ASURS 2026

Applied Sciences Undergraduate Research Sessions

ABSTRACTS

Applied Sciences Undergraduate Research Sessions

ASURS 2026

25th June 2026

Faculty of Applied Sciences

Rajarata University of Sri Lanka

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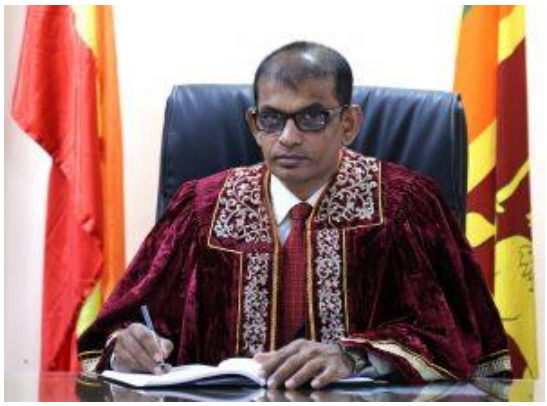
Message from the Vice Chancellor



It gives me great pleasure that I extend my warmest congratulations to the Faculty of Applied Sciences on the occasion of the eight Applied Sciences Undergraduate Research Sessions (ASURS) in 2026. Research and innovation have always been a cornerstone of academic advancement at the Rajarata University of Sri Lanka. As a university, we are committed to fostering a vibrant academic environment that encourages critical inquiry, intellectual curiosity and the generation and dissemination of knowledge across diverse disciplines. In this context, undergraduate research also serves as an essential foundation for developing future scholars, innovators, and professionals.

ASURS 2026 provides an excellent platform for showcasing the scholarly contributions of our undergraduates in the fields of Physics, Mathematics, Health Promotion, Computing, Chemistry, and Biology. The multidisciplinary nature of these research highlights the faculty's commitment to academic diversity and interdisciplinary collaboration in addressing contemporary scientific and societal issues. I further encourage our young researchers to continue disseminating their findings beyond academic forums and to engage actively with society through knowledge sharing and evidence based dialogue.

I would also like to express my sincere gratitude to the Dean, the academic and non-academic staff of the Faculty, and the ASURS 2026 Organising Committee for their dedication and tireless efforts in organizing this important academic event. Your collective commitment continues to strengthen the research culture of the university and enhance its academic reputation both nationally and internationally.

To all the undergraduates presenting at ASURS 2026, I extend my heartfelt congratulations and best wishes. May this event provide you with an intellectually enriching, inspiring, and memorable experience as you achieve another significant milestone in your academic journey.

Professor P.M.B. Jayathilake
Vice Chancellor
Rajarata University of Sri Lanka
Mihintale

Message from the Dean

It is with great pleasure and excitement that I extend my warm wishes to all participants, contributors and organizers of the Applied Sciences Undergraduate Research Sessions (ASURS) 2026. ASURS has become a distinguished annual academic event of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, providing an invaluable platform for our undergraduate students to showcase their research achievements, innovative thinking, and scholarly contributions. This abstract volume stands as a testament to the vibrant research culture that continues to flourish within our faculty and reflects our commitment to nurturing inquiry, creativity, and evidence-based problem-solving among future scientists and professionals.

The abstracts presented in this publication represent the culmination of rigorous research undertaken by undergraduate students across the disciplines of Biology, Chemistry, Computing, Health Promotion, Mathematics, and Physics. Collectively, these studies address a broad spectrum of contemporary scientific, technological, environmental, and societal challenges, demonstrating the relevance of applied sciences in improving lives and contributing to sustainable development. Undergraduate research is far more than a curriculum requirement. It is a transformative educational experience that nurtures critical thinking, creativity, analytical skills, and scientific integrity. The abstracts in this volume demonstrate the dedication of our students and the invaluable mentorship and guidance provided by the academic staff of the faculty. ASURS 2026 further enriches the undergraduate research experience through events such as the Three Minute Thesis (3MT) Competition and the Poster Presentation Session. These activities encourage students to communicate scientific knowledge effectively to diverse audiences.

This year's sessions are organized by the Department of Health Promotion. I sincerely appreciate the dedication, commitment, and professionalism demonstrated by the organizing committee, academic staff, and student volunteers who have worked tirelessly over the past several months to ensure the success of this event. I congratulate all student researchers and extend my heartfelt gratitude to their supervisors for their invaluable mentorship. I am confident that the research presented here will inspire further inquiry, stimulate academic dialogue, and contribute to addressing real-world challenges through scientific knowledge and innovation. As we celebrate the achievements of our young researchers, I encourage them to continue questioning, discovering, and innovating. The future of science and society depends on individuals who are willing to seek new knowledge, challenge conventional thinking, and apply their expertise for the betterment of humanity.

I wish ASURS 2026 every success and hope that this event will continue to serve as a catalyst for excellence in undergraduate research for years to come.

Dr. Manoj Fernando
Dean of the Faculty of Applied Sciences
Rajarata University of Sri Lanka
Mihintale

Message from the Chairperson

On behalf of the Organizing Committee, I extend my warm greetings to all participants of the 8th Applied Sciences Undergraduate Research Sessions (ASURS 2026), organized by the Faculty of Applied Sciences, Rajarata University of Sri Lanka. It is with great pleasure that I serve as the Chairperson of ASURS 2026. This year's symposium is held under the theme of "Sustainable Living," a subject of great relevance in a world increasingly challenged by environmental, social, and public health concerns.

ASURS 2026 is a celebration of undergraduate research excellence, and the young researchers who have contributed deserve recognition of a very special kind. According to the National Science Foundation of Sri Lanka, there are only around 258 researchers per million people in our country, meaning active researchers constitute little more than 0.02% of the national population. Of the students who sit the G.C.E. Advanced Level examination each year, only a small fraction gains admission to a state university. Fewer still secure a place in a science faculty, and among science graduates, only a select few engage meaningfully in research. These undergraduates belong to that rare and distinguished group, carrying with them a profound national responsibility. Their research is conducted not merely for personal academic advancement, but on behalf of the many millions of Sri Lankans who have never had such an opportunity.

This year's sessions feature oral and poster presentations spanning Biological Sciences, Chemical Sciences, Computing, Health Promotion, Mathematics, and Physics. These presentations reflect the creativity, critical thinking, and scientific rigour of our undergraduates, demonstrating their commitment to addressing challenges of regional, national, and global significance. Situated in the heart of the North Central Province, our university is uniquely positioned to generate research that matters to surrounding communities while contributing to the broader scientific conversation. I commend all presenters and their supervisors for the dedication and perseverance that have brought their work to this stage.

The successful organization of ASURS 2026 is the fruit of collective effort and shared commitment. I sincerely thank the Vice Chancellor of Rajarata University of Sri Lanka, the Dean of the Faculty of Applied Sciences, and all Heads of Departments for their leadership and encouragement. I also extend my heartfelt appreciation to all members of the Organizing Committee, academic and non-academic staff members, abstract reviewers, the keynote speaker, panelists, sponsors, and well-wishers whose generous support has made this event a resounding success.

I wish all young researchers every success in their future academic and professional endeavours. Research is not a privilege reserved for the few; it is a responsibility entrusted to the few, for the benefit of all. I hope these sessions inspire you to pursue knowledge with passion, integrity, and a lifelong commitment to the service of humanity.

Professor G.N. Duminda Guruge
Chairperson
ASURS – 2026

Profile of the Keynote Speaker – Prof. T.M.W.J. Bandara

Prof. T.M.W.J. Bandara is the Chairman to the Sustainable Energy Authority of Sri Lanka. Ranked as the second-leading scientist in Sri Lanka in the field of Energy Engineering, Prof. Bandara is a B.Sc. special honors graduate and secured his M.Phil. from the University of Ruhuna and earned his PhD from the University of Peradeniya and Chalmers University of Technology, Sweden. Prof. Bandara assumed duties on 04th November 2024 as the 08th Chairman of Sri Lanka Sustainable Energy Authority (SLSEA). Prof. Bandara is a distinguished figure whose commitment to sustainable energy, scientific research, and education is well recognized.

Prior to this role, Prof. Bandara was a respected professor in the Department of Physics at the University of Peradeniya, known for his approachable teaching style and his ability to mentor future scientific leaders. Prof. Bandara is a renowned figure in sustainable and renewable energy, recognized for his contributions to both theoretical and applied sciences in the field of sustainable energy. With over 70 international journal articles, more than 100 conference presentations, and multiple book chapters, his work has positioned Sri Lanka in the global scientific community. Further, he has conducted several invited and keynote speeches at international conferences.

He has received several prestigious awards, including the Presidential Award for Best Research Publication (2001,2009,2010 2012,2013,2014,2015,2016,2019) for 9 times, and NRC Research Awards (2011,2017 and 2018), along with Excellence in Research and Teaching Awards from the University of Peradeniya.

Prof. Bandara has made several key initiatives as the Director of the Solar Energy Research Center and Chairperson of the Faculty Research Committee at the University of Peradeniya. He also teaches annually for more than 10 years as a visiting researcher at Chalmers University of Technology in Sweden, fostering international collaboration. As a Tier 4-star researcher, the highest designation by the UGC in Sri Lanka, Prof. Bandara continues to advance the field of sustainable energy, both locally and globally. In addition, Prof Bandara was a visiting Professor at University of Malaya Kulalumpur, Malaysia.

With his appointment as the Chairman of the Sustainable Energy Authority of Sri Lanka, Prof. Bandara is committed to achieving national energy goals by promoting renewable resources, energy efficiency, and reducing the country’s carbon footprint. He is leading initiatives to integrate sustainable practices across various sectors, ensuring that clean energy is accessible and economically viable for all Sri Lankans.

Abstract of the Keynote Speech

Research and Innovation for Sustainable Living: Transforming Challenges into Opportunities

(Prof. T.M.W.J. Bandara, Chairman, Sustainable Energy Authority of Sri Lanka)

Sustainable living has emerged as a global priority in response to challenges such as climate change, energy insecurity, environmental degradation, resource scarcity, and public health concerns. Addressing these interconnected issues requires innovative solutions supported by scientific research, technological advancement, and responsible decision-making. Research plays a vital role in generating new knowledge, developing sustainable technologies, and providing evidence-based solutions that contribute to long-term societal well-being.

A clear understanding of the nature, purpose, and responsibilities associated with research is essential for achieving meaningful outcomes. The selection of appropriate research methodologies, effective analysis and interpretation of findings, and responsible dissemination of knowledge are key components of successful research. These practices ensure that research outcomes are reliable, impactful, and beneficial to society.

Research-driven innovation has created opportunities for cleaner energy systems, efficient resource utilization, sustainable industrial practices, improved healthcare solutions, and environmentally responsible development. Achieving sustainable progress requires interdisciplinary collaboration that integrates knowledge from physical sciences, biological sciences, computing, health sciences, and other related fields. Such collaborative approaches enable the development of comprehensive solutions to address complex sustainability challenges.

Transforming challenges into opportunities depends on the ability of researchers to bridge the gap between scientific discoveries and practical applications. Universities and research institutions play a crucial role in this process by promoting creativity, critical thinking, entrepreneurship, and innovation among future generations. Strengthening research capacity and fostering an innovation-oriented culture can significantly contribute to sustainable development while creating new social, environmental, and economic opportunities.

Adherence to research ethics and maintaining academic integrity through the prevention of plagiarism are fundamental principles of responsible research. With the increasing use of advanced technologies, researchers must be equipped with the knowledge and skills required to apply these tools responsibly while upholding ethical standards. Building capacity in research ethics and responsible technology utilization is essential for developing a credible and sustainable research culture.

Advancing sustainable living requires not only technological progress but also a commitment to responsible research, knowledge sharing, and collaborative action. Through research and innovation, current challenges can be transformed into opportunities for building a resilient, inclusive, and sustainable future for Sri Lanka and the global community.

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BIOLOGY

THE USE OF FRESHWATER ALGAE FOR SUSTAINABLE BIODIESEL PRODUCTION

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Freshwater algae can accumulate substantial amounts of lipid relative to their dry cell weight (DCW) by sequestering atmospheric CO_2 and using sunlight as the primary energy source. These lipids, predominantly in the form of triglycerides, can be converted into combustible, energy-rich fuels such as biodiesel. This study investigated the potential of a filamentous freshwater green alga, morphologically identified as *Rhizoclonium*, as a locally available feedstock for biodiesel production under low-input outdoor cultivation in Sri Lanka. Algal biomass was collected from a flowing river, inoculated into a glass tank containing natural well water, and cultivated outdoors under ambient sunlight without synthetic nutrient supplementation or artificial aeration, yielding sufficient biomass over successive 2-week batches for downstream processing. The harvested biomass was oven-dried and subjected to lipid extraction using both hexane-based Soxhlet extraction and a laboratory-scale screw-press, thereby comparing a conventional solvent-based method with a mechanically oriented approach of relevance to practical processing. The isolated lipids were converted into fatty acid methyl esters (FAMEs) via base-catalyzed transesterification, and the resulting FAMEs were analyzed by gas chromatography with flame ionization detection to determine the fatty acid profile and assess suitability for diesel-range fuel applications. The algal biomass yielded measurable quantities of lipid, with gravimetric lipid recovery reaching approximately 22% of DCW under Soxhlet extraction. In contrast, screw-press extraction produced lower lipid recovery but demonstrated direct oil liberation without solvent use. Transesterification of the recovered oil yielded discernible biodiesel fractions, whose FAME profiles were dominated by C16 and C18 species spanning saturated and unsaturated chains within the C14–C22 range, consistent with the chain lengths typical of biodiesel fuels. A simple qualitative cotton-ball combustion test indicated that the produced biodiesel exhibited flame behaviour broadly comparable to that of mineral diesel under identical conditions, providing preliminary support for its combustibility as a diesel-range fuel. Collectively, these findings suggest that indigenous *Rhizoclonium* sp. from Sri Lankan freshwater systems can serve as a candidate feedstock for third-generation biodiesel production under low-input cultivation, while highlighting the need for further work on molecular-level strain characterization, process optimization for mechanical oil recovery, comprehensive fuel property testing against established biodiesel standards and techno-economic assessment within the Sri Lankan renewable energy context.

Keywords: *Biodiesel, Freshwater algae, Lipid extraction, Transesterification, Renewable energy*

Acknowledgements: The authors are grateful to the academic, administrative and non-academic staff of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale for their contribution to the successful implementation of the study.

SEED DORMANCY CLASS, STORAGE BEHAVIOUR AND SEED TRAITS OF *Trema orientale, Lagerstroemia speciosa* AND *Filicium decipiens*: IMPLICATIONS FOR RESTORATION IN SRI LANKA

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Pioneer tree species and tree species commonly associated with disturbed or secondary forests and play an important role in forest restoration by rapidly establishing vegetative cover, improving soil conditions and facilitating the regeneration of late-successional species. However, restoration programmes in Sri Lanka show low success rate due to the lack of basic seed biological information, including seed traits, dormancy class, storage behaviour and intraspecific variation. This study aims to determine the seed dormancy class, storage behaviour and seed traits of *Trema orientale*, *Lagerstroemia speciosa* and *Filicium decipiens*, and to investigate intraspecific variation in seed traits parameters among individual trees of *F. decipiens*. The thousand-seed weight (TSW) significantly varied among the three species (Kruskal–Wallis test: $\chi^2 = 38.46$, $P < 0.001$). *Filicium decipiens* had the highest TSW (358.7 g), followed by *L. speciosa* (5.57 g) and *T. orientale* (2.93 g). Hundred-seed weight varied significantly among five individual *F. decipiens* (Kruskal–Wallis test: $P < 0.001$). Eccentricity index (EI) and spherical index (SP) were normally distributed among species. One way ANOVA indicated clear interspecific variation in EI ($F = 50.82$, $P < 0.001$) and SP ($F = 505.8$, $P < 0.001$). All pairwise comparisons were significant. Flatness index (FI) violated normality assumptions ($\chi^2 = 52.57$, $P < 0.001$). *Lagerstroemia speciosa* recorded the highest EI (1.87 ± 0.48) and FI (5.55 ± 1.02). *Trema orientale* recorded the highest SP (0.90 ± 0.06). The EI data were not normally distributed among *F. decipiens* individuals (Kruskal–Wallis test: $\chi^2 = 10.74$, $P = 0.030$). Seed moisture content (SMC) varied significantly among species (ANOVA: $F = 278.8$, $P < 0.001$). *Filicium decipiens* had the highest SMC (52.0%). *Lagerstroemia speciosa* had the lowest SMC (9.8%). SMC among *F. decipiens* individuals varied from 48.0 ± 3.2 (Tree A) to 55.5 ± 3.6 (Tree E). Tree E had significantly higher SMC than all the others. Seed coat ratio (SCR) of *L. speciosa* (0.850) was significantly higher than that of *F. decipiens* (0.162) ($t = -39.09$, $P < 0.001$). SCR ranged from 0.144 ± 0.026 (Tree A) to 0.216 ± 0.087 (Tree C) and varied significantly (Kruskal–Wallis test: $P = 0.001$). Under standard conditions, *F. decipiens* showed the highest germination%, while *T. orientale* seeds did not germinate. Germination% from five individual *F. decipiens* were not statistically significant. Seed mass increase showed a significant difference between manually scarified seeds (MS) and control seeds, indicating differential water uptake behaviour. MS seeds showed up to 17.5% mass increasement. The control replicate showed minimum mass increasement (0.83%). Among four pre-sowing treatments, the highest germination% was recorded in MS seeds (13%). Control and GA_3 treated intact seeds show no germination. A significant difference in germination % was observed between scarified seeds and GA_3 treated scarified seeds ($P = 0.049$). According to TSW-MC criteria, *L. speciosa* and *T. orientale* were classified as desiccation tolerant, while *F. decipiens* was classified as non-desiccation tolerant. 100 seed test revealed that all the non-stored and moist stored *F. decipiens* germinated rapidly, but that the desiccated seeds did not germinate and were not viable. This study provides the essential seed traits, storage behaviour and suitable dormancy-breaking methods for a major pioneer tree species and two tree species commonly associated with disturbed or secondary forests in Sri Lanka.

Keywords: *Trema orientale, Lagerstroemia speciosa, Filicium decipiens, Storage behaviour, Intraspecific variation*

Acknowledgements: I would like to thank Professor Gehan Jayasuriya, Dr Asanga Wijetunga, Miss Hiruni Kumarasinghe, Miss Hasini Poornima and my parents for their guidance and support.

LABORATORY SCALE ESTABLISHMENT OF AN ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL (EBPR) BIOREACTOR SYSTEM FOR ENRICHMENT OF POLYPHOSPHATE ACCUMULATING MICROORGANISMS (PAOs)

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A leading globally recognized environmental crisis is eutrophication, which is driven by excess phosphorus in aquatic ecosystems. Enhanced biological phosphorus removal (EBPR) has emerged as a sustainable, microbe-driven and cost-effective alternative to chemical precipitation of phosphorus from wastewater. EBPR relies on the metabolic mechanisms of polyphosphate accumulating (micro)organisms (PAOs) that cycle between anaerobic and aerobic conditions to remove phosphorus from wastewater. However, laboratory-scale EBPR systems remain underexplored in the literature that is constructed from inexpensive materials, especially suited to resource-limited and tropical settings such as Sri Lanka. Thus, this study aimed to enrich the PAOs and to evaluate phosphorus removal performance under aerobic and anaerobic conditions through the establishment and operation of a cost-effective laboratory-scale EBPR bioreactor system. Microbial inoculum was sourced from well-functioning activated sludge that was collected from the municipal wastewater treatment plant in Negombo. The laboratory-scale reactor operated for 50 days with glucose-based synthetic wastewater and a cyclic operation of feed/famine conditions imposed on the microbial community within the bioreactor. Phosphate dynamics, chemical oxygen demand (COD) and microbial community were analyzed to assess the reactor performance. Microbial characterization was performed using fluorescence *in-situ* hybridization (FISH) with the PAO-specific PAO651 probe and bacterial EUB mix probes. The elevated anaerobic phosphate release (fed conditions) and efficient aerobic phosphate uptake (famine conditions) confirmed the successful PAO enrichment of the EBPR system. COD reduction over the operational period, confirmed the efficient substrate utilization by the bacterial consortium. FISH analysis identified the presence of *Candidatus* Accumulibacter phosphatis (PAO651 probe) in the enriched biomass, and qFISH analysis revealed a progressive increase in PAO biovolume fraction over the operational period, corresponding to a decline in filamentous bacterial abundance. These findings demonstrate a successful operation of cost-effective EBPR system and PAO enrichment under laboratory conditions that provides a foundation for further optimization and scale-up in developing countries.

Keywords: *Enhanced biological phosphorus removal, Polyphosphate accumulating organisms, Eutrophication, Activated sludge*

Acknowledgements: The authors are grateful to the academic and administrative staff of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale for their contribution to the successful implementation of the study.

TAXONOMIC CHARACTERIZATION OF RHIZOSPHERIC FUNGI ASSOCIATED WITH WILD *Oryza* spp. AS POTENTIAL CANDIDATES FOR BIOFORTIFICATION OF MICRONUTRIENTS IN CULTIVATED RICE

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Micronutrient deficiencies, particularly zinc deficiency, remain a major global nutritional concern affecting both human health and agricultural productivity. Microbial-assisted biofortification has emerged as a sustainable alternative to chemical fertilizers for enhancing nutrient content in crops. Therefore, this study aimed to identify and characterize the rhizospheric fungi associated with wild *Oryza* spp. in Sri Lanka and to evaluate their potential for micronutrient biofortification, emphasizing the use of wild rice-associated mycobiota as a novel and underexplored alternative to cultivated rice systems. A total of 23 rhizosphere soil samples were collected from wild *Oryza* spp. across five (05) geographical locations in Sri Lanka. Ninety-two fungal isolates were obtained and screened for zinc solubilization ability using mineral salts medium amended with 1% insoluble ZnO. Twelve isolates demonstrated outstanding zinc-solubilizing activity through halo zone formation, with the highest halo-zone diameter recorded as 76 ± 2 mm. Zinc solubilization index (ZSI) ranged from 1.77 ± 0.07 to 3.32 ± 0.30, while zinc solubilization efficiency (ZSE) ranged from 76.87 ± 6.60% to 232.27 ± 29.65%. Morphological identification of the selected isolates was performed based on colony and microscopic characteristics. For molecular characterization, genomic DNA was extracted. The internal transcribed spacer (ITS) region of fungal DNA was amplified by polymerase chain reaction (PCR). PCR products were visualized by 2% agarose gel electrophoresis. The amplified products were purified and sequenced by Sanger DNA sequencing. Newly generated sequences were incorporated in phylogenetic analysis to determine the taxonomic identity and phylogenetic relationships. The resulting phylograms revealed that the selected isolates belonged to four (04) fungal genera: *Aspergillus*, *Penicillium*, *Talaromyces* and *Sarocladium*. The selected isolates were further evaluated through a pot experiment for rice plants (LD 253) under plant-house conditions. Among the isolates tested, NH04 (*Talaromyces* sp. 01) showed the highest plant growth-promoting effects, with significantly increased shoot height, leaf length, leaf width and leaf number compared to negative controls. The findings of this preliminary study suggest that rhizospheric fungi associated with wild *Oryza* species have significant potential as zinc-solubilizing bioinoculants for sustainable rice biofortification and environmentally friendly agricultural practices. However, detailed field trials are needed to validate their performance under diverse soil and environmental conditions, followed by optimization of formulation and delivery methods to ensure effective root colonization and stability.

Keywords: *Hidden hunger, ITS, Microbial-assisted biofortification, Zinc solubilization*

Acknowledgements: The authors gratefully acknowledge the financial support provided by a University Research Grant (no. RJT/R&PC/2026/R/FOAS/02) from Rajarata University of Sri Lanka.

VARIATION OF BUTTERFLY SPECIES DIVERSITY AND RICHNESS ALONG THE ELEVATIONAL GRADIENT OF KODIGALA MOUNTAIN, THE HIGHEST PEAK OF RITIGALA MOUNTAIN RANGE

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Butterflies play an important ecological role by acting as pollinators. Their ability to travel across long distances allows them to transfer pollen, supporting plant reproduction and enhancing biodiversity in fragmented habitats. They are important ecological indicators because they are sensitive to environmental variation, making them useful for assessing biodiversity patterns along elevational gradients. This study investigated variation in butterfly species diversity, richness and community composition along the elevational gradient of Kodigala Mountain in the Ritigala Mountain Range, Sri Lanka. It examined the relationship between butterfly distribution and environmental variables. Field sampling was conducted across three elevational zones: low (<300 m), mid (300–500 m) and high (>500 m), using fifteen transects established along the mountain gradient from January to April 2026. Butterfly census data were collected through systematic observations, while environmental variables, including ambient temperature, relative humidity and light intensity, were recorded at each sampling plot. Species richness and the Shannon diversity index were calculated, and multivariate analyses, including non-metric multidimensional scaling, permutational multivariate analysis of variance and canonical correspondence analysis, were performed to evaluate community patterns and the relationship between butterfly species and environmental variables. A total of 2,688 sightings representing 58 butterfly species from five families were recorded. Species richness was highest at lower elevations, while species diversity varied across the gradient. Distinct species assemblages were observed among elevational zones, with several species restricted to specific elevations. Environmental variables significantly influenced butterfly community composition, with temperature and humidity showing strong associations with species distribution. The findings demonstrate that elevation strongly shapes butterfly diversity and community structure in Kodigala Mountain. This study provides baseline ecological information for Ritigala and highlights the importance of conserving elevationally heterogeneous habitats for butterfly biodiversity conservation in Sri Lanka.

Keywords: *Butterfly diversity, Elevational gradient, Species richness, Community composition, Environmental variables*

Acknowledgements: The authors are grateful to the academic and administrative staff of Rajarata University of Sri Lanka, funding agencies (Rajarata University Research Grant, Oklahoma City Zoo and Botanical Garden–Sri Lankan Biodiversity Research Grants) and supporting institutions (Department of Wildlife Conservation) for their guidance and assistance throughout this study.

BIODEGRADATION OF XENOBIOTIC DYE COMPOUNDS BY ALGINATE-ENCAPSULATED AND IMMOBILIZED ENVIRONMENTAL HALOPHILIC MICROORGANISMS

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Synthetic dyes are compounds used in industrial dyeing processes and pose significant environmental and health risks due to their colour persistence, toxicity, mutagenicity and carcinogenicity. They are often used with highly saline solutions in the textile industry to drive the dyes efficiently into the textile substrates. Methyl orange (MO) is a widely used industrial azo dye, categorized as a xenobiotic compound. This study investigated the possibility of utilizing environmental halophilic microbial consortia isolated from dried fish and seawater for the biodegradation of MO under highly saline conditions. The research aimed to compare microbial consortia in planktonic form and sodium alginate-based immobilization systems within batch bioreactors to evaluate their biodegradation kinetics using first-order kinetic constants (k) and decolorization efficiency. The microbial consortia were tested under different concentrations of MO (20, 50, 100 and 200 ppm) in a synthetic saline medium named base saline mineral medium (BSMM), and decolorization performance was determined over time through UV-Visible spectrophotometric analysis. The results demonstrated that both environmental halophilic sources were capable of degrading MO, with high decolorization percentages ranging between 79.3 to 96.29%. Halophilic microorganisms with dye degradation capability were isolated from both sources on tryptone soy broth plates and subjected to molecular characterization for identification. Two-way ANOVA, three-way ANOVA and Tukey's HSD test results indicated that system type, microbial source and dye concentration all had highly significant effects on biodegradation ($P < 0.05$). Overall, planktonic systems showed higher biodegradation rates at low MO concentrations, while immobilized systems provided improved operational stability over high MO concentrations. The dried fish-derived microbial consortium exhibited higher k values than seawater, demonstrating the suitability of dried fish as a promising source for treating xenobiotic industrial pollutants under highly saline conditions.

Keywords: *Biodegradation, Methyl Orange, Planktonic, Immobilization, Consortium*

Acknowledgements: The authors are grateful for the support and guidance provided by the academic and non-academic staff of the Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

ISOLATION AND CHARACTERIZATION OF SALT-RESILIENT *Rhizobium* SPECIES FROM COASTAL LEGUME *Vigna marina* AND EVALUATION OF THE CROSS-INOCULATION EFFICIENCY IN CULTIVATED LEGUMES

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Salinity is major stress condition which limits legume growth, nodulation and biological nitrogen fixation in salt affected soil. To improve legume cultivation under saline soil, the rhizobia associated with naturally salt-tolerance legumes may be employed, provided that they establish effective symbiosis and form functional nodules. This study was conducted to evaluate the cross-inoculation (CI) group flexibility of *Rhizobium* spp. isolated from *Vigna marina* under both saline and non-saline conditions, and their salt tolerant ability. Rhizobial isolates were obtained from the root nodules of *Vigna marina*, *Vigna radiata* (mung beans), and *Vigna unguculata* (cowpea) using standard isolation techniques on yeast mannitol agar (YMA) media. A total of eleven different isolates were chosen. Primary characterization was carried out based on the colony morphology, Gram staining, growth behaviour and salt tolerance assay only for *Rhizobium* spp. from *V. marina*. Molecular characterization was done by using 16S rRNA gene amplification using universal primers 27F and 1492R. The confirmation was done by agarose gel electrophoresis to ensure successful amplification. Sanger sequencing of the 16S rRNA gene enabled the identification of bacterial species including *Martinezella tropici* strain 33_10, *Arthrobacter ramosus*, *Rhizobium* sp. strain CA34, *Enterobacter cloacae* strain CIFRI.F1, *Bradyrhizobium japonicum* strain CK-11, *Rhizobium* sp. L-14, *Priestia megaterium* strain RT17 and *Klebsiella pneumoniae* strain TZT-18-63. Salt- tolerance assay showed that the *Rhizobium* spp. of *V. marina* can grow up to 3% (513.3 mM) NaCl and confirmed their adaptation to saline soil. A greenhouse inoculation experiment was conducted using mung bean and cowpea under four treatments including uninoculated control (T1), inoculation with *Rhizobium* spp. isolated from *V. marina* (T2), inoculation with *Rhizobium* spp. isolated from *V. marina* combined with salt treatment (T3) and inoculation with isolated native rhizobia (T4). Re-isolation of rhizobial species obtained from the nodules of the cultivated legumes confirmed the nodulation ability of inoculants. The results confirmed that *Rhizobium* spp. from *V. marina* has the ability to cross- nodulate both cultivated *Vigna* spp. supporting the concept of CI group flexibility. However, the native rhizobial isolates produced comparatively high nodule count and shoot growth than the isolates from *V. marina*. Although the *Rhizobium* spp. isolated from *V. marina* indicated host compatibility and effective symbiosis with both crops, salt stress significantly reduced nodulation and plant growth. The findings of this study suggest that the *V. marina*-associated rhizobia harbour considerable salt tolerant ability and are capable of cross-nodulating cultivated *Vigna* spp. However, the effectiveness of this symbiotic association can depend on not only the salinity tolerance of the host plant species but also the existing environmental conditions.

Keywords: *Vigna marina, Rhizobia, Cross-inoculation, Salt- tolerance, Nodulation*

Acknowledgements: The authors are grateful to the academic and administrative staff of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale for their contribution to the successful implementation of the study.

EXPLORATION OF WILD *Oryza* RHIZOSPHERE MYCOBIOTA AS A SOURCE OF NOVEL BIOCONTROL AGENTS AGAINST *Bipolaris oryzae*, THE CAUSAL AGENT OF BROWN SPOT DISEASE IN RICE

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Brown spot disease in rice caused by the fungal pathogen *Bipolaris oryzae* is one of the significant constraints in rice production, which leads to major quality and yield losses worldwide. As a sustainable approach, biological control has attracted considerable attention in disease management. The rhizosphere represents a key zone where essential microbial interactions occur. Although the rhizosphere of cultivated rice has been widely studied, the rhizomicrobial communities associated with wild *Oryza* species remain largely underexplored for their biocontrol potential. The present study aimed to isolate and characterize the wild *Oryza* rhizosphere-associated fungi as a promising resource to explore novel biocontrol agents against *B. oryzae*. A total of 92 rhizosphere fungal isolates were obtained from the rhizosphere of three (03) wild *Oryza* spp., including *Oryza rufipogon*, *Oryza rhizomatis* and *Oryza nivara* collected from five (05) different geographical locations in Sri Lanka. The isolates were initially screened using a dual culture plate assay to evaluate their antagonistic activity. Morphological and molecular analyses were conducted to identify the fresh fungal isolates. The internal transcribed spacer 1 and 2 with 5.8S region (ITS) was sequenced and used in phylogenetic analysis following DNA extraction, polymerase chain reaction (PCR) and gel electrophoresis. Several isolates were successfully identified to the species level, whereas the remaining isolates could only be resolved to the clade or species-complex level. Results revealed that eight (08) fungal isolates exhibited notable antagonistic activity with PIRG value, ranging from 45.90 to 55.45%, within 14 days post-incubation. Among them, an isolate belonging to the genus *Fusarium, incarnatum-equiseti* species complex demonstrated the highest dual culture inhibition (55.45%). The others belonged to the genera *Aspergillus* (03), *Fusarium* (02), *Penicillium* (01) and *Talaromyces* (01). Subsequently, a pot experiment was conducted using the disc inoculation method, and the disease reduction percentage was estimated based on variations in brown spot lesion size. A significant lesion size reduction was observed with two (02) isolates (24.40 and 21.27%), and the remaining showed comparatively low disease reduction rates. A negative correlation was observed between the dual culture and pot trial results, indicating that *in vitro* performance may not reliably predict *in vivo* biocontrol efficiency. However, the findings of this preliminary study highlight the wild *Oryza* rhizosphere as a promising reservoir for the discovery of potential fungal biocontrol agents against *B. oryzae*, emphasizing the need for further investigations into their functional mechanisms and field-level applicability for future advancements in sustainable rice disease management.

Keywords: *Dematiaceous Hyphomycetes, Dual culture, ITS, Pleosporaceae*

Acknowledgements: The authors gratefully acknowledge the financial support provided by a University Research Grant (no. RJT/R&PC/2026/R/FOAS/02) from Rajarata University of Sri Lanka.

RESOLVING HIDDEN DIVERSITY IN SRI LANKA'S ENDEMIC GREEN VINE SNAKE THROUGH INTEGRATIVE TAXONOMY

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Cryptic species pose significant challenges to accurate biodiversity assessment and habitat conservation by masking true species diversity. In Sri Lanka, the Green Vine Snake (*Ahaetulla nasuta*) was previously considered a single endemic and widespread species distributed throughout the island. However, subtle morphological differences observed between populations inhabiting the dry and wet zones prompted the present study, which aimed to elucidate the true diversity of Sri Lankan *Ahaetulla* species through an integrated morphological and molecular approach. Samples were systematically collected along a transect spanning the entire country, ensuring comprehensive geographic coverage. Morphometric and meristic data were recorded from each specimen, and tail tip tissue samples were collected for molecular characterization using the mitochondrial Cytochrome-b (Cyt-b) gene region. Molecular phylogenetic analyses based on the Cyt-b gene revealed three genetically distinct green vine snake lineages, each further confirmed by morphological characterization through multifactor analysis and principal component analysis. Consequently, *Ahaetulla nasuta* was confirmed to be restricted to the wet zone; *Ahaetulla oxyrhyncha*, previously considered endemic to India, was recorded from the northern coastal dry zone of Sri Lanka for the first time; and an unrecognized *Ahaetulla* sp., genetically closely related to the Sri Lankan Brown Vine Snake *Ahaetulla pulverulenta*, was found to be distributed across the dry zone and a few wet zone localities. The presence of *A. oxyrhyncha* in addition to *A. nasuta* and *A. pulverulenta* in Sri Lanka is formally confirmed by this study. However, the taxonomic status of the unrecognized green *Ahaetulla* lineage remains unresolved and warrants further investigation through advanced molecular approaches such as whole-genome sequencing or microsatellite analysis.

Keywords: *Cryptic species, Cytochrome-b, Conservation, DNA barcoding*

Acknowledgements: This research was financially supported by the Oklahoma Zoo and Botanical Garden Foundation (25-03-RUSL), whose generous funding made this study possible.

COMPARATIVE ANALYSIS OF SOIL BACTERIAL COMMUNITES WITH POTENTIAL AS BIOFERTILIZER INOCULANTS IN NATURAL FOREST AND CORN CULTIVATED SOILS IN MIHINTALE, NORTH CENTRAL PROVINCE OF SRI LANKA

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Natural forest ecosystems represent one of the richest reservoirs of beneficial soil bacteria, that can be exploited as biofertilizers. Changes in land use from forest to agricultural field can significantly impact soil bacterial community. This study was aimed to comparatively analyze the soil bacterial communities in a natural forest and adjacent corn-cultivated soils in Mihintale, North Central Province, Sri Lanka, and to evaluate their potential for use as biofertilizer inoculants. Soil samples were collected from both sites and used to isolate nitrogen fixing (NFB) and phosphate solubilizing bacteria (PSB) using Jensen and Pikovskaya media, respectively. A total of 12 prominent bacterial isolates were characterized based on morphological, biochemical, functional and molecular methods using 16S rRNA gene amplification. *Pantoea* sp., *Enterobacter* sp., *Achromobacter xylosoxidans* and *Bacillus cereus* were isolated from the natural forest, while *Acinetobacter* sp., *Burkholderia cepacia* and *Citrobacter* sp. from the corn field soil. Phosphate solubilizing isolates formed halo zones on Pikovskaya media with solubilization indices ranging from 1.40 to 1.71, while nitrogen fixing isolates changed bromothymol blue supplemented Jensen media from blue to yellow within 72 hours. A pot experiment was carried out to evaluate the effectiveness of the isolates using the corn (*Zea mays* L.) variety of Pacific 999. Treatments were synthetic fertilizer, phosphate solubilizing bacterial inoculum from forest (PSB-F), nitrogen fixing bacterial inoculum from forest (NFB-F), combined bacterial inoculum from forest (PSB-F+NFB-F), phosphate solubilizing bacterial inoculum from corn field (PSB-C), nitrogen fixing bacterial inoculum from corn field (NFB-C), combined bacterial inoculum from corn field (PSB-C+NFB-C) and the control. A completely randomized block design was used under sterilized soil conditions with three replicates. Biometric parameters including plant height, number of leaves, leaf length, leaf width and the corn yield parameters were measured after 2 months. Biometric parameters were higher in the corn plants grown under the combined bacterial inoculum from forest soil. Leaf width of corn plants was significantly higher under the combined bacterial inoculum from forest (3.900 ± 0.211^{a}) than phosphate solubilizing bacterial inoculum from forest (2.966 ± 0.211^{b}). Combined bacterial inoculum from corn field soil showed the highest number of corn cob formation. It can be concluded that beneficial bacterial consortia from both soils positively influenced maize growth and highlighted their potential as biofertilizer inoculants for sustainable agriculture.

Keywords: *Soil bacterial community, Biofertilizer, Forest soil, Corn growth, Sustainable agriculture*

Acknowledgements: The authors are grateful to all the individuals, organizations and the university research grant (RJT/R&PC/2026/R/FOAS/04) for the valuable contribution and support throughout the research.

MICROPLASTICS CONTAMINATION IN FOOD FISH OF VARYING DIETARY HABITS IN SELECTED WEWA ECOSYSTEMS IN ANURADHAPURA DISTRICT

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Microplastics (MPs) are the particles smaller than 5 mm. It has emerged as a major global environmental threat. Although there were many studies focus on marine ecosystems, there were few studies in inland freshwater ecosystems in Sri Lanka. In this study, mainly investigate MPs contamination in dietary habits of food fish of major three Wewa in Anuradhapura District. They are Nachchaduwa Wewa, Nuwara Wewa and the Mahakanadarawa Wewa. Water, sediment and biota samples including *Oreochromis sp.*, *Puntius sp.*, *Etroplus suratensis*, *Mystus ankutta* and *Heteropneustes* sp. were collected during the second inter monsoon period of 2025. KOH: NaClO digestion and density separation with the NaCl was used for the sample Analysis. Visual identification and quantification were performed by using a Nikon SMZ18 stereo microscope, and polymer types were confirmed with Bruker ALPHA II FTIR analysis. Past 4.17 software was used and relative abundance was calculated for the data analysis. According to the lack of statistically significant differences in MPs types and the sizes in water and the sediment samples, indicates the homogenous environmental pollution by the activities around the Wewa area. However, the statistical association between the sample types in both water and the sediment, showed that the MPs partioning between the water column and the sediment layer is site specific. This variation directly correlates with the MPs found within the food fish with their varying dietary habits and ecological niches. In Nuwara Wewa, the significant association between MPs type and fish confirms the distinct feeding habits, such as filter feeding and benthic grazing. Conversly in Nachchaduwa Wewa, according to the highly significant association between the MPs size and fish species indicates that the feeding behaviours and mouth morphology are related with the ingestion of MPs. Further these positive statistical tendencies of fish dietary habits also interact with the characteristics of Wewa with proving the fish's specific tropic levels and the feeding zone are related with the bioaccumulation of MPs.

Keywords: *Microplastics, Freshwater ecosystems, Anuradhapura Wewa, Dietary habits, Environmental toxicology*

Acknowledgements: the authors are grateful to the academic and non-academic staff of the Faculty of Applied Sciences and Faculty of Technology, Rajarata University of Sri Lanka, Mihintale for their contribution to the successful completion of this study.

EXPLORING AND CHARACTERIZING ENDOPHYTIC MICROBIAL COMMUNITIES ASSOCIATED WITH SELECTED SEAGRASS SPECIES IN THE COASTAL REGIONS OF JAFFNA AND EVALUATING THEIR BIOACTIVE INTERACTIONS

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Seagrasses are ecologically important marine angiosperms that support coastal biodiversity, nutrient cycling and carbon sequestration. However, the diversity and ecological roles of seagrass-associated endophytic fungi remain poorly understood, particularly in Sri Lankan coastal ecosystems. This study explored and characterized endophytic microbial communities associated with selected seagrass species collected from four coastal locations in the Jaffna region of Sri Lanka, namely Sangupiddy Coastal Lagoon, Ariyalai–Navatkuli Lagoon, Pooneryn Beach and Kankesanthurai Beach. Eight seagrass species belonging to the families Hydrocharitaceae and Cymodoceaceae were identified based on morphological characteristics. Endophytic fungi were isolated from root and leaf tissues using different potato dextrose agar (PDA) media preparations. A total of 36 fungal isolates and two bacterial isolates were obtained, with the highest number of fungal isolates recorded from PDA prepared with seawater and tetracycline. Morphological characterization of fungal colonies revealed considerable variation in colony colour, texture, margin, elevation and pigmentation. Selected dominant fungal isolates were subjected to molecular analysis through DNA extraction, PCR amplification and ITS region sequencing for their identification. Dual culture assays demonstrated antagonistic interactions among fungal isolates and between fungal and bacterial isolates, indicating potential antimicrobial activity. No arbuscular mycorrhizal fungi (AMF) colonization was observed in the examined seagrass root samples. Overall, this study provides baseline information on seagrass-associated endophytic fungi in the coastal regions of Jaffna and highlights their potential ecological and biotechnological significance.

Keywords: *Seagrass, Endophytic fungi, Antagonistic interactions, Jaffna coast, Molecular identification*

CONSERVATION OF LAND-SNAIL DIVERSITY IN A FRAGMENTED RAINFOREST LANDSCAPE

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Forest fragmentation is a major driver of biodiversity loss in the forested tropics. It is is now well-established that the composition and survival of animal and plant communities in fragmented forest are profoundly affected by the surrounding non-forest habitats. However, data on the effects of forest fragmentation are scarce for the Asian tropics, and research across the tropics continues to be disproportionately focused on plants and vertebrates. This study investigates the species composition of land-snail assemblages across a fragmented tropical rainforest landscape. It has two objectives: (1) to understand the potential role of diverse forest and non-forest habitats for conserving rainforest land snails and (2) to investigate species compositional change over a 19-year period. The study was conducted in a 10 × 10 km lowland rainforest landscape situated along the western boundary of the Kanneliya-Dediyagala-Nakiyadeniya forest complex in Galle District, southwestern Sri Lanka. Using a standardized 2 × 100 m belt transect protocol, land-snail diversity and abundance were sampled and 8 environmental variables were measured. The environmental variables were habitat type, slope parallel to the transect, cross slope (i.e. slope at right angles to the transect), canopy density, soil pH, longitude and latitude. Two datasets were analysed using a multivariate approach. The role of habitat type (objective 1) was analysed using metric multidimensional scaling (MDS) on data sampled by one of us (D.C.R.) in 2007 from 37 transects (i.e. 37 sites) across four habitats. The four habitats were: fragmented rainforest (11 sites/transects), abandoned cultivation (7 sites/transects), home gardens (3 sites/transects) and monoculture cultivation (i.e. tea, rubber, oil palm and coconut; 16 sites/transects). Using MDS and distance-based redundancy analysis, we investigated the effect of time (objective 2) by combining data from 11 transects that were originally sampled in 2007 and resampled by both of us in January–February 2026. The 11 transects were from three habitats: fragmented rainforest (7 transects/sites), abandoned cultivation (2 transects/sites) and home gardens (2 transects/sites). Our investigation of the role of habitat, identified habitat type ($r^2 = 0.520$, $P < 0.0005$), canopy density ($r^2 = 0.551$, $P < 0.0005$) and cross slope ($r^2 = 0.405$, $P < 0.0025$) as principal drivers of compositional variation. The effect of habitat was particularly strong: the more diverse forest assemblages were richer and dominated by forest specialists and disturbance-tolerant forest species, whereas non-forest assemblages were a mixture of disturbance-tolerant forest species and non-forest species. Our analyses of the effect of time identified habitat (12.41%, $P = 0.001$), longitude (8.62%, $P = 0.001$) and elevation (6.69%, $P = 0.01$) as the strongest predictors, with time having a smaller but clearly detectable effect (2.59%, $P = 0.0034$). These analyses point to the overall resilience of the rainforest fauna over the last 19 years, with rainforest continuing to be strongly dominated by forest specialist species or taxa that are primarily dependent on forest habitats. Our findings underscore the irreplaceable conservation value of the remaining fragmented forests; the important supplementary role of key non-forest habitats and the need for habitat restoration and long-term monitoring.

Keywords: *Land snails, Forest fragmentation, Assemblage composition, Temporal change, Habitat*

Acknowledgements: This study was made possible by a grant (no. 26-02-RUSL) from the OKC Zoo Sri Lanka Biodiversity Grants Program of the Oklahoma City Zoo and Botanical Garden, Oklahoma City, Oklahoma, USA.

EVALUATION OF SPATIAL-TEMPORAL CHANGES OF CARBON STORAGE IN RESPONSE TO LAND USE CHANGES IN THE THABBOWA WEWA ASSOCIATED ECOSYSTEM

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Climate change and high concentration of atmospheric carbon dioxide (CO_2) level is critical global crisis. Vegetation significantly involves in mitigating climate change through carbon sequestration. This study assessed aboveground biomass (AGB), belowground biomass (BGB) within moderate to high vegetation strata and carbon storage potential in relation to land use land cover (LULC) changes from 2005 to 2035 in the Thabbowa Wewa associated ecosystem in Puttalam District of Sri Lanka. Field based inventory methods, remote sensing, geographic information systems (GIS) and the InVEST Carbon Storage and Sequestration model were used in for the analysis. The study area was stratified using the normalized difference vegetation index (NDVI) derived from Sentinel 2 imagery, and 42 circular sample plots were located in moderate to high vegetation strata to measure tree diameter and height. LULC maps dating from 2005, 2015 and 2025 were prepared using Landsat 5 TM and Sentinel 2 imagery through supervised classification with the maximum likelihood algorithm, while future LULC conditions for 2035 were predicted using an artificial neural network (ANN) model. The results showed AGB and BGB in moderate to high vegetation were 104.71 t ha^{-1} and 27.22 t ha^{-1}, with corresponding carbon pools of 49.21 t C ha^{-1} and 10.62 t C ha^{-1}. A strong positive relationship between LULC area and carbon storage was observed (r = 0.888), while the regression model confirmed a significant influence of LULC change on carbon dynamics (R^2 = 0.9889). Overall, the findings reinforce the importance of ecosystem conservation in sustaining carbon storage and mitigating climate change effects.

Keywords: *Land use land cover changes, Carbon storage, Ecosystem services, InVEST model, Sentinel 2 Level 2A*

Acknowledgements: The authors gratefully acknowledge the guidance and support provided by the supervisors and academic staff of the Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka and the Sri Lanka Forest Department, and the financial support received through the Oklahoma City Zoo and Botanical Garden, Sri Lankan Biodiversity Research Grant.

CHEMISTRY

BANANA PSEUDO-STEM DERIVED MICROCRYSTALLINE CELLULOSE AND CARBOXYMETHYL CELLULOSE REINFORCED POLYVINYL ALCOHOL FILMS WITH ENHANCED MOISTURE BARRIER AND BIODEGRADABILITY PROPERTIES

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Banana pseudo-stem waste has emerged as a promising reinforcing material for the development of sustainable and eco-friendly food packaging systems. In response to the growing global demand for alternatives to petroleum-based plastics, this study addresses the knowledge gap concerning the combined effect of cellulose derivatives isolated from the same agricultural waste source on biopolymer film performance. Biodegradable composite films were fabricated by blending a Polyvinyl Alcohol (PVA) matrix with microcrystalline cellulose (MCC) and carboxymethyl cellulose (CMC) derived from banana pseudo-stem powder. The cellulose derivatives were successfully extracted through sequential chemical treatments, including dual alkali purification for lignin and hemicellulose removal, two-step alkaline hydrogen peroxide bleaching for cellulose isolation, and controlled acid hydrolysis to obtain fine crystalline cellulose particles. The composite films were prepared using the solution casting method with glycerol as a plasticizer. The study primarily investigated the influence of the simultaneous incorporation of MCC and CMC on the physicochemical and biodegrability properties of PVA-based films. CMC was incorporated to improve hydrophilicity and flexibility through its water - attracting functional groups while MCC acted as reinforcing agent to enhance structural integrity and reduce excessive solubility. Structural, morphological, and optical analyses were carried out using Scanning Electron Microscopy (SEM), Fourier Transform Infrared (FTIR) spectroscopy, and UV–Visible spectrophotometry. Biodegradation behavior was assessed over a 30-day period through percentage weight loss measurements. Results demonstrated that 1% PVA formulations exhibited satisfactory film-forming ability and provided a suitable matrix for cellulose incorporation. Pure PVA films exhibited the lowest biodegradability (~23.5% weight loss), whereas the PVA 1% + MCC + CMC composite films showed the highest degradation rate (~63.7%). Physicochemical evaluations revealed complementary roles of the cellulose derivatives: CMC enhanced hydrophilicity, swelling, and water absorption, while MCC improved structural reinforcement and reduced overall water solubility. Additionally, water vapor permeability and accelerated aging studies confirmed that the developed films maintained satisfactory structural stability and storage durability for 21–30 days under ambient conditions. Overall, this dual-derivative strategy provides a viable closed-loop approach for converting agricultural waste into high-value biodegradable packaging materials.

***Keywords**: Banana pseudo-stem, Polyvinyl alcohol (PVA), Bio-composite films, Microcrystalline cellulose, Carboxymethyl cellulose (CMC)*

Acknowledgments: Financial support from RJT/R&PC/2026/R/FOAS/08 is highly acknowledged.

SYNERGISTIC ANTIOXIDANT EFFECTS OF SELECTED *Camellia sinensis* EXTRACT BLENDS ON FISH OIL OXIDATIVE STABILITY

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Tea (*Camellia sinensis*) is one of the most widely consumed beverages worldwide and contains a diverse range of bioactive compounds whose concentrations vary depending on tea type, leaf maturity, and manufacturing process. The objective of this study was to evaluate the antioxidant potential of different tea varieties based on flavour and tea manufacturing process, optimize selected tea extract combinations, and investigate their effectiveness in improving the oxidative stability of fish oil. Fifteen tea samples belonging to four categories, namely green tea, white tea, black tea, and tea flower infusion, were selected for analysis. The ethanolic tea extracts were prepared and determined antioxidant activity using the DPPH (1,1-diphenyl-2-picrylhydrazyl) free radical scavenging assay, total phenolic content (TPC) by the Folin-Ciocalteu method, and total flavonoid content (TFC) by $AlCl_3$ colorimetric method. Qualitative phytochemical screening was also carried out to identify the presence of alkaloids, flavonoids, polyphenols, tannins, saponins, terpenoids, carbohydrates, reducing sugars, steroids, and resins. Among the analyzed samples, three tea samples from each category demonstrated the highest values for DPPH scavenging activity, TPC, and TFC. The highest antioxidant activity was observed in cinnamon green tea (72.02%), followed by pure green tea (71.36%) and silvertip tea (70.05%). The highest TPC values were recorded in green tea with citrus (200.2 mg GAE/g extract), gun powder tea (199.97 mg GAE/g extract), and organic green tea (165.4 mg GAE/g extract). Similarly, the highest TFC values were observed in gun powder tea (105.08 mg QE/g extract), followed by black tea curl (57.33 mg QE/g extract), and both pure green tea and decaffeinated tea (53.08 mg QE/g extract). Overall, the findings suggest that green tea and minimally processed white tea possess comparatively higher antioxidant activity and phytochemical content than black tea varieties. Based on statistical analysis, gunpowder tea, cinnamon, and pure green tea were identified as the samples exhibiting the highest antioxidant activity. Based on the selected tea extracts, ten mixture combinations were formulated using a mixture design of experiments (DOE) approach and assessed for antioxidant activity using DPPH, TPC, and TFC analyses. The results were statistically analysed to identify the mixture with the highest antioxidant activity by using total score. Based on the overall antioxidant performance, the most effective mixture ratios selected for further evaluation were (1:0:0), (1:1:0), and (1:1:1). These ratios were introduced to fish oil and stored at 60 °C for 15 days with 2-day sampling intervals. Lipid oxidation during storage was evaluated using peroxide value, p-anisidine value and GC-MS. The GC-MS peak area integration was used to determine and confirm the relative percentages of EPA and DHA. The combination treatments demonstrated significant inhibition of lipid oxidation over the storage period by comparing the control. Overall, the combination of extracts exhibited a synergistic effect in significantly reducing lipid oxidation compared to the control, as evidenced by lower peroxide and p-anisidine values, thereby improving the oxidative stability of fish oil under accelerated storage conditions.

Keywords: *DPPH assay, Total phenolic content, Total flavonoid content, Lipid oxidation, Fish oil stability*

GREEN SYNTHESIS OF SILVER NANOPARTICLES USING *Azadirachta indica* (NEEM) FOR THE ADSORPTIVE SEPARATION OF SYNGAS (CO AND H_2)

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The increasing demand for sustainable nanomaterials has encouraged the development of environmentally friendly methods for nanoparticle synthesis and their application in gas adsorption technologies. In this study, silver nanoparticles (AgNPs) were synthesized through a green and cost-effective route using *Azadirachta indica* (neem) leaf extract as both reducing and capping agent. The phytochemicals present in the neem extract facilitated the reduction of silver ions (Ag^+) from aqueous silver nitrate solution under ambient conditions without the use of hazardous chemicals. The synthesis process was initially confirmed by a visible color change from pale yellow to brownish-black, indicating the formation of colloidal silver nanoparticles. The synthesized AgNPs were characterized using ultraviolet–visible (UV–Vis) spectroscopy and Fourier-transform infrared (FTIR) spectroscopy. UV–Vis analysis showed a characteristic surface plasmon resonance (SPR) absorption band in the 400–500 nm region, confirming the successful formation of AgNPs. FTIR spectra revealed the presence of biomolecular functional groups such as O–H, C=O, and C–O stretching vibrations, indicating that phytochemicals from neem extract acted as stabilizing and capping agents on the nanoparticle surface. To examine the interaction of these green-synthesized AgNPs with syngas components, namely carbon monoxide (CO) and hydrogen (H_2), a laboratory-scale gas adsorption system was designed and assembled. CO and H_2 gases were generated in situ through suitable chemical reactions and purged through the nanoparticle samples for exposure durations of 20, 40, and 60 minutes. After gas exposure, the samples were characterized using FTIR spectroscopy and thermogravimetric analysis (TGA) to investigate adsorption-induced surface and thermal changes. FTIR analysis of gas-exposed AgNPs revealed gradual variations in peak intensities and slight shifts in band positions with increasing exposure time, with the most significant spectral changes observed after 60 minutes of purging. These modifications suggest interactions between CO and H_2 molecules and the biomolecule-coated AgNP surfaces, likely involving physisorption and weak surface interactions mediated by phytochemical functional groups. TGA studies of CO-exposed AgNPs demonstrated gradual mass loss with increasing temperature, which may be associated with the removal of surface-bound species and thermal decomposition of biomolecular capping agents. The thermal behavior further indicated moderate stability of the phytochemical-coated nanoparticles after gas exposure, highlighting the role of the capping layer in nanoparticle stabilization and surface interaction processes. Overall, this study demonstrates a facile, eco-friendly, and scalable approach for synthesizing biomolecule-capped AgNPs using *Azadirachta indica* leaf extract and provides preliminary evidence of their interaction with syngas components under controlled exposure conditions. The findings suggest that green-synthesized AgNPs possess potential for gas adsorption and separation-related applications. Further studies involving adsorption kinetics, thermodynamic analysis, advanced surface characterization techniques, and recyclability assessments are recommended to better understand the adsorption mechanism and evaluate the practical applicability of the developed nanomaterial system.

Keywords: *Green synthesis, Silver nanoparticles (AgNPs), Gas-surface interaction, FTIR spectroscopy, Thermogravimetric analysis (TGA)*

Acknowledgements: Financial support from RJT/R&PC/2025/R/FOAS/07 is highly acknowledged. The authors sincerely thank Dr. H. A. N. Dharmagunawardhane, Head of the Department of Materials Technology and Eng.W. D. C. Weerasinghe the Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka for providing instrumental facilities and technical support.

GREEN SYNTHESIS OF LIGNIN-BASED SCHIFF BASE FUNCTIONALIZED Fe_3O_4 NANOPARTICLES FOR METAL ION REMOVAL

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Coconut coir is an abundant lignocellulosic agricultural residue that remains largely underutilized despite its high lignin content and potential as a renewable resource for value-added functional materials. This study aimed to extract lignin from coconut coir using a pseudo-deep eutectic solvent (pseudo-DES), depolymerize the lignin through microwave-assisted treatment, synthesize a lignin-based Schiff base, incorporate Fe_3O_4 nanoparticles, and evaluate the resulting magnetic nanocomposite for Cu^{2+} ion adsorption and magnetic recovery from aqueous solutions. A lactic acid–glycerol (LA–Gly) pseudo-DES was employed as a greener alternative to conventional lignin extraction systems. Extraction conditions were optimized, yielding 11.11 wt% lignin based on raw biomass, corresponding to approximately 34% of the native lignin content. UV–Visible spectroscopy showed the characteristic aromatic absorption band of lignin near 280 nm, while FTIR analysis confirmed the successful extraction of lignin and preservation of its characteristic functional groups. The extracted lignin was subsequently depolymerized using microwave-assisted treatment in methanol with chemically synthesized CuO nanoparticles as heterogeneous catalysts. Successful synthesis of CuO nanoparticles was confirmed by FTIR analysis. Depolymerization was evidenced by changes observed in both UV–Vis and FTIR spectra, indicating structural modification of the lignin and generation of lower-molecular-weight lignin fragments with enhanced reactivity. To improve metal-binding capability, the depolymerized lignin was functionalized through Schiff base condensation with aniline. FTIR analysis confirmed Schiff base formation through the appearance of characteristic imine (C=N) functionality. Magnetite (Fe_3O_4) nanoparticles were synthesized via alkaline co-precipitation of Fe^{2+} and Fe^{3+} salts and subsequently incorporated into the Schiff base-modified lignin matrix. FTIR spectra confirmed the presence of Fe–O vibrations, indicating successful incorporation of magnetite and formation of the magnetic nanocomposite. Batch adsorption studies conducted at room temperature demonstrated effective Cu^{2+} ion removal from aqueous solutions. The adsorbent also enabled rapid magnetic separation and recovery after treatment. Overall, this work presents a sustainable approach for converting coconut coir lignin into a magnetically recoverable adsorbent by integrating green solvent extraction, microwave-assisted depolymerization, chemical functionalization, and magnetic nanocomposite engineering for potential wastewater remediation applications.

Keywords: *Coconut coir, Lignin extraction, Pseudo-deep eutectic solvent, Microwave depolymerization, Schiff base*

Acknowledgements: Financial support from RJT/R&PC/2026/R/FOAS/08 is highly acknowledged.

CYTOTOXIC, ANTIOXIDANT, AND PHYTOCHEMICAL CHARACTERISATION OF MARINE SPONGE EXTRACTS: PHARMACEUTICAL POTENTIAL AND GC-MS PROFILING

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Marine sponges are prolific sources of structurally diverse bioactive secondary metabolites with significant pharmaceutical relevance. Despite documented sponge biodiversity along Sri Lankan coastlines, specimens from the Southern coast remain largely uncharacterised, representing a geographically distinct and unexplored chemical resource compared to previously studied Indo-Pacific populations. This study evaluated the cytotoxic and antioxidant activities of nine crude extracts from marine sponges collected at Kudawella, Southern Sri Lanka, and characterised their phytochemical profiles by GC-MS. Nine specimens were collected by scuba diving and morphologically identified to genus level by spicule isolation and light microscopy, yielding *Clathria* sp. (n=2), *Axinella* sp. (n=2), *Suberites* sp. (n=2), *Halichondria* sp. (n=1), and Order Tethyida (n=2). Sequential crude extracts were prepared by maceration in methanol, dichloromethane, and hexane (extraction yield: 1.2–4.7% dry weight). Cytotoxic activity was assessed using the Brine Shrimp Lethality Test (BSLT) with *Artemia salina* nauplii (n=3 replicates per extract), and LC_{50} values were determined by probit regression (Finney's method). Antioxidant activity and total phenolic content (TPC) were evaluated by the DPPH free radical scavenging assay and the Folin–Ciocalteu colorimetric method, respectively. GC-MS profiling was performed to characterise the secondary metabolite composition. BSLT revealed high cytotoxicity in *Clathria* sp. (S02; LC50 = 14.03 ± 1.2 ppm) and *Axinella* sp. (S05; LC50 = 36.18 ± 2.1 ppm and S04; LC50 = 57.54 ± 1.8 ppm), while *Suberites* sp. showed moderate toxicity and Order Tethyida specimens were non-toxic. DPPH assays indicated generally low antioxidant activity across extracts, with the highest scavenging observed in Order Tethyida (S07; %FRSA = 14.55 ± 0.9%), well below reference standards (ascorbic acid: 86.85%; BHT: 73.83%). TPC value among active samples were highest in *Halichondria* sp. (S06) with 5.43 ± 0.8 mg GAE/g extract. The absence of correlation between TPC and %FRSA values suggests non-phenolic origins of antioxidant activity. GC-MS analysis revealed a secondary metabolite profile dominated by fatty acid methyl esters, long-chain hydrocarbons, and sterols, with pharmacologically relevant compounds including ergosterol, cholesta-5,22-dien-3-ol, and tetradecyl isothiocyanate detected in the most cytotoxic extracts. These findings identify *Clathria* sp. and *Axinella* sp. as priority candidates for bioassay-guided fractionation and support further exploration of Southern Sri Lankan coastal sponges as sources of novel marine-derived pharmaceutical compounds.

Keywords: *Marine sponges, Brine Shrimp Lethality Test, GC-MS profiling, Antioxidant activity, Total phenolic content*

PHYTOCHEMICAL INVESTIGATION, BIOGENIC SILVER NANOPARTICLE SYNTHESIS, IN VITRO ANTIBACTERIAL EVALUATION, AND GC-MS GUIDED FABI-TARGETED MOLECULAR MODELING OF *Jeffreycia zeylanica* AS A SOURCE OF NOVEL ANTIBACTERIAL AGENTS

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Antibiotic resistance is a critical global health threat, driving the urgent need for novel plant-derived antimicrobial agents. This study aims to characterize the phytochemical profile, antioxidant potential, antibacterial efficacy, nanoparticle-mediated activity, and target-specific molecular mechanisms of *Jeffreycia zeylanica* (Asteraceae). *Jeffreycia zeylanica* is a Sri Lankan medicinal plant, traditionally used for fractures, skin diseases, asthma, and wound healing. Methanolic, hexanic, and aqueous leaf extracts were prepared by Soxhlet extraction. Qualitative phytochemical screening confirmed the presence of alkaloids, tannins, terpenoids, steroids, saponins, and flavonoids. The DPPH radical scavenging assay showed moderate antioxidant activity, with an IC_{50} value of 34.13 mg/mL. Agar well diffusion assays demonstrated that the aqueous extract exhibited the strongest antibacterial activity against Gram-positive *Staphylococcus aureus* (18.7 ± 0.9 mm), whereas none of the crude extracts inhibited Gram-negative *Escherichia coli*. Green-synthesized silver nanoparticles mediated by the aqueous leaf extract showed antibacterial activity against both bacterial strains. AgNP formation was confirmed by UV–Vis spectroscopy, with surface plasmon resonance maxima at 404–405 nm, and XRD analysis, which indicated a face-centered cubic crystalline silver structure. GC-MS analysis of the methanolic extract identified 30 compounds; major constituents were n-hexadecanoic acid (17.83%), 9,12,15-octadecatrienoic acid (9.30%), neophytadiene (8.26%), and lupeol acetate (7.76%). To investigate possible antibacterial mechanisms, 22 GC–MS-identified compounds were docked against DNA gyrase B, PBP4, PBP2a, and FabI. Docking results identified FabI as the most favorable target, and the top 13 FabI-binding compounds were further evaluated using 100 ns molecular dynamics simulations and MM/GBSA binding free-energy calculations. AFN-1252, the co-crystallized FabI inhibitor in PDB ID 4FS3, was used as the reference ligand; it is a highly potent *S. aureus* FabI inhibitor with a reported IC_{50} of 14 nM. Several plant-derived compounds showed calculated FabI binding free energies comparable to or stronger than AFN-1252 (−107.85 ± 11.80 kcal/mol), particularly methyl 9-cis,11-trans-octadecadienoate (−109.68 ± 10.94 kcal/mol), palmitoyl chloride (−108.71 ± 17.95 kcal/mol), and 3,7,11,15-tetramethyl-2-hexadecen-1-ol (−108.03 ± 16.19 kcal/mol). Overall, this integrated experimental and computational study identifies *J. zeylanica* as a promising source of antibacterial phytochemicals and plant-mediated AgNPs, with selected compounds warranting further isolation and experimental FabI inhibition studies.

Keywords: *Jeffreycia zeylanica, Antibacterial activity, Silver nanoparticles, GC-MS, Molecular dynamics simulation*

Acknowledgements: This research project is supported by Wayamba University Research Grant SHRDC/URG/2024/02. The authors thank Dr. Asanga Wijetunga, Dr. P.G.D.C.K. Karunarathna, Dr. S.N.T.D. De Silva, and Miss H.P.S. Jayaweera for their technical support, and the National Herbarium, Peradeniya, for plant authentication.

EXTRACTION, METAL CHELATION AND CHARACTERIZATION OF SOIL DERIVED HUMIC ACID AND FULVIC ACID

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Humic acid (HA) and Fulvic acid (FA) were extracted from mound soil through alkaline extraction using 0.1M NaOH followed by acid fractionation (pH 1-2). Experiments were conducted to evaluate their surface acidic functional groups, physicochemical properties, metal-chelation behavior and spectroscopic and electrochemical characteristics. UV-Visible spectroscopy of HA revealed stronger absorbance than FA, indicating greater aromaticity, molecular condensation and chromophoric complexity of the humic fraction. Chemical oxygen demand (COD) analysis of HA (106.4 mg/L) revealed substantially higher oxidable content and chemical demand reactivity than FA (53.2 mg/L). This suggests the presence of more condensed aromatic and redox active constituents in the humic fraction. Surface acidity characterization showed that FA possessed higher total acidity (6.0 meq/g) and carboxylic acidity (5.6 meq/g), indicating the oxygenated and hydrophilic functional group abundancy, whereas HA exhibited higher phenolic acidity (1.6 meq/g) reflecting greater aromatic hydroxyl and humified structures. Metal chelation studies with Ca^{2+}, Mg^{2+}, Al^{3+}, Pb^{2+}, Cr^{3+} and Cr^{6+} at concentration of 0.1 M for both HA and FA showed pH dependent complexation behavior influenced by metal ionic properties and the protonation of oxygen-containing functional groups. FTIR spectroscopy revealed that both HA and FA were rich in hydroxyl, carboxylic, and carbonyl functional groups and metal chelation led to significant shifts in the O-H stretching region (≈3200-3600 cm^{-1}), carboxylate-associated bands (≈1600-1400 cm^{-1}), and aromatic C=C related absorptions, indicating the active participation of oxygenated and aromatic functionalities in complex formation. Excitation of HA and FA at wavelength 370 nm and 330 nm showed strong fluorescence emission at 420–650 nm and 380–580 nm respectively, indicating structurally heterogeneous fluorophoric environments. Stern–Volmer plots demonstrated distinct metal-dependent fluorescence quenching and enhancement behaviors. HA exhibited broader emission profiles, stronger fluorescence perturbations and heterogeneous Stern–Volmer responses with significant quenching constants for Al^{3+} (K_{SV} = 32076.19 L/mol) and Cr^{6+} (K_{SV} = 32541.07 L/mol), which may reflect highly condensed aromatic and humified structures. FA displayed comparatively sharper fluorescence responses, with strong fluorescence enhancement toward Pb^{2+} (K_{SV} = −27263.58 L/mol) and pronounced quenching for Cr^{6+} (K_{SV} = 30624.35 L/mol), indicating greater fluorophore accessibility and more homogeneous oxygen-containing binding environments. Cyclic voltammetry studies at glassy carbon electrode in 0.1 M H_2SO_4 revealed two redox couples for FA at -0.25 V, -0.46 V and +0.45 V, +0.28 V and a weak redox couple at -0.19 V, +0.07 V for HA. The redox behavior is characterized by quinone, hydroquinone and phenolic moieties present in both HA and FA fractions. The less defined redox transitions of HA suggest restricted accessibility of electroactive sites due to greater molecular condensation, whereas FA exhibited comparatively higher current response and enhanced electron-transfer accessibility owing to its lower molecular complexity and greater abundance of exposed oxygen-containing functional groups. Overall, these findings highlight the crucial role of localized soil organic fractions in regulating metal complexation, binding affinity, and mobility.

Keywords: *Humic acid, Fulvic acid, Metal chelation, Spectroscopic characterization, Cyclic*

EFFECT OF THERMAL PRE-TREATMENT AND ACID LEACHING ON THE ELECTROCHEMICAL CHARACTERIZATION OF PULMODDAI ZIRCON MINERAL

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Zircon ($ZrSiO_4$) from Sri Lanka's Pulmoddai deposit has immense value, but iron (Fe) impurities restrict its use in high-end optical, ceramic and electrochemical industries. While existing literature focuses strictly on chemical purification or standalone mineralogical characterization, a major research gap remains, no prior studies combine thermal pre-treatment, acid leaching and cyclic voltammetry (CV) in a unified workflow for Pulmoddai zircon, nor do they directly compare HCl versus H_2SO_4 leaching across multiple heating states. This study addresses these gaps by introducing a novel three factor workflow (heat treatment, acid type, concentration/time) where iron extraction is quantified via UV-Vis spectroscopy and surface modifications are evaluated through electrochemical fingerprinting on a glassy carbon electrode (GCE). To optimize purification, samples were thermally treated at 200°C, 500°C and 800°C against a room temperature (RT) control. Low temperature treatments (200°C and 500°C) initiated thermal transition states of structural iron surface impurities, altering color from brownish-tan to deep hues. High temperature treatment (800°C) further immobilized lattice and surface iron into stable, less electrochemically active oxide phases. To eliminate these color inducing oxides, samples were leached using HCl and H_2SO_4 (20%, 40%, 60%) for 2 and 6 hours, turning all samples grey to white, visually confirming surface iron dissolution. Leachate analysis via the thiocyanate colorimetric method showed that the RT sample leached with 60% HCl for 6 hours achieved the highest iron removal efficiency. HCl outperformed H_2SO_4 due to the strong complexing capability of chloride ions (Cl^-) with ferric species. Surface reactivity was evaluated by coating variants onto a GCE for CV analysis in a 0.1M HCl electrolyte (pH 1.0). By CV profiles, raw thermal treatments suppressed baseline redox peaks due to iron oxide stabilization. Compared to the RT control (6.5×10^{-6}A), raw thermal treatments at 200°C and 500°C reduced anodic peak currents to 5.1×10^{-6}A (21.5% reduction) and 4.5×10^{-6}A (30.8% reduction) respectively, while the 800°C treatment resulted in a complete loss of redox peaks, yielding a featureless, purely capacitive profile. Acid leaching successfully stripped these dead surface oxide layers, re-exposing underlying electroactive mineral facets and restoring the redox peaks. Notably, the 60% HCl leached, 800°C heated, 6-hour variant emerged as the most altered, refined configuration; it revealed a prominent positive potential shift in the anodic peak from 0.29V to 0.42V (ΔE_p = +0.13V), a cathodic shift from 0.56V to 0.53V and a substantial 72.3% peak current reduction (1.8×10^{-6}A) relative to the raw RT baseline. In conclusion, low temperature thermal treatments alter surface iron impurities, while high temperature treatments immobilize them into stable phases. Subsequent acid leaching strips these dead layers to refine the zircon surface. For maximum chemical iron removal, the optimum parameters are an RT pre-treatment with 60% HCl leaching for 6 hours, capitalizing on chloride complexation. However, for advanced electrochemical applications, the 60% HCl leached, 800°C heated, 6-hour variant is best, re-exposing electroactive facets with a minimized peak current profile.

Keywords: *Zircon ($ZrSiO_4$), Acid leaching, Thermal pre-treatment, Iron extraction, Cyclic voltammetry*

THERMALLY MODIFIED PINE RESIN–COCONUT OIL COATING FOR ENHANCING MOISTURE-RESISTANT AND MECHANICAL PROPERTIES OF CASSAVA STARCH BASED BIOPOLYMER

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Starch-based bioplastic films have emerged as a promising renewable and biodegradable alternative to conventional synthetic plastics, addressing growing environmental concerns over plastic waste. However, their inherent hydrophilicity remains a critical limitation that restricts their practical applications due to loss of rigidity and potential for contamination with microbes. This study presents a post-fabrication surface coating strategy designed to enhance the water resistance and overall performance of cassava starch-based films plasticized with 20% glycerol. The resin samples were prepared by heating a mixture of pine resin and coconut oil at 180°C for 45 minutes and letting it cure at room temperature. Then the resulting product was dissolved in butyl acetate to make a coating solution and applied onto the film surface via brush coating at varying coconut oil concentrations. After the coating was dried, the samples were heated at 75°C for 15 min and allowed to cool down to room temperature. Several key properties were evaluated to assess film performance, including water absorption capacity (WAC), moisture content, area swelling index, and biodegradability. The WAC was measured at 75% relative humidity for 24 hours and the lowest WAC was shown in the 4% oil-containing resin-coated polymer, while the uncoated one showed the maximum of 13.9%, which is a WAC reduction of about 73%. The area swelling ratio was assessed after 1 hour of immersion in water. The uncoated one showed 67.5% while the 10% oil-containing resin-coated one showed the lowest value of 6.7%, which is about a 90% reduction. In the moisture content test, the uncoated one showed the highest moisture content of 16.4% while the 6% oil-containing resin-coated one showed 10% moisture content. The biodegradability was monitored after 10-days and 20-days. After 10 days of soil burial, uncoated films showed a degradation of 16%, while films coated with 4% coconut oil concentration exhibited the highest degradation of 25.2% among coated samples. After 20 days, uncoated films reached a maximum degradation of 50.6%, whereas films with 0% coconut oil containing coating were recorded the lowest degradation of 35.2%, and these results confirm that all formulations remained biodegradable, which is essential for their environmental acceptability. Overall, the findings of this study highlight the thermally modified pine resin–coconut oil coating system as a simple and sustainable approach for improving the moisture resistance of cassava starch-based bioplastic films without significantly compromising their biodegradability. This work contributes valuable insight toward the development of fully bio-based, functional, and environmentally friendly materials derived from locally available and renewable resources.

Keywords: *Bioplastic, Hydrophilicity, Pine resin, Surface coating, Thermally modified pine resin, Biodegradability*

ELECTROCHEMICAL CHARACTERIZATION OF SULFUR DIOXIDE – BENZOIC ACID SYSTEM IN ACETONITRILE

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Sulfur dioxide (SO_2) exhibits unique electrochemical behavior in non-aqueous media due to the formation of relatively stable sulfur-centered radical intermediates. The present study aimed to investigate the electrochemical behavior of the sulfur dioxide–benzoic acid system in acetonitrile and evaluate the influence of benzoic acid on sulfur dioxide electrochemical response and product formation. Electrochemical measurements were carried out in purified acetonitrile containing 0.1 mol dm^{-3} lithium perchlorate as the supporting electrolyte using a glassy carbon working electrode (GCE), platinum counter electrode and non-aqueous silver reference electrode. Sulfur dioxide was generated in situ and introduced into the electrolyte solution. Cyclic voltammetry (CV) experiments were performed under varying scan rates and concentrations, and bulk electrolysis was carried out at selected reduction potentials for product generation and characterization. In CV, sulfur dioxide exhibited a well-defined cathodic peak at approximately −0.52 V corresponding to one-electron reduction of SO_2 to sulfur dioxide radical anion and a minor oxidative peak at −0.19 V, while benzoic acid showed a reductive peak at −0.85 V. Peak currents increased with scan rates between 50–500 mV s^{-1}, indicating electrochemical activity influenced by mass transport processes. Bulk electrolysis performed at −0.60 V in the presence of benzoic acid resulted in the formation of a noticeable white film-like deposit on the GCE surface. In the mixed sulfur dioxide–benzoic acid system, enhanced cathodic current response and modified voltametric behavior were observed compared with the individual components, suggesting electrochemical interaction between sulfur dioxide-derived species and benzoic acid. Cyclic voltammograms obtained for the isolated product showed new electrochemical features compared with both sulfur dioxide and benzoic acid, indicating the formation of a new electroactive species. UV–Visible spectroscopic analysis revealed absorption characteristics different from those of benzoic acid, providing additional evidence that the isolated product was chemically distinct from the starting material. These findings demonstrate that sulfur dioxide undergoes quasi-reversible reduction in non-aqueous acetonitrile and that benzoic acid influences the electrochemical behavior of the system, resulting in formation of a chemically distinct electroactive product. This study provides preliminary insight into sulfur-centered electrochemistry and electro-organic transformations in non-aqueous media.

Keywords: *Sulfur dioxide radical anion, Benzoic acid, Acetonitrile, Cyclic voltammetry, Bulk electrolysis*

GREEN SYNTHESIS OF *Syzygium cumini* DERIVED COPPER NANOPARTICLES FOR SELECTIVE CO AND H_2 ADSORPTION TOWARD SYNGAS SEPARATION

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Increasing emissions of industrial gases, especially carbon monoxide (CO) and hydrogen (H_2) from petrochemical and industrial processes have created a significant demand for efficient gas adsorption and separation technologies. Conventional gas separation methods often involve high energy consumption and expensive operating conditions, which create the need for sustainable and cost-effective adsorption materials. In recent years, green-synthesised metal nanoparticles have gained considerable attention due to their enriched surface properties, environmental compatibility, and potential applications in selective gas adsorption technologies. For syngas purification, catalytic processes, and the use of hydrogen fuel, the selective separation of CO from H_2 is of particular interest because CO can poison industrial catalysts and reduce process efficiency. The study aimed to synthesize and characterize copper nanoparticles (CuNPs) using *Syzygium cumini* and assess their potential applicability as environmentally sustainable adsorbent materials for CO and H_2 gas adsorption relevant to syngas purification technologies. The nanoparticles were synthesised using leaf extract of *Syzygium cumini* (Java Plum) as a natural reducing and stabilising agent owing to its rich phytochemical composition. Preliminary phytochemical tests confirmed the presence of flavonoids, polyphenols and tannins. Biosynthesis of CuNPs was performed by preparing fresh leaf extract from *Syzygium cumini* and reacting with copper sulphate solution under controlled conditions. UV- Visible spectroscopy revealed the surface plasmon resonance band of copper nanoparticles between 520 and 600 nm. The presence of these copper surface species is considered to provide active sites that may facilitate CO adsorption via π-backbonding interaction. TGA studies of CO-adsorbed CuNPs showed a gradual mass loss with increasing temperature, which may be associated with the removal of surface-bound species and the thermal decomposition of biomolecular capping agents. The thermal behaviour indicates the stability of the phytochemical-coated nanoparticles after gas exposure, showing the role of the capping layer in nanoparticle stabilisation and surface interaction processes. FTIR spectra of the CO and H_2 gas-adsorbed CuNPs were performed, however, the results were insufficient for conclusive confirmation. Therefore, further characterization studies are required for the conformation.

Keywords: *Adsorption, Stabilizing, Nanoparticle, Surface plasmon resonance, Chemisorption*

Acknowledgements: Financial support from RJT/R&PC/2025/R/FOAS/07 is highly acknowledged. The authors also sincerely thank Dr. H. A. M. Dharmagunawardhana, Head of the Department of Materials Technology and Eng. W. D. C. Weerasinghe the Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka for providing instrumental facilities and technical support.

PHOTODYNAMIC ACTION OF 5,10,15,20-TETRAKIS(4-CARBOXYPHENYL) PORPHYRIN (H_2TcPP)-Fe_3O_4 NANOCOMPOSITES AGAINST PATHOGENIC *Aspergillus niger* AND *Rhizopus sp*.

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Pathogenic filamentous fungi, specifically *Aspergillus niger* and *Rhizopus sp.*, represent severe clinical threats as opportunistic pathogens. Both are airborne saprophytic fungi that propagate via resilient spores, but they cause different diseases. *A. niger* usually causes otomycosis and pulmonary aspergillosis while *Rhizopus sp*. causes mucormycosis that affects the brain, lungs, and paranasal sinuses. A widespread, rapidly escalating resistance to conventional antifungals make treatment of these mycoses extremely difficult, underscoring the critical need for non-antibiotic alternatives. Antimicrobial photodynamic therapy (aPDT) provides a promising solution by utilizing a photosensitizer that generates reactive oxygen species (ROS) upon visible light irradiation to destroy microbial structures. In this study, photosensitizer 5,10,15,20-tetrakis(4-carboxyphenyl) porphyrin (H_2TcPP) was used as a photosensitizer and magnetic Fe_3O_4 nanoparticles were synthesized by reducing $FeCl_3.6H_2O$ with $NaBH_4$ and formed magnetic Fe_3O_4 sonicated with H_2TcPP to yield an integrated H_2TcPP-Fe_3O_4 composite framework. The Fe_3O_4, H_2TcPP and H_2TcPP-Fe_3O_4 composites were characterized by UV-Visible, FTIR, fluorescence spectroscopy and Cyclic Voltammetry (CV). UV-Visible spectral analysis exhibited detectable shifts and electronic deviations in both the soret band (421nm) and the distinctive Q-bands (500-700nm) of porphyrin, confirming the binding of metal oxide to the porphyrin molecule. FTIR spectroscopy revealed the successful chemisorption on the Fe_3O_4 surface. Composite formation was validated by the shifting of aliphatic (C-H) stretches and broadening of the carbonyl (C=O) band into coordinated carboxylate resonances, together with unique metal-oxide vibrations. The characteristic dual-peak fluorescence emission (650nm, 715nm) of porphyrin was showed significant quenching upon Fe_3O_4 conjugation to the core. This behavior was quantified via Stern-Volmer analysis, confirming efficient, interaction-driven quenching kinetics. The photodynamic inactivation mediated by Fe_3O_4-H_2TcPP composite was compared with H_2TcPP and Fe_3O_4 on *A. niger* and *Rhizopus sp.* applying the well-diffusion method. For the antifungal susceptibility testing, 500 ppm concentrations of the formulations were prepared and evaluated at a controlled pH of 4.5. The prepared Fe_3O_4 was dissolved in sterilized distilled water, while free H_2TcPP and the H_2TcPP-Fe_3O_4 composites were dissolved in DMSO, with testing conducted under light and dark conditions separately. Against *A. niger*, the maximum zone of inhibition resulted exclusively under light conditions, yielding a diameter of 13.17 mm for the H_2TcPP-Fe_3O_4 composite. In contrast, Rhizopus sp. showed complete resistance, with no effective susceptibility to any of the compounds under both light and dark conditions. Independent solvent matrix screening confirmed that neither DMSO nor sterilized distilled water possessed independent antifungal activity, proving that the structural eradication of *A. niger* was purely a light-triggered phenomenon. Overall, this study demonstrates that the integrated H_2TcPP-Fe_3O_4 composite functions as a highly synergistic photosensitizing platform capable of mediating efficient, localized photodynamic inactivation against *A. niger* while highlighting distinct variations in susceptibility profiles among different filamentous fungal species.

Keywords: *Antimicrobial photodynamic therapy (aPDT), Photosensitizer, Porphyrin, Fluorescence spectroscopy, Susceptibility*

Acknowledgements: The authors gratefully acknowledge all the staff members of the Department of Microbiology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, for their valuable guidance and support throughout this research.

DEVELOPMENT OF A NUTRITIONALLY ENHANCED MAYONNAISE USING OPTIMISED EDIBLE OIL BLENDS: FATTY ACID PROFILING AND MULTIVARIATE ANALYSIS

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Increasing consumer awareness regarding the relationship between dietary fat intake and health has increased the demand for food products containing balanced fatty acid compositions and improved nutritional properties. However, limited information is available on the fatty acid composition and nutritional potential of traditional Sri Lankan rice oils and their comparison with commercially available rice oil. Therefore, this study aimed to evaluate the fatty acid composition of selected edible oils and develop a nutritionally enhanced mayonnaise formulation using optimised edible oil blends with improved nutritional characteristics and acceptable sensory quality. Fatty acid profiles of coconut oil, commercial rice oil, rice oils extracted from twenty traditional rice varieties, flaxseed oil, and chia seed oil were analysed using gas chromatography–mass spectrometry (GC–MS). Rice oils were extracted using Soxhlet extraction with petroleum ether and converted into fatty acid methyl esters (FAMEs) using methanolic sodium hydroxide and heptane prior to GC–MS analysis. GC–MS analysis revealed that the major fatty acids present in rice oils were oleic acid (44.19%), linoleic acid (28.11%), and palmitic acid (19.90%). The analysed rice oils contained 25.26% saturated fatty acids, 44.77% monounsaturated fatty acids, and 29.00% polyunsaturated fatty acids, indicating a favourable fatty acid balance. Flaxseed oil contained 11.57% saturated fatty acids, 20.72% monounsaturated fatty acids, and 66.57% polyunsaturated fatty acids, with α-linolenic acid as the predominant fatty acid. Chia seed oil contained 11.47% saturated fatty acids, 11.44% monounsaturated fatty acids, and 75.95% polyunsaturated fatty acids. Coconut oil exhibited a high proportion of saturated fatty acids, particularly lauric acid. Flaxseed oil was identified as the most suitable omega-3-rich oil source due to its favourable unsaturated fatty acid composition. Multivariate statistical analyses, including Principal Component Analysis (PCA) and discriminant analysis, demonstrated considerable diversity among the traditional rice varieties analysed, with the first four principal components explaining 79.586% of the total variance. Oil blend ratios for mayonnaise formulation were optimised using Stat-Ease Design-Expert software based on fatty acid composition and nutritional quality parameters. Six mayonnaise formulations containing different ratios of coconut oil, rice oil, and flaxseed oil were prepared and evaluated for sensory attributes including appearance, colour, aroma, texture, taste, and overall acceptability. Sample B received the highest sensory scores and was selected for shelf-life evaluation. Shelf-life studies conducted using free fatty acid (%FFA) analysis indicated gradual lipid deterioration during storage while maintaining acceptable product stability and sensory quality. The findings demonstrate the feasibility of using optimised edible oil blends for developing nutritionally enhanced mayonnaise with improved fatty acid composition, acceptable storage stability, and favourable consumer acceptability.

Keywords: *Fatty acid profile, GC–MS analysis, Rice oil, Principal component analysis, Mayonnaise formulation*

ELECTROCHEMICAL VALORIZATION OF COCONUT HUSK LIGNIN: A SUSTAINABLE BIOREFINERY APPROACH TO VALUABLE CHEMICAL PRECURSORS

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This study addresses agricultural waste valorization by converting coconut husk into high-value chemical precursors through a sustainable electrochemical biorefinery approach. Coconut husk is a viable biomass source due to its low cost, widespread availability, and high natural lignin content (32–45%). To isolate this biopolymer, an alkaline extraction method was utilized, yielding an extraction efficiency of 29.93%. The isolated lignin's identity was confirmed via UV-Vis spectroscopy, exhibiting characteristic absorption bands at 200–208 nm, 227–233 nm, and 268–287 nm. For the subsequent depolymerization stage, selective nickel (Ni) and non-selective lead dioxide (PbO_2) catalytic anodes were fabricated via electrodeposition on titanium plates. Cyclic voltammetry (CV) determined optimal conditions for controlled electrolysis. For the Ni electrode, an anodic current increase near the Ni(III)/Ni(II) redox couple indicated active electrocatalytic lignin oxidation. Conversely, adding lignin to the PbO_2 electrode increased the oxygen evolution potential and decreased reaction kinetics, suggesting lignin adsorption onto the surface, which suppresses competing water oxidation and focuses electrical energy toward organic cleavage. Following controlled electrolysis, product mixtures were analyzed. Intact lignin exhibited a broad absorption band centered at 275–280 nm, driven by $\pi \rightarrow \pi^*$ transitions within its interconnected aromatic rings (guaiacyl and syringyl units). Post-electrochemical treatment, UV-Vis spectra demonstrated prominent modifications: broad absorbance shoulders extending toward 340–380 nm—indicative of highly conjugated carbonyl and ketone linkages—flattened significantly. Concurrently, a hypsochromic shift of the primary 280 nm peak toward shorter wavelengths occurred, paired with a relative intensity increase near 298–300 nm. This spectral transformation confirms macromolecular network breakdown via aryl-ether linkage cleavage, yielding lower-molecular-weight, unconjugated monomeric and oligomeric phenolic fragments rich in free hydroxyl groups. Furthermore, Fourier-transform infrared (FTIR) spectroscopy interrogated the structural evolution across electrochemical treatments. Overlapping FTIR profiles for both electrode trials demonstrated a shared depolymerization pathway. Post-electrolysis spectra revealed a significant intensity increase in the broad hydroxyl (-OH) stretching band at ~3300cm^{-1} and a significant reduction in aliphatic ether linkage intensities (~1000-1200cm^{-1}), confirming extensive inter-unit aryl-ether bond cleavage. Concurrently, the sharp preservation and relative enhancement of aromatic skeletal and conjugated carbonyl (C=O) vibrations at ~1640cm^{-1} provide empirical evidence of a controlled, self-limiting depolymerization process. This indicates that easily cleavable inter-unit linkages break rapidly to form a stable equilibrium of oligomers and monomers, protecting the core aromatic frameworks from over-oxidation into smaller organic acids. Operating under mild ambient conditions, this electrocatalytic system using fabricated Ni and PbO_2 anodes demonstrates a highly selective, environmentally benign pathway for transforming lignocellulosic waste into stable platform chemical precursors.

Keywords: *Lignin, Coconut husk, Depolymerization, Lead oxide, Nickel*

Acknowledgements: Financial support from RJT/R&PC/2026/R/FOAS/08 is highly acknowledged.

GREEN APPROACH TO SYNGAS SEPARATION USING *Syzygium aromaticum* MEDIATED IRON NANOPARTICLES

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The increasing demand for sustainable and efficient gas separation technologies has encouraged the development of eco-friendly nanomaterials for industrial applications. Carbon monoxide (CO) and hydrogen (H_2) gas mixtures are commonly encountered in industrial applications, particularly in syngas production, hydrogen purification processes and various chemical industries. The separation of these gases is an important challenge due to their physical characteristics and the need for efficient purification techniques. Iron nanoparticles (FeNPs) have attracted considerable attention due to their high surface area, unique physicochemical properties, and ability to interact with gas molecules, making them promising candidates for gas adsorption and separation applications. This study focuses on the green synthesis of FeNPs and evaluates their potential for CO/H_2 separation. The nanoparticles were synthesised using *Syzygium aromaticum* (clove) extract as a natural reducing and stabilising agent, with ferric chloride ($FeCl_3$) as the precursor. Bioactive compounds in the clove extract facilitated the reduction of Fe^{3+} ions and promoted controlled nanoparticle formation, providing an environmentally friendly alternative to conventional synthesis methods. The synthesised nanoparticles were characterised using Ultraviolet–Visible (UV–Vis) and Fourier Transform Infrared (FTIR) spectroscopy to confirm formation and identify functional groups with UV–Vis absorption peaks observed between 216–268 nm, indicative of FeNP formation. To investigate the potential of Fe nanoparticles for CO/H_2 gas separation preliminary adsorption studies were carried out by separately exposing the synthesized nanoparticles to CO and H_2 gases using a laboratory-scale gas adsorption system designed for this study. The generated gases were first passed through a moisture-removal stage before entering the nanoparticle chamber under controlled pressure conditions. Following gas exposure, the nanoparticles were further analysed using UV–Vis, FTIR, and Thermogravimetric Analysis (TGA) to examine changes in material properties, functional groups, and thermal behaviour. Slight but notable variations in the spectral characteristics after gas exposure suggested interactions between gas molecules and the nanoparticle surfaces. These results highlight the potential of green-synthesised FeNPs for selective CO/H_2 gas separation and demonstrate a simple, cost-effective, and sustainable approach for developing nanoparticle-based materials for industrial gas purification applications. Further studies are required to investigate the selectivity and adsorption efficiency of green-synthesised FeNPs and optimise their performance for practical CO/H_2 gas separation applications.

Keywords*: Iron nanoparticles, Green synthesis, Gas adsorption, CO/H_2 separation, Syzygium aromaticum*

Acknowledgements**:** The authors gratefully acknowledge Dr. H. A. Naveen Dharmagunawardhane and Eng. W. D. C. Weerasinghe, Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka, for facilitating Thermogravimetric Analysis (TGA), and appreciate the financial support provided through RJT/R&PC/2025/R/FOAS/07.

ANALYSIS OF NITRATE AND NITRITE AT FERRIPROTOPORPHYRIN (IX) CHLORIDE MODIFIED GLASSY CARBON ELECTRODE

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Nitrate and nitrite are important nitrogen-containing ions commonly found in natural waters, groundwater, drinking water, agricultural runoff, and wastewater. Their detection and monitoring are essential because excessive concentrations can seriously affect human health, aquatic ecosystems, and water quality**.** Therefore, a sensitive electroanalytical method was developed for quantifying nitrate and nitrite in water. The electrochemical probing is based on the surface modification of a glassy carbon electrode with ferriprotoporphyrin(ix) chloride. This study investigates the detection of nitrate and nitrite using a hemin-coated GCE in acetate buffer solutions. Cyclic voltammetry (CV) was performed at a bare glassy carbon electrode in a pH 4.0 buffer, and the potentials were reported with respect to an Ag/AgCl reference electrode. At a bare GCE in a pH 4.0 buffer, nitrate exhibited a reduction peak at −0.6 V. In contrast, nitrite showed an oxidation peak at +0.8 V. CV performed on hemin-coated GCE exhibited a cathodic peak at −0.15 V for the reduction of Fe(III) ions, which gradually diminished with the addition of nitrite ions. Hemin-modified GCE, in the presence of nitrite, exhibited a cathodic peak at −0.6 V and an anodic peak at +0.8 V with enhanced current. Peak current at these potentials increased linearly with nitrite addition. At the modified electrode, nitrate showed an irreversible cathodic peak at −0.15 V and -0.6 V. The cathodic peak at -0.15 V decreased, whereas the peak at -0.6 V increased with nitrate addition. Addition of chlorides, sulphates, and phosphates did not exhibit any additional peak. This confirms better selectivity from other ions. UV-visible spectrophotometric studies for the dye confirmed the Soret band at 400 nm and Q bands at 510, 540, and 650 nm. In the presence of nitrite and nitrate, the absorbance of these peaks was decreased, and new peaks emerged at 570 and 600 nm. These changes were due to coordination state, axial ligand binding, solvent, and aggregation. The bulk electrolysis, separately carried out at a modified electrode for 40 mM nitrite and nitrate at -0.44 V and -0.60 V, respectively, showed a decrease in nitrite concentration from 40 to 1 mM, and an increase in nitrate from 40 to 237 mM. This confirms the reduction of nitrite to nitrogen-containing species such as nitrous oxide (N_2O), nitric oxide (NO), or ammonia (NH_3) and the reduction of nitrate to nitrite. Square wave voltammetry was employed for quantitative analysis of nitrate and nitrite and found to be more sensitive, with the limits of detection (LOD) of 70 nM for nitrite and 18 nM for nitrate. The hemin-modified electrode demonstrated better selectivity and sensitivity with lower detection limits and enhanced current. These findings demonstrate that the hemin-modified GCE is a promising low-cost electrochemical platform for sensitive nitrate and nitrite monitoring in water-quality analysis.

***Keywords**: Cyclic voltammetry, Glassy carbon electrode, Hemin, Square wave voltammetry, UV-Vi's spectrophotometry*

COMPUTING

A DUAL STREAM DEEP LEARNING APPROACH FOR EARLY KNEE OSTEOARTHRITIS DETECTION VIA LEARNING LOCATION-INDEPENDENT PATHOLOGICAL FEATURES AND ANATOMICALLY RELEVANT REGIONS FROM RADIOGRAPHIC IMAGES

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Knee Osteoarthritis (KOA) is a progressive degenerative joint disease that affects 364.6 million people globally. It is projected to reach 642 million by 2050, creating a significant burden on patients and health care systems. Radiographic assessment using the Kellgren-Lawrence (KL) grading system is the standard clinical method. However, early-stage KOA detection at KL-1 and KL-2 is challenging due to subtle radiographic features and high inter-observer variability, with reported Cohen's Kappa values as low as 0.08 to 0.31 among radiologists. Existing deep learning-based computer-aided diagnosis (CAD) systems learn both the appearance of pathological features and their spatial relevance simultaneously within a single entangled stream. Attention-based approaches do not explicitly model clinically meaningful anatomical relevance. Consequently, these models tend to learn location-dependent representations. As a result, current deep learning CAD approaches remain limited in their ability to detect early-stage KOA. Therefore, this study proposes a Dual-Stream Deep Learning approach that explicitly separates pathological feature learning from anatomical region segmentation and integrates them through an integration mechanism to predict the KL grade. The first stream, the Pathological Feature Learning Model, employs a three-block convolutional neural network trained on 32 x 32-pixel patches to classify radiographic features into Joint Space Narrowing, Osteophyte, and Normal Tissue. It generates probability maps via sliding window prediction. The second stream, the Anatomical Region Segmentation Model, uses SE-ResUNet, a custom encoder-decoder architecture with five validated contributions over the standard U-Net: a learned grayscale input projection, a pretrained ResNet50 encoder, residual decoder blocks, Squeeze-Excitation channel attention, and a deep supervision auxiliary head, which produce anatomical segmentation masks for five knee joint regions. The integration algorithm multiplies the probability maps from the first stream with the anatomical masks from the second stream and computes normalised Joint Space Narrowing and Osteophyte evidence scores. The evidence scores are then passed to classify knees as Normal (KL-0) or Early Stage (KL-1/KL-2). The solution was trained and evaluated using the publicly available OAI Knee Osteoarthritis Severity Grading Dataset from the Osteoarthritis Initiative, which contains 8,329 posteroanterior radiographs. For pathological feature learning, a consultant radiologist guided the extraction and verification of 5,342 image patches. The dataset was divided into training, validation, and test sets using a 70:15:15 split. For anatomical segmentation, 120 radiographs were manually annotated for five anatomical regions and split into training, validation, and test sets using the same 70:15:15 ratio. Experimental results demonstrated that the integrated system achieved an accuracy of 92.40% on binary Normal versus Early-Stage classification, with a blind-reader evaluation showing a Cohen's Kappa of 0.8136 and 90.9% agreement with a medical professional, outperforming the ViT-SSPE model, which achieved 89.80% accuracy. The findings indicate that explicitly separating pathological feature learning from anatomical relevance region segmentation significantly improves early-stage KOA detection performance and clinical interpretability. It is recommended that future work incorporate longitudinal time-series data to model disease progression and optimise the sliding window approach to reduce computational overhead.

Keywords: *Deep learning, Dual stream model, Early detection, Knee osteoarthritis, X-ray analysis*

ACCURACY-PRESERVING ON-DEVICE KEYWORD SPOTTING SYSTEM FOR RESOURCE-CONSTRAINED MICROCONTROLLERS

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TinyML enables on-device keyword spotting on resource-constrained MCUs; however, achieving reliable accuracy under real-world noisy conditions and across larger keyword sets remains a persistent challenge when applying model compression techniques such as quantisation. Compression methods that reduce model size often degrade the decision boundaries that distinguish acoustically similar commands, and this degradation intensifies as task complexity increases. Most existing TinyML-based KWS studies report satisfactory accuracy only on clean audio keyword classes, and few evaluate their compressed models on actual microcontroller hardware. This study addresses these limitations by proposing an integrated optimisation pipeline that combines three techniques within a single framework: baseline lightweight convolutional neural network (CNN), teacher–student knowledge distillation (KD) framework with logit and feature-level knowledge transfer using SpecAugment-based training, and quantisation-aware training (QAT) to INT8 bit-depth. The teacher model used for knowledge distillation training is trained using SpecAugment, which applies time and frequency masking to generate a noise-robust internal representation that can be transferred to the student model through combined logit and feature-level distillation. Since logit-level distillation alone has shown unsatisfactory performance due to the large capacity difference between teacher and student, the combination of feature and logits distillation was used to improve the knowledge transfer. The experiments were carried out using the Google Speech Commands V2 dataset with a 12-class setting, including ten main keywords, silence, and unknown. The tested models were evaluated in clean setting and four different SNR noise levels: 0 dB, 5 dB, 10 dB, and 20 dB. Compared to the baseline model, which achieved an accuracy of 91.40% on clean data and dropped to 59.48% at 0 dB SNR, the proposed model achieved 92.07% accuracy in clean conditions while maintaining 63.59% at 0 dB SNR, while reducing the model size by 80.7% from 98.8 KB to 19.1 KB. Moreover, the macro F1 score increased from 0.8924 of the baseline model to 0.9287 of the proposed model, showing improved per-class accuracy, including the more difficult silence and unknown classes. The proposed model showed better performance than the baseline model at every noise level, especially at the lowest SNR level when model robustness becomes crucial. The proposed model was run on an ESP32-S3 microcontroller board to verify model deployment feasibility. On this microcontroller board, the quantised model uses approximately 200 KB of SRAM as a tensor arena, and takes an average of 16.24ms of inference latency per frame. These characteristics demonstrate that the proposed model is capable of performing in real-time on keyword-detection frames lasting one second while staying within general-purpose embedded MCU resource limits.

Keywords: *Keyword spotting, Knowledge distillation, Quantisation, SpecAugment, TinyML*

A VISION TRANSFORMER BASED MODEL FOR CLASSIFICATION OF SCHIZOPHRENIA SEVERITY CATEGORIES USING MANDALA DRAWINGS

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Schizophrenia is a long-term mental disorder that affects how a person thinks, feels, and behaves. Knowing how severe the symptoms are is important for treatment planning and follow-up. The Positive and Negative Syndrome Scale (PANSS) is the most widely used tool for measuring symptom severity, but it is administered by a clinician, takes a long time, and can be affected by personal judgment, especially in settings with limited mental health staff. To address this gap, this study developed a Vision Transformer (ViT)-based model that classifies schizophrenia severity into four PANSS-aligned categories (Healthy, Minor, Medium, and Severe) using Structured Mandala Colouring (SMC), supported by a simple behavioural feature. A cross-sectional observational study was carried out at the National Hospital, Kandy, Sri Lanka. Forty-four mandala drawings were collected in total, thirty-one from clinically diagnosed schizophrenia patients and thirteen from healthy controls. Each participant coloured the same A4 mandala template using the same six coloured pencils, and the completion time was recorded. Drawings were scanned at 300 dots per inch. PANSS scores were collected for every schizophrenia participant by a trained psychiatrist, and severity labels were clinician-confirmed using PANSS-derived cut-off values from the international literature, as no Sri Lankan-specific thresholds are available. The original samples were divided using a stratified split of 50% training, 25% validation, and 25% testing. The training set was then expanded to 144 images using flips, rotations, and prompt-based synthetic generation that preserved each severity category. The model used a ViT-Base Patch16 224 backbone pretrained on ImageNet-21k to capture global mandala features such as radial symmetry and relationships between distant zones. The visual feature vector from the ViT was combined with the standardised completion time through late fusion and passed to a small classification head. Training was carried out in two stages using the AdamW optimiser, class-weighted cross-entropy loss, label smoothing, and early stopping. The proposed model achieved a test accuracy of 72.73% and a macro F1-score of 71.79%, correctly classifying 8 out of 11 test samples. This indicates that the ViT-based model can effectively learn the visual and behavioural patterns associated with each severity category. For the Severe class, both precision and recall reached 1.00, meaning every Severe sample was correctly identified and no other class was predicted as Severe. All misclassifications occurred between adjacent severity levels, mainly at the Minor–Medium boundary, and no clinically distant errors (such as Healthy predicted as Severe) were observed. Gradient-weighted Class Activation Mapping visualisations showed that the model focused on clinically meaningful mandala regions when making decisions. The proposed model is recommended as a low-cost, supportive tool for schizophrenia severity assessment alongside routine PANSS evaluation, particularly in resource-limited clinical settings. The main limitations of this study are the small, single-site dataset of 44 original samples, which restricts generalisability, and the cross-sectional single-session design, which does not account for possible task-familiarity effects in repeated assessments. A key future direction is the collection of a larger, multi-site dataset along with richer behavioural features such as stroke order and pause patterns to improve robustness and clinical applicability.

Keywords: *PANSS, Schizophrenia, Structured mandala colouring, Vision transformer*

Acknowledgements: The authors thank the Consultant Psychiatrists and clinical staff at the National Hospital, Kandy, and the participants and their families for their support throughout this study.

FUSIONSHIELD: PHISHING URL DETECTION VIA DUAL-STREAM FEATURE FUSION AND DOUBLE DEEP Q-NETWORKS

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Phishing continues to represent one of the most critical cybersecurity threats, leading to large-scale financial losses, data breaches, and identity theft worldwide. Despite significant advancements in detection mechanisms, existing approaches remain constrained by key limitations, including reliance on shallow feature representations, dependency on external services, and limited adaptability to rapidly evolving adversarial techniques such as obfuscation, homograph attacks, and AI-generated phishing URLs. These shortcomings hinder real-time deployment and reduce resilience against zero-day attacks. To address these challenges, this study introduces FusionShield, a novel reinforcement learning-based phishing URL detection framework that operates exclusively on the intrinsic properties of URLs. The proposed system leverages a dual-stream feature fusion architecture, combining high-dimensional semantic embeddings derived from transformer-based representations with carefully engineered lexical features that capture structural and statistical characteristics of URLs. This fusion enables the construction of a rich, multi-dimensional representation that overcomes the limitations of isolated feature categories while maintaining computational efficiency. At the core of FusionShield is a Double Deep Q-Network (DDQN) agent that models phishing detection as a reinforcement learning problem. Leveraging the fused feature representation, the agent learns an adaptive detection policy that improves robustness against evolving phishing patterns and adversarial URL manipulations. Unlike conventional supervised classifiers that optimise fixed classification mappings from labelled training data, the reinforcement learning paradigm enables policy-based decision optimisation through reward-driven learning, allowing the model to better generalise under adversarial obfuscations and emerging attack strategies. FusionShield was initially trained and tested using the publicly available LegitPhish dataset, comprising over 100,000 labelled URLs with an imbalanced class distribution, achieving strong performance with an accuracy of 99.96%, a false positive rate (FPR) of 0.02%, and a Matthews Correlation Coefficient (MCC) of 0.9994, demonstrating both precision and reliability under class imbalance. To further assess generalisation capability, cross-dataset evaluations were performed on the independently collected PhiUSIIL dataset containing over 235,000 URLs and a synthetically generated adversarial dataset containing diverse obfuscation patterns. The model maintained strong performance, achieving accuracies of 95.88% and 91.20% with MCC scores of 0.92 and 0.85, respectively, confirming its robustness under distributional shifts and adversarial conditions. Comparative benchmarking against state-of-the-art reinforcement learning baselines, including the HARE model and the approach proposed by Jabbar and Al-Janabi, highlights the effectiveness of FusionShield in terms of detection accuracy, false positive reduction, and adaptability. Additionally, ablation studies validate the effectiveness of the dual-stream feature fusion strategy, demonstrating significant performance degradation when either semantic or lexical components are removed. To validate real-world applicability, a lightweight browser-based plugin was developed, showcasing low-latency inference and seamless integration into user workflows without reliance on external services. This confirms the practicality of the proposed approach for real-time deployment in resource-constrained environments. Overall, FusionShield establishes a scalable, efficient, and adaptive framework for phishing URL detection, demonstrating the effectiveness of combining multi-dimensional URL representations with reinforcement learning for robust phishing URL detection.

Keywords: *Adversarial robustness, Cyber threat detection, Deep reinforcement learning, Feature fusion, Phishing URL detection*

DEEPFAKE IMAGE DETECTION THROUGH SPATIALLY GUIDED SEMANTIC FEATURE LEARNING WITH AN INTEGRATED CONVOLUTIONAL NEURAL NETWORK AND DATA-EFFICIENT IMAGE TRANSFORMER

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Deepfake image generation has rapidly advanced with the development of Generative Adversarial Networks (GANs) and diffusion-based models, making manipulated images increasingly realistic and difficult to identify. These deepfake images create serious concerns related to misinformation, privacy violations, and digital trust. Existing deepfake detection methods mainly use Convolutional Neural Networks (CNNs) to identify local spatial artefacts such as texture inconsistencies and noise distortions, while Transformer-based models focus on learning global semantic relationships and contextual inconsistencies within images. However, most existing hybrid approaches fail to effectively combine these two feature types during feature learning. Some methods preserve the connection between CNN and Transformer while losing spatial locality, whereas others preserve spatial information but learn spatial and semantic features independently without interaction. Therefore, this study proposes a spatially guided hybrid deepfake detection framework that preserves spatial artefact information while enabling meaningful interaction with semantic reasoning. The proposed framework consists of three main components: a Spatial Feature Detector CNN (SpFD-CNN) based on EfficientNet-B0, a semantic feature detector based on Data-Efficient Image Transformer (DeiT-Small), and a Spatial-Guided Attention Mechanism (SGAM). Initially, the SpFD-CNN extracts pixel-level spatial artefacts from face-cropped images and generates spatial activation maps highlighting manipulation-relevant regions. These spatial activation maps are then directly integrated into the DeiT self-attention process through the SGAM, guiding the Transformer towards important manipulated regions during semantic feature learning. This allows the framework to preserve spatial locality while simultaneously learning contextual and structural inconsistencies across the image. The proposed model was trained and evaluated using a subset of the DeepFakeBench dataset consisting of 3200 face-cropped images, including 1600 real and 1600 fake images generated using multiple deepfake generation methods. Experimental results demonstrated that the proposed framework achieved an accuracy of 98.18%, a Recall of 99.67%, and an F1-score of 98.36%, outperforming existing state-of-the-art hybrid approaches, including CAMME and CAE-Net. The findings indicate that integrating spatial artefact information with semantic reasoning through spatial-guided attention significantly improves deepfake image detection performance and enhances the model's ability to identify complex manipulations. Future research can extend the proposed framework towards video-based deepfake detection by incorporating temporal feature learning to identify motion inconsistencies, lip-sync mismatches, and temporal artefacts across consecutive video frames in real-world multimedia content.

Keywords: *CNN, Deepfake detection, DeiT, Semantic feature learning, Spatial-guided attention*

MITIGATING COLD START LATENCY IN SERVERLESS PLATFORMS USING AN INVOCATION INTENT AWARE AI MODEL

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Serverless computing has revolutionised the deployment of cloud-native applications by enabling automatic scaling and efficient resource utilisation. However, cold start latency remains a significant challenge. This issue occurs when an inactive function must reinitialise its container, set up the runtime, and reload dependencies before handling a request. This delay can severely impact latency-sensitive sectors such as finance, healthcare, and e-commerce, where even minor response delays can lead to poor user experience. Current methods to reduce this delay, such as static pre-warming, heuristic-based scaling, and container reuse, offer only partial solutions. They rely on fixed rules or historical averages that demonstrate limited adaptability to varying workload patterns. Unlike these approaches, this study introduces a predictive, intent-aware warmup framework that anticipates user actions from sequential interaction data and proactively warms serverless functions before invocation occurs. This framework preloads serverless functions before requests arrive by predicting the next likely user action. The methodology employed a quantitative experimental approach on the faasd (OpenFaaS) serverless platform. Within the experimental environment, the backend services of the online learning platform CodeMentor were modularised into seven independent serverless functions: signup, login, logout, category selection, sub-category selection, question selection, and password reset. The proposed model focused on four main user intent-related features: user identity, invoked function, temporal context (date-time), and HTTP/function status code, derived from session behaviour patterns. It was built using an Adaptive Attention-based Gated Recurrent Unit (GRU) neural network architecture that processes sequential interaction data and learns temporal dependencies in user behaviour. An attention mechanism was incorporated to highlight important interaction steps over routine actions, allowing the model to focus on the most significant transitions for improved prediction accuracy. Adaptive learning was used to adjust to changing user behaviour patterns during runtime. In this adaptive process, a focal loss function was applied to address class imbalance and reduce the influence of repetitive, easily classified actions while emphasising rare but important actions such as “Forgot Password” and “Signup.” More than 7,500 live interaction records were gathered through a real-time logging pipeline over a four-month multi-user experimental deployment period, beginning with 8 users and scaling up to 12 active users to train and evaluate the system. Test results showed that the model achieved approximately 96% prediction accuracy, along with strong precision, recall, and F1-score values for infrequent functions. At the system level, the AI-driven proactive warmup mechanism reduced average function execution latency by approximately 77% compared to the default serverless environment. When compared to a Q-learning-based baseline, the proposed framework improved response times by 49%, reduced CPU usage by 6.25%, and decreased overall CPU consumption by 13.35% relative to the default setup. These results demonstrate that combining sequence-based deep learning with proactive orchestration strategies can effectively create low-latency, cost-efficient serverless execution environments, particularly for workload patterns with dynamic, user-driven invocation behaviour.

Keywords: *Adaptive learning, Cold start latency, GRU, OpenFaaS, Serverless computing*

Acknowledgements: We extend heartfelt gratitude to Prof. M.S.D. Fernando and all other academic and non-academic staff at Rajarata University.

A RADIOGRAPHIC FEATURE-AWARE SWIN TRANSFORMER FOR DIFFERENTIATING PNEUMONIA AND LUNG CANCER ON CHEST X-RAYS

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While chest X-rays are the primary tool for assessing lung diseases, differentiating pneumonia from lung cancer remains challenging due to overlapping radiographic features such as opacities, consolidations, nodules, and masses, often leading to diagnostic uncertainty and delayed treatment. Although many deep learning models have been developed for chest X-ray classification, most are designed for general disease detection, and their reliability is limited in differentiating pneumonia from lung cancer with overlapping radiographic features. The aim of this study was to develop a radiographic feature-aware deep learning model to improve the differentiation of pneumonia and lung cancer in chest X-ray images, with particular emphasis on clinically ambiguous cases. To achieve this, a custom dataset was constructed by combining three publicly available datasets: NIH ChestX-ray14, CheXpert, and JSRT. The final dataset contained 2,000 chest X-ray images, with 1,000 pneumonia cases and 1,000 cancer-related cases. The dataset was designed to include both clear and clinically ambiguous cases characterised by overlapping radiographic features such as opacities, consolidations, and masses, with sample selection guided by a clinical expert. A Swin Transformer-S model was used as the backbone architecture because of its ability to capture both local and global image features through hierarchical attention. A multilayer perceptron (MLP) classification head was added to refine the extracted features and improve classification performance. The model was trained and evaluated using an 80:10:10 split for training, validation, and testing. The proposed model achieved an accuracy of 86.5%, an F1-score of 86.5%, and an AUC of 0.9442 on the test set, indicating strong overall classification performance and excellent discriminative ability. It outperformed DenseNet-121 (80.0% accuracy) and Vision Transformer (76.0% accuracy) baselines, demonstrating improved performance in differentiating pneumonia and lung cancer in the presence of overlapping radiographic features. Grad-CAM visualisations showed that the model focused on clinically relevant regions, including opacities, consolidations, and masses. Overall, the results demonstrate that the proposed approach is a reliable and interpretable method for differentiating pneumonia and lung cancer from chest X-ray images. Future research should focus on validating the model using larger multi-centre clinical datasets to further assess its generalisability and real-world applicability.

Keywords: *Chest X-ray, Explainable AI, Lung cancer, Pneumonia, Swin transformer*

TRANSFORMER-BASED CLASSIFICATION OF READING COMPREHENSION IN GRADE 3 SINHALA LEARNERS USING PIRLS COGNITIVE PROCESSES AND BEHAVIOURAL INDICATORS

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Reading comprehension in early primary education is a critical foundation for long-term academic success. Around Grade 3, children shift from learning to read to reading to learn, making it crucial to address any comprehension difficulties as these can lead to long-term consequences if unrecognised. The Progress in International Reading Literacy Study (PIRLS) framework defines four cognitive processes underlying reading comprehension: literal, inferential, evaluative, and metacognitive. Many grade 3 students in Sri Lanka struggle across these dimensions, but teachers lack reliable tools to identify specific comprehension weaknesses. No automated classification system exists for Sinhala medium primary learners. This study had four objectives: building a validated dataset, grouping students into cognitive reading profiles, developing a transformer-based classification model, and evaluating it both statistically and with clinical input. A nine-question assessment instrument, aligned with the National Institute of Education (NIE) Sri Lanka curriculum and covering four cognitive domains, was administered to 177 grade 3 students in two government schools in the Kandy district. Written responses were collected under standard classroom conditions with parental consent. A concurrent behavioural checklist captured observable indicators during the assessment session. Nine behavioural and linguistic features were extracted from student responses and the checklist, including total response time and self-correction frequency. Both instruments were validated through an expert review involving subject teachers and a speech and language therapist. K-Means clustering (k=3, confirmed by the elbow method and silhouette scores) grouped students into three cognitive profiles: surface comprehender, strategic comprehender, and developing comprehender. Significant differences across all four cognitive process scores were confirmed by ANOVA ($p < 0.001$). The Cognitive Process-Aware Transformer (CPAT) was developed using a shared DistilBERT backbone, modified with cross-process attention injected at layer 2. This enables the deeper transformer layers to encode all four cognitive processes jointly, allowing cross-process relationships to influence higher-level semantic representations. Behavioural and linguistic features were integrated at the final stage through sigmoid gate fusion. CPAT achieved a Macro F1 score of 0.8899 and 91.52% accuracy across five-fold cross-validation, compared to 0.6527 for the baseline concatenation model. The developing comprehender group, the smallest profile (n=10), was classified with a recall of 1.00, demonstrating the model's sensitivity to minority profiles. A speech and language therapist independently confirmed the clinical interpretability and practical relevance of all three profiles. CPAT offers a practical diagnostic tool to support teachers and therapists in identifying reading comprehension difficulties in early primary learners and planning targeted interventions.

Keywords: *Cognitive profiling, DistilBERT, PIRLS cognitive processes, reading comprehension, transformer-based model*

Acknowledgements: The authors gratefully acknowledge the participating schools, the expert panel, and the Ethical Review Committee of the Faculty of Applied Sciences for their support.

HEALTH PROMOTION

EVALUATING THE EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION TO IMPROVE PHYSICAL ACTIVITY LEVELS AMONG SCHOOL-GOING ADOLESCENTS IN A SELECTED SCHOOL IN ANURADHAPURA DISTRICT

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Adolescent physical activity is crucial for healthy development and lifelong behaviours. Physical activity includes walking, cycling, sports, and recreation. WHO recommends that children and adolescents aged 5–17 years engage in at least 60 minutes of moderate-to-vigorous physical activity daily. Insufficient activity to meet global recommendations is defined as physical inactivity, a silent global health threat. National data indicates 84% of Sri Lankan adolescents fall below recommended physical activity levels. Few interventions have implemented participatory methods with adolescents to promote physical activity. This study aimed to evaluate the effectiveness of a health promotion intervention in improving physical activity levels among adolescents in a school in Anuradhapura District. A quasi-experimental design with intervention and control groups was conducted in two government, type 1C schools in Anuradhapura, recruiting adolescents aged 13–14 years of both genders. The study consisted of three phases: pre-intervention, intervention, and post-intervention. In the pre-intervention phase, self-administered questionnaires and focus group guides were developed to assess physical activity levels, attitudes, and knowledge, and baseline quantitative data were collected. During the intervention phase, a participatory health promotion intervention was co-designed and implemented with the intervention group. Following the successful engagements and facilitation by the researcher. Participants identified and prioritized determinants of physical inactivity, such as poor time management, low motivation, and low awareness, and collectively implemented actions, including playing during school intervals, walking with friends, reducing screen time, and engaging in peer group games. The participants continuously monitored progress and identified changes. In the post-intervention phase, quantitative data were collected from both groups using the same questionnaire, and qualitative data were gathered through focus groups with the intervention group. Quantitative data were analysed using independent-samples t-tests and descriptive statistics, as baseline and post-intervention responses could not be matched at the individual level. Qualitative data were analysed thematically. Knowledge related to physical activity improved significantly ($p < 0.001$), and a positive attitude toward physical activity showed a positive trend ($p = 0.07$) between groups. Daily activity minutes increased similarly in both groups, from 17 to 21 in the intervention group and from 16 to 21 in the control group. Independent-samples t-tests revealed no significant differences at baseline $t(121) = 0.26$, $p = .798$, 95% CI [−6.56, 8.51] or post intervention $t(117) = -1.35$, $p = .180$, 95% CI [−13.28, 2.54]. A small proportion of adolescents met the WHO guideline of 60 minutes daily, rising from 6.5% to 9.8% in the intervention group and 6.6% to 10.3% in the control group. These differences were not statistically significant at baseline ($\chi^2(1, N = 123) = 0.001$, $p = 0.981$) or post-intervention ($\chi^2(1, N = 119) = 0.008$, $p = 0.927$). Based on the findings of this study, it can be concluded that while behavioural changes in physical activity levels were not statistically significant within the limited intervention period, the participatory health promotion intervention effectively improved knowledge and attitudes, which may support future behavioural change if sustained over a longer period, and it was effective in addressing determinants that influenced adolescents' physical activity.

Keywords: *Physical activity, Health promotion intervention, Adolescents, School health*

Acknowledgements: The authors are grateful to the administration of both schools.

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN IMPROVING MENSTRUAL HEALTH AMONG GARMENT FACTORY FEMALE WORKERS IN A SELECTED MID-SCALE GARMENT FACTORY IN ANURADHAPURA DISTRICT

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Menstrual health remains a neglected area of women's health, particularly among women in low-income occupational settings, where workplace constraints and socio-cultural stigma negatively affect menstrual practices and functional ability. Although most existing interventions focus on school-aged girls and are largely education-based, evidence on workplace health promotion interventions among adult women is limited. This study aimed to assess the effectiveness of a health promotion intervention to improve menstrual health among female garment factory workers in a selected mid-scale garment factory in Anuradhapura district. A single-group pre-test post-test study was conducted at Compass International (Pvt) Ltd., Anuradhapura. Baseline data were collected using a structured questionnaire assessing menstrual hygiene, dietary practices, pain management, and functional ability. A four-month health promotion intervention was developed and implemented through a participatory process based on core principles of health promotion. Initially, the goal of improving menstrual health through better menstrual-related practices was identified through facilitation. Low awareness of menstrual health and low priority given to it in daily life were identified as key determinants affecting menstrual-related practices, and appropriate actions were collaboratively planned with the participants, implemented, monitored, and modified throughout the intervention. Major activities included interactive group discussions, self-monitoring of menstrual cycles and symptoms, menstrual preparedness planning through period bags, workplace peer support, and continuous follow-up to reinforce behavior change. Effectiveness was assessed by comparing paired pre- and post-intervention measurements from the same participants using the same questionnaire and analyzed using McNemar's test, while Focus Group Discussions explored participants' experiences and perceived changes. Among the 75 participants, significant improvements were observed across major outcome areas following the intervention. Menstrual hygiene practices of participants improved in both home and workplace settings, particularly safe disposal practices (34.7% to 100%) and genital washing practices (41.3% to 72.0%) ($p < 0.001$). Dietary practices improved significantly, particularly increased consumption of iron-rich foods, with green leafy vegetable consumption increasing from 22.7% to 93.3%, alongside improved hydration during menstruation (24.0% to 93.3%) ($p < 0.001$). Pain management practices improved significantly, particularly requesting extra breaks during menstruation (6.7% to 94.7%) and discussing menstrual discomfort with coworkers or seeking support (9.3% to 96.0%) ($p < 0.001$). Ability of participants to engage in day-to-day functions during menstruation improved significantly both at work (69.3% to 90.7%) and at home (70.7% to 89.3%) ($p < 0.001$). The intervention was associated with improvements in menstrual-related practices and functional ability among working women. These findings suggest that health promotion may be a practical and potentially sustainable approach for improving menstrual health in workplace settings. Further studies with comparison groups are needed to establish causal effectiveness.

***Keywords**: Menstrual health, Health promotion, Workplace health, Female garment workers*

Acknowledgements: The authors gratefully acknowledge the management and female workers of Compass International (Pvt) Ltd. for their support and active participation in the successful implementation of this study.

IMPACT OF A HEALTH PROMOTION INTERVENTION ON ADDRESSING THE DETERMINANTS OF PROCESSED AND ULTRA-PROCESSED FOOD CONSUMPTION AMONG SCHOOL-GOING ADOLESCENTS IN A SELECTED SCHOOL IN ANURADHAPURA

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Adolescence is a critical period for establishing lifelong dietary habits. The consumption of processed (PF) and ultra-processed foods (UPF) among adolescents is a significant public health concern in Sri Lanka, contributing to rising overweight, obesity, and diet-related non-communicable diseases (NCDs), with studies reporting that 75% of adolescents consume these foods weekly. Existing school-based interventions focus primarily on awareness rather than addressing determinants of dietary choice, and evidence from the Anuradhapura district remains limited. The gap is notable within the mix of rural and rapidly urbanizing communities, where industrially produced food alternatives are replacing traditional diets. This study evaluated the impact of a health promotion intervention in addressing the determinants of PF and UPF consumption among adolescents at Walisinghe Harishchandra National College (WHNC) in Anuradhapura. A pre-post design using a mixed-methods approach was employed. Independent samples were collected at baseline (n=80) and post-intervention (n=76) from purposively selected grade nine students. Baseline and post-intervention data were collected using a validated interviewer-administered Food Frequency Questionnaire (FFQ), a self-administered knowledge, attitudes, and practices survey (KAP), and focus group discussions (FGDs). Grounded in a community-based health promotion framework, a three-month intervention was designed with students. During this process, students identified and prioritized three key determinants of their food choices: inadequate label awareness, peer pressure, and media and marketing exposure. Activities targeted nutrition label awareness, improving the ability to refuse unhealthy snacks offered by peers, and analyzing advertisements and marketing tactics. Quantitative data were analyzed using descriptive statistics and chi-square tests for independent proportions ($p < 0.05$), while qualitative data were analyzed using thematic analysis. The intervention produced statistically significant improvements across all measured domains. Knowledge gains were substantial: recognition of food labels to identify UPFs increased from 36.3% to 90.8% ($p < 0.001$, $\chi^2 = 49.636$), and awareness that packaged fruit products contain more sugar than fresh fruit increased from 45.0% to 94.7% ($p < 0.001$, $\chi^2 = 45.261$). Attitudes improved markedly, with the belief that PF and UPFs harm long-term health rising from 45% to 78.94% ($p < 0.001$, $\chi^2 = 19.779$), and confidence in making healthy choices increased from 52.5% to 89.47% ($p < 0.001$, $\chi^2 = 15.832$). Dietary practices shifted significantly; skipping breakfast daily decreased from 25.0% to 6.57% ($p < 0.001$, $\chi^2 = 40.512$). The FFQ revealed significant reductions in the frequency and portion sizes of PF and UPF consumption. For example, significant reductions were observed for sugar buns ($p < 0.001$), ice cream ($p < 0.001$), and processed meats ($p < 0.001$). While portion sizes decreased significantly ($p < 0.001$), the frequency of energy drink consumption remained unchanged ($p = 0.519$, $\chi^2 = 2.268$). This participatory intervention significantly reduced PF and UPF consumption, using minimal resources, demonstrating that empowering adolescents can lead to meaningful dietary changes. Future studies would benefit from extended follow-up periods and control groups. At the same time, schools should enforce canteen regulations and restrict PF and UPF marketing to help sustain these improvements.

Keywords: *Adolescents, Determinants, Health promotion, Processed food, Ultra-processed food*

Acknowledgments: The authors are grateful to the students who participated in the intervention and the staff of WHNC, Anuradhapura, for their contribution to the successful completion of the study.

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN REDUCING DEPRESSION STIGMA AMONG UNDERGRADUATES AT RAJARATA UNIVERSITY OF SRI LANKA

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Depression is a leading cause of disability worldwide, affecting approximately 332 million people globally, with university students representing a vulnerable population due to academic pressure, financial stress, and social change, with 31% prevalence reported among Sri Lankan university students. Although depression is treatable, stigma remains a critical barrier to seeking help. In Sri Lanka, mental illness is highly stigmatised and often attributed to personal weakness, supernatural causes, or past karma. Limited research exists on interventions to reduce depression stigma, especially within low- and middle-income country university contexts. Health promotion offers a participatory and empowering framework for addressing stigma by addressing its underlying determinants. This study aimed to evaluate the effectiveness of a health promotion intervention in reducing depression stigma among undergraduates at Rajarata University by addressing its determinants. A quasi-experimental single-group pre-test-post-test design consisting of three phases was used. The absence of a control group limits causal inference. The study targeted first-year undergraduates at the Faculty of Applied Sciences, Rajarata University of Sri Lanka. Although the sample size calculation indicated a target of 70, a convenience sample of 63 students who met the inclusion criteria and provided informed consent was recruited due to practical constraints. The pre-interventional phase involved developing study instruments, including a self-administered questionnaire assessing socio-demographic characteristics, existing level of perceived depression stigma (using the Perceived Stigma Subscale of the Depression Stigma Scale), knowledge, misbeliefs, attitudes, and practices related to depression and Focus Group Discussion (FGD) guides for qualitative data collection. Following baseline data collection, the interventional phase was implemented based on health promotion principles. Through 28 participatory discussions, participants identified and prioritised determinants of depression stigma. For the three prioritised determinants: lack of knowledge, peer norms, and social media influence five activities were designed and implemented by students. The intervention was continuously monitored using indicators developed collaboratively with students. The post-interventional phase collected quantitative data using the same questionnaire and qualitative data through three FGDs including 34 participants to evaluate changes. Quantitative data were analysed using descriptive statistics and paired-sample t-tests. Qualitative data were analysed using thematic analysis. The sample consisted of 63 participants aged 21-25 years, with 63.5% of females. Following the intervention, a statistically significant increase was observed in perceived mean stigma scores, 21.95 vs. 23.94 ($p=0.002$), attributed to improved recognition of stigmatising attitudes per qualitative data. Statistically significant improvements were observed across all other domains. Knowledge scores increased from a mean of 4.97 to 9.56 ($p<0.001$). Misbelief scores decreased from 25.84 to 16.94 ($p<0.001$). Attitude scores decreased from 28.76 to 20.95 ($p<0.001$). Related practices scores decreased from 23.11 to 16.17 ($p<0.001$). Qualitative findings supported these results, with participants reporting increased awareness of stigmatising behaviours, improved willingness to support peers experiencing depression, and sustained changes in personal communication practices. These findings show that empowering students to address determinants of stigma can produce meaningful changes. This study contributes locally relevant evidence to support mental health promotion strategies in Sri Lankan universities. Further controlled research with long-term follow-up is required to validate these findings.

Keywords: *Depression stigma, Health promotion, Determinants, University students*

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION TO IMPROVE WORK-FAMILY LIFE BALANCE AMONG FEMALE OFFICERS AT THE DIVISIONAL SECRETARIAT OFFICE, MIHINTALE

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Work-family life balance (WFLB) is important for the well-being, productivity, and quality of life of employees. Female officers in the public sector often experience difficulties balancing occupational responsibilities with household and caregiving duties due to increasing work demands and sociocultural expectations. Despite growing concern, limited evidence exists regarding WFLB interventions among female public officers in Sri Lanka. This study aimed to assess the effectiveness of a health promotion intervention in addressing key determinants influencing WFLB among female officers at the Mihintale Divisional Secretariat Office. A single-group pre-post interventional study design was utilized with 63 female officers working at the Mihintale Divisional Secretariat Office. A mixed-method approach was used. In the pre-interventional phase, quantitative data on socio-demographic data, WFLB, and determinants of WFLB were collected using a pretested self-administered questionnaire with a pretested, validated instrument that measured WFLB, and participants were classified into low, moderate, and high categories using the equal interval method. Qualitative data on perception, experience, and determinants of WFLB were collected through eight in-depth interviews. In addition, the process was measured using self-reported indicators. The intervention was designed and implemented using a participatory health promotion intervention with the involvement of participants through small group discussions. Female officers identified and prioritized determinants affecting WFLB, including time management difficulties, child and elder care responsibilities, and financial problems. Intervention aimed at addressing the prioritized determinants, including experience-sharing discussions related to childcare and eldercare responsibilities, a task prioritization activity to improve time management, and a daily expenses recording activity to address financial problems. The intervention emphasized participation and empowerment by actively involving female officers in identifying and prioritizing determinants, designing activities, sharing experiences, and monitoring the progress of the intervention. The post-interventional phase used the same questionnaire to assess the WFLB. Quantitative data collected in both pre and post-interventional phases were analyzed using descriptive statistics and chi-square tests, while qualitative data gathered in the pre-interventional phase were analyzed using thematic analysis. Qualitative findings revealed that excessive workload, long working hours, household responsibilities, child and eldercare responsibilities, mental stress, and sociocultural expectations negatively affected WFLB. Participants highlighted that support from supervisors, colleagues, husbands, and family members contributed positively toward maintaining WFLB. The proportion of participants with a high level of WFLB increased from 31.7% (n = 20) before the intervention to 47.6% (n = 30) after the intervention, while the proportion with a moderate level of WFLB decreased from 68.3% (n = 43) to 52.4% (n = 33). This improvement was not statistically significant ($\chi^2 = 3.316$, $p = 0.069$), and this may be due to the small sample size and short intervention duration. However, the intervention improved participants' awareness, confidence, time management practices, coping strategies, and financial management behaviors according to self-reported data. The findings emphasize the importance of supportive workplace environments, family support systems, and improving the well-being of female public sector officers. The health promotion intervention demonstrated positive contributions to improving WFLB among female officers by addressing modifiable determinants through a participatory, empowering approach.

Keywords: *Work-family life balance, Health promotion, Female officers, Public sector, Determinants*

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN REDUCING SMOKELESS TOBACCO USE AMONG MANUAL CLEANING WORKERS IN RAJARATA UNIVERSITY OF SRI LANKA

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Smokeless tobacco (SLT), consumed without smoking or burning, increases the risk of cancers of the oral cavity, lips, pharynx and other tobacco-related problems, similar to those caused by smoking. Sri Lanka is among the top ten countries with the highest prevalence of SLT use. Different types of SLT products are available, among which betel chewing with tobacco is most prominent in rural Sri Lanka, particularly among low-income occupational groups. Manual cleaning workers are more susceptible to SLT use due to low-income levels and workplace culture. Therefore, this study aimed to assess the effectiveness of a health promotion intervention in reducing smokeless tobacco use by changing its determinants among manual cleaning workers at Rajarata University of Sri Lanka**.** A quasi-experimental, single-group pretest-posttest study was conducted among manual cleaning workers at Rajarata University of Sri Lanka. The study comprised three phases: (1) pre-intervention phase, which assessed existing knowledge, attitudes, and prevalence of SLT use using a pretested interviewer administered questionnaire; (2) intervention phase, which involved designing and implementing a health promotion intervention to reduce SLT use; and (3) post-intervention phase, which evaluated the effectiveness and explored the acceptability of the intervention using both quantitative and qualitative data. Qualitative data were collected through focus group discussions. During the intervention, participants were actively engaged in identifying determinants of SLT use and prioritizing them based on the level of influence, importance of change, and the ease of change. 'Lack of awareness of the real harm, myths on benefits of SLT use, the attractiveness of SLT use, availability and affordability, and peer influence' were prioritized determinants of SLT use among the participants. Intervention activities such as 'Establishing peer support groups, creating anti-SLT posters, and calculating expenditure for betel quid' were collaboratively developed and implemented by the workers to address the prioritized determinants, with facilitation of the researcher. Participants also developed a tool named '*Vitata thitha* (End betel quid)' to assess the changes in their SLT use by recording daily use by themselves during the implementation of activities. Ninety-three cleaning workers aged 21 to 70 years participated in the study. Changes in knowledge, attitudes and practices were analyzed using the chi-square test for pre-post comparisons. Betel quid with tobacco was the most common form of SLT use among participants and was more prevalent among males (75.0%) than females. Before the intervention, the majority of workers were daily SLT users (74.6%), and most consumed 5 betel quids per day (19.0%). After the intervention, the proportion of daily SLT users decreased to 47.5%, and the majority reported consuming one betel quid per day (11.4%). The difference in daily SLT users between pre- and post-intervention was statistically significant ($P<0.001$). Before the intervention, 2.2% of workers consumed 12 betel quids per day. Following the intervention, the highest reported daily consumption was 8 betel quids (1.1%). There were significant improvements in knowledge and attitudes regarding SLT use. Thus, the health promotion intervention was effective in reducing SLT use by changing its determinants among manual cleaning workers at Rajarata University of Sri Lanka**.**

Keywords*: Determinants, Health promotion intervention, Manual cleaning workers, Smokeless tobacco*

Acknowledgements: The authors are grateful to all manual cleaning workers at Rajarata University of Sri Lanka for their contribution to the successful completion of the study.

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN IMPROVING KNOWLEDGE, CHANGING PERCEPTION AND PRACTICES RELATED TO ALCOHOL USE AMONG YOUTH IN THE UNIVERSITY COLLEGE, ANURADHAPURA

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Alcohol is a depressant substance that primarily causes depressive behavior. Alcohol consumption is a leading preventable cause of disease, injury, and social harm. Youth aged 15-24, approximately 22.3% of males and 1.1% of females have used alcohol at least once in their lives. In 2019, the Anuradhapura district recorded the highest proportion of current alcohol users, which was 34.7 %. Most individuals begin drinking between 18 and 20 years, making youth a particularly vulnerable group for risky alcohol-related behaviours. This study aimed to assess the effectiveness of a health promotion intervention in improving knowledge, changing perceptions, and changing practices related to alcohol use among youth aged 20-24 years at the University College of Anuradhapura. A pre-post intervention study with a mixed-methods approach was conducted using the action research model and guided by health promotion principles. The 50 first-year students were selected through convenience sampling from the University College of Anuradhapura. The study was carried out in three phases: pre-intervention, intervention, and post-intervention phases. During the pre-intervention phase, data collection instruments were developed, and baseline data were collected using a self-administered questionnaire and focus group discussions. In the intervention phase, a community-based health promotion intervention was collaboratively designed and implemented with participants. The determinants of alcohol use identified and prioritized by participants included the attractive image of alcohol, beliefs and perceptions related to alcohol use, lack of awareness regarding harmful effects, and peer influence. Myth-busting sessions, media content analysis, and interactive discussions were designed and implemented with the participants to address these determinants. In the post-intervention phase, post-data were collected and analyzed. The descriptive statistics and indicators were used to summarize quantitative data, while paired *t*-tests and the McNemar test were used to evaluate the outcomes. The qualitative data collected from 5 focus group discussions were analyzed using thematic analysis to capture participants' insights. The socio-demographic characteristics remained stable between the pre- and post-intervention assessments. Participants' knowledge of alcohol use showed a statistically significant improvement ($p < 0.001$), with mean scores rising from 6.30 (SD = 2.46) to 10.06 (SD = 1.30). Perceptions related to alcohol use also improved significantly ($p = 0.009$), with mean scores increasing from 10.40 (SD = 1.616) at baseline to 11.26 (SD = 2.146) post-intervention. Although the intervention contributed to positive changes in alcohol-related practices, these changes were not statistically significant. During the intervention process, participants identified ten determinants of alcohol use with the facilitation of the researcher. The study was limited in scope and duration. Still, it provides valuable evidence that health promotion intervention can be an effective strategy to address alcohol use by improving knowledge change perception on alcohol use in university college settings. Sustained and long-term interventions may be required to achieve significant changes in alcohol-related behaviour.

Keywords: *Alcohol consumption, Health promotion, Determinants*

Acknowledgements: The authors are grateful to the students, academic and administrative staff of the University College of Anuradhapura for their inspiring support and insightful contributions.

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN IMPROVING DIETARY PRACTICES BY ADDRESSING ITS DETERMINANTS AMONG CHILDREN AT VIVEKANANDA TAMIL MAHA VIDYALAYA, ANURADHAPURA

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Dietary practices established during childhood serve as a foundation for maintaining physical well-being and consistently carry into adulthood, shaping long-term health outcomes. The prevalence of unhealthy dietary patterns and the double burden of malnutrition remain a significant global public health concern. Evidence on effective school-based health promotion interventions addressing determinants of poor childhood dietary practices in Sri Lanka remains limited, highlighting the need for context-specific, participatory approaches grounded in health promotion principles. The objective of this study was to assess the effectiveness of a health promotion intervention in improving dietary practices by addressing its determinants among school-going children aged between 10 to16 years at Vivekananda Tamil Maha Vidyalaya in the Anuradhapura district. A single-group pre-post intervention design was employed, comprising three sequential phases: a pre-interventional phase, an interventional phase, and a post-interventional phase. The sample comprised 62 school-going children of both sexes, aged 10-16 years, attending Vivekananda Tamil Maha Vidyalaya, Anuradhapura. The pre-interventional phase focused on developing study instruments and collecting pre-intervention data using a mixed-method approach. The instruments included a pretested, self-administered questionnaire that captured children's socio-demographic characteristics, baseline knowledge, current dietary practices, and knowledge on its underlying determinants. Qualitative data were collected through Focus Group Discussions (FGDs), guided by FGD topic guide exploring children's perceptions of dietary practices and their determinants. A strongly rooted, health promotion principle-based intervention was implemented during the intervention phase over four months. Determinants of dietary practices were identified and prioritized by the study participants, and activities were implemented to address prioritized determinants. The intervention was iteratively designed, implemented, and evaluated with the active, continuous participation of children throughout the study period, reflecting a process-oriented health promotion approach. The progress was monitored using mutually developed indicators. The quantitative data were analysed using descriptive statistics such as the paired t-test, the McNemar test, and qualitative data were analysed thematically. The sample comprised 62 children aged 10-16 years (male: 43.54%, female: 56.45%), with 13-year-olds constituting the largest age group. Following the intervention, notable improvements were observed in both knowledge of dietary practices and actual dietary behaviours among the children. Knowledge of dietary practices improved after the intervention, showing a statistically significant change (paired t-test, $p<0.001$). The prevalence of breakfast skipping decreased significantly from 77.4% to 66.1% post-intervention (McNemar test, $p=0.031$). The daily dietary practices showed a significant change (paired t-test, $p<0.001$) among school children. Children improved their understanding of how each factor influences dietary practices among children, a significant change (paired t-test, $p<0.05$). the thematic analysis of FGD data revealed based on three main themes such as changes in knowledge related to dietary practices, changes in daily dietary practices, barriers to healthy eating and changes happened after the intervention The participatory health promotion intervention was associated with significant improvements in dietary knowledge and practices among school-going children at Vivekananda Tamil Maha Vidyalaya, Anuradhapura, through child empowerment, improved nutritional knowledge, and promotion of healthy dietary practices.

Keywords: *Dietary practices, Health promotion, Determinants, Physical well-being*

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN ADDRESSING DETERMINANTS OF DATING VIOLENCE AMONG SECOND-YEAR UNDERGRADUATES OF THE FACULTY OF APPLIED SCIENCES, RAJARATA UNIVERSITY OF SRI LANKA

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Dating violence is an underrecognized public health issue among young adults, with university students being particularly vulnerable due to social relationship contexts. In Sri Lanka, nearly 80% of university students report experiencing some form of dating violence. This study aimed to evaluate the effectiveness of a health promotion intervention in addressing the determinants of dating violence among second-year undergraduates of the Faculty of Applied Sciences, Rajarata University of Sri Lanka. A pre-test post-test study was conducted with second-year undergraduates who were currently or previously in dating relationships. The study received ethical approval from the Ethics Review Committee of the Faculty of Applied Sciences, Rajarata University of Sri Lanka. Written informed consent was obtained from all participants. The health promotion intervention was carried out in four main phases, including the first phase, developing study instruments and identifying the existing prevalence, types, knowledge, attitudes, and perceptions of dating violence. The study instruments included the self-administered questionnaire derived from the validated questionnaires and in-depth interview guides. In the second phase, the participatory health promotion intervention was designed. And in the third phase, intervention was implemented with students, who identified and prioritized determinants (peer influence, media influence, normalization of violence) and developed activities including media analysis, role-plays, group discussions on myths, and a relationship scale. In the final phase, an evaluation of the health promotion intervention's effectiveness was conducted. Quantitative data were collected using a self-administered questionnaire before and after a three-month health promotion intervention. Qualitative data were gathered through in-depth interviews, and thematic analysis was used to analyse the data. The pre and post-intervention questionnaires were collected anonymously without unique identifiers. Consequently, due to the non-normal distribution of data and dropout of two unidentified participants (pre;n=44, post;n=42), the Mann-Whitney U test was applied. The intervention significantly reduced the total dating violence mean (SD) score from 13.45 (12.99) to 4.43 (4.87) ($p=0.002$), representing a 67.06% reduction. Significant improvements were observed in coercion ($p=0.008$), sexual violence ($p=0.001$), and detachment ($p<0.001$). However, physical violence ($p=0.162$) and humiliation ($p=0.093$) did not show significant improvements. The mean (SD) knowledge score improved from 44.50 (17.64) to 61.17 (4.80) ($p<0.001$), with the proportion of undergraduates having "good knowledge (≥75% score) " increasing from 52.27% to 97.61%. Attitude mean score improved from 75.73 (21.99) to 115.57 (10.09) ($p<0.001$), with favourable attitudes (≥75% score) increasing from 22.72% to 97.61%. Qualitative findings reinforced the quantitative results, with the changes in cognition, behavioural changes and enhanced help-seeking and self-efficacy. Key themes included de-normalization of violence, active peer support, and pre-conflict deliberation. This participatory health promotion intervention effectively reduced dating violence and improved knowledge and attitude among undergraduates. Future studies should consider the long-term follow-up for the sustainability and to test the intervention across diverse target groups. The approach is contextually appropriate and effective.

Keywords: *Dating violence, Determinants, Health promotion, Participatory intervention, Undergraduates*

Acknowledgements: The authors are grateful to the academic staff and the undergraduates of the Faculty of Applied Sciences for their contribution to the successful completion of the study.

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN MANAGING BODY IMAGE CONCERNS AMONG STUDENTS AT CENTRAL COLLEGE ANURADHAPURA

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The issue of body image concerns (BIC) among adolescents has emerged as a notable public health challenge on a global scale. Adolescents are dissatisfied with their body image due to rapid physical, psychological, and social changes during puberty, combined with influences such as media exposure, peer comments, and societal beauty standards. There is limited evidence on school-based interventions for BIC in Sri Lankan settings. Without evidence-based interventions, they remain vulnerable to negative health outcomes, including disordered eating, low self-esteem, and academic impairment. As conventional school health programs rarely address the determinants of body image, evaluating a participatory health promotion intervention is essential to fill this gap and guide adolescents in managing BIC. This study aimed to assess the effectiveness of a health promotion intervention in reducing BIC among students at Central College, Anuradhapura, by addressing its underlying determinants. A quasi-experimental pre-test–post-test study was conducted among Grade 11 students at Central College, Anuradhapura. Ninety students from two conveniently selected classes participated in the intervention. Quantitative data were collected using a pre-tested self-administered questionnaire, while qualitative data were obtained through focus group discussions. Grounded in health promotion principles and a participatory action research approach, the intervention actively engaged students in identifying and prioritizing determinants, planning intervention strategies, implementing activities, and monitoring progress. The prioritized determinants included personal attitudes and beliefs, peer influence, and media influences. Intervention strategies included peer-led discussions, role-plays, critical thinking exercises, and social media literacy activities. Quantitative data were analysed using descriptive and inferential statistical methods, while qualitative findings were analysed using thematic analysis. The sample consisted of students aged 15 years, all of whom were Sinhalese (Male: 48.9%, Female: 51.1%). Pre-intervention findings revealed a 60.5% prevalence of body image concerns among participants. 56.8% students reported a desire to change their appearance. The intervention demonstrated statistically significant changes in determinants related to own attitudes and beliefs (χ^2 (1) = 12.461, p <0.001), as well as media influence (χ^2 (1) = 6.096, p = 0.014). A significant change in the prevalence of body discrepancy score (BDS) was observed (χ^2 (2) = 6.876, p = 0.032), indicating the meaningful positive effect of the intervention on BDS. The proportion of students with high body satisfaction increased from 21.0% to 42.1% following the intervention. The difference in body satisfaction levels between pre- (N=81) and post- (N=76) intervention assessments was statistically significant (χ^2=8.158, df=2, p=0.017). Qualitative themes corroborated these findings, showing improved critical thinking skills, greater acceptance of body diversity, enhanced confidence, and better ability to resist negative influences related to body image. The health promotion intervention was effective in reducing body image concerns among adolescents by empowering students to identify and address underlying determinants collaboratively. This underscores the value of utilizing participatory Health Promotion approaches in school settings to foster positive body image and enhance adolescent well-being.

Keywords: *Adolescents, Body image concerns, Health promotion, Participatory intervention*

Acknowledgements: Authors are grateful to the academic staff of the Central College, Anuradhapura for their contribution to the successful implementation of the study.

EFFECTIVENESS OF A HEALTH PROMOTION INTERVENTION IN REDUCING SEXUAL HARASSMENT AMONG YOUTH IN A VOCATIONAL TRAINING INSTITUTE, ANURADHAPURA

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Sexual harassment is a significant public health and social issue affecting young people worldwide, with substantial consequences for physical, psychological, and social well-being. Despite increasing global attention, limited evidence exists regarding interventions addressing sexual harassment among youth in vocational training settings in Sri Lanka. This study aimed to assess the effectiveness of a health promotion intervention in improving knowledge, attitudes, and practices related to sexual harassment among youth attending the Vocational Training Institute (VTI), Anuradhapura. A mixed-method single-group pre–post study design was conducted among 50 youth aged 17–26 years from three vocational courses at VTI, Anuradhapura, selected through convenience sampling. The intervention was developed and implemented using health promotion principles with active youth participation. Priority determinants identified through participatory discussions included inadequate knowledge, negative attitudes, and limited skills in responding to sexual harassment. Intervention activities included interactive discussions, role-plays, peer support activities, and awareness initiatives. Quantitative data from self-administered questionnaires were analyzed using paired t-tests, while qualitative data underwent thematic analysis. The majority in the sample from the electrician course (n= 25, 50%) and the proportions of male and female participants were (n=28, 56%) and (n=22, 44%), respectively. Most participants represented the "below 19 years old" age category (n=31, 62%). The findings demonstrated significant improvements following the intervention. Mean knowledge scores increased from 20.82 (SD=7.70) to 28.00 (SD=5.49) ($p<0.001$), the highest knowledge score increased from (n=20, 40%) to (n=41, 82%). Attitudes from 25.92 (SD=4.52) to 31.40 (SD=2.92) ($p<0.001$) the highest attitude score increased from "score 36" (n=4, 8%) to (n=8, 16%) and lowest attitude score increased from "score 18" (n=1, 2%) to "score 24 (n=1, 2%). Practices from 1.60 (SD=0.55) to 5.00 (SD=0.71) ($p=0.001$), highest scores shifted from "score 2" (n= 4, 66.7%) to "score 6" (n= 1, 12.5%) and determinant scores from 29.90 (SD=4.52) to 36.60 (SD=2.92) ($p<0.001$), highest determinant scores increased from (n=27, 54%) to (n=41, 94%). Qualitative findings further indicated positive changes in awareness, reduced victim-blaming attitudes, improved reporting behaviours, and enhanced bystander responses. The health promotion intervention was effective in improving knowledge, attitudes, and practices related to sexual harassment and addressing associated determinants among youth in the vocational training setting. These findings suggest that participatory health promotion approaches may serve as an effective strategy for preventing sexual harassment among young populations.

Keywords: *Sexual harassment, Health promotion, Determinant, Youth*

Acknowledgements: The authors are grateful to the study participants, academic and administrative staff of the VTI Anuradhapura, for their contribution to the successful implementation of the study.

MATHEMATICS

NUMERICAL APPROXIMATION OF CAPUTO FRACTIONAL DERIVATIVE USING HYPERCOMPLEX STEPS

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Fractional calculus is a branch of mathematics that studies derivatives and integrals of non-integer order. Fractional derivatives have gained significant attention due to their ability to model memory-dependent and nonlocal behaviours observed in many real-world systems. Applications of fractional derivatives can be found in physics, engineering, control theory, signal processing, biology, and finance and more. Among the various definitions of fractional derivatives, the Caputo fractional derivative allows initial value problems to be modelled with classical derivative initial conditions, which can be physically interpreted, making it particularly well suited for practical applications. However, the numerical evaluation of the Caputo fractional derivative remains challenging due to the presence of weakly singular integral kernels and embedded classical derivatives, which often lead to reduced accuracy and numerical instability in conventional approximation methods. This study proposes a numerical approximation method for the Caputo fractional derivative using hypercomplex-step differentiation combined with numerical integration techniques. The hypercomplex-step differentiation method is an extension of the classical complex-step method and provides higher-order derivative approximations while avoiding subtractive cancellation errors commonly encountered in finite difference methods. In the proposed approach, the classical derivative appearing in the Caputo formulation is approximated using hypercomplex perturbations. The resulting integral term is then evaluated numerically using the Composite Trapezoidal Rule. Additional numerical experiments are also performed using Simpson's Rule to investigate the influence of different numerical integration schemes on approximation accuracy. Fast Fourier Transform based implementation is incorporated to improve computational efficiency and derivative extraction from hypercomplex perturbations. The proposed method is implemented in MATLAB and tested using several standard analytic functions, including polynomial, exponential, trigonometric, and logarithmic functions. The performance of the proposed method is analysed for different fractional orders(α), hypercomplex dimensions(n), step sizes(h), and subinterval values(N). Numerical results demonstrate that the proposed HCS-based method produces highly stable and accurate approximations of the Caputo fractional derivative. Comparisons with the standard Complex-Step (CS) method show that the proposed method consistently provides smaller relative errors and improved approximation accuracy. The results further indicate that increasing the number of subintervals and hypercomplex dimensions enhances convergence and numerical precision. In this study, no strict theoretical upper limit was imposed on the parameters α, n, h, and N. These parameters were selected within practical computational ranges based on considerations of numerical stability and accuracy. Overall, this research establishes Hypercomplex-Step differentiation as a promising numerical tool for approximating Caputo fractional derivatives. The proposed framework provides improved accuracy, robustness, and, making it suitable for applications in fractional differential equations, scientific computing, engineering analysis, and biomedical modelling.

Keywords: *Hypercomplex step differentiation, Complex step method, Composite trapezoidal rule, Simpson's rule, Fast fourier transform*

Acknowledgements: With sincere appreciation, the authors would like to thank everyone who guided and supported her throughout the progress of this study.

ENHANCE THE ANT COLONY ALGORITHM FOR MINIMAL INSPECTION SELECTION AND SEQUENCING IN ZERO-DEFECT QUALITY CONTROL

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This study explores the problems with inaccurate inspections and high costs in incoming quality control. Basically, incoming quality control is the initial inspection that ensures items from outside suppliers meet quality standards. Traditionally, inspectors would look at each item for a particular component, stop if something appeared incorrect, and then move on to the next thing. But in today's manufacturing, inspection is crucial to achieving perfect products and zero defects. The thing is thorough inspections consume many resources. To deal with this issue, the study suggests a smarter approach, which is a hybrid metaheuristic method that streamlines both the sequence in which items are inspected and the selection of what gets inspected initially. It uses a binary matrix to represent which items can detect what kind of defects. A1 in the matrix means that an item is able to detect a defect. So, the first stage applies a refined ant colony optimization algorithm to figure out the smallest number of inspection items needed to cover all possible defects. The algorithm keeps updating its choices, promoting items that perform well and dropping the ones that do not. Next, in the second stage, a genetic algorithm starts working to find the most efficient order for inspecting those chosen items. Here, each chromosome represents a sequence; the aim is to determine a sequence that reduces detection time, cost, or both. The method was tested on three datasets of increasing size: small (5 parts × 4 items), medium (10 × 8), and large (500 × 50). Results show that the Genetic Algorithm boosts operational efficiency, and Ant Colony Optimization consistently identifies the inspection sets with full coverage. Together, this approach reduces inspection time, saves effort, and trims costs without sacrificing quality. The experimental results demonstrate that, in comparison to the existing method, the proposed approach is substantially more effective.

Keywords: *Ant colony optimization, Genetic algorithm, Minimal inspection items, Sequencing, Zero-defect quality control*

Acknowledgements: I would like to express my heartfelt thanks to my supervisor, Dr. E. M. U. S. B. Ekanayake, Senior Lecturer, Rajarata University of Sri Lanka, for his valuable guidance and support throughout this project. His advice and encouragement helped me stay focused and motivated. I'm also grateful to the Department of Physical Science, Faculty of Applied Sciences, Rajarata University of Sri Lanka, for providing the necessary resources and a positive learning environment.

AN ENHANCED FIREFLY ALGORITHM FOR GENERALIZED TRANSPORTATION AND TRAVELING SALESMAN PROBLEMS

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One of the most important aspects of operations research is the transportation and traveling salesman problem. In order to identify the best solution, this study examines the Transportation Problem (TP) and the Travelling Salesman Problem (TSP). The literature demonstrates that various methods for solving the TP and TSP have been devised in the past. Finding the best solution to the TP and TSP is the main focus of certain strategies, while others concentrate on finding an initial, basic, feasible solution. The TSP is among the most famous optimization problems in computer science. It asks for the quickest route that stops exactly once in each city before heading back to the beginning. The goal is to lower the total cost or trip distance. There are several approaches to solving the TSP, such as brute-force methods, dynamic programming, and approximation algorithms. Optimizing the distribution and allocation of goods from various sources to various destinations is the TP. It offers an organized mathematical framework for examining actual logistics situations. Its ability to transform complicated logistical systems into linear models that can be solved and provide exact solutions using techniques like Vogel's Approximation Method and the Modified Distribution Method makes it significant in mathematics. Recent studies show that a variety of methods are used to identify the best or nearly optimal solution in TSP and TP. The purpose of this study is to investigate new or improved methods that can explain the constraints and offer more precise, flexible, and effective solutions to TSP and TP utilizing a modified Firefly Algorithm (FA). The FA is a novel type of swarm intelligence that effectively addresses combinatorial optimization problems. In this study, a novel approach is proposed for creating a Hamiltonian Cycle that changes the distances between edges based on the average value of the connected vertices and prioritizes edges by their attractiveness value in the modified firefly algorithm. A novel approach for selecting the lowest-cost cell by modifying the cost value based on average values. Then, the attractiveness value is calculated using a modified firefly algorithm, and the maximum possible amount is allocated to the cell that prioritizes its attractiveness value. The algorithm consistently provided more efficient and scalable solutions for the TSP than traditional heuristics such as the nearest neighbour and Hungarian methods. For the TP, the strategy demonstrates superior performance in generating feasible and optimal solutions for both balanced and unbalanced scenarios. By enhancing computational efficiency and accuracy, this innovative algorithm provides a valuable tool for decision-makers seeking to streamline logistics and achieve significant operational savings in dynamic, real-world environments. The proposed method's outcomes are contrasted with those of alternative algorithms. Finally, the effectiveness of the proposed algorithm is investigated.

Keywords: *Attractiveness value, Firefly algorithm, Travelling salesman problem, Transportation problem*

Acknowledgements: Authors are grateful to the academic and administrative staff of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, for their contribution to the successful implementation of the study.

HYPERCOMPLEX-STEP APPROACH TO NEWTON AND HALLEY ROOT-FINDING METHODS

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Root-finding for nonlinear equations is one of the most challenging fundamental problems in numerical mathematics and has numerous applications in mathematics, science, engineering, and more related fields. The difficulty arises because many nonlinear equations do have solutions, but existing analytical methods fail to find them in closed form. Consequently, approximate root-finding techniques have been developed over many years and continue to be refined. Classical derivative-based methods such as the Newton–Raphson Method (NRM) and Halley's Methods (HM) are widely used due to their quadratic and cubic convergence properties, respectively. Therefore, both methods exhibit rapid convergence to the exact roots. However, the NRM requires the evaluation of the first derivative of the nonlinear function, and HM requires the evaluation of both the first and second derivatives. Consequently, these methods become ineffective when the analytical computation of the derivatives are difficult or impossible. To alleviate this, derivatives are often approximated by Finite-Difference (FD) quotients. However, these FD approximations are contaminated by cancellation errors (as well as truncation errors when the step size is not small enough). This study does not introduce a new differentiation algorithm instead; it adapts an existing Fast Fourier Transform (FFT) based HCS differentiation technique to compute the derivatives required by the NRM and Halley root-finding methods. By employing an n-dimensional hypercomplex number system together with the FFT and inverse FFT, the method provides accurate higher-order derivative approximations. Unlike the conventional Complex-Step (CS) method, which is mainly limited to first-derivative computation, the HCS technique efficiently computes higher-order derivatives with improved accuracy and numerical stability. The HCS method can approximate any derivative of sufficiently smooth functions with an accuracy of a desired order. This study aims to apply the HCS differentiation technique to approximate the roots of nonlinear equations, thereby alleviating the derivative-evaluation requirement in the NRM and HM. The performance of proposed methods has been evaluated using numerical experiments with a variety of nonlinear test functions. The convergence speed, number of iterations, relative errors, and computing efficiency are studied and compared to classical, FD, and CS methods. For example, the relative error(number of iterations) of $f(x) = \sin(x)\, e^x + \ln(x^2 + 1)$ in (0.5,-0.5) is obtained using HM, HM with FD(HM-FD), HM with HCS(HM-HCS),NRM,NRM with FD(NR-FD),NRM with CS(NR-CS),NRM with HCS(NR-HCS),RFM and SM are 6.1629758220e-33(6), 5.5218856108e-09(4), 3.9720425685e-07(4), 5.9051596750e-20(7),1.9262147761e-09(6),1.4027115126e-10(6),1.4029932072e-10(6), 9.7355081574e-01(23), 1.1924101952e-09(7). The corresponding computational times (in seconds) in the same order of methods are 0.007819, 0.006953, 0.004363, 0.007620, 0.006506, 0.006344, 0.006527, 0.014962 and 0. 003621.The results show that HCS based algorithms provide improved accuracy, stability, and computational efficiency. The HM when paired with HCS differentiation, outperforms the NRM when paired with HCS differentiation in terms of convergence speed and precision. Furthermore, the proposed approach is able to maintain the theoretical convergence order of both methods without degrading them. Overall, this study demonstrates HCS differentiation as an effective and efficient tool for improving derivative-based root-finding algorithms, with practical advantages for solving challenging nonlinear problems in scientific and engineering applications.

Keywords: *Nonlinear equations, Root-finding methods, Newton–raphson method, Halley's method, Hypercomplex-step differentiation*

Acknowledgements: The authors thank the Department of Physical Science, Faculty of Applied Sciences, Rajarata University of Sri Lanka, for its constant support during this research.

A NEW FOURTH-ORDER DIFFERENCE APPROXIMATION FOR FRACTIONAL DERIVATIVES AND APPLICATIONS

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Fractional derivatives are useful mathematical tools for modelling of nonlocal and memory-dependent phenomena, such as anomalous diffusion, viscoelasticity, and complex transport systems. These applications extensively use fractional derivatives such as Riemann–Liouville (RL), Caputo, and Grünwald–Letnikov derivatives, and better describe hereditary and long-range interaction effects than classical integer-order models. Developing stable and higher-order accurate numerical approximations for fractional derivatives has become a challenge due to the nonlocality of most fractional derivatives and their singular kernels. The existing Grünwald approximations are first-order accurate and, unstable when used without an appropriate shift (i.e., when r is not equal to 1). Further in the literature, a new second-order accurate finite difference approximation with shift was proposed for fractional derivatives, and it was successfully applied to the space-fractional diffusion equation, with confirmed stability and convergence. This study uses a weighted combination of the forgoing approximation with three distinct integer shift values (r = -1, 0, 1) and obtained a new fourth-order approximation for RL derivatives. The Grünwald type weights required for the proposed approximation are recursively calculated. The numerical validation is performed by applying polynomial test functions. Furthermore, the proposed method was applied to the one-dimensional space fractional boundary value problem using the Crank–Nicolson discretisation method. The numerical results confirmed that the proposed approximation is fourth-order accurate for various fractional-order values and exhibits weight behaviour and smooth asymptotic error decay for mesh refinement. The proposed approximation is a mathematically sound and efficient scheme for high-order numerical solution of fractional derivatives and fractional differential equations.

Keywords: *Fractional derivatives, Fourth-order scheme, Fractional differential equations, Grünwald approximation, Numerical stability*

Acknowledgements: The authors sincerely appreciate the support, encouragement, and valuable assistance provided by the academic and administrative staff of the Department of Physical Science throughout the successful completion of this research work.

INTRICATE INTERCONNECTIONS AMONG SOUTH ASIA'S ECONOMIC GROWTH, ENVIRONMENTAL SUSTAINABILITY, AND SOCIAL PROGRESS FROM 2000 TO 2023

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From 2000 to 2023, this study examines the complex relationships between environmental sustainability, social development, and economic growth in eight South Asian nations: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. This study models three dependent variables: GDP per capita (economic), life expectancy (social), and CO_2 emissions per capita (environmental) using a panel data set of 192 country-year observations from the World Bank Development Indicators. For each dimension, five candidate linear regression models were specified and estimated using two parallel estimation methods: parametric (ordinary least squares) and non-parametric (rank-based) regression techniques. The selection of models relied on four criteria evaluated simultaneously: Adjusted R^2, Residual Standard Error (RSE), Cross-Validated Mean Squared Error (CV-MSE), and Akaike Information Criterion (AIC). Multicollinearity was checked using Variance Inflation Factors (VIF), with a VIF < 5 considered acceptable and VIF > 10 indicating severe multicollinearity. Non-linearity was tested through quadratic model extensions, with significance confirmed by ANOVA F-tests. The Shapiro-Wilk test showed that most variables did not follow normal distributions, requiring robust non-parametric methods along with classical regression. Three final optimal models were developed. The economic model ($Adj\_R^2 = 0.9495$) confirmed that foreign direct investment ($\beta = 0.109$), life expectancy ($\beta = 0.463$), and CO_2 emissions ($\beta = 0.341$) are positive predictors of GDP per capita, with a significant quadratic acceleration effect from life expectancy. The social model ($Adj\_R^2 = 0.9602$) showed that GDP per capita ($\beta = 0.528$), mortality rate ($\beta = -0.484$), access to basic drinking water services ($\beta = 0.219$), and inflation ($\beta = 0.033$) best explain life expectancy, with a quadratic term for GDP showing diminishing health returns from wealth. The environmental model ($Adj\_R^2 = 0.9130$) found that CO_2 emissions primarily come from GDP per capita ($\beta = 0.709$), urban population ($\beta = 0.177$), total population ($\beta = 0.268$), and unemployment ($\beta = 0.064$), with renewable energy consumption showing a significant curvilinear relationship with emissions. These findings hold important policy implications for sustainable development planning across the South Asian region. The study calls for integrated strategies that promote economic growth, reduce environmental degradation, and improve social well-being.

Keywords: *GDP per capita, Non-parametric regression, Cross-validation, Life expectancy, Carbon dioxide emission*

RAINBOW CONNECTION NUMBER OF SPECIAL TYPE OF FLOWER GRAPHS

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Let *G* be an undirected, nontrivial connected graph. A rainbow *k*- colouring on *G* is defined as c: *E*(*G*) → {1, 2, …, k} for some $k \in N$. A path *P* in *G* is a rainbow path if no two edges of *P* are coloured the same. A graph is rainbow connected if every pair of distinct vertices $u, v \in V(G)$, has at least one rainbow path between them. The rainbow connection number *rc*(*G*) of a connected graph *G* is the minimum of *k* for which there exists a *k* edge colouring. In this paper, we introduce three new graph classes, the Triangular petal flower graph$(GT_{n,m})$, Quadrilateral petal flower graph $(GQ_{n,m})$ and Pentagon petal flower graph$(GP_{n,m})$. Every petal in that graph shares a single central vertex. A chain of shape of flower petal makes up each of the n petals. The i^{th} petal has exactly i number of shape flower petals, where $1 \leq i \leq n, i \in n$ and $n \in N$ and *j* is the number of vertices in a petal, where $j = i + 1$ for Triangular flower graph $j = 2i + 1$ for the Quadrilateral flower graph and $j = 3i + 1$ Pentagonal flower graph and $j \in$ N. In this work, we have shown that there is a rainbow path between every distinct vertex in these graphs and then proved that these graphs are rainbow connected and the rainbow connection number of the Triangular petal flower graph, $rc(GT_{n,m}) = 3$ and the rainbow connection number of the quadrilateral petal flower graph, $rc(GQ_{n,m}) = \frac{n^2+3n}{2}$, and rainbow connection number of Pentagonal petal flower graph, $rc(GP_{n,m}) = \frac{1}{6}n^3 - n^2 + \frac{17}{6}n + 1$; n is the number of petals of the flower graph, and m is the number of outer petal vertices.

***Keywords**: Rainbow colouring, Rainbow connected, Triangular flower graph, Quadrilateral flower graph, Pentagon flower graph*

AN IMPROVED ANT COLONY OPTIMIZATION TECHNIQUE FOR TYPICAL TRANSPORTATION PROBLEMS

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Planning is an integral part of many activities in our daily life, particularly in times of scarce resources. Allocation and distribution of goods from several origins to several destinations represent a transportation problem. It offers a methodical mathematical framework for examining actual logistical situations. Its ability to transform intricate logistical systems into linear models that can be solved, offering both an initial basic feasible solution and an optimal solution, is what makes it significant in mathematics. The Modified Distribution Method (MODI) provides an ideal solution and a variety of initial basic feasible solutions. This paper's goal is to investigate more effective initial basic feasible solutions (IBFS) to transportation-related balanced and unbalanced problems. NewM algorithm's specialized handling of unbalanced circumstances is its most important contribution. In contrast to traditional approaches. The novelty of this study is the introduction of a dynamic penalty-based method that solves complex transportation problems automatically, without the need for manual adjustments like dummy rows or columns. While dynamic penalties enable the algorithm to adjust to the shifting "economic landscape" of the cost matrix in unbalanced cases when rows and columns are exhausted, fixed penalties are utilized for balanced issues to save time. The performance of NewM was validated against many transportation problems. In some balanced benchmarks as 10 cases, NewM matched the performance of newly proposed method in existing paper, reaching the global optimum in 60% of cases and outperforming VAM in complex scenarios. More profoundly, across 10 tested unbalanced problems, the NewM algorithm achieved the exact optimal solution in 100% of cases. These results demonstrate that NewM is a superior and efficient tool for solve the typical transportation cases, particularly for real-world unbalanced distribution networks. Furthermore, NewM achieved an optimal or near-optimal solution for both balanced and unbalanced problems.

Keywords: *Transportation problem, Optimal solution, Ant colony optimization, Modified distribution method, Dynamic penalty*

INCIDENCE COLORING OF NEWLY DEFINED GRAPH FAMILIES

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Graph theory is a branch of discrete mathematics concerned with the study of graphs - mathematical structures composed of vertices and edges that model pairwise relationships between objects. Graph colouring is one of the most important concepts in the subject of graph theory. There are various types of graph colouring, such as vertex colouring, edge colouring, incidence colouring, total colouring, and list colouring, among others. Incidence colouring, which assigns colours to vertex-edge pairings, or incidences, as opposed to vertices or edges alone, is the central focus in this study. An enhancement of standard vertex and edge colouring, incidence colouring assigns colours to incidences (v, e) where vertex v is incident to edge e.Two incidences (v, e) and (u, f) are adjacent, provided one of the following conditions holds: a) $v = u$, b) $e = f$ and c) $vu = e \text{ or } f$ .The incidence chromatic number of graph G, which is represented as $\chi_i(G)$,is the smallest number of colours needed to guarantee that no two adjacent incidences obtain the same colour. In this study, we introduce and analyse the incidence colouring of three novel graph structures, namely the recursive modified claw graph, the triangular blossom graph, and the core centric expansion star graph. For each graph family, we have constructed and derived formulas for incidence colouring patterns, incidence chromatic numbers, and structural properties accordingly, while checking whether incidence colouring properly satisfies the newly defined graphs under this research. Through the recursive modified claw graph (G_n) ,where n is the level of graph, cycling a five colour palette {1,2,3,4,5} is introduced by rotating a level colour c_n. This always gives a proper incidence colouring with $\chi_i(G_n) = 5$ for all $n \geq 1$. A systematic three-rule colouring scheme is introduced for the triangular blossom graph (B_n) , which is created around a single central vertex c by adding triangular petals at each level in an anticlockwise direction where $\chi_i(B_n) = 2n + 3$ for all $n \geq 1$.The core centric expansion star graph was introduced as an expanding star structure centred around a single core vertex. At each level, one new leaf vertex was connected directly to the centre vertex by an edge where $\chi_i(G_k) = k$ where k is the level of the graph. So, this study will assist in constructing certain graph family expansions by applying distinctive incidence colouring patterns that correctly fulfill incidence colouring properties.

Keywords: *Core centric expansion star graph, Incidence chromatic number, Incidence colouring, Recursive modified claw graph, Triangular blossom graph*

Acknowledgements: With sincere appreciation author thanks to everyone who guided and supported her during the progress of this study, including her supervisors Prof. A. A. I. Perera and Mr. M. A. M. Mohamed.

IMPACT OF TOURISM AND DEMOGRAPHIC FACTORS ON SRI LANKA'S GDP AND ITS FORECASTING

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Gross Domestic Product (GDP) serves as a major measure of a country's economic activity, reflecting production, income generation, and overall economic progress. In Sri Lanka, tourism and demographic conditions are important contributors to economic performance. Nevertheless, many previous studies have investigated these factors independently and mainly depended on single forecasting techniques, limiting understanding of their combined long-term effects. Accordingly, this study examines how tourism and demographic indicators, including population, birth rate, and death rate, influence Sri Lanka's GDP using annual data from 1970 to 2022, while also identifying appropriate forecasting approaches for GDP estimation. The research incorporates Multiple Linear Regression, Markov Chain analysis, ARIMA, ARIMAX, Random Forest, and XGBoost models. Data preparation procedures such as transformation, stationarity assessment, and outlier identification were carried out to enhance model stability and reliability. Forecasting accuracy was assessed using RMSE, MAE, and MAPE measures. In addition, an interactive GDP prediction system was developed to generate GDP estimates based on user-provided tourism and demographic values. The regression results indicated the presence of autocorrelation and heteroskedasticity, suggesting violations of key OLS assumptions. The ARIMA(0,1,0) model showed that GDP follows a persistent trend-oriented process. The ARIMAX(1,1,1) model improved explanatory capability through the inclusion of external variables and produced a significant autoregressive coefficient (AR = 0.9843). The four-state Markov Chain framework effectively represented GDP transition behavior and long-run equilibrium patterns, with the "Small Increase" state recording the highest stationary probability ($\pi = 0.512$). Among the forecasting approaches, XGBoost demonstrated the best predictive performance by achieving the lowest RMSE (1.23E+09) and MAE (7.55E+08), whereas Random Forest produced weaker results because of its limited ability to extrapolate long-term trends. The findings highlight the importance of tourism and demographic variables in shaping Sri Lanka's economic growth and demonstrate that integrated modelling frameworks provide more dependable GDP forecasts. The study also offers practical insights for policymakers and economic planners in promoting tourism resilience and managing demographic changes to support sustainable economic development.

Keywords: *GDP, Tourism, Demographic factors, ARIMAX, XGBoost*

Acknowledgements: With sincere appreciation, the authors thank everyone who guided and supported them during the progress of this study, especially their supervisors, Dr. N. Varathan, Dr. R. Tharshan, and MR. M. A. M. Mohamed, for their valuable guidance and continuous support throughout this research.

A STUDY ON TOURIST ARRIVALS IN SRI LANKA: A TIME-SERIES AND MACHINE LEARNING APPROACH

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Tourism is a key contributor to Sri Lanka's economy; however, the sector is highly vulnerable to external shocks, economic fluctuations, and structural changes, making accurate forecasting essential for effective tourism planning and policy formulation. Although several studies have applied statistical or machine learning approaches for tourism forecasting, limited studies have comparatively evaluated multiple forecasting techniques using Sri Lankan tourism data. Therefore, this study aims to develop and compare forecasting models for tourist arrivals in Sri Lanka using annual tourist arrival data from 1970 to 2024, excluding 2021 due to abnormal disruptions caused by the COVID-19 pandemic. Prior to modelling, descriptive analysis was conducted, revealing substantial variation in tourist arrivals, with values ranging from 39,654 to 2,333,796 and a mean annual arrival of 603,610.5 tourists. The dataset was analysed using Markov chain models, ARIMA and ARIMAX time-series models, and machine learning approaches including Random Forest and XGBoost. For forecasting evaluation, the dataset was divided into a training period (1970–2018) and a testing period (2019–2024). Before model development, logarithmic transformation, differencing, stationarity testing using ADF and KPSS tests, and residual diagnostic checks were performed to ensure model adequacy and reliability. Forecast performance on the testing dataset was evaluated using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE). The Markov chain analysis indicated long-run dominance of growth states with a steady-state probability of ($\pi = 0.72$). The ARIMA(0,1,1) model generated comparatively more stable forecasts, while the ARIMAX(0,1,1) model incorporated exchange rate as an external explanatory variable, indicating its influence on tourist arrivals. Among all forecasting models, XGBoost achieved the best predictive performance (MAE = 6.725047e+05, RMSE = 8.154636e+05, MAPE = 84.993085), followed by Random Forest (MAE = 7.520293e+05, RMSE = 9.174555e+05, MAPE = 103.236486), whereas ARIMA, ARIMAX, and Markov models exhibited comparatively higher forecasting errors. Overall, the findings indicate that machine learning approaches, particularly XGBoost, provide comparatively better forecasting performance than traditional statistical approaches for Sri Lankan tourist arrival data. The proposed framework integrating Markov chain, time-series, and machine learning techniques offers a comprehensive approach for tourism forecasting and supports informed decision-making in tourism planning and policy development.

Keywords: *Sri Lanka tourism, Markov chain, ARIMA, ARIMAX, XGBoost*

Acknowledgements: With sincere appreciation, the authors thank everyone who guided and supported them during the progress of this study, especially their supervisors, Dr. N. Varathan, Dr. R. Tharshan, and Dr. E. M. U. S. B. Ekanayake, for their valuable guidance and continuous support throughout this research.

AN INNOVATIVE ONE-PHASE APPROACH TO SOLVING THE TWO-DIMENSIONAL BIN PACKING PROBLEM

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The Bin-Packing Problem (BPP) is a popular combinatorial optimization problem. The task is to fill various goods into as few bins as possible. Packing items into bins is something we use in our daily lives. The problem of bin packing has drawn a lot of attention from logistics research and business. The Two-Dimensional Bin Packing Problem (2DBPP) includes trying to put a collection of items of different sizes into containers of a specified size to minimize the height of the containers required to accept a particular set of objects. This study presents a novel approach for 2DBPP using a line-orientated technique. The literature shows that several methods, such as Next-Fit Decreasing Height (NFDH), First-Fit Decreasing Height (FFDH), Best-Fit Decreasing Height (BFDH), and others, have been developed in the past to solve the 2DBPP. These computational techniques first sort the pieces from tallest to shortest, then intelligently arrange them on the shelves inside the bin to conserve space. By increasing the packing effectiveness of shelf-based approaches, this study presents a novel one-phase heuristic algorithm for solving the two-dimensional bin packing problem. A line-orientated shelf packing strategy is used in the suggested method. Every object is first arranged by height in descending order. The shelf height is determined by placing the first item in the bottom-left corner of the bin and measuring its height. The optimal item is selected to minimize vacant space in either the present orientation of the items or by rotating them 90 degrees. It is then positioned so that it does not surpass the shelf's height and width. When an item cannot fit on the present shelf, the next highest item is placed on a new shelf that is started above the existing shelf. Until every item is successfully packaged, the procedure is repeated. The proposed method performed better than the existing methods, such as the NFDH, FFDH, and BFDH algorithms. Here, the novel algorithm that was proposed was used to construct Python-based software. The developed program offers a faster and more accurate solution for 2DBPPs when compared to human computations. Comparative examples demonstrate that the suggested method outperforms existing methods and offers a useful tool for resource allocation optimization in real-world systems.

Keywords: *Two-dimensional bin packing problem, Heuristic algorithms, Optimal packing, Optimization, Line-oriented*

Acknowledgements: Authors are grateful to the academic and administrative staff of the Faculty of Applied Sciences, Rajarata University of Sri Lanka for their contribution to the successful implementation of the study.

A DETERMINISTIC CONSTANT-TIME SOLVER FOR FACTORISABLE QUADRATIC CONGRUENCES VIA HIGH-PRECISION TRIAGE

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Resolving quadratic polynomial congruences of the form $ax^2 + bx + c \equiv 0 \pmod{p^k}$, where the coefficients a, b, c are integers, p is a prime, and k is a positive integer, whose underlying polynomial admits a linear factorization over the ring of integers $\mathbb{Z}$, constitutes a foundational operation within cryptographic protocols and computational number theory. The conventional benchmark approach, Hensel's Lemma, depends on a sequential root-lifting mechanism that incurs heavy computational overhead at elevated prime powers and introduces systemic bottlenecks at degenerate singularities where the local derivative vanishes modulo p. This study proposes an Integer-Factorisation Triage Method (IFTM), a highly efficient algorithmic framework designed specifically for factorisable quadratic congruences. Shifting away from standard recursive approximation, the IFTM leverages structural integer factorisation to execute a triage defined as deterministic structural classification pass to partition problems statically into three structural topologies: Simple, Double, and Degenerate root environments. By executing a deterministic decision tree, the framework directly maps each algebraic state to an exact, closed-form solution set parameterised by arithmetic progressions, completely eliminating the iterative modular computations tied to traditional lifting. Analytical and empirical validations demonstrate that the IFTM achieves exact mathematical convergence, maintaining absolute deterministic accuracy across all solution fields while fundamentally transforming execution complexity from linear-time recursion, to true constant-time execution. This performance leap is especially pronounced in volatile, highly ramified degenerate spaces where standard iterative techniques either degrade in efficiency or fail to resolve the solution space cleanly.

Keywords: *Quadratic congruences; Hensel's lemma; Constant-time complexity; Root classification*

Acknowledgements: The authors express their sincere gratitude to the academic and administrative staff of the Faculty of Applied Sciences at Rajarata University of Sri Lanka for their invaluable support and contributions toward the successful execution of this study.

INTEGRATIVE MULTI-OMICS ANALYSIS TO IDENTIFY DISEASE RELEVANT BIOMARKERS IN PARKINSON'S DISEASE

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Parkinson's disease (PD) is a progressive neurological disorder caused by the loss of dopaminergic neurons, and its molecular basis remains incompletely understood. Most studies have relied on single-omics approaches, which capture only limited aspects of disease biology. This study aims to integrate multi-omics datasets to identify key biomarkers and molecular mechanisms underlying Parkinson's disease. This study analyzed GSE68719 dataset from NCBI GEO database. It contains transcriptomic (29 patients and 44 controls) and proteomic profiles (12 patients ,12 controls) of Parkinson's patients and controls. The data were filtered and normalized using the DESeq2 R package**.** Following the two vertical integration methods, Data Integration Analysis for Biomarker discovery using Latent components (DIABLO) from the R package mix Omics and Multi Omics Factor Analysis (MOFA) from the R package *MOFA2* were applied independently. Then the top features from each method were extracted and the intersection of selected features was taken to determine the common features. DIABLO identified features linked to Parkinson's disease, while MOFA identified features driving variation across the multi-omics data. By focusing on the overlapping features selected by both methods, this study identified biomarkers that were not only associated with disease status but also represented important underlying biological signals, increasing confidence in their relevance to Parkinson's disease. Then transcriptomic and proteomic data were filtered to overlapping genes and aligned across matched samples. The outcome was next used to build an integrated correlation network was built to capture intra-layer (RNA–RNA, protein–protein) and inter layer (RNA–protein) interactions. Only strong associations with a correlation higher than 0.6 ($|r|>0.6$) were kept. To preserve biological layer information, each gene was represented as two nodes corresponding to its transcriptomic (_RNA) and proteomic (_PROT) states. Network analysis of the 12 common MOFA–DIABLO features identified several highly connected hub nodes within the multi-omics interaction network. Within the multi-omics interaction network, the strongest hub was MAN1A1_RNA (strength=5.57), followed by GNG13_RNA, KIAA1107_RNA, CNGB1_RNA, SHROOM2_RNA, TUNAR_RNA, VPS33B_RNA, and LMNTD2_RNA, along with protein-level hubs such as SHROOM2_PROT and KIAA1107_PROT. VPS33B is associated with vesicle trafficking, SHROOM2 with cytoskeletal organization, and CNGB1 with neuronal signaling, while other hub genes such as MAN1A1, GNG13, KIAA1107, TUNAR, and LMNTD2 are linked to cellular regulation and signaling processes, suggesting potential involvement in Parkinson's disease related neurobiological dysfunction. Gene Ontology enrichment analysis was performed to further interpret the biological functions associated with the identified interactions. Gene ontology analysis highlighted pigmentation and calcium regulation pathways linked to Parkinson's disease. Overall, this study demonstrates that integrating multi-omics datasets using DIABLO and MOFA, followed by intersection-based feature selection and network analysis, can effectively identify biologically consistent RNA and protein signals associated with Parkinson's disease. Collectively, the findings suggest that Parkinson's disease involves interconnected molecular disruptions across transcriptomic and proteomic layers rather than isolated gene level effects. The identified biomarkers provide a systems level framework for understanding disease associated molecular mechanisms and provide a basis for future diagnostic or therapeutic investigations following further experimental and clinical validation.

Keywords: *Biomarkers, Multi-omics, Network analysis, Parkinson's disease (PD), Proteomic profile*

A STUDY ON GRACEFUL LABELLING GRAPHS

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Graceful labelling is an important area in mathematics. Let $G = (V, E)$ be a simple graph with vertex set V and edge set E. Let $|V| = n$ and $|E| = m$,Then a vertex graceful labelling of G is an injective function $f : V \to \{0, 1, 2, \dots, m\}$ such that the induced edge labels, defined by $f^*(uv) = |f(u) - f(v)|$ for every edge $uv \in E$, are distinct and form the set $\{1, 2, \dots, m\}$. In simply vertex labelling is each vertex is assigned a unique integer between 0 and m , the label of an edge is the absolute difference between the labels of its endpoints and also the all edge labels must be distinct and cover every integer from 1 to m. In this study we introduce graceful labelling of centipede ladder graph, zigzag fan graph and k-block diamond necklace graph. The main objective of this research is to determine whether these graph families admit graceful labelling and to develop suitable labelling formulas for each of them. This study developed explicit vertex labelling functions for each graph and proved them mathematically. Then the edge labels are distinct and cover all integers from 1 up to the number of edges in the graph. As a result of this work show that all three graph families are graceful. This research contributes to the development of graph theory by introducing generalized labelling formulas and extending graph labelling to new families of graphs with complex structures.

Keywords: *Centipede ladder graph, Graceful labelling, Graph theory, K-block diamond necklace graph, Zigzag fan graph*

Acknowledgments: Authors are grateful to the academic and administrative staff of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale for their contribution to the successful implementation of the study.

PHYSICS

SPIN-COATED THIN-FILM NANOCOMPOSITE MEMBRANES INCORPORATING IRON-REMOVED MULTI-WALLED CARBON NANOTUBES FOR ENHANCED WATER PURIFICATION

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Increasing global demand for clean water has intensified interest in energy-efficient membrane technologies for desalination and water purification. Thin-film nanocomposite (TFN) membranes incorporating multi-walled carbon nanotubes (MWCNTs) have demonstrated improved water transport and enhanced mechanical stability compared to conventional thin-film composite membranes. However, MWCNTs synthesized through floating catalyst chemical vapor deposition (SS-FCCVD) often contain residual iron catalyst particles that can adversely affect membrane performance. In this study, iron impurities were removed from MWCNTs using different chemical purification methods. One purification approach involved heat treatment followed by concentrated HNO_3 acid washing under ultrasonication, while another applied heat treatment followed by concentrated HCl acid washing under ultrasonication. The third approach consisted of prolonged HCl ultrasonication without prior heat treatment, followed by filtration and drying. The structural and chemical characteristics of the purified MWCNTs were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD). Comparative XRD analysis revealed that thermal treatment combined with HCl purification effectively reduced Fe and Fe_3C impurity peaks, demonstrating enhanced iron removal efficiency. The purified MWCNTs were subsequently functionalized using concentrated HNO_3 and incorporated into spin-coated TFN membranes via interfacial polymerization (IP). Membranes prepared with different spin accelerations (40–80 rpm/s) and containing 0.004% MWCNT loading were evaluated using a crossflow filtration system operated at 600 kPa. The spin acceleration process promoted uniform removal of excess amine solution, resulting in the formation of a thinner and defect-free polyamide (PA) layer. Among the fabricated membranes, TFN membranes incorporating non-treated MWCNTs exhibited lower $MgSO_4$ and Na_2SO_4 rejection values of 61.36% and 59.15%, respectively, along with a significantly lower water permeability of 9.64 L m^{-2} h^{-1} bar^{-1}. In comparison, the membrane prepared with purified MWCNTs at 40 rpm/s demonstrated superior performance, achieving 69.43% $MgSO_4$ rejection and 65.45% Na_2SO_4 rejection, together with a water permeability of 34.60 L m^{-2} h^{-1} bar^{-1}. These results indicate that purification and iron removal from MWCNTs positively influenced membrane permeability and salt rejection performance. Furthermore, the complete removal of iron particles trapped within the inner channels of MWCNTs has not yet been fully confirmed. Therefore, further optimization of MWCNT purification and surface functionalization is necessary to enhance membrane stability and separation efficiency.

Keywords: *Carbon nanotubes, Desalination, Interfacial polymerization, Thin-film nanocomposite, Spin coating method*

DESIGN AND PERFORMANCE EVOLUTION OF REDUCED GRAPHENE OXIDE ELECTRODE FOR ELECTRIC DOUBLE-LAYER SUPERCAPACITORS: AN INTEGRATED EXPERIMENTAL AND COMPUTATIONAL STUDY

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Supercapacitors hold a great ability in supplying the growing demand for energy storage. They are widely used in electric vehicles and renewable energy systems due to their ability to charge and discharge faster than batteries, long life cycle, and high-power density. These features make supercapacitors a reliable solution in energy storage applications. This study contains integrated experimental data with computational simulations. Here, Sri Lankan Vein Graphite (GR) was used to produce reduced graphene oxide (rGO) and used for the electrodes of an electrical double-layer supercapacitor (EDLCs). Graphene oxide (GO) was synthesized from Bogala Natural vein graphite using "Improved Hummer's Method". Then, the synthesized GO is heat-treated at 450 °C to produce reduced graphene oxide (rGO), which was mixed with Polyvinylidene fluoride (PVDF) binder dissolved in N,N-Dimethylformamide (DMF) and coated onto stainless steel plates using the "Doctor Blade" method to form electrodes. The Supercapacitor was prepared according to the "Sandwich" method, and 4M KOH was used as electrolyte. The synthesized rGO was characterized by X-ray diffraction (XRD), Raman Spectroscopy, and Scanning Electron Microscopy (SEM). Also, the supercapacitor was characterized by Cyclic Voltammetry (CV), Galvanostatic Charge-Discharge (GCD), and Electrochemical Impedance Spectroscopy (EIS). The electronic structure and energy levels (Density of States, Band Gap) of the material were analyzed using the principles of Density Functional Theory (DFT). Computational simulations of graphene and rGO were performed using the Quantum ESPRESSO software, enabling an accurate characterization of their atomic-level behavior and properties. The results show that the prepared supercapacitor achieved a specific capacitance of 16.44 F/g. It was observed that pure graphene produces a Fermi energy of -2.3463 eV and a total energy of -12546.6536 eV. For rGO Fermi energy and total energy are -2.7294 eV and -13691.1913 eV, respectively. The shift in the Fermi energy is due to the reduction of functional groups in rGO. These results clearly demonstrate that low-cost, high-quality, efficient supercapacitors can be produced using Sri Lankan vein graphite. The use of both experimental and computational methods will lead to the production of more accurate and efficient electrodes. These findings will be very helpful in the development of future energy storage technologies.

***Keywords**: Supercapacitors, Reduced Graphene Oxide (rGO), EDLC, Computer simulation, Density Functional Theory*

Acknowledgements: The authors gratefully acknowledge the National Institute of Fundamental Studies, Kandy, Sri Lanka, for their contribution to the successful implementation of this study.

ASSESSING CRUSTAL CONTINUITY BETWEEN SRI LANKA AND PENINSULAR INDIA BASED ON GRAVITY AND MAGNETIC LINEAMENTS

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The tectonic relationship between Sri Lanka and Peninsular India is crucial in understanding the breakup of East Gondwana and the evolution of the Indian Plate. Several plate reconstruction models suggested that Sri Lanka remained attached to India during its northward movement since Gondwana breakup. However, the exact crustal continuity and tectonic linkage between the two regions remain uncertain. Most of the previous studies mainly relied on plate kinematic reconstructions, marine magnetic anomalies and regional geological correlations. At the same time, limited attention has been given to integrated regional geophysical evidence preserved within the continental crust. The lack of detailed structural comparison between Sri Lanka and southern Peninsular India remains a major limitation in evaluating existing Gondwana reconstruction models. The present study investigates tectonic continuity between Sri Lanka and southern Peninsular India using integrated gravity and magnetic anomaly data. The study area covers Sri Lanka, southern Peninsular India and the adjacent offshore region of the Bay of Bengal and the Indian Ocean. The selected region was defined based on tectonic configurations proposed in previous reconstruction studies. Satellite-derived gravity and magnetic datasets were processed to identify basement structures, tectonic lineaments and regional structural trends associated with Gondwana breakup and later Indian Plate evolution. Regional and residual anomaly separation, derivative enhancement and structural extraction techniques were applied to enhance crustal discontinuities and tectonic patterns within the study area. Structural orientations derived from interpreted lineaments were analyzed to evaluate regional tectonic trends and possible crustal continuity between Sri Lanka and southern Peninsular India. The results show several major tectonic lineaments and basement structural trends extending across southern Peninsular India and Sri Lanka. The interpreted structural patterns indicate disturbed crustal continuity and tectonic displacement between the two land masses. The integrated gravity and magnetic interpretation suggests that Sri Lanka was originally positioned farther east relative to Peninsular India during the early stages of Gondwana breakup. Later tectonic evolution was accompanied by southward relative crustal movement of Sri Lanka with respect to Peninsular India. These observations show stronger agreement with reconstruction predictions that propose an eastward initial position of Sri Lanka, rather than with conventional models that place Sri Lanka continuously attached to the southern tip of India. The integrated geophysical interpretation therefore strongly supports a more complex tectonic relationship between Sri Lanka and Peninsular India within the East Gondwana framework.

***Keywords**: Gondwana breakup, Crustal continuity, Gravity and magnetic anomalies, Peninsular India-Sri Lanka tectonics, Integrated geophysical interpretation*

STRUCTURAL CONTROL OF THE WAHAWA GEOTHERMAL FIELD INFERRED FROM COMBINED GRAVITY, MAGNETIC, RESISTIVITY AND VLF DATA

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The Wahawa geothermal field, in the Eastern Province of Sri Lanka, is a significant low-enthalpy, amagmatic system hosted within Precambrian crystalline terrain where geothermal activity is sustained by deep fluid circulation along structurally controlled pathways. Although various preliminary studies have been conducted, reliance on isolated geophysical methods has previously led to uncertainty and inadequately assessed subsurface structural constraints. To resolve these uncertainties, an integrated geophysical investigation was performed utilizing gravity, magnetic, electrical resistivity and Very Low Frequency (VLF) techniques. Initially, regional structural features were identified through gravimetric and magnetic mapping, which revealed significant lateral density heterogeneity within the crystalline basement. These results were characterized by a prominent central gravity low flanked by gravity highs to the northeast and southwest directions. A localized gravity high was found to correlate with a dense dolerite dyke (near-vertical igneous body) intrusion, while gravity lows were associated with zones of enhanced fracturing or hydrothermal alteration. Once these regional anomalies were observed, electrical resistivity and VLF profiles were established perpendicular to the identified anomalous trends to delineate water bearing conductive zones and near-surface structural discontinuities. The resistivity mapping, conducted using a Schlumberger array with maximum spread of 500m, successfully identified a distinct path of low apparent resistivity (< 30 Ωm). Through the synthesis of these geophysical datasets and the analysis of one long 2D profile, approximately 1500 m in length, conducted across the hot spring field, the major feeding fracture patterns and near surface structures governing geothermal fluid migration were successfully demarcated. From the 2D structure depicted, a water-conducting fracture pattern was observed continuing towards the dolerite dyke. Within the identified geothermal regime, surface manifestations such as hot water springs and wells were observed at locations where fractures crosscut with shear zones. These findings suggest that the hot springs are fed by lateral movement of geothermal fluids guided by these identified structural features, providing a robust framework for identifying potential drilling targets for direct energy utilization.

Keywords: *Geophysical integration, Structural control, Wahawa geothermal field, Feeding fracture pattern, Very low frequency*

Acknowledgements: The authors gratefully acknowledge the Geological Survey and Mines Bureau and Sabaragamuwa University of Sri Lanka for providing geophysical equipment, and Rajarata University of Sri Lanka for financial support through the research grant (RJT/R&PC/2024/R/FOAS/05).

REAL-TIME ECG AND PULSE MONITORING SYSTEM WITH MACHINE LEARNING INTEGRATION FOR CARDIAC ARRHYTHMIA DETECTION

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Cardiovascular diseases continue to be one of the main causes of death in the world and there is an urgent need for the early diagnosis of cardiovascular diseases and continual monitoring of the heart. The conventional electrocardiogram (ECG) monitoring systems tend to be costly, portable, and intelligent solution suitable for home healthcare, ambulatory monitoring and real-time analytical functions, which makes them less desirable for continuous patient monitoring. To overcome these drawbacks, the current work presents an Internet of Things (IoT) enabled intelligent cardiac monitoring system to connect electrocardiogram (ECG) and photoplethysmography (PPG) sensors with machine learning algorithms for real-time monitoring, arrhythmia detection and predictive cardiac analysis. The developed system is expected to be cost-effective, portable and lightweight, and applicable to the remote healthcare system like home monitoring, ambulatory care, and telemedicine. The use of similar ECG monitoring methods based on IoT has demonstrated much promise in real-time health care applications and detecting arrhythmias. The hardware architecture is an ESP8266 microcontroller and a finger pulse sensor which is connected to an AD8232 ECG sensor. The AD8232 sensor is responsible for capturing and filtering cardiac electrical activity signals, and the PPG sensor is responsible for measuring changes in blood volume through the use of infrared light technology. The accurate waveform sampling and analysis are achieved at a sampling rate of 100 Hz for ECG signals and 20 Hz for pulse signals. The ESP8266 provides signal conditioning, data acquisition and wireless transmission using the MQTT protocol, which enables low bandwidth, low latency data streaming. The publish subscribe MQTT architecture enables multiple devices and users to concurrently access physiological data in real-time. Extracted ECG features such as time domain statistical parameters, FFT coefficients, HRV parameters, and morphological waveform parameters such as R-peak detection were fed into a Random Forest (RF) classifier. A dashboard based on Python language was designed to visualize the ECG and PPG signals in real-time, heart rate variability and arrhythmia risk level. The R-peak detection algorithm achieved 94.7% sensitivity and 96.2% positive predictive value, while the Random Forest classifier achieved 91.8% arrhythmia detection accuracy after training with samples. The system was more reliable in non-clinical settings due to added features like lead-off detection, signal quality evaluation, and artifact rejection. In conclusion, the proposed system proves the efficient implementation of advanced machine learning techniques in resource constrained IoT devices to offer cost effective, intelligent and real-time cardiac healthcare monitoring solutions for state-of-the-art telemedicine applications.

Keywords: *ECG monitoring, Arrhythmia detection, Machine learning, Real-time monitoring, Heart rate variability*

DEVELOPMENT OF AN ULTRASONIC BASED LIQUID FLOW VELOCITY MONITORING SYSTEM

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Sensing techniques are widely used in industries and scientific applications because they do not disturb the system, enabled real time monitoring, and cost effective. In this study, an ultrasonic sensing system was developed to measure the velocity of fluids. Fluid flow monitoring was widely used in industrial, scientific, and engineering fields because non-invasive sensing techniques can provide real time measurements without disturbing the flow system. Ultrasonic transmitter and receiver transducers were connected to an Arduino Mega 2560 microcontroller for signal generation and detection. The 40 kHz Ultrasonic transmitter was used to send ultrasonic waves through a liquid flow channel, while a separate receiver was used to detects signal variations caused by the moving liquid. A flow was constructed using a clear tube, and water was selected as the working fluid due to its interaction with ultrasonic waves. Small air bubbles were naturally present in the water to improve the scattering and reflection of ultrasonic signals. The ultrasonic receiver output was analyzed in real-time using the Arduino Serial Monitor and Serial Plotter interfaces. Experiments were conducted first without the flow channel, then with the flow channel but without liquid, followed by tests with liquid under no flow conditions and finally with the flowing liquid. These stages were used to observe the changes in ultrasonic signal behavior. Stable signal patterns were observed when the liquid remained unchanged, whereas noticeable fluctuations and variations were detected when the liquid was flowing. The flow velocity was also estimated using the conventional flow ate calculation based on the measured fluid volume, flow duration and cross sectional area of the channel. From the experimental measurements the theoretical fluid velocity was calculated as 0.7424 ms^{-1}, while the velocity obtained from the ultrasonic velocity system was measured as 0.5903 ms^{-1}. A comparison between these two values indicate that the developed setup achieved an approximately accuracy of 79.5%. The difference between the theoretical and measured velocities could have resulted from signal attenuation, scattering losses, alignment errors of the transducers and noise in the received signals. This study was based on the Doppler Effect, in which the characteristics of a received wave change when relative motion exists between the source and the moving medium. The developed system demonstrated the principles of ultrasonic motion sensing and fluid flow monitoring. Although the proposed system is simple to implement and suitable for preliminary research and educational applications. Furthermore, the modular design allowed future improvements such as signal amplification and advance Doppler shift calculations to improve measurement accuracy and system performance.

***Keywords**: Ultrasonic sensing, Doppler effect, Fluid flow velocity, Arduino Mega 2560, Ultrasonic transducers*

CRUSTAL CONFIGURATION AND TECTONIC CONTROL IN THE CENTRAL BAY OF BENGAL: AN INTEGRATED APPROACH

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The central Bay of Bengal is one of the most significant and complex geological prominent region in the Indian Ocean due to its complicated tectonic history and its association with the world's largest submarine sedimentary fan system. Understanding the crustal configuration of this region is essential for interpreting the geodynamic processes related to the breakup of Eastern Gondwana and the subsequent northward drift of the Indian plate from the East Antarctica. However, the nature of the crust beneath the thick sedimentary cover remains poorly constrained, particularly regarding the transition between continental and oceanic crust and the tectonic influence of major structures such as the 85°E Ridge and the 90°E Ridge. This study employs an integrated geophysical approach to delineate the crustal architecture and identify tectonic controls within the central Bay of Bengal. The methodology combines multi-scale analysis of high-resolution satellite-derived gravity data, ship-borne gravity observations, and available deep seismic reflection profiles. Gravity forward and inverse modeling techniques were applied to estimate Moho topography and crystalline crustal thickness beneath the Bengal Fan. To improve the accuracy of sediment thickness estimation beneath the massive sedimentary load, which exceeds 10 km in several regions, sediment density variation was modeled as a quadratic function with depth and incorporated into the 3D gravity inversion process. Gravity reduction procedures were systematically conducted to remove the effects of elevation, latitude, and surrounding topography from the observed gravity data, thereby enhancing the reliability of the final gravity anomalies for sediment thickness interpretation. The modeled sediment thickness values were validated against seismic-derived sediment thickness data and showed a strong correlation, expressed by the relationship: $y_{seismic} = 1.2122x_{modeled}$. By integrating the derived sediment thickness with bathymetric data, a new basement configuration model for the central Bengal Fan was developed. The results reveal a highly heterogeneous crustal structure and clearly delineate the subsurface expression of the 85°E Ridge, characterized by prominent gravity anomalies. The integrated model successfully reconciles discrepancies among individual geophysical datasets and provides a more coherent understanding of the deep crustal structure and tectonic evolution of the central Bay of Bengal.

Keywords: *Central Bay of Bengal, Crustal configuration, Tectonic control, Gravity inversion, Sediment variation*

SEQUENTIAL ADSORPTION OF ANTHOCYANIN AND NOVEL NUTMEG MACE CAROTENOID DYES FOR IMPROVED DYE - SENSITIZED SOLAR CELL

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Dye-Sensitized Solar Cells (DSSCs) have emerged as a promising low-cost and environmentally friendly alternative to conventional silicon-based solar cells. The performance of DSSCs is highly dependent on the sensitizing dye used for light absorption and electron injection. In this study, natural dyes extracted from *Clitoria ternatea* and *Myristica fragrans* mace were investigated as co-sensitizers for DSSC applications. Butterfly pea extract, rich in anthocyanins, was used as the primary sensitizer due to its strong binding affinity toward TiO_2, while nutmeg mace extract, containing carotenoid pigments, was employed to enhance visible light absorption. The TiO_2 photoanodes were prepared by spray-coating TiO_2 onto fluorine-doped tin oxide (FTO) glass prior to the sequential dye adsorption process. The TiO_2 photoanode was first immersed in the butterfly pea dye solution followed by immersion in the nutmeg mace extract using a sequential co-sensitization method. An iodide/triiodide (I^-/I_3^-) electrolyte system was used as electrolyte. Ultraviolet–Visible Spectroscopy (UV–Vis) measurements, Fourier Transform Infrared Spectroscopy (FTIR) analysis, and current–voltage (I–V) measurements were carried out to evaluate the optical properties, functional groups, and photovoltaic performance of the fabricated DSSCs. The fabricated solar cell exhibited a power conversion efficiency (PCE) of 0.158% with a fill factor (FF) of 0.712, indicating effective charge transport and reduced internal resistance within the cell. The high fill factor suggests that the sequential adsorption technique improved dye loading and minimized recombination losses at the TiO_2 interface. The study demonstrates that butterfly pea and nutmeg mace extracts can be applied as sequential natural co-sensitizers in DSSCs. The obtained photovoltaic performance confirms the suitability of combining anthocyanin and carotenoid pigments for solar energy harvesting. Furthermore, the introduction of nutmeg mace as a novel DSSC dye source highlights its potential for future sustainable and low-cost photovoltaic research.

***Keywords**: Co-sensitization, Anthocyanins, Carotenoids, PCE, Fill factor*

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We sincerely appreciate the generous support provided by Prof. Alam Yoosuff, Finley Regional Care, NSW, Australia, toward the success of ASURS 2026.

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