how these businesses were affected by the outbreak of COVID-19 and how they changed their operations to deal with the difficulties presented by the crisis. Using Google Form, information was collected from 60 members of six interior design and build companies selected based on a researcher-designed questionnaire survey. Graphs were used to evaluate responses and display data, providing insight into the adaptation and durability of these businesses during and after the pandemic.

12. How frequently did your company use hybrid design methods during the pandemic?
61 responses

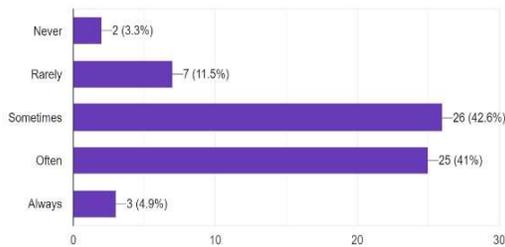


Fig. 2. Adaptability of hybrid design 61 responses

A. Impact of Design Process

1. Resilience: Reuse Practices

According to the research, during the pandemic, a substantial majority of businesses (93.2%) modified their reuse procedures to some degree. Just 6.8% of businesses said they rarely or never used reuse techniques.

06. Has your company adapted reuse practices during the pandemic?
61 responses

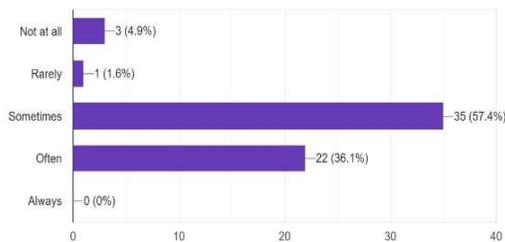


Fig. 3. Resilience, reuse practices

2. Retrofitting Projects

Retrofitting projects were sometimes (60.7%) or often (29.5%) undertaken, highlighting an adaptive response to new demands and safety requirements during the pandemic.

07. Did your company engage in retrofitting projects as a response to COVID-19?
61 responses

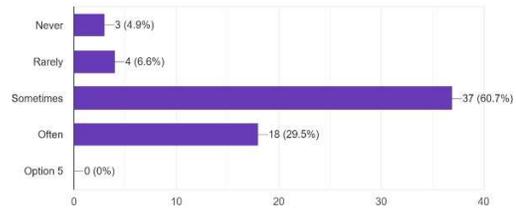


Fig. 4. Resilience, retrofitting projects

B. Adaptability

1. Hybrid Design

A sizable portion of businesses (41%) frequently employed hybrid design techniques, suggesting a strong propensity for adaptable and flexible procedures. Adopted: A reasonable percentage (42.6%) occasionally used hybrid techniques, demonstrating a moderate degree of adaptability.

12. How frequently did your company use hybrid design methods during the pandemic?
61 responses

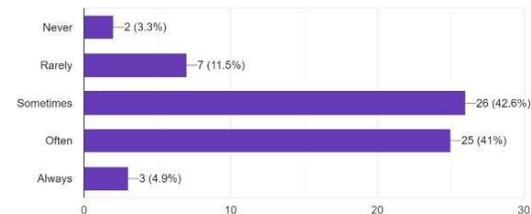


Fig. 5. Adaptability of hybrid design 61 responses

2. Online Platforms

Common Practice - 49.2% of businesses routinely use online platforms, with "Sometimes" being the most common response. This suggests a balanced approach to digital collaboration. Frequent Use: At 32.8%, "Often" was the second most popular response, indicating a high dependence on internet resources for communication.

14. How often did your company use online platforms for meetings and project discussions?
61 responses

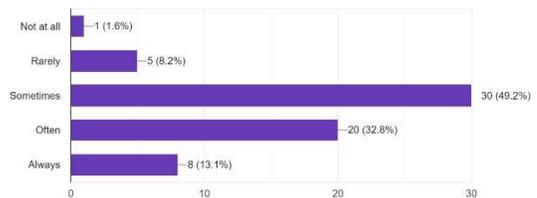


Fig. 6. Adaptability of online platforms

C. Impact of COVID 19 Pandemic

1. Design Process

Most responses (50.8%) indicated a significant impact, suggesting that COVID-19 greatly influenced design processes, likely requiring substantial adjustments. Moderate Impact - A notable portion (41%) experienced a moderate impact.

16. How did COVID-19 affect your design process?
61 responses

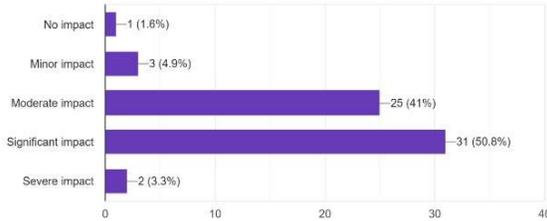


Fig. 7. Impact of design process

2. Supply Chain

Most respondents (55.7%) experienced moderate disruption, indicating significant challenges that required adjustments in the supply chain. High Disruption - A substantial number (39.3%) faced high disruption, suggesting major difficulties that likely demanded extensive changes to operations.

17. To what extent was your supply chain disrupted due to the pandemic?
61 responses

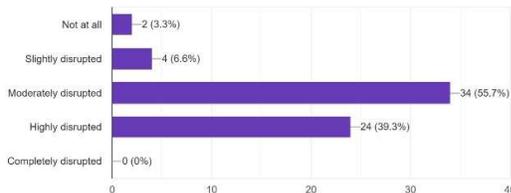


Fig. 8. Impact of supply chain

3. Financial Variables

This analysis demonstrates that the pandemic had a variety of effects on financial elements, the most significant of which being a change in material pricing, which may have required many design and build companies to adjust their operating and budgetary plans.

18. What financial variables were most impacted by the pandemic? (Select all that apply)
61 responses

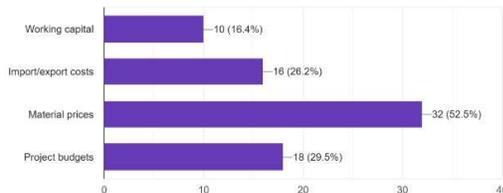


Fig. 9. Impact of financial

V. CONCLUSION

A. Introduction of the conclusion

To give readers a thorough overview of the entire study, Chapter 06 will highlight all the major discoveries made during the investigation. This chapter will provide a succinct and understandable summary of the findings made by the researcher during the investigation. Drawing on these conclusions, the researcher will provide useful suggestions. These suggestions will be clear-cut and simple to understand, guaranteeing that they can be used successfully. They will come from the research's specific findings and content. The intention is to offer practical guidance that will enhance interior design and build companies capacity for resilience

and adaptation, particularly considering current events like the COVID-19 epidemic.

B. In summary

This chapter looked at the adaptation and resiliency of Colombo, Sri Lanka's interior design and construction industries during and after the COVID-19 epidemic. The goal of the study was to determine how the pandemic affected these businesses and how they changed how they operated to meet the difficulties. 60 employees of six interior design companies provided information via a Google Forms survey. The investigation offered insightful information about these businesses' resilience and adaptation tactics both during and after the pandemic.

C. Key Findings

- General Workforce Demographics
- Company Size and Impact
- Resilience Strategies
- Adaptability Tactics
- Impact of COVID-19
- Resilience and Adaptability Outcomes

D. Comparing During and Post COVID-19

1. Design Process: During COVID-19

Significant changes were implemented to meet new health and safety requirements, such as social distancing, enhanced sanitation, and remote working conditions. Hybrid design techniques, combining traditional and digital methods, became more prevalent to facilitate collaboration and project management despite physical distancing. Many businesses adopted digital tools for design, communication, and project management, allowing for seamless remote operations and client interactions.

2. Post COVID-19

The flexible design processes and hybrid techniques adopted during the pandemic persisted, becoming standard practice in many companies. Continued use of digital tools and hybrid methods improved efficiency and collaboration, even as some in-person activities resumed. The industry saw a lasting shift towards more flexible and adaptive design processes, with an increased emphasis on health and safety in workspace layouts and project planning.

3. Materials and Supply Chain: During COVID-19

Timeliness and budgets for projects were severely disrupted by material shortages and pricing swings. To alleviate shortages, businesses were forced to implement reuse tactics and repurpose materials from ongoing projects. In the face of disruptions to the global supply chain, it became imperative to investigate alternative materials and sources to ensure project continuity. Companies were forced to create backup plans and new procurement techniques to handle unforeseen supply chain problems.

4. Post COVID-19

While some supply chain interruptions persisted, businesses had developed more robust procedures, like

strategic material storage and varied sourcing. Businesses were better able to address continuing issues because of stronger connections with suppliers and improved supply chain management.

The pandemic experience highlighted the value of supply chain flexibility, resulting in more resilient and flexible procurement tactics.

5. *Financial Variables: During COVID-19*

There was a serious threat to its financial stability due to declining income and rising operating expenses. To keep going, a lot of companies looked outside for finance, such as loans, investor capital, and government assistance programs. It was common practice to implement cost-cutting strategies such staff reduction, overhead expense reduction, and operational optimization. To sustain income streams and financial viability, diversifying services and investigating new markets became essential tactics.

6. *Post COVID-19*

Businesses that weathered the pandemic successfully preserved their financial stability by demonstrating enhanced financial management and strategic planning. Some companies were still having trouble managing their finances, and they had to cope with residual issues including missed payments, loan repayments, and decreased cash flow. Businesses should prioritize creating financial buffers and investigating novel revenue streams to maintain a flexible financial strategy.

VI. COMPREHENSIVE SUMMARY

Comparing corporate operations during and post COVID-19 demonstrates notable changes to financial strategies, materials and supply chain management, and design processes. Rapid modifications were required because of the epidemic, and resilience was encouraged. Many of these adaptations have since become standard practices in company operations. The long-term effects of COVID-19 have highlighted how crucial it is for interior design and construction companies to be adaptable, creative, and have solid planning to ensure their survival and expansion.

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EmoLand: Enhancing Facial Emotion Skills among Children with Autism Spectrum Disorder (ASD) in Sri Lanka

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Abstract—Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by a variety of symptoms, one of which is difficulties in emotional intelligence (EI). Children with ASD frequently find it challenging to recognize and express facial emotions, which could significantly harm their overall well-being. There remains a notable gap in access to effective early intervention methods for children with ASD in Sri Lanka, particularly for the 2-7 age group. This research addresses this necessity by utilizing recent advancements in artificial intelligence (AI), intense learning (DL), to implement a user-friendly mobile application designed as an early intervention solution enhancing facial emotion recognition (FER) and production. The proposed solution leverages Ekman's six basic emotions framework for facial emotion detection, progressive learning materials with familiar faces, and context-based evaluations to monitor the children's development. The research includes developing a custom model for face emotion recognition utilizing the DeepFace library and the Flutter framework for the mobile application.

Keywords—autism spectrum disorder, facial emotion recognition, early intervention, emotional intelligence, DeepFace

I. INTRODUCTION

Autism Spectrum Disorder (ASD) includes a spectrum of neurodevelopmental challenges, including impairments in social skills, communication, and cognitive abilities such as facial emotion recognition (FER) and theory of mind (ToM). Individuals with ASD frequently have lower emotional intelligence (EI), particularly in understanding emotions within their surroundings, being empathetic to others' experiences, interpreting emotions from social cues, and being in control of both their own and others' emotions [1]. FER is a critical aspect of non-verbal and social interaction that significantly impacts social interactions, effective communication, and the overall well-being of individuals with ASD [2] [3].

The ability model of EI, based on Ekman's six basic emotions (happy, sad, angry, fear, disgust, surprised), introduces a framework for analyzing emotional difficulties experienced by people with ASD. Empathy, a core factor of EI, requires accurately understanding and responding to others' mental states. While people with ASD face challenges in FER, they often possess innate or heightened systemizing abilities, which can facilitate cognitive empathy, particularly in recognizing emotions [4]. Enhancing emotional skills is essential for children, as it supports effective communication and helps them navigate social interactions more positively. Despite the global recognition of the difficulties faced by individuals with ASD, Sri Lanka presents unique challenges.

Families with autistic children come across complications in various aspects of life. Due to a lack of knowledge and resources, Sri Lankan schools often discourage the enrollment of students with ASD. The term "early intervention" is essential to meet the developmental needs of children with ASD aged 7 and below. It is fundamental for autistic children to enhance their quality of life. Play-based therapies that target imperative brain developmental stages are the main focus [5]. Following the American Academy of Pediatrics' recommendations for developmental and behavioral examinations at 9, 18, and 30 months, early intervention is emphasized to alleviate the negative impacts of neurodevelopmental disorders. Existing interventions, however, encounter challenges in recognizing facial emotions specific to ASD, as well as issues shared by parents and therapists. ICT plays a key role in helping individuals with ASD overcome these obstacles by providing them with resources for skill development, communication, and emotional exploration [3].

The researchers [6] observe that advancements in mobile computing have facilitated the integration of FER systems into smartphones, making them a viable platform for EI-enhancing applications for children with autism. In order to bridge this gap, this study will implement a user-friendly mobile application that leverages artificial intelligence (AI) to improve the ability of Sri Lankan children with autism, particularly those between the ages of 2 and 7, to recognize and produce facial emotions.

II. LITERATURE REVIEW

A. Existing System Analysis

Facial Expression Wonderland (FEW) and "Let's Face It!" application are notable examples of computer games. FEW prototype [2] is inspired by the Walt Disney film "Alice in Wonderland." It aims to improve autistic children's FER skills by providing voice prompts and animated characters to help them navigate diverse emotional situations. There are concerns regarding the necessity of careful emotion selection and the use of cartoon expressions for emotion assessment. They stress the need for real experiments and eye tracking for precise gaze detection during games. Similarly, "Let's Face It!" [8] has seven interactive games that are divided into three categories: facial identity and expression detection, social context facial cue interpretation, and attention to faces. Although it has been successful in teaching emotional skills, there are still challenges with its effectiveness and its inability to transfer abilities outside of computerized contexts.

Another strategy to assist ASD children is using serious games such as JEMImE and EmoTEA. JEMImE [7] is designed to improve facial expression production in social contexts and includes distinct training and playing phases. It utilizes Curapy.com for data recording, C#, Unity 3D, and Pairwise Conditional Random Forests for evaluation. A small sample size and the requirement for a child-specific facial expression classifier are among the drawbacks. The Android-based serious game EmoTEA [9] is aimed for children between the ages of 6 and 12. To improve EI, it integrates Affective Computing, Tangible User Interfaces (TUIs), and Ekman's six basic emotions methodology. Positive results validate its effectiveness, although there are challenges with the age range and possible interruptions to routines.

Mobile applications, such as World of Kids and Emotions on the Go, offer accessible platforms for emotional learning. World of Kids [10] is a personalized game series designed for mobile and tablet devices. It utilizes FER algorithms and voice recognition tools to provide customized learning experiences, using AndEngine, a 2D game engine library. The limitations include reliance on a local SQLite database, mainly the storage capacity and accessibility. Emotions on the Go [11] is a mobile-based emotion detection system that uses OpenFace for real-time facial expression analysis. The study incorporates Orbeus ReKognition API, AFFDEX SDK, and Fraunhofer SHORE. The study is limited by a short training duration and a small sample size.

Another approach is provided in "The Transporters" DVD series for kids ages 2 to 8. This series enhances the ability to understand and recognize emotions by using animated vehicles to represent them [4]. Despite its effectiveness, the DVD format lacks the accessibility and user-friendliness of mobile applications, limiting its broader application.

B. Technological Analysis

FER has been significantly advanced by the technological developments in machine learning (ML) and deep learning (DL). ML algorithms have shown remarkable efficiency in categorizing high-dimensional facial expression data, particularly Support Vector Machines (SVMs) [5] [12]. Viola-Jones Feature Detection System effectively manages luminosity variations by using rapid object detection and grayscale image enhancement [10]. In facial geometry detection and emotion classification, the modified eyemap and mouthmap algorithm has shown promising results, which uses TensorFlow for neural network execution [13].

In DL techniques, convolutional neural networks (CNNs) are widely used for FER due to their automatic learnability from data. CNN accuracy is significantly enhanced by ReLU activation, maximum pooling, and dropout [5]. Infant facial emotions have been recognized by pre-trained models like ResNet50, VGG19, and MobileNetV2, with transfer learning (TL) serving as an effective method to fine-tune these models [14]. Google Teachable Machine is a user-friendly platform for developing custom classification models through TL, enabling easy integration into lightweight web apps [5] [15].

In ML and DL applications, OpenCV plays a key role as an open-source tool for image processing [5]. Sefik Ilkin Serengil's DeepFace framework is prominent for its high accuracy in face recognition tasks. As evidence in its versatility, DeepFace use CNNs for facial attribute analysis

such as age, gender, emotion, and race and integrates state-of-the-art pre-trained models, including VGG-Face, Google FaceNet, OpenFace, Facebook DeepFace, DeepID, ArcFace, Dlib, and SFace [16]. Its CNN architecture is renowned for its simplicity and effectiveness in attaining competitive accuracy in emotion prediction when evaluated against benchmark datasets [17]. OpenCV and DeepFace framework combination forms a powerful tool for facial emotion analysis across various domains, including educational technology [18].

According to the existing literature, there is a substantial research gap about the long-term impact and practical validation of AI-based solutions for enhancing autistic children's abilities for facial expression production and recognition. CNN has limitations when it comes to one-dimensional training data, training stability, and feature duplication, as discovered in technological analysis. The significance of addressing these issues is highlighted by the lack of interventions tailored to the social context of Sri Lanka. It is imperative to close this gap by offering a customized and accessible solution for the intended age group.

III. METHODOLOGY

This research utilized a mixed-methods approach combining quantitative and qualitative methodologies. Data collection involved interviews, expert opinions, and questionnaires in both pre-analysis and post-analysis phases. Pre-analysis interviews with therapists, special needs educators, doctors, and parents gathered insights into existing interventions. In the post-analysis phase, discussions with experts assessed the implemented "EmoLand" application, identifying strengths, weaknesses, and suggesting future improvements. Moreover, a post-analysis questionnaire for parents evaluates the solution's effectiveness statistically.

Thematic analysis of stakeholder interviews, including Ms. Jayani Panapitiya, Mrs. S. D. Rathuwithana, therapists Mrs. Chamila and Mr. Bharatha from Cherish Foundation, and Dr. Savithri Dias, highlighted key themes such as visualization, color preferences, multisensory learning, repetitive teaching, current methodologies, challenges, technical proficiency, and recommended features. Stakeholders emphasized challenges like children's reliance on parental facial expressions and negative home experiences, alongside their proficiency with smartphones requiring parental guidance. Recommendations included a minimalist interface, familiar images, progress tracking, and engaging content.

The proposed solution in Fig. 1, "EmoLand" Phase 1 is an innovative mobile app designed to enhance facial emotional skills in ASD children. It includes Ekman's six basic emotions and integrates DeepFace framework for FER. EmoLand provides a progressive learning strategy with lessons based on familiar faces, mainly parents, to offer an interactive learning experience. Progress tracking feedback is provided through relatable social context evaluations, allowing children to practice emotional development skills in real-life scenarios. This AI-based intervention aims to support and enrich emotional development in early stages and engages both autistic children and their caregivers.

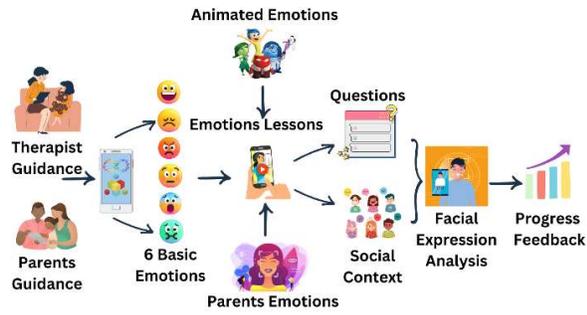


Fig. 1. EmoLand high-level conceptual solution

IV. IMPLEMENTATION

A. Technology

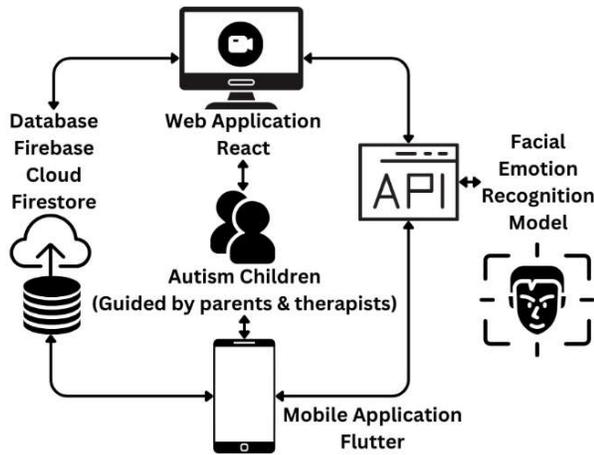


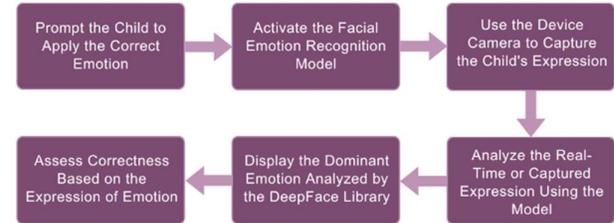
Fig. 2. EmoLand system architecture diagram

Python was used to build the facial emotion recognition model, utilizing OpenCV with Haar Cascade classifier and NumPy for image processing and face detection. DeepFace framework was significant in facial attribute analysis. Flask facilitated API development, with Ngrok ensuring secure hosting of Python APIs. The Flutter framework was used to develop a visually appealing mobile app, tested on the Android Emulator in Android Studio. Alongside, React was utilized for the web-based frontend, focusing on real-time facial emotion detection. Firebase Cloud Firestore served as the NoSQL database for storing user information. The system architecture is depicted in Fig. 2.

Facial Emotion Recognition Model

The FER model is an essential system component designed to assess children's facial emotion production skills. As shown in Fig. 3, after completing emotion lessons, the model evaluates the child's ability to express emotions and their application in real-life scenarios. The outcomes provide feedback within the app, offering insights to enhance the child's emotional development. The FER model is implemented through two methods: image-based and real-time emotion recognition. For images, Python code utilizes the DeepFace library for emotion analysis and OpenCV for face detection, processing input images and overlaying the

dominant emotion. For real-time video, frames are captured from a webcam, face detection is applied, and DeepFace analyzes emotions, providing live feedback. Both models are converted into Flask APIs, enabling seamless integration with mobile and web applications. The Fig. 4 shows the results of the real-time facial emotion recognition model.



Process of FER model



Fig. 3. Results of the real-time FER model

B. User Interface Design and Main Features

"EmoLand" mobile app User Interface (UI) design focuses on providing a practical, user-friendly experience for ASD children. It addresses the needs of ASD children emphasizing predictability and consistency. Color psychology, influenced by personal and cultural factors, is carefully applied to positively affect emotions and behaviors. Some autistic people avoid specific colors, particularly shades of red, possibly due to their universal interpretation of danger, which can trigger strong emotional actions. The UI uses easily readable fonts and minimizes complex elements to enhance usability, addressing reading comprehension challenges often faced by ASD individuals. Also, graphic cues like images and icons are included to illustrate concepts and improve understanding, based on findings from various studies. These considerations aim to design an inclusive and supportive environment for ASD children.

The mobile application incorporates components based on research and interview data analysis. Parents play an important role in the lives of autistic children, making their expressions an effective teaching tool. The application, therefore, uses familiar images of parents to effectively teach facial emotions through a unique Parent Emotions feature. Customized lessons focus on three fundamental emotions, utilizing two lesson formats, parent emotion images, and engaging cartoons images as in Fig. 5. The application features a critical evaluation component, as in Fig. 6, where children respond to emotion-based questions, display corresponding facial expressions, and upload images for assessment using the facial emotion analysis feature. If the

detected emotion matches the correct one, the child receives positive feedback, resulting in an interactive and familiar learning experience similar to the mirroring technique used in therapy. A detailed database tracks their progress, providing insights into their emotional development. The registration process ensures a personalized learning experience for children, aligning with the solution's objectives.

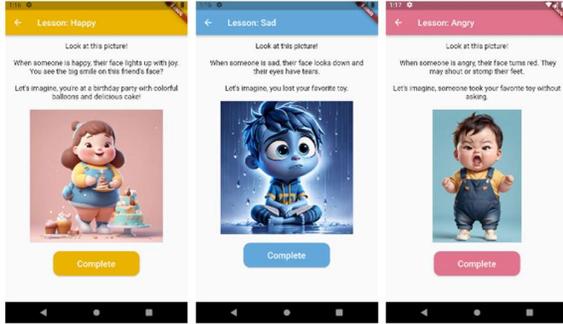


Fig. 4. Emotion Lessons Pages UI

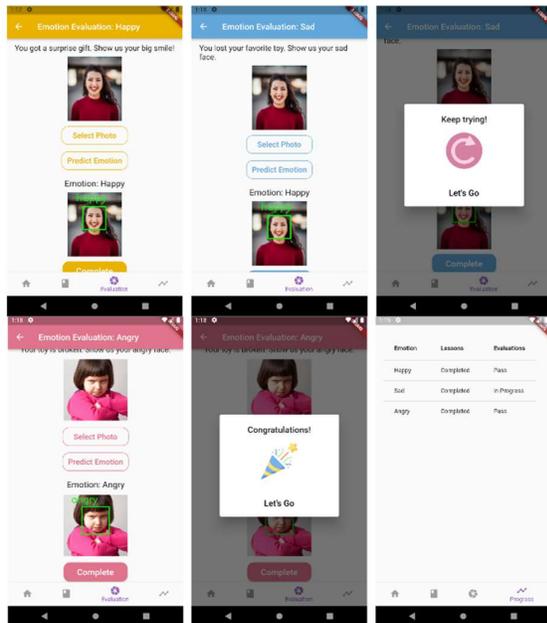


Fig. 5. Emotion evaluation pages UI

V. EVALUATION AND RESULTS

A. Model Accuracy Testing

The accuracy of the developed FER model, utilizing the DeepFace library, was assessed using a test dataset with 40 sample images per each of the 7 emotions. Python libraries facilitated the analysis, revealing varying accuracies across different emotions. As indicated in the confusion matrix, happy and sad emotion detection achieved higher accuracy likely due to their distinct expressions, while disgust and fear emotions suggested potential overlaps with other emotions, highlighting the need for differentiating visually similar expressions in Fig. 7. Concurrently, the model was

benchmarked against a Google Teachable Machine model trained on a hybrid dataset and showed varying accuracy across emotions, performing well in identifying Happy (82%) due to its distinct features but displaying lower accuracy for Angry and Disgust (40%), likely due to overlapping expressions as in Fig. 8. This comparison validated the custom DeepFace-based model's accuracy for the FER system, offering insights into performance and areas for potential improvement, with both models excelling in distinct emotions but struggling with subtle ones.

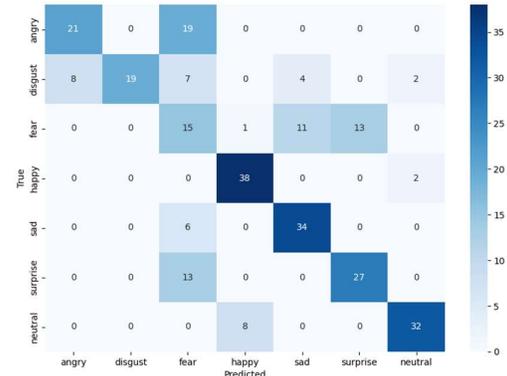


Fig. 6. Confusion Matrix of FER Model

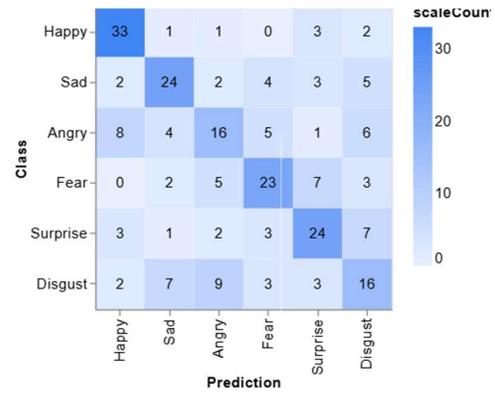


Fig. 7. Confusion matrix of Google teachable machine FER model

B. Solution Effectiveness Analysis

TABLE I. INTERVENTION RESULTS

Child	Age	Lesson Status	Evaluation Status		
			Happy	Sad	Angry
1	7	All Completed	Pass	Pass	Fail
2	7	All Completed	Pass	Fail	Fail
3	6	All Completed	Pass	Pass	Pass

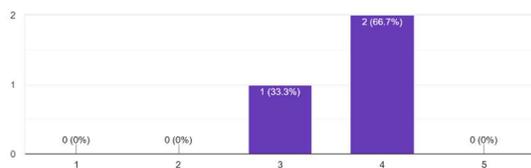
The Phase 1 prototype of the "EmoLand" application was tested with 3 ASD children currently in therapy and facing mild challenges with emotional skills. All children completed the six lessons within the app, and the evaluation results showed varying levels of success, as detailed in Table I. The findings suggest that the application prototype has differing effectiveness levels across children. While Child 3 successfully recognized and expressed all three emotions, Childs 1 and 2 encountered difficulties with specific emotions. According to the results, all the children passed the Happy emotion evaluation, likely due to the FER model's higher

accuracy to detect Happy emotion. These findings indicate that while the application effectively supports some children, individual differences and challenges play a significant role in outcomes. Further insights and refinements are necessary to personalize the application and adapt it to each child's unique needs for enhanced effectiveness.

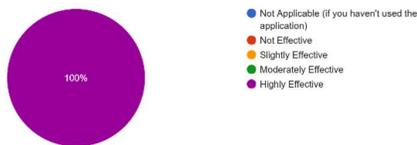
C. Expert Opinions and Survey Results

"EmoLand" mobile application is a user-friendly AI-based early intervention tool designed for children aged 2-7 with ASD in Sri Lanka. Expert discussions and feedback from parents confirmed its positive impact on emotional development. Tailored to the preferences and challenges of ASD children, the app has been praised for its visual learning approach, use of familiar images, and expression evaluation features. Survey results in Fig. 9 indicate high parent satisfaction levels, highlighting the app's usage and effectiveness. Results mentioned the need for personalization, gamification, and expanded emotion categories to sustain long-term engagement. Evaluation results from 3 ASD children provide real-world validation, aligning with research objectives to evaluate familiar images, assess AI-based interventions, and apply learned emotions to real-life contexts. These insights suggest ongoing improvements to meet evolving needs.

If yes, please rate your overall satisfaction with the application on a scale of 1 to 5 (1 being very dissatisfied and 5 being very satisfied).
3 responses



Do you find the utilization of parents' emotion images in the application effective for teaching facial emotions to children with ASD?
3 responses



How effective is the application's evaluation component in assessing a child's ability to recognize emotions and their learning progress?
3 responses

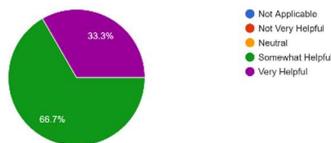


Fig. 8. Satisfaction survey results

VI. ETHICAL CONSIDERATIONS

Ethical concerns significantly impacted the personal data collection process. Privacy issues also impacted and limited the sharing of personal data and direct communication.

Furthermore, it is important to acknowledge that ethical considerations and time constraints limited the sample size to only 3 children for testing the application, which may restrict the comprehensive evaluation and validation of system effectiveness. Additionally, given the need for repetitive learning in ASD children, the relatively short testing duration of approximately 2-3 hours highlights the necessity for further evaluation to thoroughly assess the application's impact.

VII. FUTURE RECOMMENDATIONS

The "EmoLand" app shows promise for future improvements. Recommendations include expanding the emotion list, diversifying lesson delivery methods, and introducing more comprehensive evaluations. Personalization can be enhanced by tailoring content to individual needs based on age, cognitive abilities, and learning styles. Integrating voice instructions and interactive UI would create a more engaging experience. Additionally, improving the accuracy of the FER model is essential, suggesting the exploration of neural networks for enhanced emotion detection and evaluation.

VIII. CONCLUSION

The primary goal of this research was to analyze and implement an AI-based solution to improve facial emotional skills among ASD children in Sri Lanka. By conducting a thorough investigation and gathering requirements, a functional prototype was implemented. The results and effectiveness assessment indicate substantial promise for the system. The app's integration of parent emotion images and personalized lessons is highly valued. These features address an unexplored area in ASD interventions, particularly in the Sri Lankan context. Despite the current developmental challenges, the application shows strong potential for future enhancements.

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Effect of Creatine as a Supplement: A Mini-Review

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Abstract— Creatine is popular as a supplement, especially for strength and power activities. Even though most of the studies performed on creatine, have been focused on its efficacy as an ergogenic aid, there have been multiple therapeutic benefits as well. Creatine supplementation has been reported as beneficial for a plethora of medical conditions such as diabetes, heart disease, and sarcopenia. Additionally, creatine is an antioxidant, reducing the risk of progression of some cancers, reducing liver fat accumulation, minimizing bone loss, and increasing cognitive function in the aging population. Creatine is essential in cellular metabolism and the body's phosphagen energy system leading to better endurance and increased levels of energy in short time intervals such as during a sprint or a fast set of weightlifting. Usage of creatine, short-term or over a long period is safe, with no effects of renal dysfunction, gastrointestinal issues, musculoskeletal injuries, or cognitive functioning. This review article explains the benefits of creatine primarily from an athletic standpoint and concludes that creatine supplementation is safe with little to no side effects. Nevertheless, the quality and purity of creatine supplements vary significantly due to variable regulation and manufacturing procedures, which pose possible health concerns to consumers.

Keywords—Creatine, ergogenic aid, metabolism, supplements, physical performance

I. INTRODUCTION

Creatine is a general ergogenic aid used by sportspersons of multiple sports backgrounds to increase physical strength and fat-free mass, decreasing protein breakdown, and enhancing physical performance by increasing anaerobic energy capacity [1, 2]. Other than that, creatine has also been found to have therapeutic benefits regarding a variety of medical conditions like diabetes, sarcopenia, osteoarthritis, cancer, cognition, and cardiovascular fitness [3, 4]. With over 40 years of research and 700 studies on human subjects backing its potential, creatine is coined as one of the safest sports supplements currently available [5]. Most of this research has been focused on creatine monohydrate although there is a wide variety of creatine forms such as creatine hydrochloride, creatine ethyl ester, and creatine phosphate commercially available [6]. Most of these research studies have been performed with a short-term supplementation of creatine which consisted of an intensive dosing phase followed by a reduced dosage maintenance phase with concurrent heavy resistance training [7]. Although a few studies have seen positive increases in long-term endurance training due to creatine supplementation, primarily it is seen that the impact of creatine diminishes as the duration of time performing an exercise increases [7]. Thus, this suggests that creatine is better utilized during short-term high-intensity exercises such as a fast set of heavy bench press repetitions or a sprint [7]. This review article aims to provide a

comprehensive idea about the role played by creatine regarding different medical conditions and its efficacy as a sports supplement as well as the safety of creatine usage when administered over a long period.

II. CREATINE METABOLISM

Creatine (N-aminoiminomethyl-N-methylglycine) is a naturally occurring tripeptide constituted of the three amino acids glycine, methionine, and arginine and is synthesized in our bodies naturally at a rate of about 1g/day from arginine and glycine by arginine: glycine amidino transferase (AGAT) to guanidinoacetate (GAA). This GAA is then methylated by the enzyme guanidinoacetate N-methyltransferase (GAMT) with S-adenosyl methionine (SAME) to form creatine. This biosynthesis of creatine is primarily done by the kidneys, pancreas, liver, and certain regions of the brain [4]. This endogenous synthesis of creatine accounts for around 50% of the daily requirement, and the other part should be found via one's diet which is unlikely to happen with a regular omnivorous diet since creatine is primarily found in raw, uncooked red meats but is exposed to high temperatures during the cooking process denatures it [8]. About 95% of the body's creatine is deposited in muscles with the other part saved in other tissues such as the heart, brain, and testes [9, 10]. Over 60% of this creatine is in a phosphorylated form, complexed with inorganic phosphate (Pi) and deposited as phosphocreatine (P-Cr) with the other part saved as free creatine (Cr). The amount of creatine stored in one's body can be determined based on several reasons such as the prevailing muscle mass and skeletal muscle fiber type. On average, a 70kg person who upholds a regular diet including red meats and fish was found to have a total creatine pool of about 120 mmol/kg of dry muscle mass, which is around 120g-140g [11]. Due to their dietary restrictions, vegetarians are noted to possess muscle creatine and P-Cr levels approximately 20-30% lower than that of non-vegetarians. Creatine uptake is controlled by multiple processes, including phosphorylation and glycosylation, as well as the extracellular and intracellular levels of creatine. This creatine is then transported to the cells by the transporters CreaT1 and CreaT2 which is predominantly present in testes [12]. Approximately 1-2% of the muscle mass creatine pool is degraded daily into creatinine which is then removed through urine [13, 14]. The rate of degradation of creatine differs from individual to individual but is generally high when there is a greater muscle mass and elevated levels of physical exercise. Thus, to maintain optimum muscle creatine levels, a normal-sized adult might require consuming at least 2-3g of creatine per day. Wallimann and colleagues [15] reported that individuals with vegan or normal omnivore diets don't have saturated creatine stores. Since these diets typically provide either 0 or 0.75-1.5

g/day of creatine, daily dietary intake requirements may be around 2–4 g/day per person to support optimal general health.

Creatine plays a very important role in the body's energy supply. CreaT1 is mainly activated when the interior creatine levels of a cell go down and a mitochondrial isoform of CreaT1 transports creatine to the mitochondria. Creatine serves as a non-mitochondrial energy buffer, quickly transferring energy via a reversible process mediated by the creatine kinase enzyme. The energy yielded from the process of breaking down phosphocreatine into creatine and inorganic phosphate, which is around 10.3 kcals of free energy is used to resynthesize ATP via $ADP + Pi$ [16–20]. This shows the significance of creatine within the phosphagen energy system which largely contributes to rapid ATP generation in short time intervals of around 10s – 30s, which can greatly aid during intense physical exertion, where energy production is impaired or insufficient due to increased demand.

III. BENEFITS CREATINE

While most of the studies on creatine are focused upon its benefits from a physical performance standpoint, creatine has also shown many therapeutic benefits. It has been reported that creatine supplementation, when done properly, saturates the muscle creatine stores, enhancing the acute exertion capacity [9, 21] in athletes a variety of sports such as swimming [22, 23], sprint performance [24], football [25] and in strength athletes [26] among others. Although most of these in research on males, creatine supplementation has been proven to have favorable benefits on females, children, adolescents as well as older populations. As a result of these studies, the International Society of Sports Nutrition has determined that creatine “is the most effective ergogenic nutritional supplement currently available to athletes in terms of increasing high-intensity exercise capacity and lean body mass during training” with the American Dietetic Association and American College of Sports Medicine reaching similar conclusions [26].

Apart from all the ergogenic benefits, creatine supplementation has also shown many benefits from a therapeutic standpoint. Creatine supplements have proven to decrease cholesterol and triglyceride levels better manage blood lipid levels reduce the lipid accumulation in the liver [27–30]. Creatine supplementation has additionally proven to decrease homocysteine, lessening the risk of heart disease [31]. It has also been found that creatine can reduce cancer risk [31] and act as an antioxidant. The additional benefits of creatine supplementation include increasing muscle mass and strength [11], reduction of bone loss, and increase cognitive function in aging populations [30, 32].

A. Effects of Creatine on Physical Performance

When creatine is given as an oral supplement, the body's creatine pool increases. According to many studies, it can be seen indicating a positive relationship between muscle creatine uptake and exercise performance [21]. It was also seen that the body's fat-free mass significantly increased when creatine levels were increased. Concerning a meta-analysis conducted by Scott C. Forbes et al [30], supplementing with creatine alongside Intensive resistance training has demonstrated the potential to reduce body fat in adults over the age of 50 years. Volek et al [33] observed enhanced fat-

free mass, physical performance, and muscle morphology in response to heavy resistance training after creatine supplementation of 25g per day for a week followed by a maintenance phase of 5g day⁻¹ for 11 weeks. These results can be explained by the increase of the body's creatine pool, which leads to quicker adenosine triphosphate (ATP) regeneration between sets, enabling athletes to sustain a higher training intensity throughout their workouts. According to a 2003 meta-analysis [34], an average increase in muscle strength when performing 1RM (rep max), 3RM or 10RM resistance training was greater by 8% and a 14% greater weightlifting performance compared to the placebo group. R B Kreider and colleagues in their study on how creatine affected the performance in football players reported that creatine supplementation alongside a glucose /taurine /electrolyte supplement enhanced fat-free mass, bone-free mass, isotonic lifting volume, and sprint performance during high-intensity exercise [24].

Even though some researchers have shown positive effects, others have reported no statistically significant impact from creatine supplementation. Bemben et al have shown no additional positive effects by creatine supplemented combined with whey protein after 14 weeks of heavy strength training (3 days a week) to improve muscular strength and muscle mass in middle-aged men [11]. Another study reported that after 4 weeks of creatine supplementation in junior swimmers, it did not substantially enhance single sprint performance, but it did enhance swim bench test performance [22]. Jakobi et al also detected no impact of short-term creatine supplementation compared to the placebo group when performing isometric elbow flexion in both voluntary and stimulated contractions [35]. Although no effects were seen upon elbow flexion strength, significant weight gain was seen in the creatine group compared to the placebo group. These results may be caused by the possibility of the research subject groups majorly consisting of non-responders.

More recent scientific literature has conclusively found that creatine supplementation does show performance-enhancing and muscular development including a scientific summary consisting of over 100 citations reviewing the available knowledge up till 2007 published by the International Society of Sports Nutrition [9]. Hespel et al suggest that these anabolic effects have been a result of satellite cell proliferation, myogenic transcription factors and insulin-like growth factor-1 signaling [36]. This study also showed increased muscle glycogen storage and glucose transporter (GLUT4) expression, when creatine supplementation was done alongside training. Saremi et al [37] observed a difference in myogenic transcription factors when supplemented with creatine combined with heavy resistance training in healthy young males and found that the serum levels of myostatin which is a catabolic regulator of skeletal muscle mass decreasing in the creatine group.

Thus, according to most of the scientific literature, even though certain studies have identified no additional benefits of creatine supplementation, collectively it can be concluded that supplementing with creatine alongside heavy resistance training enhances physical performance in addition to promoting muscle hypertrophy.

B. Effects of Creatine Supplementation on Skeletal Muscle Hypertrophy

Other than increasing physical strength and enhancing ATP regeneration during exercise sets reducing fatigue, creatine supplementation has also shown an increase in fat free mass by promoting muscle growth. Wu et al. found that Creatine is an effective supplement for boosting muscular strength, muscle mass, and athletic performance in healthy young people with proper training in a range of dosing schemes and sporting activities [38]. In a meta-analysis by Burke et al [39] shows that creatine supplementation, when combined with a structured resistance training program, fosters a modest increase in skeletal muscle hypertrophy in both upper and lower body muscles. This meta-analysis also suggests that these muscular hypertrophic benefits are greater in young adults compared to older individuals. Another study discovers greater improvements in 1RM, lean body mass, fiber cross-sectional area and contractile protein in trained young males when supplemented with creatine monohydrate combined with a multi-nutrient supplement and resistance training[40]. This research found improvements in body composition at the cellular and sub cellular-levels in resistance-trained participants which was a novel finding. It was conducted at a supplement loading dosage of 20g day-1 followed by a maintenance phase of 0.03g/kg/day[40]. The reduction of the serum levels of myostatin [37] also promotes muscle gain as myostatin is a muscle growth inhibitor and reduction of it allows skeletal muscle hypertrophy.

Deldicque et al performed a study where out of 9 subjects, a creatine group and a placebo (maltodextrin) group were chosen and the creatine group went through a loading phase of 5 days [41]. They commented on a 250% increment in collagen mRNA, a 45% increment in glucose transporter-4 (GLUT4) and a 70% increment in myosin heavy chain IIA levels. This study concluded that within the 5 days, creatine supplementation did not improve any anabolic signaling but increased the expression of certain targeted genes which are responsible in skeletal muscle hypertrophy [41].

According to many studies, creatine supplementation has also shown a rise in muscle insulin-like growth factor (IGF-1) concentrations. IGF-1 is a hormone that controls the growth hormone levels which directly impacts muscular growth. Burke et al [39] performed an 8-week research by supplementing 22 subjects (male and female) with creatine (0.25g/kg of lean body mass per day for 1 week followed by a 0.06g/kg of LMS for the next 7 weeks) and having a placebo group containing 20 subjects (male and female), with all the participants performing a regimented resistance training plan. A 67% increase in of intramuscular IGF-1 levels has been seen after the resistance training with a greater accumulation from the creatine group (78%) compared to the placebo group (54%). The study also found no difference in the IGF-1 levels between vegetarians and non-vegetarians as well as seeing similar results between the males and females. The authors hypothesized that the increase in muscle IGF-1 concentration in the creatine group may be attributed to the increased metabolic demand caused by a more rigorous training session. These enhancing effects could be caused by the increased total creatine stores in skeletal muscles. It is probable that the addition of creatine and the preceding rise in total creatine and phosphocreatine storage may have directly or indirectly

improved muscle IGF-I production and muscle protein synthesis, resulting to an increase in muscle growth [39].

In summary, creatine supplementation has been demonstrated to enhance skeletal muscle hypertrophy when done concurrently with resistance training.

IV. SAFETY OF LONG-TERM CREATINE SUPPLEMENTATION

Given that creatine is one of the most popular performance-enhancing supplements currently available for athletes, numerous research has been carried out on the safety of creatine supplementation. Kreider et al. after conducting a study on supplementing with creatine monohydrate over a long period (up to 30g/day for 5 years) found that weight gain was a consistently reported side effect of creatine supplementation [24]. However, this weight was intramuscular water retention and fat-free mass. They concluded that none of the research shows that creatine supplementation leads to renal dysfunction, gastrointestinal issues, muscle cramping or musculoskeletal injuries. In actuality, they found that taking creatine as a supplement reduced the aforementioned anecdotally reported side effects. Longobardi I. et al [42] reported that creatine intake might enhance serum creatinine levels but has not shown any indications of renal dysfunction and has been proven to be safe for human use.

According to the Juhn MS et al [43] study, short-term use of creatine has not been demonstrated to cause any notable side effects. Juhn and Tarnopolsky [43] in their long term oral creatine supplementation study concluded that neither short-term nor long-term supplementation resulted in any harmful effects on the kidneys of healthy persons. Similar conclusions were drawn by Baracho et al. [44] where they stated that oral creatine supplementation did not lead to kidney or liver toxicity.

Based on the above research, it can be concluded that creatine usage, short-term or over a long period of time is safe or does not cause any detrimental side effects.

V. CHALLENGES OF CREATINE AS A SUPPLEMENT

Creatine supplementation is highly popular among athletes due to its possible performance-enhancing effects; nonetheless, it poses substantial quality and purity concerns that must be carefully addressed [45, 46]. The lack of consistency among creatine supplements on the market might be related to many important variables. For example, the lack of FDA regulation leads in a huge discrepancy across products, making it difficult for customers to comprehend the composition of the supplements they are purchasing [47]. Also the manufacturing process of creatine supplements might introduce potentially hazardous chemicals such as dicyandiamide, dihydro triazines, and creatinine, which must be carefully monitored to assure user safety [46]. Research suggests that some products may contain harmful amounts of heavy metals, which can accumulate in the body and create health difficulties [48]. The creatine supplement industry provides several products, including creatine monohydrate, creatine ethyl ester, buffered creatine, and micronized creatine. While creatine monohydrate is the most researched and extensively utilized, other types are marketed for their alleged benefits, although the data supporting these claims is sometimes lacking [49]. The lack of defined techniques for

testing the safety of creatine in humans raises concerns regarding contaminants and appropriate doses, as the quality control standards of these products may not meet those of medicines [45].

Also commercially marketed creatine supplements do not have the same stringent quality control requirements as medicines since they follow lower Dietary Supplement Health and Education Act (DSHEA) regulations. As a result, it is difficult to adapt the effectiveness and safety findings from published studies to everyday practice. A commercially accessible product's dosage may be higher or lower than the labeling suggests. This might affect creatine's efficacy. Lack of appropriate quality control might result in contaminants in creatine supplements, that might result in unexpected negative consequences [45]. This gap in quality control might result in changes in creatine content in supplements, possibly exposing consumers to contaminants or wrong doses, emphasizing the need to ensure the purity and quality of creatine supplements for consumer health and safety.

VI. CONCLUSION

When considering creatine, especially creatine monohydrate, it remains one of the few ergogenic aids that have dependably proven to be effective and safe for human consumption. Given that many studies have observed strength gain, muscle hypertrophy, fat-free mass gain and performance enhancement in physical exercises, the efficacy of creatine as a performance-boosting supplement for athletes is undeniable. Additionally, creatine supplementation has also shown a number of other therapeutic effects in regard to other medical conditions as well. With many studies proving that creatine does not have any detrimental side effects, it can be concluded that it is an effective and safe ergogenic aid. However, ensuring the purity and quality of creatine supplements is critical for user safety considering possible impurities and dose variations.

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Literature Review: Coping Strategies Employed by Caregivers of Dementia Patients Globally

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Abstract— The increase in the number of elderly people has made dementia a huge public health concern all over the world including Sri Lanka. Family carers, especially elderly patients who have dementia experience stigmatization, and their stress levels are usually high. This review looks at the major coping strategies adopted by caregivers by sampling 30 papers published between the years 2014 to 2024. Only those articles that met certain specified characteristics were included the included studies involved both international and Sri Lankan samples and had both quantitative and qualitative methodologies. That is, behavioral symptoms of dementia are again and again described as being pivotal sources of caregiver pressure. Some of the coping strategies that have been positively associated with health and well-being according to the literature are problem-solving, the use of social support, and prayer or other forms of religious coping. Special approaches including mindfulness-based stress reduction have also indicated positive effects in the reduction of the level of stress among caregivers. Other demographics that have also been found to affect the stress level include the gender and culture of the caregiver with female caregivers being found to be more stressed than the male ones. Currently, COVID-19 relief has made caregiving even more challenging which shows that caregivers require strong support systems and special programs. Nevertheless, the following research gaps are discernible; the dearth of geographically and socially sensitive tools, opportunities for longitudinal study, and studies involving diverse groups. Therefore, future research should aim at filling these gaps to enhance intervention strategies that can be provided to dementia caregivers about their cultural, gender, and socioeconomic backgrounds.

Keywords—elderly dementia, coping strategies, caregivers

I. INTRODUCTION

The problems of families caring for elderly sufferers of dementia are quite complex, and indeed the burdens can affect carers' mental health as well as the functioning of their bodies [1] [11]. This investigation will analyze the employment of several diverse coping strategies by the givers when faced with their stress and the strenuous nature of their jobs [2] [3] [17]. We aim to give a thorough analysis of the coping strategies adopted by caregivers for reducing stress and meeting the expectations of caregiving. For a more holistic understanding of their roles and well-being, we will also look at the difference between the coping methods that are problem-focused and those that are emotion-focused, providing both adaptive and maladaptive ones as well. Dementia leads to the condition which is described as the

process of a decline in cognitive function that involves the memory, the thinking, the orientation, the comprehension, the calculation, language, and judgment [32].

Dementia is defined as the gradual progressive loss of cognitive functions and in this form of disability, people are unable to comprehend information and undertake daily activities [32]. It is however important to note that during the early stages of Alzheimer's disease, the patient may still be capable of performing most of his or her activities. But in stage three; mild Alzheimer's, the cognitive dysfunctions are more severe, making the affected person to be more dependent on the caregivers [12] [10]. As of 2021, around 55 million people or the equivalent of the population of Texas internationally are affected by dementia, with about 10 million new cases emerging every year [32]. Most of the victims are senior citizens of 65 years and more, which shows the growing rate of dementia in the elderly society. This figure is anticipated to go up to 78 million by 2030 and 139 million by 2050, mostly because of the aging populations all around the world [3] [21]. The most common form of dementia, which accounts for 60-70% of them, is Alzheimer's disease [4] [27]. The stronger inescapable facts are urging the need for the proper survival means and for supportive social services for carers.

Dementia is one of the newest public health issues in Sri Lanka because the population of older people is growing rapidly. As per [32], it is reported that there are about 200,000 people in Sri Lanka who are suffering from dementia. This number is expected to be much higher in the future because of changes in demography and increased life expectancy. One of the most crucial concerns that are related to the aging of the population is the increasing prevalence of dementia among people who are 65 and older, thus necessitating the use of comprehensive care approaches and support systems that are suitable for the Sri Lankan context.

Caring for elderly individuals with dementia is arduous and tends to be stressful for caregivers most of the time. Responding to this type of stress properly is so vital. Problem-focused coping that depends on information seeking and respite care usage which are effective indicates that caregiver task management is one of the advantages of it [18] [25] [30]. Family-based coping, such as mindfulness and social support, serves the purpose of regulating emotional distress [6] [15]. The implementation of adaptive strategies such as maintaining a positive attitude has been related to the fact that people psychologically fare better in the end [1] [23]. The awareness of these strategies is critical for the development of the type of supportive interventions that enhance the caregiver's well-being. This review will examine and evaluate the coping

strategies used by caregivers of elderly dementia patients, aiming to bridge gaps in the literature and guide future research on caregiver well-being.

II. CHRONOLOGICAL APPROACH

Over the past decade, research on coping strategies for dementia caregivers has evolved significantly, reflecting an increasing awareness of the multifaceted challenges and diverse experiences within caregiving. Early research by [5] and [9] in 2014 focused on how effective coping interventions may decrease caregiver burden and increase well-being. These seminal contributions thus provided stimuli that further pushed research in the area, which then began to gradually move toward the positive aspects of caregiving, as seen in [6] study and [19]'s 2018 study through narratives that put a premium on resilience and personal growth from challenges in caregiving. Works by [26] considerably moved the state of knowledge toward the identification of coping measures that garner better health outcomes for carers, signalling the need for person-centered support approaches. Moving into the 2020s, new studies brought new longitudinal perspectives and pandemic impacts, charting increased stress levels but pointing out caregivers' very strong resilient responses in the face of global crises. Some, [13], brought qualitative insights to the findings, revolving around culture and emotional labor, which was very relevant to context-specific coping strategies. Innovations of the recent past—that represented an order by [12], and [16]—take another tack: new interventions and emerging trends in caregiving practices are mapping the future pathway of strategies that meld technology with community support networks [5] [14] [7]. On the other hand, such studies speak toward this fast-moving field of research not only to meet immediate challenges in caregiving but also to embrace the breadth of sociocultural contexts and innovative solutions for better quality of life for both the caregiver and the person with dementia.

III. THEMATIC APPROACH

A review of consistent themes reveals the complexity and diversity of caregiver experiences. For example, early studies by [6] and [9] looked at the importance of psycho educational interventions in identifying effective Coping Strategies to help mitigate the caregiver burden. Over time, the work of people like [5] and [19] highlighted the beneficial aspects of caregiving, such as personal growth and increased closeness of family relations, thereby negating the storyline that had been so definitively based on negative impacts. [26] characterized the coping strategies used by a caregiver as falling into one of three (distinguishable) categories: problem-focused, emotion-focused, and meaning-focused strategies with differential effects on the well-being of the caregiver. Further research on this was catalyzed by the COVID-19 pandemic, with evidence found in places like [12], and [18]. Such studies have previously shown high levels of stress alongside adaptive coping responses in granting one the chance to counter high-pressure situations. On the other hand, contribute works to this aspect are those of [13] and [20], since this brought forth deeper cultural differences in coping strategies and delved deeper into the symbolic or emotional labor involved while caregiving. This therefore brought up issues with culturally sensitive support systems. Recent studies by [8] and [16] point toward the future of caregiving,

with an emphasis on technological interventions and community-based support models. These thematic approaches underscore the evolving nature of caregiving research, expanding beyond traditional models to include resilience, cultural contexts, and innovative solutions that enhance caregiver well-being while improving care for individuals with dementia.

IV. METHODOLOGICAL APPROACH

In research on coping strategies among caregivers of persons with dementia, a wide variety of methods are applied to meaningfully capture this experience of caregiving. Probably, earlier studies, such as those done by [5] and that of [9], utilized quantitative methods normally applied in assessing intervention effectiveness, structured questionnaires, and standardized rating scales measuring burdens among caregivers and Coping Strategies. These studies initiated the establishment of baseline data on prevalence and impact, focusing on statistical analysis for the identification of correlations and predictors of caregiver well-being. Taking this first ground of studies as a steppingstone, researchers such as [6], [19] included qualitative study designs that empowered them to use in-depth interviews and thematic analyses in search of lived experiences by caregivers and more fine-grained coping strategies. Qualitative approaches underlined themes to the works on resilience, personal growth, and relational dynamics in caregiving contexts. Other important contributions from Snyder et al. also made a strong case for methodological diversity with a mixed-method design that availed itself of not only quantitative assessments of coping strategies but also qualitative understandings of caregiver narratives. In this way, the hybrid design afforded excellent opportunities for much deeper insight into Coping Strategies, together with good potential for data triangulation and exploration of the complex ways in which caregiving is known to impinge upon caregivers' lives. Longitudinal methods have been drawn on in recent research by, for example, [12]; [18], [17] investigating time-sequential responses to coping in the context of emerging challenges associated with providing informal care, such as those presented by the pandemic caused by COVID-19. Longitudinal studies contributed valuable insights into adaptive strategies by informal carers over time, these views underlined resilience and variability in coping efficacy across phases. Cultural and regional perspectives, explored by [13] and [20], placed the important contextual approaches that frame diversity in coping modes and emotional labor in global contexts of care. Some of the new methodologies, such as those put forward by [8] and [16] appear to combine technology-driven assessment with community-based participatory research for gains in scalability and effectiveness for caregiving interventions. These changes are ones that give nuance to the understanding of coping strategies among caregivers for those with dementia; they foster interdisciplinary collaborations and result in innovations for improvement in caregiver well-being and quality of care for those living with dementia.

V. THEORETICAL APPROACH

The investigation of various Coping Strategies used by carers for people with dementia reveals theoretical underpinnings in multiple techniques that can assist shed light

on the psychological, social, and relational dynamics embedded in informal caregivers' experiences. As an example, the initial studies by {Chen et al. Sun, 2014) explored the process of appraisal and coping by examining how caregivers evaluate and respond to dementia care challenges using stress and coping theories based on the Lazarus-Folkman transactional model of stress (Lazarus & Folkman, 1984). In these models, the focus is on the interactive effects of caregiving demands (stressors) and caregiver coping resources (e.g., social support, problem-solving skills). Within these theories, it is the cognitive appraisals of caregivers that are key to how they cope with their stress and in turn impact their own well-being.

On this foundation, [6] built the Skin Intersection Prediction method, which is applied herein. and [19] applied the resilience perspective to explore how family in adversity copes predominant elements of what they do (from a resource-based point of view) despite faced with adversities, render strengths and derive meaning from providing care for their wards. The resilience model points to an in-built ability of the individual to recover and thrive after exposure to a stressor which informs us about what accounts for preventing caregiver burnout or psychological adaptation. It highlights how caregiving causes trauma, and that caregivers can grow stronger in resilience responses to these demands [28] [29]. In addition, stress theories or resilience theories look at how the human being copes with stress, strain or a traumatic event in one's life. It focuses on the active construction of the individual assets and resources, which might help the people remain psychologically healthy or become healthy if they are currently unhealthy, in any given stress inciting circumstance. According to the resilience theory in caregiving, it explains how caregivers of patients with chronic diseases such as dementia can strengthen their coping mechanism to handle the demanding responsibilities that are associated with the role. It also emphasises the need for such elements as social support, problem solving, positive reappraisal in promoting the adaptive coping strategy in the context of care giving stress.

[26] [24] made an additional contribution to that literature by applying positive psychology theory, which is designed to enhance well-being via strengths-oriented coping strategies. None of which do they directly emphasize that well-being and caregiving effectiveness will depend on fostering positive emotions, resilience, or coping efficacy among caregivers.

Just in the space of a few years, there has been an increased integration of ecological systems theory in the study of caregiving in relation to families, communities and society in general. This theory, as further defined in more recent literature, investigates how macro factors such as policies, cultural norms and the like co-exist with the individual experiences of the caregivers. Using this framework, researchers argue that considering various levels of impact is critical while designing comprehensive support measures for caregivers [6] [31] [22].

There have been attempts to understand the concepts from a culture and meaning making angle, for instance studies by [13] and [20] who brought religious aspects to the fight against dementia care phenomena that have been ignored by previous researchers show. These points of view help to expand the

picture of caregiver's different faces and highlight the need for culture-tailored therapy programs.

At last, as in the case with [8] and [16] where they advocate for divorce stigma theory as the emerging contemporary correct Psychology, Theoretical contribution, intersectional and feminist. These frameworks reveal the disparities which emerge when the variables of gender, race and class are applied on the caregivers and their coping resources. Amalgamation of such eclectic theories proposes that the research on coping strategies for dementia caregivers is cross-disciplinary, lively, and focused on improving the resilience of caregivers and quality of care brought to patients suffering from dementia.

VI. TRENDS AND PATTERNS

Baseline studies by [5] and [9] highlight the importance of psychoeducational support and social networks in managing caregiver burden. Based on these investigations, [5] and [19] emphasized the positive aspects of caregiving, such as personal growth. and stronger family relationships. [26] COVID-19 outbreak It has clearly changed research trends. Studies by [12] and [18] document increased caregiver stress amid unprecedented challenges. and explore coping mechanisms Qualitative research by [13] and [20] highlights the cultural specificity of coping strategies. and emphasize the need for culturally tailored support systems.

New research by [8] and [16] highlights a new direction. This includes technology-focused interventions and community-based participatory research. These trends point to a movement towards a more holistic approach. It integrates knowledge from neuroscience and medicine with social and environmental factors such as positive psychology. and cultural sensitivities. However, this move comes with many impacts and challenges. While technological interventions are likely to increase ethical considerations related to privacy, accessibility, and their potential to further exacerbate the digital divide, integrating these innovations with existing theoretical frameworks may Existing caregiver support models need to be reevaluated to accommodate new technological and methodological advances. Future research should critically evaluate these emerging trends. Deal with potential challenges and adjust it to be in line with the specified theoretical framework. To ensure that new interventions Not only effective but it is also ethically and contextually appropriate. To explore these effects Researchers can better understand how to leverage technology and community approaches to effectively support caregivers. At the same time, the broader theoretical and practical context is considered.

VII. DEBATES AND CONTRADICTIONS

Research on coping strategies for caregivers reveals varying effectiveness, with some focusing on emotion regulation and problem-solving techniques, while others highlight challenges in implementing these techniques. Caregiving can be hazardous for caregivers, but it can also lead to personal development and bonding. The COVID-19 pandemic has further exacerbated these issues, with caregivers experiencing higher stress levels and altered Coping Strategies. The pandemic has exposed disparities in access to support services and worsened pre-existing problems. These

inconsistencies highlight the need for complex approaches considering the variety of caring experiences and the intricate relationships that shape caregiver well-being.

VIII. THE MAIN CRITICISM

Many studies of caregivers, such as Snyder et al.'s study, face important methodological limitations and generalization problems. These studies are often based on cross-sectional designs and self-report measures. This may not capture the changing nature of the caregiving experience over time. The need for culturally sensitive research methods is also highlighted by the diverse and heterogeneous nature of the caregiving population. This includes variation in relationships and care environments. This diversity complicates the development of universal interventions. To overcome these limitations Future research should consider specific methodological innovations. Longitudinal designs are important to track changes in care experiences and intervention effectiveness over time. By collecting data at many points. Researchers can better understand how survival strategies and support needs have evolved by adopting mixed methods, such as combining quantitative inquiry with qualitative interviews or focus groups. It can provide a more detailed perspective on caregivers' experiences and challenges. Interdisciplinary cooperation is also important. Partnering with experts in fields such as psychology, sociology, and cultural studies adds value to research. and help ensure that interventions are tailored to diverse cultural and socioeconomic contexts. This approach can help develop more effective and culturally sensitive support programs. Moreover, involving caregivers in the research process can increase the relevance and applicability of the results. This ensures that the intervention is based on real-world experiences and needs.

By embracing these methodological advances and collaborative efforts, Researchers will be able to produce more robust and generalizable results. This will ultimately lead to better support services and interventions for dementia caregivers around the world.

IX. RESULTS

A review of studies on coping strategies used by family caregivers of people with dementia reveals several patterns and insights. The research methods used are widely diverse. It covers both quantitative and qualitative approaches. Quantitative studies often use surveys and structured measures to assess survival strategies and stress levels. Qualitative research, on the other hand, relies on interviews and focus groups to record caregivers' lived experiences. The review focuses on peer-reviewed journal articles from 2014 to 2024, which guarantee a combination of high-quality studies with robust methodologies from diverse geographic and socio-economic contexts. in geography the study covered a wide range, with 37.4% centered in Ghana and Israel, 25% with urban caregivers, and 18.8% with rural and low-income caregivers. Among the identified coping strategies, this distribution highlights the different contexts of care [4] [23] [29]. Mindfulness was mentioned most often. Religious or spiritual coping was found in 27.3% of studies, followed by religious or spiritual coping at 22.7%. Emotional and practical support were found in 18.2% of studies, while psychoeducational programs were found in 13.6% of studies.

The remaining 18.2% included other strategies. Stress levels among caregivers varied, with 41.2% having high stress, 29.4% moderate stress, and 17.6% reporting little or no stress. Key research topics included developing coping strategies (20%), the importance of two support systems (20%), and the emotional and psychological stress of caregiving (20%).

Despite these discoveries, there are still several important gaps in literature. Specifically, 16% of studies emphasized the need for long-term research to inform long-term survival strategies, while another 16% emphasized the inclusion of more diverse populations. Additionally, 12% of studies called for better evaluation of existing interventions, and 12% supported comparative research to assess the effectiveness of different survival strategies in different contexts. To address these gaps Future research should focus on developing and validating a more context- and culturally sensitive framework for studying caregivers from marginalized areas. Exploring the causes of stress at different levels Among caregivers and evaluating the long-term effects of different survival strategies on the absence of two caregivers is also important. Interdisciplinary collaboration and innovative methodological approaches such as mixed methods and longitudinal designs. It can improve the development of personalized interventions and support systems for caregivers in diverse cultural and socioeconomic contexts.

X. LIMITATIONS

In fact, most investigations on patterns of coping among caregivers are associated with several methodological issues, especially in the analysis of different samples of caregivers. Most of the prior work is cross sectional and uses self-report assessment of coping, which fails to capture the temporal processes and trends regarding coping strategies. This restriction prevents the identification of the dynamic development of caregivers' coping strategies. Thirdly, self-report measures for the most part are subjected to such inherent biases like socially desirable or recall bias that can distort actual multi-faceted and nuanced realities of caregivers.

Another imminent issue is the fact that most of the studies are carried out in western high-income countries. It also restricts its generalization of the study to findings concerning caregivers in other geographical regions or other strata of the society with different SES. For instance, cultural approaches to stress management and care may be left out, and therefore the approaches of caring for the caregivers that may be developed in one region may not be as effective as they should be.

Hochwald and colleagues' recent works have seen it necessary to adopt culturally sensitive assessments when conducting research on coping strategies for different cultures. One of the important considerations to be addressed in this area is how to develop research instruments which are suitable in capturing variations in cultural practices of caregiver roles. Such tests need to be culturally sensitive, and therefore, must be nationally integrated with the help of more community members and cultural sensitivity gurus, and co-authors.

To overcome these limitations in the future, researchers should employ longitudinal designs to examine the patterns of coping strategies changes over the time and apply multi-

method research design to better capture caregivers' experiences in terms of both, quantitative and qualitative aspects. In the same vein, researchers need to create and calibrate culture appropriate assessment instruments and try to incorporate diverse populace in the study to boost the external validity of results. With these methodological and theoretical advances, the subsequent research will help in identifying the factors influencing the use of treatment and support services by caregivers of dementia patients cut across various cultures and income level.

XI. RESEARCH GAPS

However, there is a silent area in the literature especially dealing with the effect of cultural differences on coping styles. There have been recent attempts by some scholars, including [13], as well as [20] to explore how cultural norms, beliefs and systems or structures influence caregiving experiences, but more is still needed. There is a need to know more about these cultural aspects that influence the selection and importance of coping strategies for caregivers of different origin. It is therefore essential to fill this gap with the aim of fostering culturally appropriate interventions targeted at identified caregiving populations. This could be done through cross cultural research or in culturally sensitive indigenous population-based intervention research where those affected by the diseases; the caregivers are involved in formulation and execution of the strategies.

Another area which needs further study is the proposal to do a longitudinal study. While the presented results provide rather limited insight into the future dynamics of caregiver coping strategies, most prior research is even more constrained in this regard by either concentrating on the short-term changes of the disease or providing no follow-up assessment altogether. Longitudinal research would give a better grip on how such milestones affect such people and help in designing interventions that would assist caregivers at all the stages of dementia care. Such studies could work in low resource settings can however be challenging and may need complex strategies including use of mobile technology to reach participants or engaging local organizations to keep follow-up of the participants.

Second, there is a relative dearth of extant literature on how multiple dimensions of identity, including the caregiver's age, gender, social class, and his or her relationship with the care-recipient, influence the caregiving process. These demographic factors therefore do affect coping behaviour and the ability to access support in one way or the other. Closing this gap could include developing interventionist strategies from both the healthcare providers, social scientists and policy advisors with multi factorial approaches that may fit the caregiving needs of the different caregivers.

XII. RECOMMENDATIONS

Cultural relevance is therefore instrumental to the process of support programming since it touches on diverse cultural orientation and working up coping strategies. But the main problem is the correct use of cultural and gender sensitive measures, which is not always easy. Incorporation of culture in the existing programs can be challenging given the differences in cultural practices and thus the effort is

demanding. Another issue that may come up is some resistance from some caregivers, especially those who have been trained in the traditional way or those who may see some cultural changes as irrelevant. To overcome these difficulties, we should engage the community stakeholders in the development and assessment of the support programs to have the focus on the appropriateness of interventions.

It is therefore important to have longitudinal study designs about change of coping strategies at different time periods as well as evaluation of effectiveness of the different interventions that are implemented. Still, it can be challenging to conduct such studies because of attrition and funding, in general, the difficulty of following up on caregivers over several years. These factors may pose challenges to researchers and hence might require the use of new technologies, for instance, digital means of data assessment and distant assessment.

There is the need to apply intersectional approaches when addressing supports services since different aspects of the caregiver roles (for example, age, gender, or socioeconomic status) influence the effectiveness of support interventions. Nevertheless, setting up and employing these strategies demand massive data and cross-disciplinary cooperation to make sure that interventions meet certified caregivers' requirements.

In order to develop evidence-based practices, the interventions need to be examined for their relative efficiency. This involves the use of well-coordinated research and analysis to establish which endeavour can be most beneficial.

Last, effective collaboration and communication between research scientists, treatment givers, decision makers, and members of the community for integrating research findings into practice recommendations and influencing policies that will augment caregiver quality of life and dementia care across the world. This will therefore be very important in implementation and advocacy as some may have different priorities and / or little resources.

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Conversion of Waste Glycerol to Bioethanol via Fermentation: A Review

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Abstract— The exponential growth of population and industrialization lead to excessive consumption of fossil fuels. Dwindling fossil fuel stockpiles and elevated environmental dilemmas drive researchers to discover renewable energy sources. Bioethanol is captured worldwide attention as a biofuel due to its clean performance and renewable nature. However, the usage of traditional food crop feedstock for bioethanol production has caused a negative impact on food production and land competition. Thus, replacing the conventional feedstock with an alternative is pivotal. Approximately 10% of glycerol is formed as the primary co-product in biodiesel production during the process of transesterification. Crude glycerol consists of impurities that are harmful to human health. Purification of glycerol is convenient to convert it to a value-added commodity. The high cost associated with the purification process made the procedure infeasible for small and medium-sized producers. Within the circular economy, crude glycerol becomes an alternative to produce bioethanol through microbial fermentation. Aerobic and anaerobic are the major metabolic pathways associated with the fermentation procedure. Many microorganisms readily convert glycerol to bioethanol with various productivities under different physiological conditions. Optimization of fermentation parameters observes a high yield of bioethanol. Even the glycerol acts as a potential substrate, some undesirable drawbacks are still affiliated with bioethanol industrialization regarding favourable yield. This review mainly explores the conversion of low-cost glycerol waste to bioethanol via fermentation and fermentation kinetics of bioethanol. The value addition, characterization, and purification of glycerol are also highlighted along with future prospective.

Keywords— bioethanol, glycerol, kinetics, microbial fermentation

I. INTRODUCTION

The increasing demand driven by a complex lifestyle and growing population has intensified resource utilization, predominantly from non-renewable sources unable to meet current needs, thereby escalating costs. This trend has spurred research into technologies that utilize industrial or domestic waste and byproducts to generate valuable resources [1–3]. Among these resources, ethanol has emerged as a focal point for global production advancements. Ethanol is primarily produced through two main methods: biomass fermentation and ethylene hydration. Pre-treatment, fermentation, distillation and dehydration are the sequential stages [1,4]. Ethylene hydration, a chemical process catalysed by phosphoric acid, converts ethylene and water into ethanol [5]. The United States, Brazil, Canada, China, and the European Union dominate the global ethanol production landscape. The world's biggest producer of ethanol is the United States which primarily utilizes corn [6].

The traditional way of sugar and starch crops utilization as feedstock for bioethanol production has considerably elevated a negative impact on food production, increment of food prices, a shortage of fodder, and growth of competition for land [7]. Considering the above undesirable impact on food production, the usage of alternative substrates for bioethanol production became important. Since worldwide crude glycerol prices are decreasing and availability has continued to increase; a surplus of crude glycerol has been created. With that, ethanol fermentation using glycerol as an alternative substrate has become a promising substitution for manufacturing bioethanol and eliminating harmful effects on the environment [1,8].

The terms glycerin, glycerol, and glycerine are often used interchangeably, though there are slight differences in their definitions and usage. Glycerol refers to pure 1,2,3-propanetriol. Glycerine is the common commercial name for products primarily composed of glycerol. Glycerin refers to purified commercial products containing 95% or more glycerol [9]. Refining pure glycerine from the waste by product mixture (crude glycerol) is challenging due to various complications. The high costs associated with purification methods make this process particularly expensive for small and medium-scale plants. Additionally, the historically low market price of crude glycerol and the negative environmental impacts of improper glycerol disposal drive researchers to develop methods for converting it into value-added products [10]. Their primary focus is on transforming low-cost glycerol into valuable products. One promising method is producing bioethanol from glycerol through fermentation. This technology is an attractive and viable option for utilizing waste glycerol, as it is feasible and economical for both small and large-scale plants, with minimal environmental impact. Moreover, it significantly contributes to the production of bioethanol, a widely used alternative biofuel [11]. The review aims to discuss a practical and cost-effective method of using a significant glycerol excess to produce bioethanol, a substitute energy source, through inexpensive fermentation, thereby contributing to meeting the rise in energy demand. It is also noted that there is still a knowledge gap about the fermentation kinetics of ethanol generation from glycerol.

Under such background, the review mainly focused on the conversion of crude glycerol to bioethanol via fermentation and fermentation kinetics of bioethanol. This also provides a review of glycerol purification techniques and qualitative and quantitative analysis of glycerol and glycerol-based value-added products.

II. ORIGINATION OF RAW GLYCEROL FROM BIODIESEL PRODUCTION

Glycerol is obtained as the primary co-product of biodiesel production from vegetable oil through transesterification, which is considered the most economically viable method for biodiesel production. During the transesterification reaction, a 3:1 molar ratio of alcohol to triglyceride is used, producing three moles of esters and one mole of glycerol. Generally, crude glycerol is the main by-product of biodiesel production, with significant quantities (8% to 10%) produced during the transesterification process [8]. After a successful transesterification reaction, methyl ester and glycerol separate into distinct layers due to their polarity differences, allowing for easy separation. Methyl ester is nonpolar, while glycerol is polar [9,12].

III. RAW GLYCEROL PURIFICATION TECHNIQUES

In the literature on glycerol purification techniques, the most commonly applied methods are distillation, ion exchange resin, membrane separation technology, and acidification, followed by neutralization and solvent extraction [9]. Acidification is a common strategy to neutralize impurities like catalysts into inorganic salt [12]. Since the acidification process doesn't eliminate all impurities, it needs further purification to remove other contaminations like methanol, oil, water, and ester. However, the distillation process has some restrictions over others as it requires high energy input for vaporization and causes thermal decay [13]. Additionally, a high vacuum is also demanded [14]. Moreover, this operation involves high capital investment and maintenance expense, followed by considerable losses of glycerol [15]. In comparison, the ion exchange process is gathering wide acceptance due to its simplicity of operation, low power consumption, and energy demand, as well as the fact it has also proven efficient in taking off traces of impurities, colour, and odour [16]. In a resin-supported column of glass tube the ion exchange resins are used. They mainly absorb the free cations and anions which contaminate the glycerol [17]. Membrane filtration is an emerging technology and is much fetching because of its simple operability, low energy necessity and thus low cost, good purification performance of up to 90% weight glycerol output, and environmental friendliness [18]. A combination of any of these techniques in single or multi-stages has been utilized for glycerol purification, and according to research, this produces high-purity glycerol of more than 99.2% purity [13].

IV. RAW GLYCEROL CONVERSION TO VALUE-ADDED PRODUCTS

An increment in the exploration of crude glycerol directly for the production of value-added products has been observed in recent times. Different technologies are available for glycerol conversion to value-added products. These are biological conversion, chemical conversion, thermochemical conversion and catalytic conversion [19,20].

A. Biological Conversion

Biological conversion utilizes microorganisms and enzymes for the conversion of glycerol either by aerobic or anaerobic metabolism [9,21]. These biological reactions are carried out in a large bioreactor under aerobic, anaerobic, or micro-aerobic conditions as per the demand of different microorganisms [22]. 1,3- propanediol, ethanol, citric acid, n-butanol are some value-added products obtained via

biological conversion of glycerol using *Klebsiella oxytoca*, *Enterobacter aerogenes*, *Yarrowia lipolytica* and *Clostridium pasteurianum* respectively [18]. For a successful conversion it is important to use microorganisms tolerant to impurities in crude glycerol [19].

B. Chemical Conversion

Different value-added products are obtained such as polyglycerols, ethers, ketals, solketa, polyglycerol esters, 1,3-propanediol, malleated glycerides from the chemical processes in various industrial applications via different pathways such as polymerization, etherification, ketalisation, acetalization, esterification, dihydroxylation, and mellenization of glycerol respectively [18,19].

C. Thermochemical Conversion

Thermochemical conversion of glycerol via steam reforming, gasification, pyrolysis, and partial oxidation are acceptable methods for converting glycerol into useful forms. Carbon monoxide, methane, hydrogen, syngas, and carbon dioxide are major products produced by thermochemical conversion [9].

D. Catalytic Conversion

The conversion of glycerol to value-added products like tarttronic acid and 1,2-propanediol with the use of catalysts either basic or acidic, homogeneously or heterogeneously is termed catalytic conversion. Mostly, due to the high selectivity heterogeneous catalysts are preferred commercially. When considering each conversion method, each of them has its pros and cons from both environmental and economic points of view. Biological conversion is more economical and less polluted than chemical, thermochemical and catalytic conversions. Biological conversion needs less capital investment and lower maintenance and labour costs than other methods [19].

V. CONVERSION OF GLYCEROL TO BIOETHANOL VIA FERMENTATION

Bioconversion of crude glycerol to ethanol is carried out via aerobic and anaerobic fermentation processes from microbes [23]. Ethanol produced in these ways is affected by the glycerol concentration [24]. The first step in the passage is the movement of glycerol into the cell by simple permeases, or the cell's facilitator proteins via diffusion or active transport mechanism. The aerobic and anaerobic metabolic routes are the two main methods by which microbes transform glycerol into essential glycolytic mediates [25]. Glycerol kinase aids in transforming glycerol into G3P (glycerol-3-phosphate) during the aerobic pathway when oxygen is present. Next, through a NAD⁺-based G3P dehydrogenase, DHAP (dihydroxyacetone phosphate) is subjected to oxidation and offers one mole of NADH (Nicotinamide adenine dinucleotide hydrogen) The oxidation of glycerol to dihydroxyacetone (DHA), which yields a single mole of NADH, is the initial step in both aerobic and anaerobic passage [26]. Dihydroxyacetone kinase then converts DHA to dihydroxyacetone phosphate. Then dihydroxyacetone phosphate is followed by pyruvate. Then pyruvate to acetyl CoA, then acetaldehyde, and finally to ethanol [8,26]. Research shows many microbes efficiently convert glycerol to ethanol via fermentation under different conditions as mentioned below. *Saccharomyces cerevisiae* and some other microorganisms can be successfully genetically modified for widespread usage with the

contribution of metabolic engineering [1]. The regulatory factors of bioethanol production are; temperature, pH, transportation of metabolites within and outside the cell, carbon source, etc. Even though glycerol utilization provides a high yield, undesirable drawbacks are still associated with industrialization such as slow consumption rates of glycerol and unfavourable productivity. With that industrial-scale bioethanol production with low cost and high yield is still challenging [8].

VI. ANALYSIS OF ETHANOL AND GLYCEROL AND PRODUCT CHARACTERIZATION OF GLYCEROL

Detection of ethanol and glycerol concentration during microbial fermentation is important. Gas chromatography (GC) paired with a flame ionization detector and HPLC; high-performance liquid chromatography with a Bio-Rad Aminex HPX-87H column are the most common methods applied in many research methodologies to detect ethanol and glycerol concentration [7,27]. Other than this, ethanol assay kits-Megazyme, K-ETOH and glycerol assay kits such as Megazyme, and K-GCROL have also been employed [28]. Another rapid, spectrophotometric method has been developed for glycerol concentration analysis. Which is the periodate-chromotropic acid method [29].

Characterization of crude glycerol is more important to its value-added conversion in many industries. The water content can be measured according to the standard method ISO 2098-1972 by using the Karl- Fisher titrator V20. The ash content can be analysed with the standard method ISO 2098-1972 by burning glycerol in a muffle furnace at 750 0C for 3 hours or by oven calcinations at 520 0C until white ash is produced. Regarding AOCs recommended practice Cc 17-95 and ASTM D 4662-08, the soap content of crude glycerol can be determined. The alkalinity of crude glycerol is found according to ASTM D 4662-08 and used to adjust the soap content. Elemental analysis of crude glycerol is done by ICP-MS (Inductively coupled plasma mass spectrometry) and Fourier transform infrared spectra (FT-IR), ¹H NMR, and ¹³C NMR (nuclear magnetic resonance) spectra are also employed in research studies [30].

VII. CONCLUSION

Dependence on fossil fuels is increasingly untenable due to rising global energy demands, necessitating the development of alternative and renewable fuels for both economic and environmental sustainability. Bioethanol is in high demand as an alternative fuel, highlighting the importance of a continuous and systematic feedstock supply for ethanol production. Biodiesel production, which yields about 10% crude glycerol as a byproduct, faces the challenge of managing this surplus to maintain economic sustainability and meet environmental protocols. Researchers are exploring cost-effective methods to valorize crude glycerol, such as its use in bioethanol production through microbial fermentation, which can also contribute to waste utilization and renewable energy production. While some advancements have been made, including the use of genetically engineered microbial strains to increase ethanol yield, there remains a knowledge gap in the fermentation kinetics of ethanol production from glycerol, essential for industrial-scale efficiency. Thus, further research is needed to improve these technologies. Given the growing population and vehicle numbers, bioethanol alone cannot meet the energy demand, necessitating government regulations to ensure a sufficient bioethanol supply. Promoting bioethanol over petrol and diesel is also crucial. Biodiesel, derived from the transesterification of vegetable oil, cooking oil, or animal fat, produces glycerol as a byproduct, and its surplus has led to a low market value. Direct disposal of crude glycerol is hazardous due to impurities, making it preferable to convert to value-added products through biological and chemical methods. This glycerol can be used as a substrate for bioethanol production via microbial fermentation, feasible for small-scale industrialization. Understanding fermentation kinetics and optimizing reaction conditions are key to maximizing ethanol yield from various microorganisms, with techniques like HPLC and GC used for analysis. Bioethanol, a renewable and eco-friendly fuel, blends with gasoline and is effective in reducing greenhouse gas emissions while addressing fossil fuel scarcity. Additionally, ethanol has potential applications in various commercial industries.

TABLE 1. MICROORGANISMS USED FOR ETHANOL PRODUCTION BY FERMENTATION PROCESS FROM GLYCEROL WASTE

Microorganisms	Ethanol yield or productivity	Microorganisms	Ethanol yield or productivity	Microorganisms	Ethanol yield or productivity
<i>K. cryocrescens</i> S26	27 g/L, 0.61 g L ⁻¹ h ⁻¹	<i>P. tannophilus</i> Y-475	0.63 ± 0.02 g L ⁻¹ h ⁻¹	<i>Klebsiella variicola</i> TB-83D	14.6 g L ⁻¹
<i>Enterobacter aerogenes</i> ATCC 13048	12.8 g L ⁻¹	<i>Enterobacter sp.</i>	50.77 mmol L ⁻¹	Mixed cultures of <i>E. coli</i> CECT432, <i>Enterobacter cloacae</i> MCM2/1 <i>E. coli</i> CECT434,	1.21 mol mol ⁻¹
<i>Enterobacter aerogenes</i> TISTR 1468	12.33 g L ⁻¹	<i>Klebsiella aerogenes</i> ATCC 29007	51.09 mmol L ⁻¹	<i>Enterobacter aerogenes</i> KKU-S1	116.2 mmol L ⁻¹
Recombined strains <i>Ogataea polymorpha</i>	10.7 g L ⁻¹ 3.55 g L ⁻¹	<i>K. pneumoniae</i> Kp17	17.3 g L ⁻¹ , 0.59 g L ⁻¹ h ⁻¹	<i>Saccharomyces cerevisiae</i>	2.4 g L ⁻¹
		<i>Pachysolent amophilus</i> CBS404	28.1 g/L, 0.11 g L ⁻¹ h ⁻¹	<i>Escherichia coli</i> K12	3.6 g L ⁻¹

(Source: [31], [32], [33], [34], [35], [36], [36], [37], [1], [38], [39], [40], [41], [42], [28])

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POSTER PRESENTATIONS

Developing Healthy Initiatives to Encourage Healthier Food Choices in Sri Lankan Supermarkets

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Abstract— Promoting the awareness and adoption of healthier food choices is crucial for enhancing the overall health of the population. In Sri Lanka, the rise of modern food retail environments, such as supermarkets, are leading to a change in the dietary habits of people. Unhealthier food habits is a major reason in the current alarming increase in non-communicable diseases. To address this issue, a cross-sectional survey was conducted involving 1067 participants to understand supermarket consumers' perceptions of healthy food choices. The survey results indicated a strong consumer interest in learning about healthy food options. Thus, this research further aimed to develop innovative initiatives for supermarkets, including the creation of a comprehensive guidebook that classifies food items as "healthy" or "unhealthy" based on their nutritional composition and relevance to the health status and dietary needs of the local population. The guidebook was compiled using the latest scientific literature on food, disease prevention, and established dietary guidelines. Research articles were sourced from databases such as Google Scholar and PubMed, using defined inclusion and exclusion criteria. A panel of nutrition experts meticulously evaluated the guidebook's content to ensure accuracy and relevance. The outcome of this research is a comprehensive guidebook (ISBN 978-624-97482-1-7) that features tailored healthy food selections linked to specific health conditions, age groups, and nutritional needs of various population segments. This guidebook serves as a practical resource for supermarket management, guiding to promotion of healthier food choices. It aims to facilitate changes within the store environment and support economic and educational interventions to encourage healthier dietary habits among supermarket customers.

Keywords— Dietary Guidelines, Food Retail Environment, Healthy Food Choices, Supermarket Intervention

Plastic Degradation Methods: A Review

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Abstract— Plastic is a versatile invention with a wide range of applications in medicine, engineering, agriculture, and other industries. However, its large release and accumulation in ecosystems and organisms, has caused plastic pollution which has become a pressing public and environmental concern. As a result, there is a growing demand for sustainable methods to manage and eliminate plastic waste. Studying the composition and properties are essential because it can provide insights into various degradative methods, solutions and alternatives to plastic waste. Plastic degrades naturally through external environmental factors such as sunlight, temperature, and biological activity, but it takes hundreds to thousands of years. In response to public and governmental pressure, manufacturers are modifying polymers to accelerate their environmental degradation and find similar substitutes to reduce plastic usage and accumulation. The primary degradation methods are categorized into physical, chemical and biological processes. These include and cover other sub-methods such as photodegradation, thermal degradation, hydrolysis, biodegradation, and the use of nanotechnology. These degradation methods have their advantages and limitations. Understanding them is crucial for their elimination and the development of substitutes. Different factors including plastic type, additives, environmental factors, etc. affect these processes. Technological advancements and modifications in synthetic materials have paved the way for the development of more compostable, photodegradable and water-soluble plastics. These approaches are also essential for improving the efficacy and efficiency of recycling procedures and turning them into value-added products. This review emphasizes multi-method analysis and a holistic perspective critically evaluating both chemical/physical and biological degradation methods, highlighting their effectiveness and limitations across various polymer types. It also showcases the practical implications, by outlining degradation mechanisms and conditions for effectiveness and on emerging research.

Keywords—Plastic, Degradation, Biodegradation, Nanomodification, Polymerization

Targeting Akt1 in Breast Cancer Cells with Gomesin Peptide Drug: A Computational Approach

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Abstract— In silico is a promising and efficient approach to developed drug repositioning using multi-omics data, which offers a more effective alternative to traditional drug discovery and development for new cancer therapies. Anticancer peptide-based drugs are identified as excellent candidates due to their unique properties, including varying amino acid charges, sizes, and polarities, which contribute to the effectiveness of tumor cells with biocompatibility, high specificity, and selectivity between cancerous and non-cancerous cells. Gomesin, a natural antimicrobial peptide from the *Acanthoscurria gomesiana* spider, has demonstrated potential cytotoxicity against cancer cells. This study interprets peptide-protein interactions between Gomesin and a suitable target the Akt1 protein; an activator in cancer cell growth signaling, was identified as the target protein using the PharmMapper server. The homology structure of Gomesin was obtained from the Protein Data Bank via the RCSB server, while the homology modeling of Akt1 was conducted using the CHARMM-Gui web server, with the sequence obtained from the UniProt database; the Ramachandran plot displayed 84.2 % stability with 362 in favored region indicating acceptable stereochemical quality of the generated model. Molecular docking via HADDOCK provided evidence that specific binding areas during peptide-protein complex production are expected to inhibit cancer growth signals through allosteric inhibition. The molecular docking simulations revealed strong binding affinity between Gomesin and Akt1, with key interactions at Trp80, Glu114, and Ser56 in the Akt1 PH domain suggesting Allosteric inhibition of Akt1 by Gomesin that supports inhibition of cancer growth signaling. The dynamic motion behavior of the Gomesin-Akt1 complex was analyzed for 100ns using the NAMD, demonstrating increased affinity and stability with RMSD, RMSF, and PCA supporting its potential to inhibit Akt1-driven cancer cell survival, suggesting that Gomesin is a viable candidate for anticancer peptide drug development.

Keywords— Anticancer Peptide, Akt1, Cancer Drug, MD Simulation, Molecular Docking

Appointment Lanka: Appointment Booking System for Government Services in Sri Lanka

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Abstract— This paper examines developing and deploying an appointment scheduling system known as Appointment Lanka for government tasks in Sri Lanka. Focused on overcoming the weaknesses of the conventional appointment management system, which requires appointment booking through a call center, this digital solution embraces the latest technologies. It underlines the value of users and positive experiences to lower the time spent on waiting lists and increase the percentage of satisfied customers. The study employs both qualitative questionnaires in interviews with the officials and quantitative questionnaires in terms of user satisfaction with the system. The outcomes focus on the enhancement in service delivery and as such serve to augment discourse and debates on e-governance and the e-governance of public services.

Keywords- Digital Governance, E-Government, Public Services, User Satisfaction, Sri Lanka

Unraveling the Antioxidant and Antibacterial Potential of Leaves of *Phyllanthus acidus* and *Phyllanthus emblica* in a Sri Lankan Setting

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Abstract—Phytochemicals, exhibit robust antioxidant characteristics and auspicious antibacterial effects, positioning them as resources for the advancement of natural antioxidant and antibacterial agents. The current study assessed the phytochemical composition, antibacterial and antioxidant power of leaves of *Phyllanthus acidus* and *Phyllanthus emblica* in aqueous extracts. Total Phenolic Content (TPC), Total Flavonoid Content (TFC) and the Total Antioxidant Capacity (TAC) were quantified by Folin Ciocalteu, Aluminum Chloride colorimetric and Phosphomolybdate assays respectively. Free radical scavenging power was determined utilizing 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. *Escherichia coli* and *Staphylococcus aureus* were used to test the antibacterial power by twain approaches: well diffusion and disc diffusion. TPC of *P. acidus* and *P. emblica* were 76.01 ± 0.1 mg GAE/g and 130.8 ± 0.1 mg GAE/g respectively. 24.7 ± 0.02 mg QE/g and 82.4 ± 0.01 mg QE/g were the contents of flavonoids in *P. acidus* and *P. emblica* ($p > 0.05$). TAC values were 524.9 ± 0.01 mg AAE/g (*P. emblica*) and 1094.5 ± 0.02 mg AAE/g (*P. acidus*) ($p > 0.05$), Free radical scavenging ability was significantly higher in *P. emblica* ($IC_{50} = 136.03$ μ g/mL) than *P. acidus* ($IC_{50} = 292.4$ μ g/mL) ($p < 0.05$) emphasizing its remarkable antioxidant power over *P. acidus*. Both *P. emblica* and *P. acidus* inhibited *S. aureus* in the well diffusion approach compared to disc diffusion with respective zone of inhibitions as 22.7 mm and 23 mm. Nonetheless, the antibacterial efficacy against *E. coli* was comparatively modest for both leaf extracts at a concentration of 20 mg/mL. Hence, the examined *Phyllanthus* species exhibited diverse phytochemical profiles and demonstrated substantial antioxidant and antibacterial potential. *P. emblica* has emerged as a compelling prospect for further investigation owing to its high levels of polyphenols, antioxidant power, and antibacterial properties.

Keywords- Antibacterial, Antioxidant, Leaves, *Phyllanthus*, Phytochemicals

Comparative Analysis of Neural Networks and Conventional Machine Learning Methods for Credit Card Fraud Detection

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Abstract -Fraudulent activities in credit card transactions have become increasingly common as the use of credit card payments has grown more frequent, driven by technological advancements and the rise in online transactions. This surge has led to significant financial losses, underscoring the need for effective methods to mitigate these losses. Fraudsters employ various tactics to steal users' credit card information, including fake SMS and calls, masquerading attacks, phishing attacks, and more. This paper proposes using multiple machine learning algorithms, such as support vector machines (SVM), k-nearest neighbors (KNN), and artificial neural networks (ANN), to predict fraudulent transactions. Additionally, we compare the effectiveness of these supervised machine-learning techniques and deep-learning methods in distinguishing between fraudulent and legitimate transactions.

Keywords - Credit Card Fraud Detection, Machine Learning, Algorithms

Cloud Cryptography: A Leading-Edge Solution for Modern Cybersecurity

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Abstract— Low cost, high capacity, low maintenance cost, efficient resource utilization, and strong performance are some advantages that have contributed to rapid growth in the field of cloud computing. These benefits have encouraged organizations in major fields such as business, technology, health care, and other developments to apply cloud computing techniques in order to enhance their operations. Among the major challenges that face cloud computing techniques is how to guarantee confidentiality, integrity, and availability of data. Users rely on strong cloud security, and these three attributes form the base for cloud security. It goes without saying that the cloud environment puts much pressure on ensuring security, especially when data is transferred, or services are scaled. The increase of cyber threats and demands for more efficient hybrid cryptographic systems have accentuated that cloud security needs even further reinforcement. Recent research has attempted to respond to these issues by examining the use of quantum-resistant cryptographic algorithms, homomorphic encryption, blockchain-based cryptography, and emphasizing the need for updates of traditional techniques. While many excellent cryptographic solutions have been deployed over the years, the rapid growth of cloud usage has rendered some of the older algorithms less useful. It also reviews modern cryptographic structures applied in cloud services and goes forward to review recent research trends, highlighting the gaps that need further exploration in improving the security of the cloud or countering emerging threats.

Keywords— Cloud Cryptography, Hybrid Cryptography, Homomorphic Encryption, Elliptic Curve Cryptography, Quantum Cryptography

Vibration Based Fault Detection in Induction Motors used in Manufacturing Machinery Employing Supervised Classification

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Abstract—Sudden failures in industrial machinery causes financial losses as well as operational disruptions. This study is focused on investigating the application of supervised machine learning algorithms for vibration-based fault detection in a selected induction motor, also focusing on predictive maintenance within the manufacturing sector. A widely available accelerometer was used in the data collection process which was done using a single-phase induction motor working under normal and simulated abnormal conditions. Data smoothing techniques such as Kalman Filter and Moving Average Filter were used alongside Fast Fourier Transform to improve the data quality. Six supervised learning algorithms were tested and evaluated: Logistic Regression, Decision Tree, Random Forest, Support Vector Machine (SVM), Naïve Bayes, and k-Nearest Neighbors (k-NN). The Random Forest algorithm with the Moving Average Filter achieved the overall highest accuracy of 99.77% highlighting its potential in real-time fault detection. The findings of the study demonstrate that effective data preprocessing and the use of advanced machine learning techniques can certainly improve predictive maintenance strategies, leading to a much lower downtime and repair costs in the industry.

Keywords—Supervised Learning, Classification, Data Smoothing, Predictive Maintenance, Induction Motors

Desulfurization of Waste Oils using Heterogeneous Catalysts: A Review

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Abstract - Fossil fuels remain a dominant energy source globally, despite being non-renewable. A promising approach to mitigate fossil fuel consumption and environmental pollution is recycling waste lubricant oils (WLOs). Waste oils contain high levels of sulfur compounds, such as dibenzothiophene, 4-methyldibenzothiophene, and 4,6-dimethyldibenzothiophene, which pose significant environmental and mechanical risks. Efficient desulfurization is essential in the recycling process to address these issues. Desulfurization methods are categorized based on treating organosulfur compounds, including decomposition, separation, or a combination of both. Key methods include hydrodesulfurization (HDS), oxidation, adsorption, biodesulfurization, alkylation, extraction, precipitation, chloronolysis, and supercritical water-based desulfurization. Among these, HDS, oxidation, and adsorption prominently utilize heterogeneous catalysts. These catalysts offer advantages such as reduced activation energy and the potential for regeneration post-reaction. Heterogeneous catalysts are particularly beneficial due to their ease of recovery from reaction products. HDS is the most widely employed method for desulfurizing organosulfur compounds. Detection of these compounds is typically achieved through gas chromatographic (GC) and liquid chromatographic (LC) techniques, often combined with spectroscopic methods. This review mainly focuses on the effectiveness and mechanisms of various desulfurization methods, with a particular emphasis on the role of heterogeneous catalysts.

Keywords— Desulfurization, WLOS, Hydrodesulfurization

Wide Awake: Neural Network-Driven Real-Time Drowsiness Detection System for Enhancing Driver Safety

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Abstract - Drowsy driving is a critical issue contributing to a significant number of road accidents globally, resulting in substantial loss of life and property. Traditional methods for detecting driver drowsiness, such as physical monitoring and vehicle behavior analysis, have inherent limitations in accuracy and practicality. This research focuses on developing a drowsy driver detection system utilizing advanced neural networks, particularly convolutional neural networks (CNNs), to analyze drivers' eye closure and behavior through real-time video input. The system's architecture comprises several components, including a deep learning model trained on extensive image datasets, integrated with computer vision and image processing technologies to enhance detection accuracy. Data collection involved diverse datasets of driver images and videos under varying conditions to ensure robustness. The CNN model processes these images to classify the driver's state of alertness. Experimental results demonstrated high accuracy, with precision and recall rates significantly outperforming traditional methods. The system's ability to process real-time video input and accurately classify eye states provides a robust solution for drowsy driver detection. The research discusses the methodology, training process, implementation, and potential implications for improving road safety. Ethical considerations, such as ensuring driver privacy and data security, are also addressed. Future work will focus on enhancing system robustness under various real-world conditions and integrating additional data sources to improve detection accuracy. The Wide-Awake system represents a promising advancement in leveraging deep learning and computer vision technologies to reduce the incidence of accidents caused by driver fatigue.

Keywords -Drowsiness Detection, Driver Fatigue, Neural Networks, Convolutional Neural Networks (CNNS), Real-Time Monitoring

A Narrative Review of Genetic and Epigenetic Factors in Glioblastoma: Implications for Pathogenesis and Therapeutic Strategies

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Abstract - Glioblastoma is recognized as one of the most aggressive malignant brain tumors which predominantly affects adults and constitutes 14.7% of all intracranial tumors. It is classified into two main types: Primary Glioblastoma which arises without precursor lesions, and Secondary Glioblastoma which evolves from lower-grade gliomas. Unfortunately, glioblastoma carries a dismal prognosis with a median survival rate of only 14 to 16 months. This study aims to delve into genetic and epigenetic factors that contribute to the progression and treatment responses of glioblastoma thereby facilitating the development of more personalized and therapeutic strategies. A narrative review of existing literature was conducted to highlight the critical genetic alterations and epigenetic modifications including IDH mutations, MGMT-promoter methylation, and TERT promoter mutations alongside their roles in tumor behavior and patient outcomes. The latest World Health Organization Central-Nervous-System Classification 5th edition (2021) glioblastoma classified as a Grade-4 adult-type diffuse glioma by emphasizing the importance of genetic markers for accurate diagnosis. Glioblastoma originates from various cell types in the brain with mutations in these cells driving cancer development. Tumor location significantly impacts prognosis with frontal lobe tumors generally yielding better outcomes than those in the temporal lobe or deep brain structures. Key genetic and epigenetic factors have notable effects on tumor behaviors and treatment responses. Also, modifications like DNA methylation and histone alterations play a crucial role in glioblastoma progression. A comprehensive understanding of the genetic and epigenetic landscape in glioblastoma is essential for developing personalized therapies, improving prognostic stratification, and advancing treatment options. Continued research is vital to address the challenges posed by this aggressive tumor and enhance patient outcomes.

Keywords- Glioblastoma, Genetic and Epigenetic Factors

Navigating Ethical Dilemmas in Nursing Practice: A Review of Literature

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Abstract—Challenging situations with significant consequences in humanitarian concepts of care often result in ethical dilemmas, as healthcare professionals must weigh both desirable and undesirable effects. Changing nursing trends and the expanding scope of practice highlight the need for frameworks to manage these dilemmas effectively. This review aims to explore the ethical dilemmas encountered by nurses, examine ethical decision-making models, and analyze how these models are applied to resolve common ethical issues in nursing practice. A literature review was conducted in Google Scholar, PubMed, and Science Direct. Inclusion criteria were peer-reviewed articles published between the years 2000 and 2023, focusing on nursing ethics, available in full text in English. Exclusion criteria were non-peer-reviewed sources and studies not related to nursing practice. From 3704 articles, 32 were selected. A rapid review was performed to identify key ethical decision-making models. The findings suggest that moral distress due to inadequate staffing and workload is a common cause of ethical dilemmas. A conceptual framework was developed, categorizing ethical dilemmas based on moral reasoning, decision-making, and action. Policy changes, education, and management adjustments are needed to improve nurses' confidence and Ethical Decision-Making Skills.

Keywords—Decision-Making, Dilemma, Ethics, Models, Nursing

Evaluation of Condition of Stress among University Students in Sri Lanka: A Literature Review

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Abstract—Stress is broadly defined as the perceived discrepancy between environmental demands and an individual's capacity to meet those demands. It manifests in both short- and long-term forms, often leading to academic pressures and difficulties in social adaptation. Among university students in Sri Lanka, stress has a profound impact on academic performance and overall well-being. This literature review explores the prevalence of perceived stress, contributing factors, outcomes, and the coping mechanisms employed by students to manage stress during their university experience. A comprehensive search of databases like Google Scholar, PubMed, and ScienceDirect yielded twenty relevant research articles published in Sri Lanka between 2014 and 2024. These studies reveal varying levels of stress among university students from different academic disciplines and identify several influencing factors, such as academic workload, examination pressures, gender differences, and self-perceived physical health. While moderate stress levels can serve as a motivating force, high levels are consistently linked to adverse outcomes, including anxiety, depression, and diminished academic performance. The literature survey highlights that students adopt a range of coping strategies, from effective methods like planning, time management, and seeking social support, to fewer effective behaviors such as avoidance and smoking. Understanding these dynamics is essential for developing targeted interventions that support student well-being and academic success in Sri Lanka's universities, thereby contributing to the overall betterment of future generations.

Keywords— Factors, Sri Lanka, Stress, University Students

General Framework for Sustainability Measurements in the Tourism Sector in Sri Lanka

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Abstract—This research aims to measure and enhance the sustainability levels of tourism companies in Sri Lanka. By addressing environmental, socio-cultural, and economic impacts, the study provides a comprehensive framework for sustainability assessment, action planning, and reporting. It focuses on key performance indicators (KPIs) such as water and electricity consumption, carbon footprint, waste management, and supply chain ethics, enabling companies to evaluate and improve their practices. However, tourism companies, especially smaller businesses, often face significant challenges in adopting sustainability practices, such as high implementation costs and a lack of expertise in sustainability management. A unique grading system offers clear feedback on performance, guiding businesses in creating actionable strategies for improvement. The platform's user-friendly interface, combined with insights from industry experts and a robust literature review, aims to make sustainability accessible and affordable for all tourism companies. This initiative aligns with global sustainability standards, promoting transparency and positioning Sri Lanka as a sustainable tourism destination. The project successfully integrates technology with practical industry needs, fostering sustainable growth in the tourism sector.

Keywords—Sustainability, Tourism, Web-Based-Platform

Studying the Potentials of Manufacturing Particle Boards from Dry Leaves for Interior Partitioning

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Abstract- Simply particle board is created by combining a wood particle with binding material and compressing and drying under high temperature and pressure. Dry or raw leaves are a great substitute for traditional raw materials for particle boards. The study discusses 5 different existing leave particle boards the manufacturing processes the properties of the leave particle boards and the existing particle board market in Sri Lanka. The study was conducted as a two-part first systematic literature review based on previous research articles and the second part was an industrial survey done by taking 20 particle board selling shops in the western province as a sample for the survey. Considering the results of the survey study found several potentials of manufacturing leave particle boards developing the properties and trying to manufacture low-cost leave particle boards gives more practicability to the leave particle boards to achieve and build it is own market for dry particle boards. Improving the marketing knowledge about the leaves particle board and creating confidence about the application and using leaves particle board among the public and laborers will gain more practicability toward the potentials of manufacturing particle boards from dry leaves and introducing them to the current particle board market.

Keywords - Leaves Particle Board, Dry Leaves, Sustainable, Properties, Substitute, Current Materials

Automated News Scraping and AI-Powered Summarization Tool for Efficient News Consumption

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Abstract—In an era marked by information overload and the spread of biased or misleading content, efficient news consumption is a significant challenge. This research addresses these issues by developing an AI-powered tool that automates the scraping and summarization of news articles from diverse sources, including social media platforms. Leveraging advanced web scraping and Natural Language Processing (NLP) techniques, the tool aims to provide concise, unbiased summaries, enabling users to cross-verify information effectively. The study follows a three-phase methodology: tool development, usability testing with a diverse user base, and data-driven analysis. The findings not only assess the tool's effectiveness in improving information accessibility and reliability but also uncover unexpected insights into user engagement with news in the digital landscape.

Keywords — NLP, web scraping, news biases, misinformation, efficient news consumption

Comparative Analysis of Bacterial Communities in Vermicompost and Traditional Compost

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Abstract—Bacterial communities are crucial for compost production, as microorganisms play a central role in biodiversity and ecosystem function. Several key factors influence bacterial diversity in composting and vermicomposting. The makeup of organic material, such as waste and the carbon-to-nitrogen ratio, is crucial since different materials supply various nutrients that affect bacterial growth. Additionally, microbial communities are greatly influenced by environmental factors like temperature, moisture levels, and aeration. Vermicompost and traditional compost differ significantly in their environmental conditions and biological processes, resulting in distinct bacterial communities within each type of compost. Composting is the biological breakdown and stabilization of organic materials in circumstances that permit high temperatures because of biologically produced heat. Conversely, vermicomposting utilizes earthworms in a mesophilic environment to produce vermicompost. Earthworm gut contains a wide range of microbes and creates a heterogeneous environment that supports a broader range of microbial populations. Vermicompost generally features a more diverse bacterial community than traditional compost, which can impact nutrient cycling, soil health, and plant growth promotion in agricultural systems. Therefore, this review aims to comprehensively analyze the bacterial diversity in vermicompost and traditional compost, focusing on the comparative identification of bacterial species. Furthermore, it will examine the microbial ecology in both compost systems, providing insights into the functional roles of bacteria in organic matter decomposition and nutrient cycling.

Keywords—Bacterial Communities, Traditional Compost, Vermicompost

Investigating Functionality and Spatial Layout of Traditional Ayurvedic Hospitals for Contemporary Ayurvedic Healthcare Centers Interior Layout

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Abstract— This study examines the internal design layouts of Ayurvedic healthcare facilities in Sri Lanka, focusing on both ancient Ayurvedic hospitals and modern Ayurvedic resorts. For that, the Mihinthale Ancient Hospital and the layout of Polonnaruwa's Alahana Piriwena are being studied. Heritance Ayurveda Maha Gedara, Jetwing Ayurveda Pavilion and Santani Wellness Resort are being studied for modern ayurvedic resorts. By comparing this layout, the study highlights the evolution of Ayurvedic healthcare architecture. The aim is to identify key similarities and differences in interior design layouts, contributing to the integration of traditional and contemporary architectural elements in Ayurvedic healthcare settings. Differences can be seen here. The large rooms for each function in the old hospitals are now smaller, and the rooms are designed according to minimal anthropometrics. Alternative materials are used due to the difficulty of finding the materials used in the past, and now new materials have been identified. The shrine room used for worship in the past has disappeared. Some of the medical equipment used in the past has become showpieces today. This comparison underscores the importance of preserving cultural heritage while incorporating modern amenities, promoting a blend of tradition and modernity for enhanced well-being. These findings provide valuable insights into the future design of Ayurvedic healthcare facilities, emphasizing sustainability and user-centered design.

Keywords— Ayurvedic Healthcare, Layout Arrangement, Interior Design, Ancient Ayurveda Hospital, Ayurveda Resort

High-Efficient Maximum Power Point Tracking of Solar Photovoltaic using Modified Particle Swarm Optimization

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Abstract—This research suggests a modified Particle Swarm Optimization (PSO) technique for the maximum power point tracking (MPPT) of solar photovoltaic (PV) panels to improve efficiency. A boost converter is integrated into the system architecture to raise battery current and increase overall efficiency. The proposed algorithm controls the interaction between generation from solar PV and connected loads in such a way as to optimize PV efficiency. In solar availability time, it gives priority to using solar energy by employing MPPT for extracting the maximum power possible. The novelty of this study is the application of a modified PSO for the MPPT in solar panels. The performance of the proposed algorithm is validated by a simulation review and analysis via experiments. The key performance indicators include efficiency of charging, the level of renewable energy utilized and availability. Through this research, it was observed that by using the proposed modified PSO-based MPPT an efficiency of 94.7% could be achieved.

Keywords—MPPT, Optimization, Particle Swarm Optimization, Solar Photovoltaic, Efficiency

Why ERP Systems Fail: A Research Synthesis

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Abstracts - Enterprise Resource Planning Systems (ERP) are often utilized in worldwide business organizations. A good ERP system directly impacts the business organization's success. Organizations spend millions of dollars and considerable time implementing good ERP systems, and it has been observed that many organizations fail to generate expected outcomes. Significant research was conducted to determine failure factors. It is important to evaluate the reasons for ERP system failure. A literature review over the last five years was conducted to understand what factors affect ERP system failure in organizations. Different case study examples were discussed, the objective of this research is to understand the factors affecting ERP system implementation. It was identified that pre-implementation, implementation, and post-implementation stages, factors affecting the ERP implementation top management support, ERP training, and data quality are some of the most important factors for ERP failure.

Keywords - Enterprise Resource Planning (ERP), Information Technology (IT), Business Process Reengineering (BRP)

Enhancing Blood Supply Chain Management through Predictive Analytics: A Machine Learning Approach for the National Blood Transfusion Service of Sri Lanka

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Abstract -Effective management of blood inventory is significant for ensuring an efficient and secure supply of whole blood and other blood products throughout the healthcare network. Managing blood inventory, however, poses a set of unique challenges, necessitating a distinctive approach tailored to the intricacies of the Blood Demand and Supply Chain. In response to these complexities, this research proposes a Smart Blood Inventory Management Platform, employing a predictive approach designed specifically for the National Blood Transfusion Service of Sri Lanka to address the complex dynamics of blood supply chain management. By leveraging predictive analytics, the platform aims to mitigate issues related to overstocking and understocking, enhancing the overall efficiency of blood inventory management. Underlining the study, a prediction model is presented for the monthly blood demand prediction of the 8 blood types, including an evaluation of its performance using metrics such as Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Coefficient of Determination (R^2). The results indicate promising outcomes, with the predictive model demonstrating a trend of improved accuracy in forecasting blood demand. Hence, this research will contribute to the domain of blood supply chain management by emphasizing the role of data-driven decision-making and predictive modeling in its inventory echelon.

Keywords -Blood Inventory Management, Blood Supply Chain, Decision Tree Regression, Demand Prediction, Machine Learning, National Blood Transfusion Service

Study of Plant-Based Natural Treatments for Diabetes: *Datura Metel* Phytochemistry & Its Antidiabetic Potential- A Mini-Review

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Abstract - Diabetes mellitus (DM) is a common disorder in the metabolism of macronutrients. Diabetes and associated complications are currently treated with chemically produced pharmaceuticals; however, considering these drugs' negative effects and high costs, there is a trend toward alternative herbal remedies made of natural ingredients. Many medicinal plants have been traditionally used to relieve diabetes over the years. One such plant with several pharmacological properties, including antidiabetic potential, is *Datura metel*. Most of these medicinal plants, including *Datura metel* contain bioactive compounds known as phytochemicals. These phytochemicals, which are secondary metabolites of the plant are responsible for its pharmacological activity with neurological, cytotoxic, insecticidal, analgesic, antibacterial, antidiabetic, anti-asthmatic, anti-inflammatory, and antioxidant properties. *Datura metel* leaves, seeds and roots are particularly rich in these phytochemicals, majorly alkaloids, polyphenols, terpenes, etc. *Datura metel* seed and leaf extracts have been proven for hypoglycemic activity, without any adverse effects, in in-vivo studies. These extracts lower post-prandial blood glucose levels, by inhibiting α -amylase, and α -glycosidase enzymes. However, consuming higher doses can cause toxic effects, therefore further studies must be done to confirm the optimal dosage.

Keywords- Diabetes Mellitus, *Datura metel*, Hypoglycemic Activity, Phytochemicals, Alkaloids

Enhanced Performance of Fast Fourier Transform-Based Indoor Positioning Systems Using Machine Learning in Dynamic Environments

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Abstract - The ongoing challenge of accurate indoor positioning exists due to the problems posed by interference and signal degradation in dynamic environments. This research fills a gap by analyzing the improved effectiveness of indoor positioning systems through the combination of Fast Fourier Transform (FFT) with assorted machine learning models. The goal is to evaluate how the conversion of time-domain signals to the frequency domain can raise positioning accuracy and reliability in dynamic environments. Six models were evaluated: The analysis involved Decision Tree Regression (DTR), Random Forest (RF), XGBoost (XGB), Feedforward Neural Network (FNN), Support Vector Regression (SVR), and Linear Regression (LR). The XGB model demonstrated superior performance with a root mean square error (RMSE) of 0.4234 meters and an R^2 value of 0.9899, followed by DTR with RMSE of 0.4922 meters and R^2 of 0.9851. The FNN model also showed considerable improvement, producing an RMSE of 1.3743 meters and an R^2 of 0.8955. This study provides a pathway for developing high-precision indoor positioning solutions, with potential future research focusing on integrating FFT with more advanced models to push the boundaries of existing systems.

Keywords - Data Preprocessing, Indoor Positioning, Machine Learning, Regression Algorithms, Wireless Sensor Network

Evaluating the Significance of Artificial Lighting for Sexually Abused Victims in Trauma Treatment Centers

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Abstract - The research investigates the importance of artificial lighting in trauma treatment centers catering to sexually abused victims. By focusing on the impact of lighting design on emotional well-being and recovery, the study explores therapeutic benefits through a mixed-methods approach combining quantitative data from questionnaires and qualitative insights from observations. Key elements examined include effects on circadian rhythm, relaxation, stress reduction, visual comfort, and emotional and psychological support.

Keywords - Trauma treatment Centers, Abused victims, Artificial Lighting

Predictive Modeling for Heart Disease Risk using Machine Learning

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Abstract - Heart disease is a significant factor of death on a global scale, therefore, risk assessment as well as identification of the determining factors boosts the health prognosis. This work aims at predicting the probability of a person being at risk of heart disease given some health and demographic characteristics and this is done by applying a prediction model formulated by using machine learning algorithms. The inadequate time to diagnose and the inability to perform a conventional risk assessment make heart disease one of the prevalent diseases in society despite the advancements in medical fields. To develop and evaluate the predictive model utilizing Kaggle's dataset containing blood pressure, cholesterol, age, and sex, varieties of the machine learning algorithm were utilized. Age, chest pain, sex, blood pressure, and cholesterol levels can be revealed as primary influencing parameters: According to the obtained results, it is possible to state that machine learning applications surpass classical methods regarding the evaluation of heart diseases. The created model has the potential of early detection of those at risk of heart diseases and the respective early intervention hence the favorable health results. However, more study is needed to validate the model across several populations and to increase the model's accuracy.

Keywords - Heart Disease, Machine Learning, Predictive Modeling, Public Health, Risk Assessment