



PAPER COLLECTIVE *of* IRCYS

United in Ideas, Diverse in Perspectives

Organized by:



Welcome Message

Dear Participants,

On behalf of the Bandung Creative Society, it is my great pleasure to welcome you to the *Abstract Collective of IRCYS 2025*. This gathering represents not only the creativity and dedication of young researchers, but also the spirit of collaboration and innovation that drives the future of science and knowledge-sharing.

Through your abstracts, ideas, and perspectives, we celebrate diversity in thought, discipline, and culture. We believe this collection will inspire meaningful dialogue, foster cross-border connections, and spark fresh opportunities for discovery.

Thank you for contributing your work to IRCYS 2025. May this collective be a source of learning, pride, and inspiration for us all.

Warm regards,

Rahadian Sri Pamungkas

Project Manager of IRCYS 2025

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About IRCYS 2025

The International Research Competition for Young Scientists (IRCYS) 2025 is a global platform dedicated to showcasing the creativity, innovation, and research excellence of young minds from around the world. Organized by Bandung Creative Society, the competition brings together students and early-career researchers between the ages of 10 and 24, providing a stage for presenting scientific ideas, prototypes, and solutions that address real-world challenges.

Held in Bali, Indonesia, IRCYS 2025 gathered participants across disciplines such as science, technology, engineering, and social innovation. The event encouraged participants not only to compete, but also to learn from one another, exchange perspectives, and experience the richness of cross-cultural collaboration. Through exhibitions, presentations, and dialogues, young scientists had the opportunity to sharpen their communication skills, expand their networks, and gain international recognition.

At its core, IRCYS 2025 reflects a commitment to nurturing future leaders in research and innovation. By celebrating diversity of thought and fostering a spirit of inquiry, the competition empowers youth to become problem-solvers and change-makers in their communities. The achievements of this year's participants serve as a powerful reminder that with curiosity, collaboration, and perseverance, young researchers can drive meaningful progress for a better world.

People of Excellence

Steering Committee

Prof. Goib Wiranto., B.S El.Eng.	:	Badan Riset dan Inovasi Nasional
Prof. Dr. Lilik Hasanah, S.Si, M Si.	:	Universitas Pendidikan Indonesia
Dr. Indrawati	:	SEAMEO QITEP in Science

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Prof. Dr. Lilik Hasanah, S.Si, M Si.	:	Universitas Pendidikan Indonesia
I K. Putra Juliantara	:	Universitas Udayana
Dr. Drs. Agus Dei, M. Fis., AIFO	:	Universitas PGRI
Dr. Indrawati	:	SEAMEO QITEP in Science
Dr dr Agung Wiwiek	:	Universitas Udayana
Indrayani, M.Kes	:	

Editor

Ahmad Yusuf S.Si., M.T.
Rofiq Fadillah Awal S.Si.

Conference Schedule

Parallel session Room 1

Time	Title	Participants Code	Author
10.00 – 10.15	Smart Monitoring and Control System to Prevent Electrical Hazards in Flood-Prone Areas	JAS-I25-17	Arzhila Vidya Andrina; Orchidia Maghfira Yugandhini; Raisah Kei Laiqa; Anamuto Andisyah Pratamadinejad;
10.15 – 10.30	TRANSINSO: Transforming Rambutan Seed into Sustainable Oil	JAS-I25-19	Ignatia Karren Yolanda; Janita Beloven Lakasama;
10.30 – 10.45	Utilization Of Organic Agricultural Waste for Biogas Production as A Potential for Energy Diversification for Local Communities in Berastagi District of North Sumatera	JAS-I25-32	Raavish Hizkia Lumban Gaol; Adrian Raja Erbinar Kaban; Ralph Timothy Elgera Bernanke Purba; Marcello Oliver Marbun; Credolih Atora Jordan Lingga;
10.45 – 11.00	Innovation In the Integration of The Hydrodynamic Disk System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers	SAS-I25-21	Elnino Bintang Pratama; Kemas Rangga Nur Akbar; Saladin Prakaza Ivanka; Chandra Erkam Lesmana;
11.00 – 11.15	SAVIOR: A Robust Edge-AI Framework for Autonomous Zoonotic Symptom Classification Leveraging Hybrid Deep Learning for Public Health Resilience	SAS-I25-42	Anindhita Dea Shafira; Cheelsy Ameylia Lubis;
11.15 – 11.30	Development of an IoT-Based Waste Bin with Real-Time Ultrasonic Fill-Level Monitoring to Support Improved Hygiene Management	SAS-I25-59	Ali Koosha Farzan; Halim Umar Karim;
Break			
13.30 – 13.45	AI-Optimized Microturbines: Harnessing Wind Energy for Rural Areas in Nusa Tenggara Timur, Indonesia	STS-I25-27	Nicholas Chandra; Cedric Gregory Maximillian Gunawan; Jason Christopher Ajiarto; Kevin Jayson Wijaya; Shania Graciella Santoso;
13.45 – 14.00	Risk and Flow-Based Infrastructure Optimization: Humanitarian Supply Aid in the Gaza Strip	STS-I25-44	Joshua Alexander Tanudirjo; Edmund William Sutantio;
14.00 – 14.15	To What Extent Does the Minimum State of Charge Influence Charging Efficiency in iPhones	STS-I25-46	Patricia Adeline Purbowo;
14.15 – 14.30	VOLTURA (Voltage and Structural Architecture): A Next-Generation Structural Battery Composite for Electric Vehicles via Carbon Coating and Vacuum Assisted Resin Infusion (VARI)	STS-I25-60	Pierce Rainier Damian Kristanto; Steven Ernesto Sasmita Oei; I Gede Made Kenan Putra Dharma; Revino Pratama Putra Amalo;

14.30 – 14.45	Innovation in the Digital Complaint System to Address Bandung's Stunting and Increase Social Assistance Transparency	CHS-I25-18	Bintang Sukma Dewa; Raihan Eka Saputra; Zachra Siti Utami Khoerunissa;

Parallel Session Room 2

Time	Title	Participants Code	Author
10.00 – 10.15	3-in-1 Face Mask, Face Scrub and Face Wash from Goji Berry (<i>Lycium Barbarum</i>) Extract and Astaxanthin to Protect Skin from Free Radicals, Prevention of Acne and Premature Skin Aging	JAS-I25-55	Akila Elmira Latif; Adhwa Danika Allura Setiawan; Navisya Hypatia Putri Wijaya; Safina Rafanda Fathina Kurniawan;
10.15 – 10.30	Quercetin-Loaded Microneedle Patch from Red Onion Peel Extracts (<i>Allium cepa</i> L.) as a Safer Alternative of NSAIDs in Osteoarthritis Therapy	JAS-I25-58	Ahmad Gathan Juliansyah; Bianca Reguna Daben; Nadhifa Earlyta Arsyfa; Muhammad Alhafiizhu Aziz; Kimi Awdyra Teddy;
10.30 – 10.45	Modified Levee with Pump System Integrated with Zeocarbon Nanofiltration from Zeolite and Water Hyacinth (<i>Eichhornia Crassipes</i>) For River Overflow Control and Filtration	SAS-I25-25	Yasmine Bitra Roshanfekrana;
10.45 – 11.00	Glucoaid: Smart Hydrocolloid Patch for Non-Invasive Blood Glucose Monitoring Via Enzymatic Sweat Analysis and Ph Indicator	SAS-I25-26	Azkea Kamila Hasbi; Nada Dzikri Nashita; Lovely Mischa Nur Zatna;
11.00 – 11.15	Biodegradable Cardboard-Based Ecowrap Innovation with Adaptive Folding Patterns as An Environmentally Friendly Alternative to Bubble Wrap	SAS-I25-28	Kenzie Lintang Hakim; Shandy Putra Pratama; Torkis Hanafi Harahap; Mochamad Sayid Azzacky Gafur;
11.15 – 11.30	MagnetO: A Household-Scale Innovation for Sustainable Electricity Generation through Magnetic Repulsion	SAS-I25-47	Omera Mysha Ashika; Syifa Avanti Aulia Ridwan; Elva Gracia Dinata Ginting; Rizqi Najma Delia;
Break			
13.30 – 13.45	Neuroscan: AI Powered Lung Cancer Detection	SAS-I25-51	Almer Rauf; Admiral Ghanim; Muhammad Habiburrahman Aziz; Khesya Firly Ade Syahrani;
13.45 – 14.00	Comparative Study of Sunbathing vs. Vitamin D Supplementation on Serum Vitamin D Levels and Cold Incidence	SAS-I25-56	Laetitia Annabelle Tanuwijaya; Javelyn Lim;
14.00 – 14.15	Scutoids As Stable Structures for The Formation of Epithelial Tissue	STS-I25-14	Mariia Yelyzaveta Rudyk;
14.15 – 14.30	General Formula of Multiple Functions on Integrals Infinite Tiny Boxes Summation	STS-I25-20	Rafie Aditya Rezha; Sultan Reynard Sadubi; Gaza Ahmad Wirasena;
14.30 – 14.45	Nonclassical Lie Symmetry Analysis of Allen-Cahn Equation	STS-I25-48	Mikael Cedricus Guido Soesanto;
14.45. – 15.00	Prediction of Missense Mutation Effects in the HBB Gene on Hemoglobin Stability	CTS-I25-64	Zuvi Fridhoriansyah; Kartika Raharja S.; Farida Noor Irfani;

	and Structure in Beta Thalassemia Patients Using a Bioinformatics Approach		

Parallel Session Room 3

Time	Title	Participants Code	Author
10.00 – 10.15	Eco-Clean Innovation: Antibacterial Potential of Longan Peel (<i>Dimocarpus longan</i>) and Cinnamon (<i>Cinnamomum verum</i>) Extracts as a Sustainable Natural Formulation	JAS-I25-43	Felice Kirana Auria Candra; Tarsicia Daveney Basuki;
10.15 – 10.30	Formation of Earth: Roblox for Education towards Middle School Students	JAS-I25-57	Ace Alexon Hartono; Daniel Devon Alexandra;
10.30 - 10.45	The Emerging Potential of Cactus Leather: A Sustainable Alternative to Traditional Leather Production	JAS-I25-6	Prottasha Roy;
10.45 – 11.00	Youth and the Javanese Language: Proficiency, Usage, and Attitudes toward Preservation Challenges in Modernity, Cultural Identity, and Sustainability	SHS-I25-41	Nadine Aina Sakhi; Cinta Lista Keiswa; Aurelia Marabel Nathania Raulinus; Bianca Carloqueen; Loryf Gaynell Corrin Latifah Santiko;
11.00 – 11.15	Melon Seeds as Sustainable-Waste-Hand Cream Product Focused on Motorcyclist in Indonesia	STS-I25-38	Gloria Lauwson; Alexander Lee Xiong Ong; Nasya Evangelia Wong;
11.15 – 11.30	Chitosan-coated Mycelium Foam as a Sustainable Alternative to Styrofoam for Food Packaging: A Literature Review on Water Resistance and Substrate Effects	STS-I25-50	Angelee Tishacorine Lawono; Jennifer Gizelle Kosasih;
Break			
13.30 – 13.45	Adaptive Aeroponic Controller with Fuzzy-Pid and Plant Database Via IOT Monitoring	CAS-I25-63	Indra Wijaya; Novia Ramadhani; Fitri Waldi; Imron Trijaya; Hafizha Khairani Atzma;
13.45 – 14.00	Innovation of Herbal Candy from Mangrove Fruit <i>Sonneratia caseolaris</i> as a Preventive, Rehabilitative, and Curative Agent for Diabetes Mellitus in Children and Adolescents	SAS-I25-31	Akram Shairazy Rizas; Nabila Carissa Putri; Aqilla Carissa Hamdel;
14.00 – 14.15	Bennovate: Innovating Mung Bean-Based Bioplastics to Increase Environmental Awareness	SAS-I25-40	Abigail Kayleen Hope;
14.15 – 14.30	Development of Cassava Peel Starch–Rice Husk Ash Bioplastic Coated with Rice Bran Wax for Sustainable Packaging Applications in Indonesia	SAS-I25-54	Quinsha Aglerina Widjaja;
14.30 – 14.45	The Production of Bioplastics from Royal Palm Leaves, Red Bean Starch, and Snake Fruit Skin	SAS-I25-62	Anselmus Joaquin Areliano; Eduardine Hedwig Adonleydia;

Abstract per Categories

Theoretical Studies

School	Title	Participants Code	Author
Lyceum No 283, Kyiv Junior Academy of Sciences	Scutoids As Stable Structures for The Formation of Epithelial Tissue	STS-I25-14	Mariia Yelyzaveta Rudyk;
Indonesian Creative School	General Formula of Multiple Functions on Integrals Infinite Tiny Boxes Summation	STS-I25-20	Rafie Aditya Rezha; Sultan Reynard Sadubi; Gaza Ahmad Wirasena;
SMA Cita Hati Christian School Surabaya	AI-Optimized Microturbines: Harnessing Wind Energy for Rural Areas in Nusa Tenggara Timur, Indonesia	STS-I25-27	Nicholas Chandra; Cedric Gregory Maximillian Gunawan; Jason Christopher Ajiarto; Kevin Jayson Wijaya; Shania Graciella Santoso;
Cita Hati Christian School Surabaya East Campus	Melon Seeds as Sustainable- Waste-Hand Cream Product Focused on Motorcyclist in Indonesia	STS-I25-38	Gloria Lauwson; Alexander Lee Xiong Ong; Nasya Evangelia Wong;
SMA Cita Hati Christian School	Risk and Flow-Based Infrastructure Optimization: Humanitarian Supply Aid in the Gaza Strip	STS-I25-44	Joshua Alexander Tanudirjo; Edmund William Sutantio;
Cita Hati Christian Senior High School East Campus	To What Extent Does the Minimum State of Charge Influence Charging Efficiency in iPhones	STS-I25-46	Patricia Adeline Purbowo;
Cita Hati Christian Senior School	Nonclassical Lie Symmetry Analysis of Allen-Cahn Equation	STS-I25-48	Mikael Cedricus Guido Soesanto;
Cita Hati Christian School	Chitosan-coated Mycelium Foam as a Sustainable Alternative to Styrofoam for Food Packaging: A Literature Review on Water Resistance and Substrate Effects	STS-I25-50	Angelee Tishacordine Lawono; Jennifer Gizelle Kosasih;
Binus School Semarang	VOLTURA (Voltage and Structural Architecture): A Next- Generation Structural Battery Composite for Electric Vehicles via Carbon Coating and Vacuum Assisted Resin Infusion (VARI)	STS-I25-60	Pierce Rainier Damian Kristanto; Steven Ernesto Sasmita Oei; I Gede Made Kenan Putra Dharma; Revino Pratama Putra Amalo;
University Of Aisyiyah Yogyakarta	Prediction of Missense Mutation Effects in the HBB Gene on Hemoglobin Stability and Structure in Beta Thalassemia Patients Using a Bioinformatics Approach	CTS-I25-64	Zuvi Fridhoriansyah; Kartika Raharja S.; Farida Noor Irfani;

Applied Studies

School	Title	Participants Code	Author
S.F.X Greenherald International School	The Emerging Potential of Cactus Leather: A Sustainable Alternative to Traditional Leather Production	JAS-I25-6	Prottasha Roy;
SMP Labschool Cirendeu	Smart Monitoring and Control System to Prevent Electrical Hazards in Flood-Prone Areas	JAS-I25-17	Arzhila Vidya Andrina; Orchidia Maghfira Yugandhini; Raisah Kei Laiqa; Anamuto Andisyah Pratamadinejad;
Jogjakarta Montessori Middle School	TRANSINSO: Transforming Rambutan Seed into Sustainable Oil	JAS-I25-19	Ignatia Karren Yolanda; Janita Beloven Lakasama;
SMPS Highscope Indonesia Medan	Utilization Of Organic Agricultural Waste for Biogas Production as A Potential for Energy Diversification for Local Communities in Berastagi District of North Sumatera	JAS-I25-32	Raavish Hizkia Lumban Gaol; Adrian Raja Erbinar Kaban; Ralph Timothy Elgera Bernanke Purba; Marcello Oliver Marbun; Credolih Atora Jordan Lingga;
SMP Cita Hati Christian School	Eco-Clean Innovation: Antibacterial Potential of Longan Peel (<i>Dimocarpus longan</i>) and Cinnamon (<i>Cinnamomum verum</i>) Extracts as a Sustainable Natural Formulation	JAS-I25-43	Felice Kirana Auria Candra; Tarsicia Daveney Basuki;
SMP Embun Pagi	3-in-1 Face Mask, Face Scrub and Face Wash from Goji Berry (<i>Lycium Barbarum</i>) Extract and Astaxanthin to Protect Skin from Free Radicals, Prevention of Acne and Premature Skin Aging	JAS-I25-55	Akila Elmira Latif; Adhwa Danika Allura Setiawan; Navisya Hypatia Putri Wijaya; Safina Rafanda Fathina Kurniawan;
SMP Montessori	Formation of Earth: Roblox for Education towards Middle School Students	JAS-I25-57	Ace Alexon Hartono; Daniel Devon Alexandra;
SMPN 252 Jakarta; SMP Budhaya III; Santo Agustinus Jakarta; SMPN 255 Jakarta; SMPN 115 Jakarta; (Liberika Academy)	Quercetin-Loaded Microneedle Patch from Red Onion Peel Extracts (<i>Allium cepa</i> L.) as a Safer Alternative of NSAIDs in Osteoarthritis Therapy	JAS-I25-58	Ahmad Gathan Juliansyah; Bianca Reguna Daben; Nadhifa Earlyta Arsyfa; Muhammad Alhafiizhu Aziz; Kimi Awdyra Teddy;
Kharisma Bangsa High School	Innovation In the Integration of The Hydrodynamic Disk System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers	SAS-I25-21	Elnino Bintang Pratama; Kemas Rangga Nur Akbar; Saladin Prakaza Ivanka; Chandra Erkam Lesmana;
Pribadi Bandung School	Modified Levee with Pump System Integrated with Zeocarbon Nanofiltration from Zeolite and Water Hyacinth (<i>Eichhornia Crassipes</i>) For River Overflow Control and Filtration	SAS-I25-25	Yasmine Bitu Roshanfekrana;
SMAS Kharisma Bangsa	Glucoaid: Smart Hydrocolloid Patch for Non-Invasive Blood Glucose Monitoring Via Enzymatic Sweat Analysis and Ph Indicator	SAS-I25-26	Azkea Kamila Hasbi; Nada Dzikri Nashita; Lovely Mischa Nur Zatna;

Kharisma Bangsa School	Biodegradable Cardboard-Based Ecowrap Innovation with Adaptive Folding Patterns as An Environmentally Friendly Alternative to Bubble Wrap	SAS-I25-28	Kenzie Lintang Hakim; Shandy Putra Pratama; Torkis Hanafi Harahap; Mochamad Sayid Azzacky Gafur;
SMA Negeri 8 Pekanbaru Riau	Innovation of Herbal Candy from Mangrove Fruit Sonneratia caseolaris as a Preventive, Rehabilitative, and Curative Agent for Diabetes Mellitus in Children and Adolescents	SAS-I25-31	Akram Shairazy Rizas; Nabila Carissa Putri; Aqilla Carissa Hamdel;
SMA Budi Utama	Bennovate: Innovating Mung Bean-Based Bioplastics to Increase Environmental Awareness	SAS-I25-40	Abigail Kayleen Hope;
MAN Insan Cendekia Kota Kendari	SAVIOR: A Robust Edge-AI Framework for Autonomous Zoonotic Symptom Classification Leveraging Hybrid Deep Learning for Public Health Resilience	SAS-I25-42	Anindhita Dea Shafira; Cheelsy Ameylia Lubis;
SMA Unggulan Rushd	MagnetO: A Household-Scale Innovation for Sustainable Electricity Generation through Magnetic Repulsion	SAS-I25-47	Omera Mysha Ashika; Syifa Avanti Aulia Ridwan; Elva Gracia Dinata Ginting; Rizqi Najma Delia;
SMAN 71 Jakarta; SMAN 103 Jakarta; SMAN 12 Jakarta; SMAN 11 Jakarta; (Liberika Academy)	Neuroscan: AI Powered Lung Cancer Detection	SAS-I25-51	Almer Rauf; Admiral Ghanim; Muhammad Habiburrahman Aziz; Khesya Firly Ade Syahrani;
Cita Hati Christian School	Development of Cassava Peel Starch-Rice Husk Ash Bioplastic Coated with Rice Bran Wax for Sustainable Packaging Applications in Indonesia	SAS-I25-54	Quinsha Aglerina Widjaja;
SMA Cita Hati Christian School	Comparative Study of Sunbathing vs. Vitamin D Supplementation on Serum Vitamin D Levels and Cold Incidence	SAS-I25-56	Laetitia Annabelle Tanuwijaya; Javelyn Lim;
Edu Global High School	Development of an IoT-Based Waste Bin with Real-Time Ultrasonic Fill-Level Monitoring to Support Improved Hygiene Management	SAS-I25-59	Ali Koosha Farzan; Halim Umar Karim;
SMA Kolese De Britto; SMA Budi Utama;	The Production of Bioplastics from Royal Palm Leaves, Red Bean Starch, and Snake Fruit Skin	SAS-I25-62	Anselmus Joaquin Areliano; Eduardine Hedwig Adonleydia;

Humanity Studies

School	Title	Participants Code	Author
Binus School Semarang	Youth and the Javanese Language: Proficiency, Usage, and Attitudes toward Preservation Challenges in Modernity, Cultural Identity, and Sustainability	SHS-I25-41	Nadine Aina Sakhi; Cinta Lista Keiswa; Aurelia Marabel Nathania Raulinus; Bianca Carloqueen; Loryf Gaynell Corrin Latifah Santiko;
Widyatama University	Innovation in the Digital Complaint System to Address Bandung's Stunting and Increase Social Assistance Transparency	CHS-I25-18	Bintang Sukma Dewa; Raihan Eka Saputra; Zachra Siti Utami Khoerunissa;

VOL. 003



THEORETICAL STUDIES

PAPER COLLECTIVE of IRCYS

IRCYS 2025

BANDUNG CREATIVE SOCIETY

Scutoids As Stable Structures for The Formation of Epithelial Tissue

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Bodies of Revolution,
Parametric Equation of a
Spatial Curve, Surface
Equation

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Abstract: The central challenge of today is to build adequate mathematical models of complex systems and predict their behavior depending on external influences. This study is devoted to the description of geometric shapes that have been studied at the cellular level. In 2018, biologists found a new type of non-classical polyhedra while studying embryonic epithelial tissue. The scutoid has curved edges and lateral surfaces. The paper investigates scutoids within some mathematical models. scutoid with a pentagon and a hexagon at the bases and one y-shaped face, twisted minimal regular scutoids, twisted minimal scutoids with semi-regular equiangular and equilateral polygons in the bases without y-shaped face. Using a Cartesian spatial coordinate system and modeling the problem using equations of analytical geometry, it was found that the equation for the lateral face describes a helicoid, while the edge repeats a helical curve, the shape of which depends on the body of revolution in which the scutoid is inscribed. It was found that minimal regular scutoids with the number of vertices at the base $N=3,4,6$ with equal polygons in cross-sections parallel to the bases fill the space or layer of space without gaps. A regular scutoid with a pentagon and a hexagon as bases can have one rectilinear lateral edge, with all lateral faces being right helicoids. Other lateral edges are helissas, the shape of which depends on the solid of revolution in which the scutoid is inscribed. The real-world applications of scutoid research are very promising. The biological origin of scutoids suggests potential biomedical uses, especially in tissue engineering and organ modeling. The study also makes it possible to create bricks and various coatings due to the property of covering a layer of space with regular scutoids, as well as due to the rotational symmetry of regular scutoids.

INTRODUCTION

The central mathematical challenge today is building adequate models of complex systems and predicting their behavior depending on external influences. This applies, for example, to economics, sociology, and the creation of

artificial intelligence. The most fascinating is the application of mathematical modeling in biology.

In 2018, biologists from Spain and the United States found a new type of non-classical polyhedra while studying embryonic epithelial tissue. Scutoids have side faces that

could be curved surfaces. Since the presence of precisely such polyhedra is observed in various tissues of the organs of biological objects, the study of the properties of scutoids is currently relevant.

The purpose of this project is to study the side faces and side edges of some scutoids.

LITERATURE REVIEW

When constructing mathematical models in biology, scientists are now interested not only in populations or individual organisms, but also in their smallest components, such as genes. This study examines geometric bodies defined at the cellular level.

Back in 1925-26, the Lotka-Volterra predator-prey model was proposed to be a pair of first-order nonlinear differential equations [5,9]. Now scientists are attracted not only to populations or individual organisms, but also to their smallest components like genes [1]. This research is devoted to describing geometric shapes that were investigated at the cellular level. Research on scutoids is very important now.

In the work of Derkach [3], some properties of classical scutoids with a pentagon and a hexagon at the bases and some properties of partial species of scutoids were studied. The shape of the lateral edges of a scutoid with a hexagon and a pentagon in the bases was not investigated by him.

Some properties of twisted minimal regular scutoids were investigated in the author's work [7,8]. However, no comparison of the use of different mathematical models has been made.

The paper investigates scutoids within some mathematical models: scutoid with a pentagon and a hexagon at the bases and one y-shaped face, twisted minimal regular scutoids, twisted minimal scutoids with semi-regular equiangular and equilateral polygons in the bases without y-shaped face.

METHOD

The following methods were used for the study:

- 1) Application of properties of semi-regular polygons [4].
- 2) Application of formulas of analytical geometry in space and on the plane.
- 3) Use of trigonometric ratios.
- 4) Use of equations of surfaces and spatial curves [6].
- 5) Numerical experiment in MATLAB 6.5 and GeoGebra.

Necessary Definitions

We will consider the definition given in [2] to be classical.

Classical definition 1 [2]. A scutoid is a geometric body contained between parallel surfaces in which lie polygons — the bases of the scutoid, and the vertices of these polygons can be connected by a straight line, or a curve, or a Y-shaped connection, and all sections of the body that are parallel to the bases are polygons (Figure 1a).

To limit research, we will also use the following definitions, introduced in the author's previous works [7,8].

Definition 2. A regular scutoid is a scutoid whose lower and upper bases are regular polygons with the same number of vertices, and the center of the upper base is orthogonally projected into the center of the lower base (Figure 1b).

Definition 3. We call scutoids minimal, in which Y—a similar face is absent (Figure 1c).

Definition 4. A twisted minimal scutoid is called a regular scutoid if its bases have the same number of vertices, besides, one base is rotated around the axis containing the centers of the bases by some angle with respect to the other (Figure 1d).

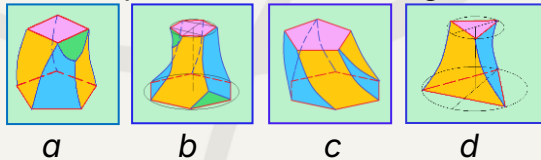


Figure 1. (a) Skutoid; (b) the regular skutoid, (c) minimal skutoid; (d) twisted regular scutoid.

Let us recall the definitions from Lopovok's article.

Definition 5 [4]: A polygon with an even number of vertices is called an equilateral semiregular polygon if its angles, taken through one, and all its sides are equal (Figure 2a).

Definition 6 [4]: An equiangular semiregular polygon is a convex polygon with an even number of vertices, all of whose angles are equal, and the sides are equal by one (Figure 2b).

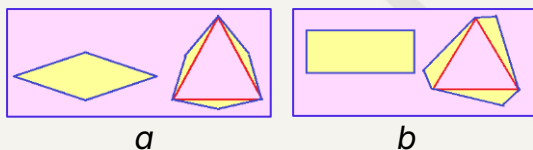


Figure 2. Semi-regular polygons: (a) equilateral (b) equiangular.

RESULT AND DISCUSSION

The paper investigates scutoids within some mathematical models. scutoid with a pentagon and a hexagon at the bases and one y-shaped face, twisted minimal regular scutoids, twisted minimal scutoids with semi-regular equiangular and equilateral polygons in the bases

without y-shaped face. Let's consider some properties of scutoids in each of the models.

The first model [7]. Twisted minimal regular scutoids inscribed in solids of revolution without y-shaped face.

Consider a twisted minimal regular scutoid (Figure 3) with curvilinear side faces, which has the radii of the circles described around the bases, R_1 and R_2 , and the height H . The angle of rotation of the upper base in relation to the lower one is φ .

To unambiguously define the twisted minimal regular scutoid and to limit the research, the following restrictions were introduced.

1. The number of side faces N is equal to the number of vertices in the base.
2. Side faces are simple smooth surfaces.
3. Side edges are simple smooth curves.
4. In sections parallel to the bases lie regular polygons are equal or similar to the bases. Their centers belong to the straight line that connects the centers of the bases.

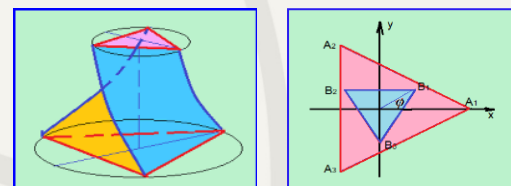


Figure 3. Twisted minimal semiregular scutoid with an equiangular semi-regular polygon at the base and modeling of its lower base in a rectangular Cartesian coordinate system.

Under such conditions, the twisted minimal regular scutoid is inscribed in some body of revolution with the axis of rotation passing through the centers of the bases.

Moreover, the inclusion in the body of rotation occurs in such a way that the vertices and side edges of the twisted minimal regular scutoid lie on the body of rotation.

Let's introduce the Cartesian rectangular coordinate system. The start of the coordinate system is the center of the polygon in the lower base of the scutoid. The direction of the abscissa axis is to the top A_1 of the lower base, the appliqué axis is perpendicular to the base, and the ordinate axis is perpendicular to the OX axis in the plane of the lower base. The angle by which the upper base rotates around its center in relation to the lower one is φ .

Let the geometric body in which the twisted minimal regular scutoid is inscribed, formed by the rotation of

the function $\begin{cases} y = f(z) \\ x = 0 \end{cases}$ around the OZ

axis. Then the surface of the body of rotation will be given as follows

$$\sqrt{x^2 + y^2} = f(z).$$

The parametric equation of spirals - side edges of a twisted minimal regular scutoid will have the form

$$\begin{cases} x(t) = f(t) \cos\left(\frac{2\pi}{N}(n-1)+t\right) \\ y(t) = f(t) \sin\left(\frac{2\pi}{N}(n-1)+t\right) \\ z(t) = t \end{cases}$$

The paper presents the results of a numerical experiment in the MATLAB environment, which confirmed the theoretical conclusions. Figure 4 shows scutoids inscribed in second-order bodies of revolution.

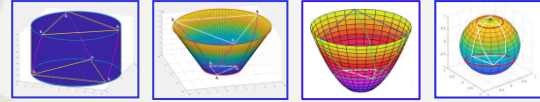


Figure 4. Scutoids inscribed in the cylinder, a truncated cone, in a paraboloid of revolution and sphere.

We get the equation of the lateral surface of the scutoid

$$y = -x \operatorname{ctg}\left(\frac{\varphi z}{H} + \frac{\pi}{N}\right) + f(z) \sin\frac{\varphi z}{H} + f(z) \cos\frac{\varphi z}{H} \operatorname{ctg}\left(\frac{\varphi z}{H} + \frac{\pi}{N}\right).$$

This equation is the equation of a linear helical surface, namely a straight helicoid. Such a surface is minimal. That is, nature creates cells in such a way that the surface area is minimal. At the same time, the connection between the cells is very strong.

Figure 5 shows a face of a twisted minimal regular scutoid with the number of vertices in the base $N=3$ inscribed in a cylinder at $\varphi = \frac{\pi}{3}$.

The graph of the function of two variables is built in the MathLab 6.5 environment.

It is possible to conclude that minimal regular scutoids inscribed in a cylinder with the number of vertices in the base $N=3,4,6$ fill a space or layer of space without gaps. This is ensured by the symmetry of scutoids and the possibility of covering the plane with semi-circular polygons. This makes it possible to offer a scutoid shape for laying bricks and all kinds of coatings.

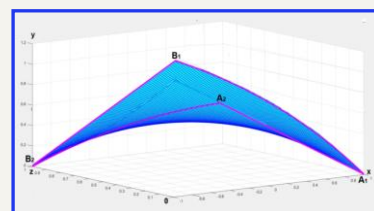


Figure 5. The face of a twisted minimal regular triangular scutoid inscribed in a cylinder.

The second model [8]. Twisted minimal scutoids with semi-regular equiangular polygons in the bases without y-shaped face. Since cells can deform under the influence of various factors, we considered scutoids with semiregular polygons at the bases. Consider minimal scutoids with semiregular equiangular polygons in the bases (Figure 6).

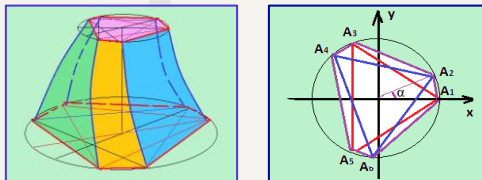


Figure 6. Twisted minimal semiregular scutoid with an equiangular semi-regular polygon at the base and modeling of its lower base in a rectangular Cartesian coordinate system.

Equiangular semi-regular polygons are inscribed. This means that the corresponding twisted minimal semi regular scutoids, as well as twisted minimal regular scutoids, will be inscribed in the body of revolution.

The equation of the side edges is the same as for twisted minimal regular scutoids, in which the number of base vertices is half as small.

It can be concluded that minimal scutoids with rectangles as a special case of an equiangular semiregular polygon fill a space or layer of space without gaps.

The third model [8]. Twisted minimal scutoids with semi-regular equilateral polygons in the bases without y-shaped face.

Let us consider minimal scutoids with semi-regular equilateral polygons at the bases (Figure 7).

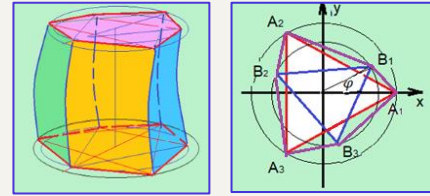


Figure 7. Twisted minimal semiregular scutoid with an equilateral semiregular polygon at the base and modeling of its lower base in a rectangular Cartesian coordinate system.

Semi-regular equilateral polygons have two base regular polygons of different circumscribed circle radii. Such polygons are formed by connecting the vertices of a semiregular polygon through one. Thus, an equilateral semiregular polygon has vertices belonging to two concentric circles. Then the twisted minimal scutoids with semi-regular equilateral polygons at the base are associated with two bodies of revolution. If we want to have similar polygons in sections parallel to the bases, then these two bodies of revolution must be similar.

Some possible combinations of second-order bodies of revolution are presented in figure 8. The 3D graphs were constructed in the GeoGebra environment.

It can be concluded that minimal scutoids with rhombus as a special case of an equilateral semiregular polygon fill a space or layer of space without gaps.

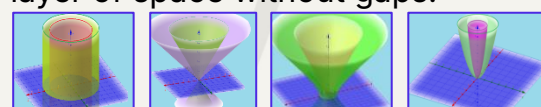


Figure 8. Some possible combinations of similar bodies of revolution

The fourth model. Classic scutoid with a regular pentagon and a hexagon at the bases and one y-shaped face.

Consider a classical scutoid with a regular hexagon and a pentagon at its bases. Let these polygons have the same circumscribed radius.

A classical regular scutoid may have one rectilinear lateral edge, with all lateral faces being straight helicoids. This is possible if one of the vertices of the upper base projects onto the vertex of the lower base. The Y-shaped face of such a scutoid can be either flat, cylindrical, or helicoidal. The lateral edge is a helissa, the shape of which depends on the body of revolution.

Figure 9 shows the lateral face of a classical scutoid. The graph of the function of two variables was plotted in GeoGebra.

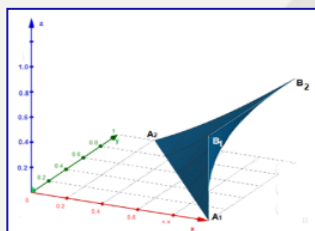


Figure 9. The lateral face of a classical scutoid.

CONCLUSION

In this work, the properties of a new type of polyhedra - scutoids - were studied. The work constructs 4 mathematical models of scutoids. The lateral faces and lateral edges of some scutoids are researched. The study of scutoids is a significant contribution to transplantology through the cultivation of artificial organs.

The study provides the opportunity to create bricks and

various coatings due to the property of covering a layer of space with regular scutoids, as well as due to the rotational symmetry of regular scutoids.

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General Formula of Multiple Functions on Integrals Infinite Tiny Boxes Summation

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Abstract: An integral can be viewed as the sum of infinitely many infinitesimal boxes whose total area represents the value of a mathematical function. This is the classical interpretation of an integral. In this work, each of these infinitesimal boxes is considered to carry its own set of reference lines, forming a new axis within the domain. This new axis serves as a framework for transforming the coordinates of a second function, depending on the values of the first function along the original axis. The aim of this study is to examine how points are distributed along the axis, since the conventional approach to integration assumes a uniform change in x or y . By characterizing this distribution, we can use it as the foundation for transforming the coordinates of a second function accordingly. This method introduces a way to compute structured, multivariable quantities while remaining in the original two-dimensional setting. It provides a potential tool for analyzing higher-dimensional structures without introducing additional coordinate axes.

INTRODUCTION

Involving a complex plane in mathematical study which may potentially contribute to many fields, this formula combines axis and multi-dimensional planes into a single, defined coordinate system. This formula uses the arclength of a lower-dimensional line function ($\Lambda_{\mathbb{R}^{k-1}}$) as an axis, against the real k -axis value of the line function (V_k). To obtain this coordinate system, this research substitutes a sequence of $V_{k-1}, V_{k-2}, \dots, V_1$ differentiation with respect to t inside the arclength parameterization into V_k as long as V_k can be written as $V_k = f(V_{n < k})$ then inverts the integration value resulting in $f(\Lambda_{\mathbb{R}^{k-1}})$. This value becomes the magnitude value inside the formula

when translating a higher dimension to two-dimensional, defining the core of this research.

This research uses a transformation-based approach to translate or represent another function or dimension with a relationship between the properties into a single, defined, and visualizable graph. The magnitude inside the formula may become an arbitrary function, but this research focuses more on higher-dimensional structure translation. We know this formula is applicable for dimension translation, for by its rule, does not ignore any $\mathbb{R}^k$ dimension property, because it uses lower-dimensional information to build the structure -- the arclength. The big question is,

how do we achieve the goal of getting the coordinates of the new perpendicular line function mathematically? How do we stack functions on one another with regards to this method? And how can we set a coordinate system based on the arclength of a function?

METHOD

Conceptual Section

First of all, we need to define the terminology of dimension. Dimension itself has multiple definitions because of its complex properties that interfere with the definition of space itself. In a more general way, the dimension is stated as a vector space that has a different direction for every axis with a 90-degree difference (called an orthogonal axis). This concept is also implemented in linear algebra or in classical geometry, where dimension is defined as $\llbracket v_1, v_2, v_3, \dots, v_n \rrbracket = \mathbb{R}^n$ with each v_m are the new vector directions that construct the structure space of $\mathbb{R}^n$. This research focuses on the linear algebra definition of dimension and how this formula's mathematical construction is only valid for vector-related dimensions.

To represent this formula, we use a three-dimensional graph and a two-dimensional graph with the axis (v_1, v_2, v_3) that we labeled as x, y, z .

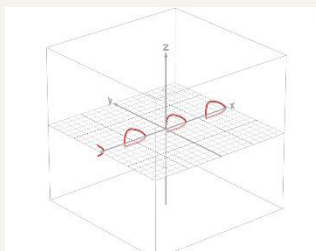


Figure 1: 3D sin function

From that three-dimensional graph, we also have 3 $\mathbb{R}^2$ function

which is (v_1, v_2) , (v_1, v_3) , (v_2, v_3) that states the value of the function in $\mathbb{R}^3$.

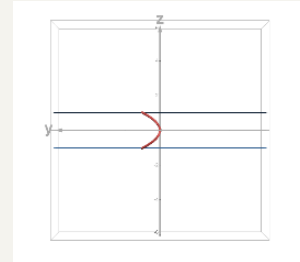


Figure 2: 2D view in z and y axes

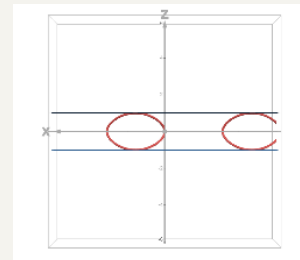


Figure 3: 2D view in z and x axes

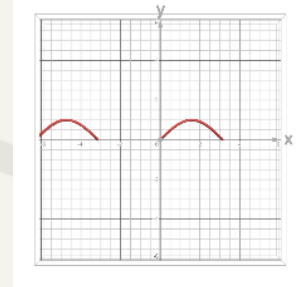


Figure 4: 2D view in x and y axes

In every dimensional line function, any $f(v_{n < k}) = v_k$ has the same output as $\vec{r}'_{k-1}(t)$, where $\vec{r}'_{k-1}(t) = \langle v_{k-1}, v_{k-2}, \dots, v_1 \rangle$.

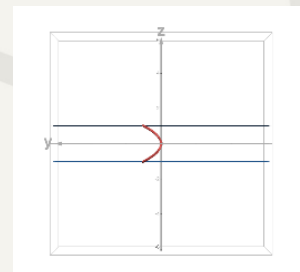


Figure 5: 2D view in y and z axes with z range

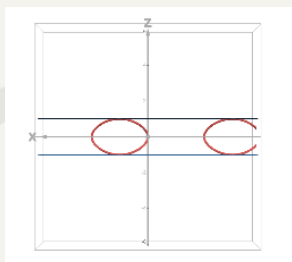


Figure 6: 2D view in z and x axes with z range

This Statement is saved for afterwards. As stated before, $\mathbb{R}^3[v_1, v_2, v_3]$ also has the property of $\mathbb{R}^2[v_1, v_2]$. By that, we make a function based on this two-dimensional graph.

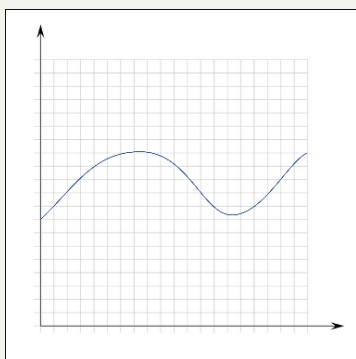


Figure 7: sin(x)

Based on basic calculus, this sine can be constructed with multiple boxes where one side of the corner touches the function.

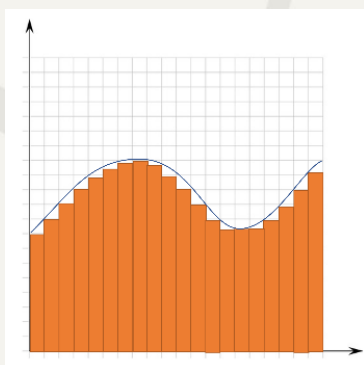


Figure 8: Integral of sin(x)

These boxes have a definitive set of heights as $f(s_2 \frac{m}{n})$ and width as $s_2 \frac{m}{n} - s_2 \frac{(m-1)}{n}$ where s_2 is the

endpoint of calculation, n is the number of boxes, and m is the term of the box. This appears in the Riemann summation method, where the coordinate of the horizontal axis can be divided evenly based on the number of boxes. When the number of boxes reaches limit-infinity, it aligns to a smooth curve of $f(x)$.

To clarify the purpose of this research, we use several boxes for explanation. If we form a straight line between 2 points of the boxes that touches the coordinate of the function, we get the result below.

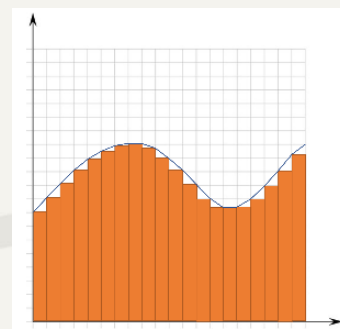


Figure 9: ArcLength of sin(x)

For each straight line that occurs on the arc length, we assume it as part of a new horizontal axis that states the value of v_3 , where v_3 acts as the vertical axis. This means all of these vertical lines are perpendicular line that acts as a vector value in the $\mathbb{R}^2$ graph.

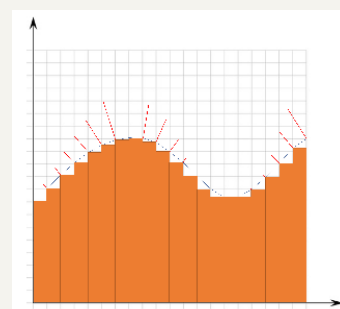


Figure 10: Perpendicular line on ArcLength of sin(x)

Depending on the value of v_3 and $\mathbb{R}^2$ function, each perpendicular line leads to its own unique coordinates. Due to the fact that we only use several boxes, the coordinates are still distinct from each other. However, when the number of boxes is increased to approaching infinity, a smooth curve that contains those unique coordinates are created.

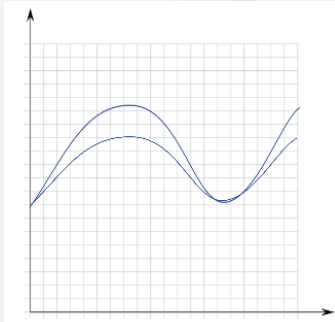


Figure 11: Recursion of dimension translation

This is the concept that this research focuses on, where the top curve is the value of the axis v_3 in $\mathbb{R}^3$, projected on $\mathbb{R}^2$. To gain the function of $\mathbb{R}^4$, we repeat this process, defining what is called as a recursion.

To achieve this specific goal, we need a mathematical logic that could generate the formula based on this concept. Thereby, the mathematical variables and notations that is used in this concept (cf. *NOTED NOTATION, BRACKETS AND VARIABLE, last page*) must be taken into consideration.

Mathematical Section: Arclength

The core value of this formula is in how we define arclength as an axis. Therefore, we need to understand the terms of arclength from a mathematical point of view.

Arclength uses the property of the Pythagorean theorem, which is $a^2 + b^2 = c^2$. The Pythagorean theorem is crucial to determine the value of a vector. A vector is a direction in a defined plane, where it has the property of axes with specific values that correspond to each other's axes in terms of t . In vector $\vec{T}_2(t)$ it has the property of $[[x,y]]$ which mean $\vec{T}_2(t)$ showing a direction in $\mathbb{R}^2$ with x and y as the axes. Which we can write $\vec{T}_2(t)$ as $\vec{T}_2(t) = \langle x_1(t), y_1(t) \rangle$.

From this statement, we can determine the arclength value as the vector is defined at a specific value of t . We need to note that the vector $\vec{T}_2(t)$ length can be written as $\|\vec{T}_2(t)\|$. We use the arclength parameterization formula, so the formula at the end has a more general range.

$$\int_0^t \|\vec{T}_2(u)\| du$$

This is the arc length parameterization formula. The advantage of using the arclength parameterization formula is that the axis values are determined by a single variable t , which simplifies the integration process with respect to t , and makes the integration variable t substitutable with its orthogonal axis v_k . This statement is kept for the next step of the formula.

We substitute the vector $\vec{T}_2(u)$ as $\vec{R}_k(t)$. So we can cover multiple dimension that occurs. One of the arc length properties is that we derive the vector $\vec{r}(t)$ inside the root before we integrate it with respect to du . u is a dummy variable that is used to avoid confusion with the integration upper boundary variable. For a more convenient presentation, we use t instead of the dummy

variable. The vector of $\vec{r}_k(t)$ contains axes value written in t variable ($\vec{r}_k(t) = \langle v_k(t), v_{k-1}(t), v_{k-2}(t), \dots, v_1(t) \rangle$). If we write $\vec{r}'_k(t)$ vector, it contains $\vec{r}'_k(t) = \langle v'_k(t), v'_{k-1}(t), v'_{k-2}(t), \dots, v'_1(t) \rangle$. But what is this derivative trying to tell us about the arclength of a function?

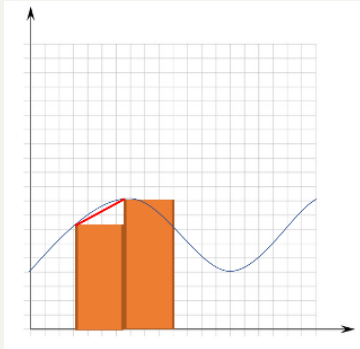


Figure 12: Derivative line

As we know from the conceptual, arclength emerged from the length of a distinct line that connected 2 dots on a function. If the values of these 2 dots are almost similar, the straight line connecting them would be more equivalent to the function.

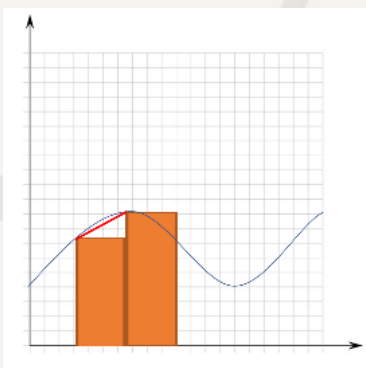


Figure 13: Derivative line

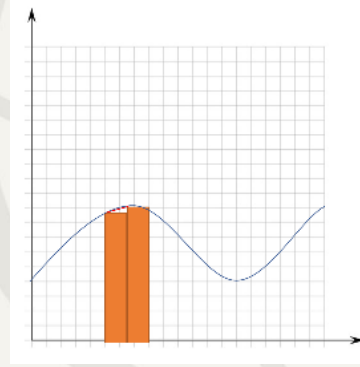


Figure 14: Smaller range of derivative line
Mathematically, the distinct line between 2 dots progression in the vector value can be written as

$$\text{in 2 dimension} \rightarrow \vec{r}'_2(t) \\ = \lim_{\Delta t \rightarrow 0} \left\langle \frac{x_1(t + \Delta t) - x_1(t)}{\Delta t}, \frac{y_1(t + \Delta t) - y_1(t)}{\Delta t} \right\rangle$$

$$\text{generally in } k \text{ dimension} \rightarrow \vec{r}'_k(t) \\ = \lim_{\Delta t \rightarrow 0} \left\langle \frac{v_k(t + \Delta t) - v_k(t)}{\Delta t}, \frac{v_{k-1}(t + \Delta t) - v_{k-1}(t)}{\Delta t}, \dots, \frac{v_1(t + \Delta t) - v_1(t)}{\Delta t} \right\rangle$$

This is why the derivative is essential to the vector in arclength parameterization. To find the length value of it, $\|\vec{r}'_k(t)\|$ which is the value of the distinct line between 2 dots. We need to use the Pythagorean theorem, resulting in:

$$\|\vec{r}'_2(t)\| = \sqrt{\left(\frac{x_2(t + \Delta t) - x_1(t)}{\Delta t}\right)^2 + \left(\frac{y_2(t + \Delta t) - y_1(t)}{\Delta t}\right)^2}$$

$$\|\vec{r}'_k(t)\| = \sqrt{\left(\frac{v_k(t + \Delta t) - v_k(t)}{\Delta t}\right)^2 + \left(\frac{v_{k-1}(t + \Delta t) - v_{k-1}(t)}{\Delta t}\right)^2 + \dots + \left(\frac{v_1(t + \Delta t) - v_1(t)}{\Delta t}\right)^2}$$

If we do the process of other dots in order, with the other dots having smaller value of t ($t - n\Delta t$) reaching the final dots where $t = 0$ as the value, we receive the result of the arclength value from points 0 until t . This is how the integration works.

$$\int_0^t \|\vec{r}'_k(u)\| du$$

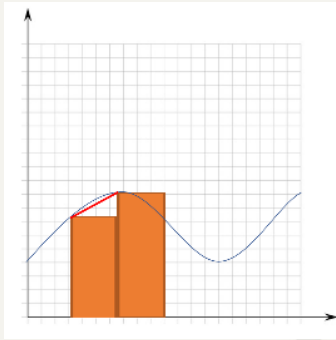


Figure 15: Derivative line

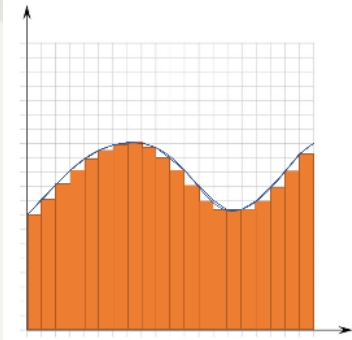


Figure 16: Integral of Arclength

We now know that because the arclength parametrization is vector-related, with any terms of axes being permissible, we can use it as the foundation of a new coordinate system that describes higher-dimensional structure without losing its property with a medium of arclength. This new coordinate system is useful as the magnitude in the $\vec{T}_k(t)$ vector.

Mathematical Section: New coordinate system based on arclength

Many coordinate systems have been made by famous mathematicians and physicists who revolutionized how we look at a graphical structure and found a hidden pattern when they shifted the coordinate system. This coordinate system is considered new, which could project a higher-dimensional structure with the axis of the dimension real axis value (v_k), with

the arclength in the lower dimension ($\Lambda_{\mathbb{R}^{k-1}}$). Therefore, we describe this function value as v_{r_k} with $\llbracket v_k, \Lambda_{\mathbb{R}^{k-1}} \rrbracket$.

The problem is the value of v_k would likely be described in terms of another real axis value of $v_{n < k}$ as long as both axes are connected in the domain $\mathbb{R}^k$ axes. Because v_k is described in another variable, not in arclength, we need some substitution process, but before that, we the logic of this arclength-based coordinate system is shown.

$$\begin{aligned} &\text{linear function in } \mathbb{R}^3 \\ &x = y = 2z \end{aligned}$$

To show a clearer dimension projection, we use v_k based axes

$$v_1 = v_2 = 2v_3$$

Vector value of $\mathbb{R}^3$ is

$$\vec{r}_3(t) = \langle v_1(t), v_2(t), v_3(t) \rangle = \langle t, t, \frac{t}{2} \rangle$$

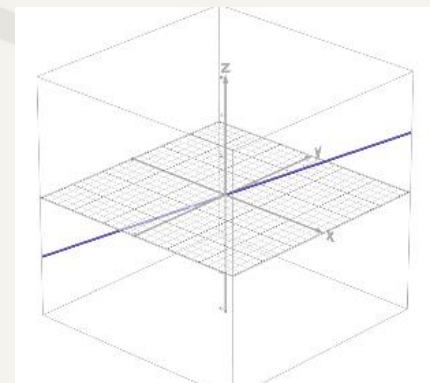


Figure 17: 3D linear function of $v_1 = v_2 = 2v_3$

The arclength of the $\mathbb{R}^2$ function can be written in an equation of

$$\Lambda_{\mathbb{R}^2} = \sqrt{v_1^2 + v_2^2}$$

Substitute v_1 and v_2 into t

$$\Lambda_{\mathbb{R}^2} = \sqrt{t^2 + t^2}$$

$$\Lambda_{\mathbb{R}^2} = \sqrt{2t^2}$$

$$\Lambda_{\mathbb{R}^2} = t\sqrt{2}$$

From here, we know that when arclength $\Lambda_{\mathbb{R}^2} = t\sqrt{2}$, $v_3 = \frac{t}{2}$ Which is

different from the real line function.

When $v_1 = t$, $v_3 = \frac{t}{2}$ and when $v_2 = t$,
 $v_3 = \frac{t}{2}$.

This indicates that when the arclength $\Lambda_{\mathbb{R}^2}$ becomes a new basis for v_3 , it creates a new function that is different from the $\Lambda_{\mathbb{R}^3}$ original axes. As we know in vector $\vec{r}_3(t)$, $v_3 = \frac{t}{2}$, $2v_3 = t$

If we substitute t with $2v_3$,
 $\Lambda_{\mathbb{R}^2} = 2v_3\sqrt{2}$

If we invert the function,
 $\frac{\Lambda_{\mathbb{R}^2}}{2\sqrt{2}} = v_3$

Here we have the function v_3 in terms of arclength $\Lambda_{\mathbb{R}^2}$. From this pathway, we know some rules that we should obey so that this pathway is valid and generally available.

all $\vec{r}_k(t)$ vector should be able written in variable (t)

$\Lambda_{\mathbb{R}^{k-1}}(v_k)$ should be inverseable

If 2 rules above are obeyed, we achieve the general pathway (*not a full formula yet*) for the new coordinate system.

$$\begin{aligned} & \int_0^t \|\vec{r}'_k(u)\| du \\ &= \int_0^t \sqrt{(v'_{k-1}(t))^2 + (v'_{k-2}(t))^2 \dots (v'_1(t))^2} dt \\ &= \Lambda_{\mathbb{R}^{k-1}}(t) \end{aligned}$$

substitute t with $f(v_k)$
 $\Lambda_{\mathbb{R}^{k-1}}(v_k) = \Lambda_{\mathbb{R}^{k-1}}(t)$

So, we got the function of graph where the axes are $\llbracket v_k, \Lambda_{\mathbb{R}^{k-1}} \rrbracket$
 $\Lambda_{\mathbb{R}^{k-1}}^{-1}(\Lambda_{\mathbb{R}^{k-1}}(v_k)) = v_k$

We change $\Lambda_{\mathbb{R}^{k-1}}^{-1}$ into more convenient symbols

$$\begin{aligned} h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k)) &= \Lambda_{\mathbb{R}^{k-1}}^{-1}(\Lambda_{\mathbb{R}^{k-1}}(v_k)) \\ &= v_k \end{aligned}$$

We name this coordinate system as Racursar

Mathematical Section: Dimensional Vector Translation Into $\mathbb{R}^2$

Our goal is to achieve a translation method that could bring a higher-dimensional structure into $\mathbb{R}^2$ without losing its real dimension property after translating it into a lower dimension. We now know the pathway for how to get the magnitude of a vector $\vec{T}_k(t)$ in any k dimension. The problem now is how to get the direction or x and y value, so that this direction is always perpendicular to the arclength progression. To achieve that, we recall the perpendicular line of the arc length from the conceptual section.

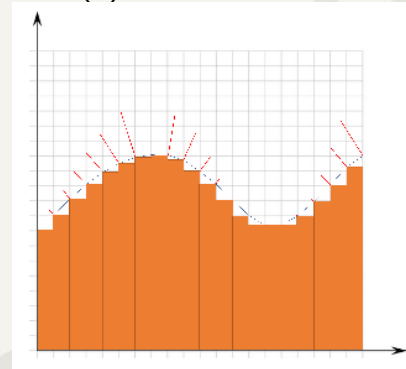


Figure 18: Perpendicular line on Arclength

As we can see, the perpendicular line has a value of v_3 with the basis of an arclength (v_{r_2}). The new coordinate that appears, we label as $\vec{T}_3(t)$ vector. We need keep in mind the fact that the perpendicular line from the derivative of the arclength is a vector. A vector in $\mathbb{R}^2$ is defined by the orthogonal axes of x and y . Which means the perpendicular lines are not only

$\|\vec{T}_3(t)\|$ against $\|\vec{r}'_2(t)\|$, but also the vector property of $\vec{T}_3(t)$ against $\vec{r}'_2(t)$ vector property. In other words, their x and y axes are also perpendicular to each other. If we form a triangle that states the value of the vector, both triangles are similar triangle. A similar triangle is one where each side has the same angle but different in size.

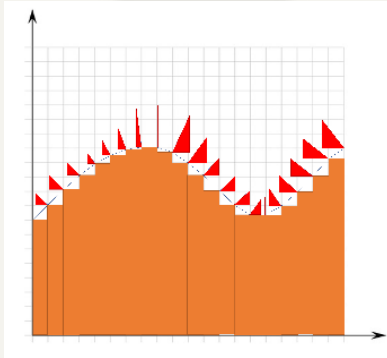


Figure 19: Vector of perpendicular line

As we know, the properties of the vector are

$$\vec{T}_3(t) = \langle x_3(t), y_3(t) \rangle$$

$$\vec{r}'_2(t) = \langle x'_2(t), y'_2(t) \rangle$$

As we know from the perpendicular rules, both triangles have the same angle. We label the angle as a_1 and a_2

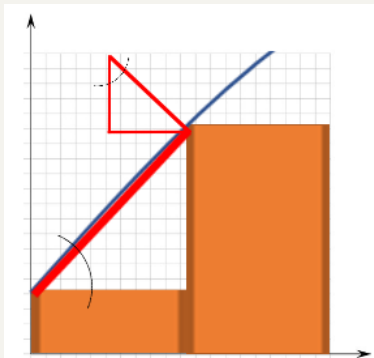


Figure 20: Figure 19's magnification

From that, we know both triangles have the same sine by $a_1 = a_2$. $\sin(a_1) = \sin(a_2)$ as well as $\cos(a_1) = \cos(a_2)$. We know that

$$\sin(a) = \frac{\text{opposite}}{\text{hypotenuse}} \quad \text{and} \quad \cos(a) = \frac{\text{adjacent}}{\text{hypotenuse}}$$

Because it is perpendicular, the triangle that is formed has an opposite axis correspondence to the side. The hypotenuse value is the length of the vector

$$\text{With } \sin(a_1) = \sin(a_2)$$

$$\frac{x_3(t)}{\|\vec{T}_3(t)\|} = \frac{y'_2(t)}{\|\vec{r}'_2(t)\|}$$

$$\text{And } \cos(a_1) = \cos(a_2)$$

$$\frac{y_3(t)}{\|\vec{T}_3(t)\|} = \frac{x'_2(t)}{\|\vec{r}'_2(t)\|}$$

As we know $\|\vec{T}_3(t)\|$ is a length value of the vector $\vec{T}_3(t)$ corresponding to the arclength. Which we can rewrite as $h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k))$

$$\text{With } \sin(a_1) = \sin(a_2)$$

$$\frac{x_3(t)}{h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k))} = \frac{y'_2(t)}{\|\vec{r}'_2(t)\|}$$

$$\text{And } \cos(a_1) = \cos(a_2)$$

$$\frac{y_3(t)}{h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k))} = \frac{x'_2(t)}{\|\vec{r}'_2(t)\|}$$

Because our goal is to find the values of the x and y axes in the vector $\vec{T}_3(t)$, we multiply both sides by $h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k))$

$$x_3(t) = h_3(\Lambda_{\mathbb{R}^2}(v_3)) \frac{y'_2(t)}{\|\vec{r}'_2(t)\|}$$

$$y_3(t) = h_3(\Lambda_{\mathbb{R}^2}(v_3)) \frac{x'_2(t)}{\|\vec{r}'_2(t)\|}$$

The result of this equation is only the value of the perpendicular triangle side, which we need to add or subtract from the coordinates of the point that the line is

perpendicular to depends on the line gradient integers.

$$x_3(t) = x_2(t) - h_3(\Lambda_{\mathbb{R}^2}(v_3)) \frac{y'_2(t)}{\|\vec{r}'_2(t)\|}$$

$$y_3(t) = y_2(t) + h_3(\Lambda_{\mathbb{R}^2}(v_3)) \frac{x'_2(t)}{\|\vec{r}'_2(t)\|}$$

When we add or subtract the triangle's side length, it depends on the derivative progression, which has a negative value or a positive value. The coordinate points in $\vec{T}_k(t)$ depends on the coordinate points before $\vec{T}_{k-1}(t)$. In the explanation above, we use $\vec{r}_2(t)$ which is be unrelated in higher k because the vector $\vec{r}_k(t)$ contains $\llbracket v_k, v_{k-1}, v_{k-2}, \dots, v_1 \rrbracket$. While in dimension translation, it is only needed v_1 and v_1 (x and y) axes because when we want to translate, the next dimension occurs, and we already have the information about the $\vec{T}_{k-1}(t)$. So that we can generalize the formula, we have

$$\vec{T}_k(t) = \langle x_k(t), y_k(t) \rangle$$

$$x_k(t) = x_{k-1}(t) - h_k(\Lambda_{\mathbb{R}^2}(v_k)) \frac{y'_{k-1}(t)}{\|\vec{T}'_{k-1}(t)\|}$$

$$y_k(t) = y_{k-1}(t) + h_k(\Lambda_{\mathbb{R}^2}(v_k)) \frac{x'_{k-1}(t)}{\|\vec{T}'_{k-1}(t)\|}$$

We name this formula as Dimensional translation into 2-dimension.

Mathematical Section: Recursive Function and Notation

Recursive calculation appears in this calculation, because the process needs to stack a function on top of one another (recursive process) and in this context, the recursive process is the dimension function that got stacked up.

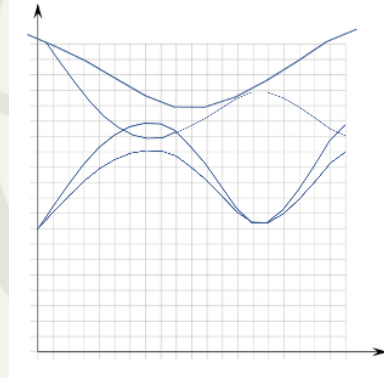


Figure 21: Recursion of the dimension translation

As we know, to make the $\vec{T}_4(t)$ coordinates, we need $\vec{T}_3(t)$ value as shown in the general translation formula.

$$\vec{T}_4(t) = \langle x_4(t), y_4(t) \rangle, \vec{T}_3(t)$$

$$= \langle x_3(t), y_3(t) \rangle$$

$$x_4(t) = x_3(t) - h_4(\Lambda_{\mathbb{R}^2}(v_4)) \frac{y'_3(t)}{\|\vec{T}'_3(t)\|}$$

$$y_4(t) = y_3(t) + h_4(\Lambda_{\mathbb{R}^2}(v_4)) \frac{x'_3(t)}{\|\vec{T}'_3(t)\|}$$

And to make $\vec{T}_3(t)$ coordinates, we need $\vec{T}_2(t)$ value

$$\vec{T}_3(t) = \langle x_3(t), y_3(t) \rangle, \vec{T}_2(t)$$

$$= \langle x_2(t), y_2(t) \rangle$$

$$x_3(t) = x_2(t) - h_3(\Lambda_{\mathbb{R}^2}(v_3)) \frac{y'_2(t)}{\|\vec{T}'_2(t)\|}$$

$$y_3(t) = y_2(t) + h_3(\Lambda_{\mathbb{R}^2}(v_3)) \frac{x'_2(t)}{\|\vec{T}'_2(t)\|}$$

If we substitute the $\vec{T}_3(t)$ value with $\vec{T}_2(t)$ value in a search for $\vec{T}_4(t)$ coordinates, it creates a long and ambiguous notation and symbols, especially if we need a higher k value. We label a recursive process to simplify the formula forms,

$$\xi_{a_n}(b)$$

= recursive of the whole function of a, untill terms n,
with input b in a_n

As stated, it is a recursion of the whole function a, until terms of n. We label the coordinate in k dimensions

as $\vec{T}_k$. Because finding coordinates in k terms involves axes x and y simultaneously. So that for the recursive process of translating coordinates, we can write as

$$\begin{aligned} & \vec{T}_k(x_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))), y_k(\xi_{\vec{T}_2}(x_1(t), y_1(t)))) \\ &= \langle x_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))), y_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \rangle \\ & x_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\ &= x_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\ &+ h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k)) \\ & \cdot \frac{y'_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t)))}{\|\vec{T}'_{k-1}(t)\|} \\ & y_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\ &= y_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\ &+ h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k)) \\ & \cdot \frac{x'_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t)))}{\|\vec{T}'_{k-1}(t)\|} \end{aligned}$$

As we can see in this generalized recursion, we changed all of the t values as $\xi_{\vec{T}_2}(x_1(t), y_1(t))$. When we use the variable t in the generalized function, it is not wrong. But the t , which is a substitute variable of the vector, only shows information about $\vec{T}_k(t)$ at a specific point on a plane written in terms of t , without showing that $\vec{T}_k(t)$ value determined by a recursive process to get its coordinates. With changing t into $\xi_{\vec{T}_2}(x_1(t), y_1(t))$, It shows the recursive process, the stop points of the recursive process, the value of the base dimension, and the vector written in t .

For the recursive process of $h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k))$, it is a little different. To find the integration function, it is unnecessary to use the recursive process as long as $\vec{r}_{k-1}(t) = \langle v_{k-1}(t), \dots, v_1(t) \rangle$ value is known. However, the endpoint of the integral needs a recursive process because the endpoints are the indication of the $\mathbb{R}^k$ structure based on the base

dimension value $\vec{r}_2(t)$ and integration of v_{r_k} . Here is the visualization of the v_{r_k} graph.

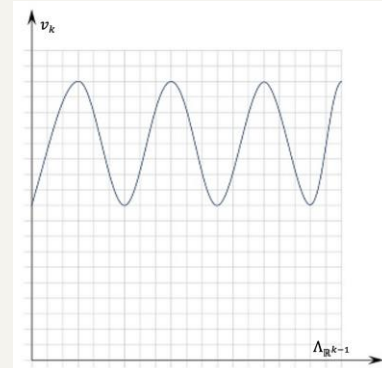


Figure 22: Racursar coordinate system graph

As we can see, to find the v_{r_k} function specific coordinates, we need to determine the value of $\Lambda_{\mathbb{R}^{k-1}}$ Which is the arc length of the function $v_{r_{k-1}}$. This process is always continued, so it is a recursive integral written as

$$\begin{aligned} & \int_0^{\xi_{v_{r_2}}(x_1(t), y_1(t))} \|\vec{r}'_k(t)\| dt \\ &= \int_0^{\xi_{v_{r_2}}(x_1(t), y_1(t))} \sqrt{(v'_{k-1}(t))^2 + (v'_{k-2}(t))^2 \dots (v'_1(t))^2} dt \\ &= \Lambda_{\mathbb{R}^{k-1}}(t) \end{aligned}$$

The recursion $\xi_{v_{r_2}}(x_1(t), y_1(t))$ is the endpoint of the integral, as mentioned before, the endpoints indicate how the $\mathbb{R}^k$ structure is. In the recursion $\xi_{v_{r_2}}(x_1(t), y_1(t))$. The choosing variable inside this formula is t , as a real vector value in real $\mathbb{R}^k$ plane is $\vec{r}_k(t) = \langle v_k(t), v_{k-1}(t), v_{k-2}(t), \dots, v_1(t) \rangle$, and a visualizable real part of $\mathbb{R}^k$ plane only occurs in $\mathbb{R}^3$ below with $\vec{r}_3(t) = \langle v_1(t), v_2(t), v_3(t) \rangle$, we make $\vec{r}_2(t)$ vector as the base because of its advantage as an easy understanding tool, natural base for a dimension structure, and more general for any related problem.

RESULT AND DISCUSSION

$$\begin{aligned}
 & \mathbb{R}^k \text{ dimension translation into } \mathbb{R}^2 \\
 & \vec{T}_k(x_k(\xi_{\vec{T}_2}(x_1(t), y_1(t)))) \\
 & = \langle x_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))), y_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \rangle \\
 & \quad x_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\
 & \quad = x_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\
 & \quad + h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k)) \\
 & \quad \cdot \frac{y'_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t)))}{\|\vec{T}'_{k-1}(t)\|} \\
 & \quad y_k(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\
 & \quad = y_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \\
 & \quad + h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k)) \\
 & \quad \cdot \frac{x'_{k-1}(\xi_{\vec{T}_2}(x_1(t), y_1(t)))}{\|\vec{T}'_{k-1}(t)\|}
 \end{aligned}$$

Racursar coordinate system,

$$\begin{aligned}
 & \int_0^{\xi_{v_{r_2}}(x_1(t), y_1(t))} \|\vec{r}'_k(t)\| dt \\
 & = \int_0^{\xi_{v_{r_2}}(x_1(t), y_1(t))} \sqrt{(v'_{k-1}(t))^2 + (v'_{k-2}(t))^2 \dots (v'_1(t))^2} dt \\
 & = \Lambda_{\mathbb{R}^{k-1}} \\
 & h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k)) = \Lambda^{-1}_{\mathbb{R}^{k-1}}(\Lambda_{\mathbb{R}^{k-1}}(v_k)) \\
 & = v_k
 \end{aligned}$$

This is the full formula on how we could get a dimensional translation into a 2-dimensional projection $\mathbb{R}^2$ and new coordinate system, which we name as Racursar.

CONCLUSION

This formula is a game-changer for many fields. Fields that have a really high chance to be affected are mathematics, physics, and robotics because of the new coordinate system that shortens or gives a new view and pattern in a calculation. Despite being a formula, it has some weaknesses that make it vulnerable in certain conditions. Such as all $\vec{r}_k(t)$ vector should be able to be written in t , most of the vectors should be reversible, and the arclength $\Lambda_{\mathbb{R}^{k-1}}(v_k) = v_k$ should also

be reversible, which really depends on the vector v_k . This formula has only been tested in a line function, not a dimensional structure that creates a new area-like property. Naturally, there still is room for improvement in this formula, as in this research, we only focused on how we can translate a higher-dimensional structure into 2-dimensional axis without removing its property. Which is the magnitude based on $h_k(\Lambda_{\mathbb{R}^{k-1}}(v_k))$.

Theoretically, $h_k(\dots)$ function may become an arbitrary function without considering the arclength variable, which will open more gates into other fields by its freedom of the magnitude.

Introducing a new coordinate system named the Racursar which utilizes the arclength of a lower-dimensional functions to define higher-dimensional projected within a visible, 2-dimensional plane. By using arclength as an axis, Racursar maintains the properties of higher-dimensional vectors while making them representable and analysable in $\mathbb{R}^2$.

Through this approach, the Racursar system provides a framework for translating multi-dimensional structures into a comprehensible plane, while maintaining their real dimensional relationships. This opens possibilities for applications in mathematical visualization, data representation, physics, and other fields where dimensional reduction and structural preservation are essential. Future research may further refine this system, explore computational implementations, and investigate practical applications in areas such as geometry, dynamical



systems, and higher-dimensional modeling.

Noted Notation, Brackets and Variable

$\llbracket \quad \rrbracket$ = this bracket means information of axis
 $\|a\|$ = this bracket means length of property a
 k = dimension number
 v_k = axis terms k in dimension $\mathbb{R}^k$
 Λ_a = arclength in plane a
 $\Lambda_a(b)$ = arclength in plane a , written in variable b
 $\mathbb{R}^k = \llbracket v_k, v_{k-1}, v_{k-2}, \dots, v_1 \rrbracket$, describe dimension in its real orthopogonal axis
 $\vec{T}_k(t)$
 $= \llbracket x, y \rrbracket$, describe higher dimension in axis $\mathbb{R}^2$ (cartesian coordinate)
 $\vec{T}_k(t) = \langle x_{r_k}(\xi_{\vec{T}_2}(x_1(t), y_1(t))), y_{r_k}(\xi_{\vec{T}_2}(x_1(t), y_1(t))) \rangle$
 $x_k(a)$
 $= x$ value of $\mathbb{R}^k$, written in variable a , special case $x_2(a)$
 $= v_1(a)$
 $y_k(a)$
 $= y$ value of $\mathbb{R}^k$, written in variable a , special case, $y_2(a)$
 $= v_2(a)$
 $\xi_{a_n}(b)$
 $=$ recursive of the whole function of a , untill terms n , with input b in a_n
 v_{r_k}
 $= \llbracket v_k, \Lambda_{\mathbb{R}^{k-1}} \rrbracket$, describe higher dimension with $\Lambda_{\mathbb{R}^{k-1}}$ and v_k as axis
 $\vec{r}_k(t) = \langle v_k(t), v_{k-1}(t), v_{k-2}(t), \dots, v_1(t) \rangle$
 $\vec{F}(a)$
 $= \langle A(a), B(a), \dots, N(a) \rangle$ vector in specific point, written in a

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(A_Classification_of_the_Recursive_Functi, n.d.; Barnett, 2021; Lan et al., 2012; Maksimović & Borković, 2021; Stephan, 2025; Yang et al., 2022)

AI-Optimized Microturbines: Harnessing Wind Energy for Rural Areas in Nusa Tenggara Timur, Indonesia

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Abstract: Indonesia's growing demand for affordable renewable energy highlights the urgent need for solutions in rural areas, where access to reliable electricity is still limited by geography and infrastructure. In Nusa Tenggara Timur (NTT), especially on Sumba Island, this challenge is evident; the national grid often fails to meet local needs despite the region's abundant wind resources, with average speeds of 12.6-15.9 knots and power densities exceeding 400 W/m², making it suitable for turbine projects (Ifanda, 2023). Microturbines offer a decentralized alternative, but their effectiveness is often constrained by inefficient placement, aerodynamic limitations, and high maintenance requirements. To address these challenges, our research integrates advanced turbine design with Artificial Intelligence (AI) for optimizing small-scale wind microturbines (2-3 m rotor, <10 kW) suited to rural electrification. Blade Element Momentum (BEM) simulations establish baseline performance, while AI techniques extend capability: hybrid LSTM-Random Forest models improve wind forecasting accuracy (MAPE ~7.8%), reinforcement learning and fuzzy logic provide adaptive blade control, convolutional neural networks enable predictive maintenance (>90% fault detection accuracy), and genetic algorithms optimize siting with ~12-15% higher annual energy yield. Integrated results show a ~20% improvement in capacity factor, ~15% reduction in lifecycle costs, and avoidance of ~1.2 tons CO₂ emissions per turbine annually compared to diesel generation. By integrating AI with advanced microturbine design, wind power in NTT, Indonesia can become more efficient, reliable, and affordable, supporting the national energy transition and offering lessons for other regions with similar conditions worldwide.

INTRODUCTION

1.1. Background

Despite Indonesia's electrification rate exceeding 95%, provinces such as Nusa Tenggara Timur (NTT) remain underserved. Many households still depend on costly diesel or kerosene, resulting in

frequent blackouts and high energy expenses (PLN, 2022).

Yet NTT possesses strong wind resources, with average speeds of 12-16 knots and power densities above 400 W/m² (Ifanda, 2023). Deployment of small turbines, however, has been limited by poor

siting, fixed-blade designs, and weak maintenance capacity.

To overcome these challenges, this research study integrates aerodynamic modeling grounded in physics with artificial intelligence (AI) techniques on how microturbines can be made more efficient, cost-effective, and sustainable for rural electrification in NTT.

1.2. Problem Formulation

Nusa Tenggara Timur (NTT) is one of Indonesia's least electrified provinces, where lots of communities still depend on diesel and kerosene for energy. It consists of scattered islands with hilly terrains and a strong monsoon wind makes centralized electrification expensive and difficult, making small wind microturbines as a promising alternative, yet some problems persist: Unreliable electricity access, dependence on diesel and kerosene is costly and unsustainable.

Complex terrain, scattered islands, coastal zones, and hills make turbine siting difficult, often leading to turbulence and underperformance. Inefficient technology, most small turbines use fixed blades without adaptive control, reducing efficiency and accelerating wear. Limited technical capacity, rural operators lack forecasting and predictive maintenance tools, causing frequent breakdowns and high costs.

1.3. Research Questions

How can the wind energy potential across NTT, particularly in Eastern Sunda, be effectively analyzed using meteorological and geographical data from atlas datasets and validated meteorological records to identify high-potential sites for microturbine deployment?

How can microturbines be designed and modeled for rural applications by integrating physics-based aerodynamic simulations with AI optimization techniques to ensure efficiency under fluctuating wind conditions?

How can AI-based solutions such as forecasting models (LSTM, GRU, Random Forest Regression) for predicting wind variations, adaptive blade control mechanisms (Reinforcement Learning, Fuzzy Logic) for real-time optimization, predictive maintenance frameworks (CNNs) for early fault detection, and siting/layout optimization algorithms (Genetic Algorithms, Particle Swarm Optimization) that account for terrain and turbulence be developed and integrated to enhance the efficiency, reliability, and sustainability of microturbine systems in NTT?

How will AI-enhanced microturbines impact socio-economic and environmental outcomes in rural NTT communities specifically in terms of affordability (capital & O&M costs, financing models), lifecycle sustainability (materials, recycling), and quantified CO₂ emissions reductions and what metrics, time horizons, and stakeholder engagement methods should be used to measure and validate these effects?

1.4. Hypothesis

Using AI-based site selection models (Genetic Algorithms, GIS, meteorological data) will identify high-potential microturbine locations in NTT more effectively than conventional atlas-only methods, yielding at least a 10-15% improvement in estimated annual energy production (AEP).

Microturbines designed through the integration of physics-

based aerodynamic modeling (BEM analysis) with AI optimization techniques will achieve a $\geq 10\%$ higher capacity factor compared to existing fixed-blade microturbines under variable wind conditions.

AI-powered forecasting models (LSTM, Random Forest, GRU) will predict wind variability in NTT with a Mean Absolute Percentage Error (MAPE) below 8%, outperforming classical statistical approaches ($>10\%$ MAPE), thus enabling better microgrid scheduling.

CNN-based predictive maintenance frameworks will detect common turbine faults (e.g., rotor imbalance, bearing wear) with $>90\%$ accuracy, reducing downtime and maintenance costs by at least 20-30% in rural deployments.

1.5. Scope and Limitations

This study focuses on the design, simulation, and optimization of small-scale horizontal-axis wind microturbines (2-3 m rotor, <10 kW) for rural electrification in Nusa Tenggara Timur (NTT), Indonesia. The analysis integrates physics-based aerodynamic modeling with artificial intelligence (AI) methods across four domains: (1) Wind forecasting using LSTM, GRU, and Random Forest regression; (2) Adaptive blade control with reinforcement learning and fuzzy logic; (3) Predictive maintenance through convolutional neural networks (CNNs); and (4) Siting optimization via Genetic Algorithms (GA) and Particle Swarm Optimization (PSO).

Environmental and meteorological datasets are derived from BMKG station records and atlas reanalysis (ERA5, NASA POWER), while geographic data (terrain, roughness, land cover) are

incorporated through GIS. The scope is limited to simulation-based evaluation; field validation and full-scale deployment are outside this research but recommended for future studies.

Key limitations include: (1) Data constraints: Sparse high-resolution wind records in remote NTT require reliance on interpolated datasets, which may reduce site-specific accuracy. (2) Technological boundaries: The study considers only horizontal-axis microturbines in the 2-3 m rotor class, excluding hybrid solar-wind systems or larger turbines. (3) Socio-economic assessment: Benefits such as affordability and health improvements are modeled from secondary data rather than field surveys. (4) Environmental scope: A full life-cycle assessment of turbine materials (e.g., GFRP blades) is not included.

1.6. Novelty

This research is novel in its integration of AI-driven optimization with physics-based aerodynamic modeling specifically for rural-scale microturbines in NTT, Indonesia. Unlike prior studies, which focus on utility-scale wind farms in data-rich regions, this study applies advanced AI methods, including forecasting, adaptive control, predictive maintenance, and siting algorithms to 2-3 m rotor turbines suited to decentralized rural electrification.

The innovation lies in combining Physics-based foundations (BEM analysis, C_p -TSR curves, turbulence effects) with AI enhancements (LSTM forecasting, RL control, CNN-based maintenance, GA siting).

By linking technical performance with socio-economic outcomes (reduced costs, improved

reliability, CO₂ reduction, and household energy savings), the study provides a scalable framework for archipelagic contexts like NTT. This dual focus on engineering rigor and rural applicability distinguishes it from previous AI applications in renewable energy, which rarely address the constraints of small, off-grid communities.

LITERATURE REVIEW

2.1. Rural Electrification and Energy Access

Despite global progress, over 700 million people, mostly in remote or island regions, remain without reliable electricity (IEA, 2022). In Indonesia, electrification officially exceeds 95%, yet provinces such as Nusa Tenggara Timur (NTT) still relies on diesel and kerosene, causing frequent outages and high household energy costs (PLN, 2022).

Extending centralized grids to these areas is often uneconomical due to challenging terrain and scattered populations. Decentralized solutions, particularly small wind microturbines, offer a practical alternative by generating power locally and reducing dependence on costly fossil fuels. However, their effectiveness depends on proper siting, reliable maintenance, and adaptability to variable wind conditions.

2.2. Microturbines and Small Wind Systems

Microturbines, defined as wind systems below 10 kW, are a solid choice for decentralized electrification in rural areas (Gipe, 2009; Hau, 2013). Horizontal-axis designs generally outperform vertical-axis types in low-to-moderate wind regimes when

properly sited and maintained (Manwell et al., 2010). However, many rural installations fail due to fixed-blade configurations, poor siting, and limited technical capacity, which accelerate fatigue and reduce community trust.

In regions like NTT, the key challenge is not conversion efficiency but long-term reliability. This underscores the need for microturbine designs that combine aerodynamic optimization with adaptive, low-cost control and maintenance strategies, an approach this study addresses.

2.3 Wind Resource Assessment

Reliable wind assessment is critical for microturbines in regions like NTT, where monsoon flows and complex topography create strong local variability (BMKG, 2020; Soeripno et al., 2017). Traditional tools such as wind atlases or sparse meteorological stations provide only coarse estimates, while advanced methods like CFD or mesoscale modeling demand extensive data and computation, often impractical for rural settings (Troen & Petersen, 1989; Draxl et al., 2015).

Recent studies recommend hybrid approaches that combine atlas data, limited ground measurements, and AI-based forecasting to improve accuracy in data-scarce regions (Mosavi et al., 2019; Kumar & Singh, 2022). This study adopts such an approach, integrating atlas and BMKG records with AI optimization to generate resource assessments tailored to NTT's rural conditions.

2.4. Artificial Intelligence in Renewable Energy Systems

Artificial intelligence (AI) has advanced wind energy systems in four key areas: (1) Forecasting: Deep

learning methods such as LSTM and ensemble models like Random Forest consistently reduce wind prediction errors to below 10% (Wang, 2022; Liu, 2025). (2) Control: Reinforcement learning and fuzzy logic improve blade and rotor adjustments under turbulence, enhancing adaptability in variable conditions (Dong, 2021; Soler, 2024). (3) Predictive Maintenance: CNNs applied to vibration and thermal data can detect turbine faults with >90% accuracy, reducing downtime (Qi, 2024; Xu, 2024). (4) Siting Optimization: Evolutionary algorithms such as GA and PSO improve turbine layouts, though mainly at utility scale (Kirchner-Bossi, 2018; Pillai, 2018).

Despite these advances, most studies focus on large wind farms in data-rich settings. Their adaptation to small, decentralized microturbines in regions like NTT remains underexplored. This research addresses that gap by embedding AI methods within physics-based turbine design for rural electrification.

2.5. Socio-economic and Environmental Considerations

For rural electrification to be sustainable, projects must provide social and environmental as well as technical benefits. In NTT, microturbines can reduce household energy costs, displace kerosene use, and improve resilience by ensuring local supply during grid failures (Bhattacharyya, 2012; Handayani et al., 2017; Mainali & Silveira, 2015).

Yet, challenges remain: high upfront costs, limited technical expertise, and maintenance delays often reduce reliability, while community exclusion can lead to resistance (Yadoo & Cruickshank,

2012). Environmental issues such as material sustainability and recycling are also underexplored.

This study therefore evaluates microturbines not only on technical performance but also in terms of affordability, reliability, and socio-economic impact in the NTT context.

2.6. Research Gap and Positioning

Most AI research in wind energy targets large-scale farms in data-rich settings, with little adaptation to small rural microturbines in complex regions such as NTT. This study fills that gap by integrating physics-based aerodynamic modeling with AI methods for forecasting, adaptive control, predictive maintenance, and siting, while also evaluating socio-economic impacts.

By uniting technical optimization with rural electrification needs, it positions AI-enhanced microturbines as a novel, practical, and scalable solution for underserved communities in Indonesia and similar contexts worldwide.

METHOD

3.1. Research Framework

This study applies a simulation-based framework that combines aerodynamic modeling with artificial intelligence (AI) to evaluate the performance of small-scale wind microturbines in Nusa Tenggara Timur (NTT), Indonesia. Meteorological data such as wind speed, direction, temperature, and pressure were found from ERA5, NASA POWER, and BMKG, while geographic input such as terrain elevation, surface roughness, and land cover were derived from GIS databases. These data sets were normalized, bias-corrected with local measurements, temporal

downscaling to sub-hourly intervals, giving boundary conditions for simulations and data-training for AI models.

A baseline horizontal-axis wind turbine (HAWT) with a 3 m rotor diameter was designed using Blade Element Momentum (BEM) theory, incorporating tip-speed ratio optimization, stall regulation, and turbulence effects. Seasonal power curves established the baseline aerodynamic performance. AI methods were then integrated across four domains: wind forecasting (LSTM, GRU, Random Forest), adaptive control (reinforcement learning, fuzzy logic), predictive maintenance (CNNs trained on synthetic SCADA-like data), and siting optimization (genetic algorithms, particle swarm optimization).

Performance outcomes were evaluated across technical (capacity factor, annual energy yield, aerodynamic efficiency), environmental (avoided CO₂ emissions), and economic (affordability, maintenance savings, payback period) dimensions. Although theoretical, this framework shows a coherent integration of physics-based and AI models, building a strong foundation for future pilot-scale trials in NTT.

3.2. Environmental and Climate Data Collection

In order to efficiently place microturbines for optimal efficiency, accurate environmental and climate data form the foundation for modeling wind energy systems in Nusa Tenggara Timur (NTT). Unlike large-scale wind farms, rural microturbines operate under complex microclimatic conditions where atmospheric parameters

directly determine both aerodynamic performance and AI forecasting requirements.

The most critical factor is wind speed, as turbine power output scales with the cube of velocity:

$$P = \frac{1}{2} \rho A v^3 C_p \dots\dots\dots (1)$$

Where P is mechanical power (W), ρ air density (kg/m³), A rotor swept area (m²), v wind speed (m/s), and C_p power coefficient (≤ 0.593 by Betz's law) (Burton, et al., 2011). Even small errors in mean wind speed strongly affect energy predictions. Additional parameters include wind directions where seasonal roses were constructed from atlas and BMKG data to capture trade winds and monsoon shifts.

Turbulence metrics, including turbulence intensity (TI), gust factors, and shear exponent α are collected to capture flow variability and structural stressors. Turbulence intensity,

$$TI = \sigma_u / U \dots\dots\dots (2)$$

Where σ_u is the standard deviation of short-term wind speed fluctuations and U is the mean speed (m/s). It quantifies short-term velocity fluctuations. $TI > 20\%$ implies high cyclic loads and fatigue, while $TI < 10\%$ indicates smoother flow. These values guide hub-height extrapolation and wake models.

3.3 Aerodynamic Efficiency, Power Curves, and Turbine Design

A baseline horizontal-axis wind turbine (HAWT) with a 3 m rotor diameter was developed to evaluate aerodynamic performance under NTT wind conditions. The model applies Blade Element Momentum (BEM) theory, which combines

conservation of momentum in the rotor wake with blade lift-drag aerodynamics.

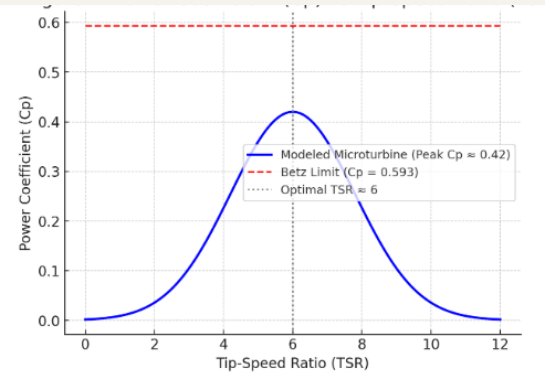


Figure 1. Power Coefficient (C_p) vs Tip-Speed Ratio (TSR)

The turbine’s power coefficient (C_p) was calculated across a range of tip-speed ratios (TSR). The C_p TSR curve showed a peak efficiency of ~0.42 at $TSR \approx 6$, representing ~71% of Betz’s theoretical limit. This value reflects realistic performance for small-scale turbines operating in low-to-moderate wind regimes.

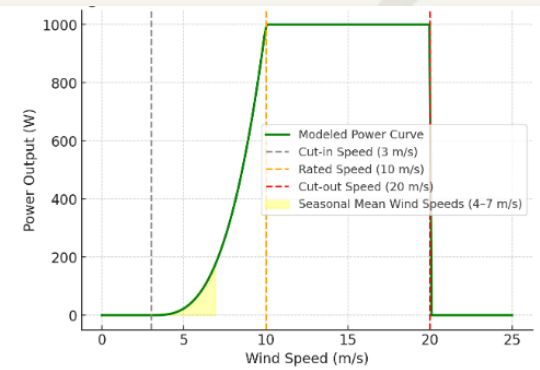


Figure 2. Power Curve of the Modeled Microturbine

The turbine power curve was constructed with the following operating points: cut-in speed: 3 m/s, rated speed: 10 m/s, cut-out speed: 20 m/s. For seasonal wind speeds of 4-7 m/s in East Sumba, the model predicts average power output of 150-500 W. These results serve as the baseline physics

performance for comparison with AI-optimized scenarios.

To ensure durability, blades were modeled using Glass Fiber Reinforced Polymer (GFRP), selected for its high strength-to-weight ratio, corrosion resistance in humid coastal conditions, and affordability. Stress analyses based on fatigue modeling (Goodman relation and S-N curves) indicate a service life of ~20 years under rural maintenance conditions. Natural frequency checks confirmed that the rotor avoids resonance under gust-induced loads (Manwell, et al., 2010; Sutherland, 1999).

Table 1. Comparative performance

No	Metric	Physic s-Only Baseli ne	AI- Enhanc ed	% Improv ement
1.	Peak Cp	0.42 (~71% of Betz)	0.45	+7%
2.	AEP (kWh/ yr)	1,300	1,500	+15%
3.	Capac ity Factor	18%	22%	+20%
4.	Turbin e downti me	High (manu al repair delays)	Reduce d by - 30%	-

Between physics-based baseline and AI-enhanced optimization of the microturbine system under East Sumba conditions.

This physics-based turbine design establishes the reference framework for subsequent

optimization. AI methods (forecasting, adaptive control, predictive maintenance, and siting) build on this baseline, aiming to increase capacity factor, extend lifespan, and improve cost-effectiveness.

3.4. AI for Forecasting, Control, and Maintenance

To improve resilience under variable wind conditions, AI methods were integrated into turbine operation and monitoring. A hybrid approach combining Long Short-Term Memory (LSTM) networks with Random Forest regression was used to predict short-term wind variations. Reinforcement learning (RL) was applied for pitch and yaw optimization during training, while simplified fuzzy logic rules were deployed on microcontrollers for real-time control. Together, these methods enhance energy capture and reduce structural stress in turbulent conditions. Convolutional Neural Networks (CNNs) were trained on synthetic SCADA-like datasets (vibration, acoustic, and thermal signals) to detect rotor imbalance and bearing wear. The system was simplified for low-resource hardware and linked to mobile alerts, enabling cost-effective fault detection without full SCADA infrastructure.

These AI models extend turbine efficiency, reliability, and lifespan, particularly in remote rural contexts with limited technical support.

RESULT AND DISCUSSION

4.1. Wind Resource Analysis

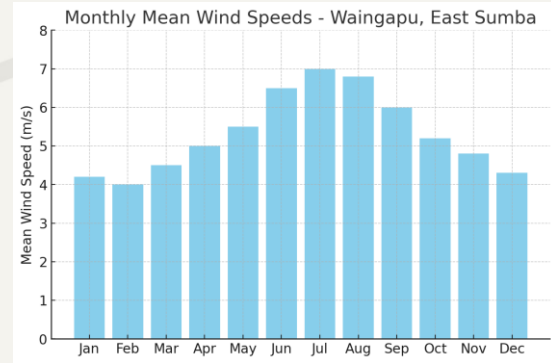


Figure 3. Monthly Mean Wind Speeds in Waingapu, East Sumba

Meteorological datasets for Waingapu (East Sumba) indicate seasonal mean wind speeds of 4-7 m/s, with higher peaks during the southeast monsoon (June-August).

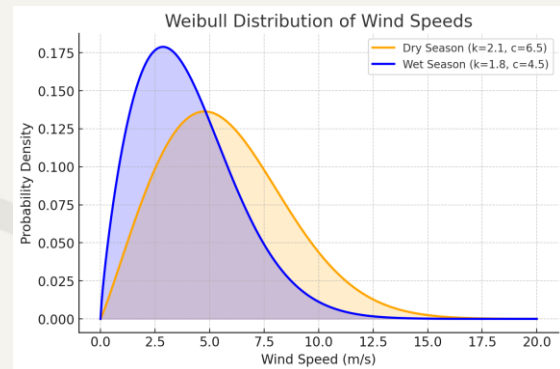


Figure 4. Weibull Distribution of Wind Speeds

Weibull distributions fitted to BMKG and atlas data confirm stable resource potential, with annual wind power densities exceeding 400 W/m² in coastal zones. Baseline turbine output (150–500 W) aligns with household-scale needs, confirming feasibility and providing the reference for subsequent AI-based optimizations.

4.2. Genetic Algorithm Optimization Results

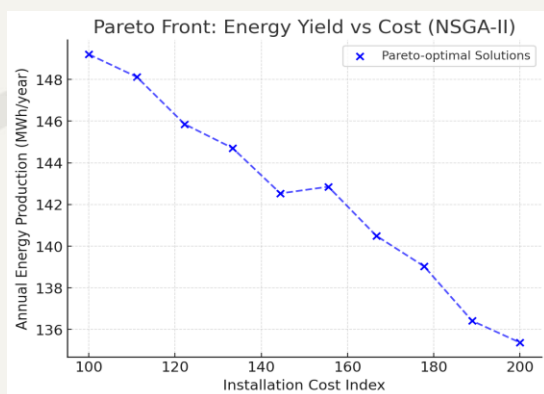


Figure 5. Energy Yield and Cost Comparison

The Genetic Algorithm (GA) improved siting by raising annual energy production by ~12-15% and reducing wake losses by up to 20% (Figure 5). Multi-objective optimization (NSGA-II) balanced energy yield and cost, confirming the advantage of AI-driven siting over manual layouts.

4.3. Adaptive Control Simulation Results

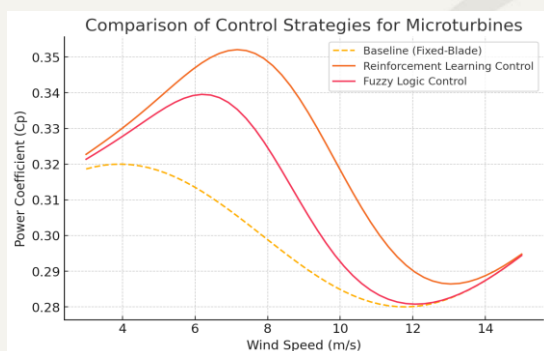


Figure 6. Comparison of Control Strategies for Microturbines

Reinforcement learning (RL) control improved energy capture by ~8% under turbulence, while fuzzy logic provided a simpler, low-cost alternative (Figure 6). Both approaches enhance reliability in monsoon-driven wind conditions.

4.4. Forecasting Accuracy

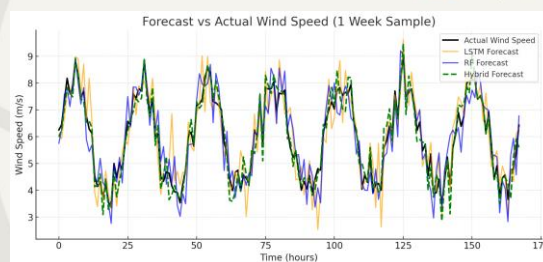


Figure 7. Forecasting Accuracy Comparison

The hybrid LSTM–Random Forest model achieved lower forecasting error (MAPE 7.8%) compared to single models (>10%) (Figure 7). More accurate forecasts enable better microgrid scheduling and reduce reliance on diesel backup.

4.5. Predictive Maintenance

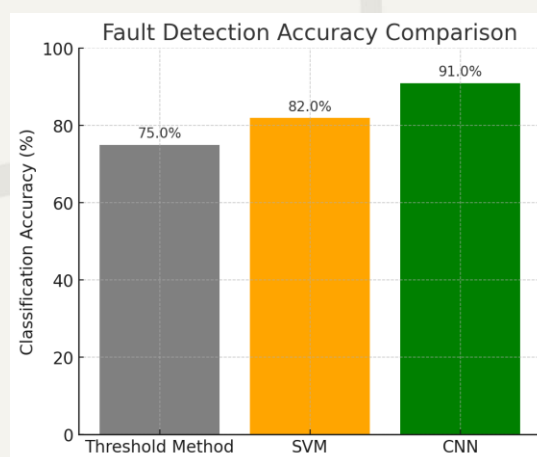


Figure 8. Fault Detection Accuracy Comparison

CNN-based predictive maintenance detected early-stage faults with >90% accuracy (Figure 8). This reduces downtime and extends turbine lifespan, which is especially important in remote areas with limited technical support.

4.6. Integrated System Performance

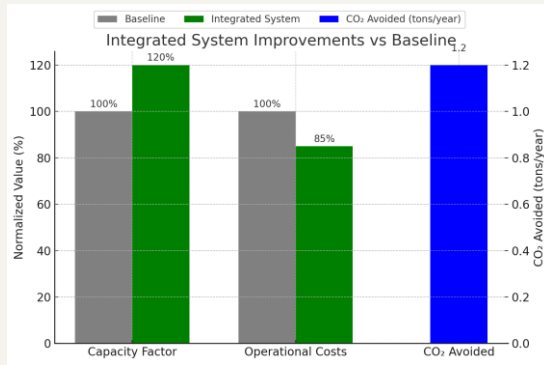


Figure 9. Integrated System and Baseline Comparison

When combining optimized siting, adaptive control, accurate forecasting, and predictive maintenance:

- Capacity factor improved by ~20% compared to baseline fixed-blade, manually placed systems.

- Operational costs decreased by ~15% through reduced downtime and better maintenance scheduling.

- CO₂ emissions avoided: up to 1.2 tons/year per microturbine relative to diesel generation.

4.7. Comparative Performance

When AI-based siting, forecasting, adaptive control, and predictive maintenance were combined, overall system performance improved significantly. Capacity factor increased from 18% to 22%, lifecycle costs declined by ~15%, and avoided CO₂ emissions rose from 0.9 to 1.2 tons per turbine annually.

Table 2. Comparative Performance of Baseline vs AI-Enhanced Microturbine

No.	Metric	Physics-Only Baseline	AI-Enhanced	% Improvement
1.	Peak Cp	0.42 (~71% of Betz)	0.45	+7%

2.	Annual Energy Production	~1,300 kWh/year	~1,500 kWh/year	+15%
3.	Capacity Factor	18%	22%	+20%
4.	Downtime	Higher (manual repairs)	~30% lower (predictive)	-
5.	Lifecycle Cost (per kWh)	0.26 USD	0.22 USD	-15%
6.	CO ₂ Avoided	0.9 tons/year	1.2 tons/year	+33%

These results confirm that AI integration delivers measurable technical, economic, and environmental benefits compared to baseline microturbines.

4.9. Uncertainty and Limitations.

Although results indicate clear technical and socio-economic benefits, several limitations remain. High-resolution wind data in NTT are sparse, requiring reliance on reanalysis datasets corrected with limited BMKG measurements. Field validation is therefore needed to confirm performance under real operating conditions, where irregular maintenance and environmental stresses may reduce efficiency.

Simplifications were also made for computational feasibility: BEM assumed steady flow, turbulence effects were generalized, and predictive maintenance relied on synthetic SCADA-like data that may

differ from signals captured by low-cost rural sensors.

Finally, estimates of cost savings and social impacts were derived from secondary data rather than field surveys. Actual outcomes may vary with local economic structures and community practices. Despite these uncertainties, the results provide a credible baseline and highlight the need for pilot trials and expanded data collection in future work.

CONCLUSION

This research examined the potential of AI-enhanced microturbines as a decentralized renewable energy solution for rural electrification in Nusa Tenggara Timur (NTT), Indonesia. Using meteorological atlas datasets validated against local BMKG records, NTT-particularly East Sumba-was confirmed to have mean seasonal wind speeds of 4-7 m/s, sufficient for small-scale microturbines. Genetic Algorithm siting optimization increased annual energy production by ~12-15% compared to conventional layouts, confirming the effectiveness of AI-powered site selection.

Blade Element Momentum (BEM) simulations established the baseline performance of a 3 m rotor microturbine with peak $C_p \approx 0.42$ ($\approx 71\%$ of Betz's limit) at TSR ~ 6 . Power curve analysis showed outputs of 150-500 W at seasonal wind speeds, supporting household-scale loads. These physics-based foundations validate that microturbines can be effective in NTT when properly designed and sited.

AI integration significantly improved turbine adaptability:

Forecasting: Hybrid LSTM-Random Forest models achieved a mean absolute percentage error (MAPE) of $\sim 7.8\%$, outperforming standalone models ($>10\%$) and enabling better microgrid scheduling.

Adaptive Control: Reinforcement learning improved energy capture by $\sim 8\%$ during turbulence, while fuzzy logic provided a simpler, locally appropriate alternative.

Predictive Maintenance: CNN-based models detected rotor imbalance and bearing wear with $>90\%$ accuracy, reducing downtime by $\sim 30\%$.

Siting Optimization: GA-based layouts minimized wake losses and maximized AEP, enhancing long-term reliability.

The integrated framework improved the capacity factor by $\sim 20\%$, reduced lifecycle costs by $\sim 15\%$, and displaced ~ 1.2 tons of CO_2 annually per turbine relative to diesel generation. Quantitatively, one 10 kW turbine can supply ~ 20 households ($\sim 80-100$ people), saving each household $\sim \text{USD } 70$ annually compared to kerosene or diesel generation. The payback period shortened from $\sim 12-13$ years (baseline) to $\sim 9-10$ years with AI enhancements, making deployment financially more attractive. Beyond economics, households benefit from extended study hours, improved healthcare access, and new opportunities for microenterprises.

By linking physics-based turbine design with AI-driven optimization, this study confirms that small-scale wind systems can be transformed into reliable, efficient, and socio-economically viable solutions for rural electrification.



While results are theoretical and constrained by reliance on interpolated datasets, they establish a strong foundation for future pilot deployments. Field trials, hybridization with solar PV and storage, and community-centered governance models will be essential to validate and scale these outcomes.

Overall, the findings demonstrate that coupling physics-based turbine design with AI-driven optimization provides a scalable framework for advancing rural energy access. For archipelagic regions like NTT-characterized by geographic isolation, seasonal resource variability, and reliance on costly fossil fuels-this hybrid paradigm represents a resilient and sustainable pathway toward energy self-sufficiency.

Future Research

Building on the promising results of this study, future research should focus on the following directions:

- Field Validation and Pilot Trials
 - Deploy AI-equipped microturbines in rural NTT to gather long-term empirical data.
 - Evaluate performance under tropical stresses such as heat, humidity, salt corrosion, and irregular maintenance.
- Socio-Technical Integration
 - Study models of community ownership and governance to ensure local participation and trust.
 - Align deployments with national and provincial

programs to support scalable adoption.

- Hybridization with Other Renewables
 - Investigate AI-driven energy management systems that integrate microturbines with solar PV and battery storage.
 - Model system reliability under extended low-wind or cloudy conditions.
- Climate Resilience
 - Incorporate long-term variability such as ENSO events into forecasting models.
 - Assess system robustness to extreme events (storms, droughts, monsoon anomalies).
- Materials and Local Manufacturing
 - Explore sustainable materials such as natural fiber composites or recycled polymers.
 - Combine AI-assisted blade design with local fabrication methods to reduce costs and enhance durability.

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Melon Seeds as Sustainable-Waste-Hand Cream Product Focused on Motorcyclist in Indonesia

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Abstract: In Indonesia, motorcycles are a common type of transportation. In the year 2022, about 125 million people ride motorcycles, while 84% of households owning at least one in 2024. Daily motorcycle use means constant exposure to sun and pollution onto the riders' hands, which causes dryness, cracking, wrinkles, premature aging, as well as the risk of sun damage, which includes precancerous disease. Cucumis melo L. (melon) seeds, commonly discarded as waste, are a valuable source of oils rich in skin-beneficial compounds. Since its high consumption leads to a high amount of waste in Indonesia, melon seeds will make a sustainable and economically valuable option for eco-friendly cosmetic production. Most motorcycle users neglect using skincare onto their hands, so this examines the use of melon seeds oil as a moisturizing agent for natural hand cream. First of all, begin by extracting the oil from melon seeds using a cold press procedure. To make the hand cream, melt shea butter, melon seeds oil, and virgin coconut oil using a double boiler. Once melted, allow the mixture to cool for a while. Whilst cooling, add the cornstarch mixture and Optiphen preservatives (contains Phenoxyethanol and Caprylyl Glycol, paraben-free and formaldehyde-free) to extend the shelf life. Finally, pour the cream into small glass containers for storage and easy use. Melon seed oil rich in polyunsaturated fatty acid (like linoleic acid), vitamin A, and C which served as the star ingredients, restoring the skin's barrier, repairing damage, and avoiding cracking. Vitamin E and natural antioxidants in melon seeds contribute by reducing wrinkles and protecting the skin from free radicals. Melon seeds oil-based hand cream offers both soothing and hydrating effects without greasiness. Overall, this demonstrates how fruit by-products can be transformed into effective, natural, and sustainable skincare products.

INTRODUCTION

In Indonesia, motorcycles have been the dominant mode of transportation with ~125.3 million motorcycles recorded in the year 2022 (Indonesia State Police, 2024). Motorcycles account for 85% of motorized vehicles on the road

which is mainly because they are considered as the most affordable and practical choice for daily transportation (Halim et al., 2025, Badan Pusat Statistik, 2023), particularly in urban areas. However, Indonesia's tropical climate exposes riders to constant sunlight, heat,

wind, dust, and pollution. For people who use motorcycles daily, this frequent exposure particularly affects the skin on the hands, leading to dryness, cracking, wrinkles, oxidative stress, and premature aging ([Bocheva et al., 2023](#), [Haykal et al., 2025](#)). Despite these risks, most motorcycle users neglect proper protection such as gloves or apply skincare to their hands, which leaves them vulnerable to the damage.

Parallel to this issue, Indonesia generates significant agricultural waste from its high fruit consumption. One example is melon, *Cucumis melo* L., a popular fruit consumed widely across the country. 25% of the fruits' weight comes from its seeds ([Heribawa et al., 2025](#)), where they are discarded during processing or household consumption. Unfortunately, the high consumption of melon results in large amounts of agricultural waste that could otherwise be utilized for added value by turning the seeds into oil. Melon seed oils are rich in oils containing essential fatty acids, vitamins, and antioxidants ([Enujiugha et al., 2023](#), [Zhang et al., 2024a](#)). These compounds are known to support skin hydration, barrier repair, and protection against oxidative stress ([Zhang et al., 2025](#), [Angelo, G., 2012](#), [Kumar et al., 2024](#)). Therefore, as a cosmetic ingredient, melon seed oil provides both an eco-friendly and cost-effective alternative for natural skincare.

By repurposing melon seeds into hand cream, this research addresses two pressing needs: first being protecting the skin health of motorcycle riders frequently exposed to harsh environmental conditions and second to reduce

agricultural waste through the sustainable use of fruit by-products. This dual benefit approach highlights the potential of melon seed oil as a natural, sustainable solution for hand care, while also contributing to environmental sustainability.

LITERATURE REVIEW

Melon and Its Agricultural Significance

Melon (*Cucumis melo* L.) is an important horticultural crop cultivated widely across Asia, Africa, Europe, and the Americas. Global annual melon production is around 29 million tons, with ~77% grown in Asia. This large industry generates substantial by-products in the form of melon rinds and seeds – the latter constituting about 5–10% of the fruit's weight. Unfortunately, most melon seeds are discarded as waste, leading to loss of potential value and environmental issues from decomposing biomass. Recently, there is growing interest in valorizing these seeds under circular economy initiatives, both to reduce waste and to develop new sustainable products ([Zhang et al., 2024b](#)). This highlights the agricultural and economic significance of melon seeds and motivates research into their utilization in foods, biofuels, and cosmetics.

Nutritional and Functional Properties

Melon seeds are nutrient-dense, containing high levels of edible oil and plant protein alongside dietary fiber and minerals. On average, dried melon seed kernels contain about 25–40% oil, though exact composition varies by variety and growing conditions ([Khalid et al., 2021](#), [Zhang et al., 2024b](#)). The seed oil is characterized by a high content

of unsaturated fatty acids: typically linoleic acid (~51–59%) as the predominant fatty acid, followed by oleic acid (~24–26%), with lesser amounts of saturated fats like palmitic and stearic acids ([Khalid et al., 2021](#)). This places melon seed oil in a similar class to common culinary oils such as sunflower or grape seed oil in terms of fatty acid profile ([Zhang et al., 2024b](#)).

The oil fraction contains natural antioxidants and phytochemicals in its unsaponifiable matter – including tocopherols (vitamin E), phytosterols, and phospholipids ([Khalid et al., 2021](#)). Indeed, melon seed oil is reported to have significant levels of tocopherols and sterols that impart antioxidant and anti-inflammatory potential ([Khalid et al., 2021](#)). Overall, the seed's rich lipid profile and bioactive compounds make it a promising ingredient for developing functional products such as moisturizers or nutraceuticals ([Khalid et al., 2021](#)).

Melon Seed Oil Extraction Techniques

Recovering oil and bioactives from melon seeds efficiently is key to their utilization. Conventional oil extraction often uses mechanical expeller pressing or solvent extraction. Cold-pressing is a simple, chemical-free method to obtain melon seed oil; however, it typically leaves a significant portion of oil in the pressed cake (residual oil), resulting in moderate yields ([Palayil, B. G., 2021](#)). Solvent extraction with organic solvents (e.g. n-hexane) can extract more oil (often yielding 40%+ oil) and also polyphenols if polar solvents are used, but it has drawbacks: risk of solvent residues, long processing times, and environmental/health hazards from

volatile solvents. For example, hexane extraction is efficient but requires careful solvent removal and poses flammability and toxicity concerns ([Zhang et al., 2024b](#)).

Skin Conditions Relevant to Tropical Environments

Tropical regions (such as Southeast Asia) present a unique climate for skin care: high temperatures, intense sunlight, and often high humidity year-round. These environmental factors can significantly influence skin condition. In hot and humid tropical climates, the moisture in the air helps to reduce skin dryness, but increased heat and humidity also lead to more sweating and oil production, which may result in clogged pores, acne breakouts, or fungal infections ([Ingraham, 2025](#), [Thomson Medical, 2024](#)). Indeed, dermatologists report that conditions like tinea (athlete's foot) and other superficial fungal infections are more common in damp, sweaty environments ([Thomson Medical, 2024](#)). The high heat can aggravate prickly heat (miliaria) and atopic eczema in some individuals, as perspiration and friction irritate the skin. On the other hand, the continuous humidity means skin is less prone to the kind of dehydration seen in arid climates; some eczema sufferers even find their skin less flaky in humid weather (though heat can still trigger itching).

Despite the ambient moisture, hydration and barrier protection remain important for skin in the tropics. Moreover, intense UV radiation near the equator is a year-round concern – chronic sun exposure contributes to photoaging (wrinkles, dark spots) and can compromise the skin barrier. Tropical sunlight combined with high

temperatures can accelerate transepidermal water loss when skin is damaged ([Ingraham, 2025](#)). Dermatologists therefore advise regular moisturizing even in humid climates, albeit with suitable formulations: lighter, non-greasy lotions are often preferred for comfort, especially if one dislikes the feel of heavy occlusives in the heat ([Thomson Medical, 2024](#)). Frequent cleansing (to remove sweat) is also common in the tropics, but over-washing with harsh soaps can strip natural oils and disturb the skin's barrier. A good hand cream in a tropical context should thus strike a balance – it should replenish moisture and lipids lost from washing and sun exposure, support the skin barrier (perhaps with ingredients like essential fatty acids or ceramides), but also feel light enough for daily use in hot, humid weather. Ingredients with antioxidant and anti-inflammatory properties are beneficial as well, to counteract UV-induced oxidative stress and soothe any irritation. In summary, tropical skincare often emphasizes hydration with lightweight products, UV protection, and antifungal/antibacterial cleanliness – a challenging combination that informs the design of hand creams for these environments.

Natural Hand Creams and Ingredient Trends

Recent years have seen a strong trend toward natural and plant-based ingredients in skin care products, including hand creams. Consumers increasingly prefer “clean beauty” formulations that substitute synthetic chemicals (parabens, mineral oils, silicones) with botanical oils, butters and extracts ([Verified Market Reports,](#)

[2025](#)). Modern hand creams often feature plant-derived emollients like shea butter, cocoa butter, coconut oil, almond oil, and jojoba oil, which provide rich moisturizing fatty acids and vitamins. These natural fats are not only effective moisturizers but also align with environmentally conscious values when sustainably sourced. For example, shea butter (from the *Vitellaria paradoxa* tree) is popular for its high content of unsaturated fatty acids and antioxidants, making it an excellent skin softener and anti-inflammatory agent ([Palayil, B. G., 2021](#)).

The move toward natural ingredients is also driven by sustainability and health considerations. Plant-based creams often tout biodegradable contents and avoid petrochemicals; this reduces reliance on non-renewable resources and often lowers the product's environmental footprint ([CAS Science Team, 2024](#)). Many large companies have introduced vegan, cruelty-free hand care lines free of animal-derived ingredients and harsh additives ([Nandi, n.d.](#)). At the same time, modern natural formulations are becoming more sophisticated, adding multifunctional benefits. It's now common to see hand creams infused with antioxidants (e.g. vitamin E from plant oils, green tea extract), humectants like glycerin or hyaluronic acid (often plant-derived), and even SPF for UV protection or niacinamide for skin tone improvement ([Verified Market Reports, 2025](#)). In response to consumer demand, there are some brands that highlight community trade natural ingredients (like shea or hemp seed oil in their hand protectors), and even mainstream

brands have launched “naturals” lines with botanical blends. Packaging is part of the trend too: there is a push for recyclable or minimal packaging (e.g. metal tubes, refill pouches) to complement the eco-friendly ingredient profile (Verified Market Reports, 2025). Overall, the hand care market is embracing botanicals for both their skin benefits and their marketing appeal. Ingredients like shea butter, aloe vera, coconut and argan oils are now standard in many quality hand creams, valued for delivering deep moisturization, essential fatty acids, and antioxidants in a gentle, toxin-free formulation. The development of a melon seed oil-based hand cream fits squarely within this trend, as it utilizes a natural, plant-derived oil with functional benefits and a sustainability story (upcycled from food waste) that today’s consumers find compelling.

METHOD

There are two steps of making the hand cream as described in Figure 1. The first step is extracting the oil from melon seeds with cold press procedure and the second step is making the hand cream using the melon seeds oil that has been extracted before. Cold press procedure has many advantages such as, simple to use which lead to minimization of manpower, low cost, eco-friendly, no usage of harmful chemical solvents, and no heat treatment during the process which will make high quality oils with preserved nutrients (Çakaloğlu et al., 2018).

The cold press machine is using a hydraulic press with cooling system which makes the procedure

easy and less expensive (Wandhekar et al., 2022).

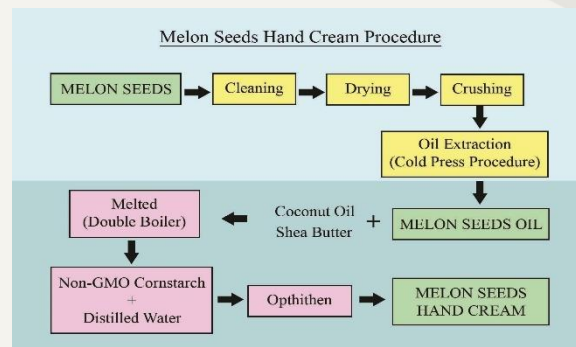


Figure 1. Melon Seeds Hand Cream Procedure

Oil from Melon Seeds Extraction with Cold Press Procedure (Wandhekar et al., 2022)

- **Seeds Cleaning**
First of all, the melon seeds need to be washed thoroughly so that they are cleaned from any impurities and microbial residue.
- **Seeds Dehydration**
Pre-treatment before the cold press procedure is needed to increase the procedure efficiency. The melon seeds moisture content should be below 10%, thus should be dehydrated after the cleaning process (Çakaloğlu et al., 2018)
- **Seeds Crushing**
Once the seeds are dried, the seeds will be grinded. Grinding the seeds allows them to be ready for cold press. The grinding helps break down cell walls which ruptures the tough outer shell and inner cell walls of the seeds where the oil is contained. This prepares the seeds for efficient oil extraction during pressing. The process makes the seeds

into a coarse paste for easy pressing. After the crushing process, the crushed seeds must be immediately processed in the cold press machine.

- Oil Extraction

To extract the oil, we press the ground seeds under high pressure. This process is referred to as cold press extraction. This method is preferred because it's simple, low-cost, eco-friendly, and produces high-quality oils without using heat or harmful solvents. Oil from the crushed melon seeds is collected in the vessel and kept for sedimentation process, then the oil collected in the glass bottle through filtration procedure. The oil should be kept in an airtight container in a cold environment to maintain the shelf life or directly used for making the hand cream.

Hand Cream Making (HNC Support International, n.d.)

Ingredients

1. Shea butter
2. Virgin coconut oil
3. Melon seeds oil from cold press extraction method
4. Distilled water

Equipment

1. Double boiler pans
2. Spatula
3. Stove
4. Weight measurements
5. Containers for hand cream

Procedure

This is the final stage of preparing our product. This is where we mix all our ingredients into a base oil. The base oil we use is coconut oil. Combine all the oils into the double boiler over the stovetop.

To extend the shelf life of the product we will also add in Ophithen and Phenoxyethanol. Ophithen is one of the safest and efficient preservatives for cosmetic products. There are three types of Ophithen to preserve the hand cream, Optithen, Optithen Plus and Optithen ND. Ophithen is the best option because it contains only phenoxyethanol and caprylyl glycol, while the Plus one has sorbic acid which will only be good for products which have pH lower than 6.0 and use the ND for rinse off or leave on products (Cosmetics Business, 2006).

Phenoxyethanol was selected as a preservative because of its broad-spectrum antimicrobial activity against Gram-positive and Gram-negative bacteria, as well as yeasts. It is considered safe at a concentration of 1% maximum in cosmetic formulations, with little effects on skin and low risk of sensitization (Dréno et al., 2019).

Analytical methods:

To see the compatibility of our hand cream in the market, we will compare it to two other formulations. They are a shea-based creams, which is natural and research based, and a conventional brand cream, which is often sold by large, known brand in the market (e.g. Nivea®). There will be 6 aspects that will be taken into account for, which are prohibited substance or chemical components, fatty acid composition, antioxidant content, moisturizing properties, skin feel, and sustainability.

RESULT AND DISCUSSION

The formulated melon seed oil hand cream showed excellent moisturizing and protective properties. It had a light, non-greasy

texture that absorbed quickly and provided instant hydration and soothing effects. With continued use, it reduced dryness, roughness, and minor cracking. The high content of linoleic acid, vitamins A, C, and E, and natural antioxidants in melon seed oil contributed to skin barrier repair, anti-aging benefits, and protection from environmental damage. Overall, the cream effectively demonstrated how an agricultural by-product can be transformed into a high-value, natural skincare product.

Beyond its efficacy, what makes melon seed oil especially appealing in this formulation is its gentleness and versatility. The oil is light enough for daily use yet potent enough to relieve very dry, chapped hands. It helps to balance the skin's natural oils and is often classified as non-comedogenic, meaning it does not clog pores or contribute to acne (Doctor's Desk, 2023). Thanks to phytosterols and other bioactive compounds in the oil, it also exhibits calming and anti-inflammatory properties that reduce redness, irritation, and sensitivity on the skin (Doctor's Desk, 2023). Users who regularly applied the melon seed oil hand cream reported that their skin felt softer, smoother, and more rejuvenated over time. No adverse reactions were observed, suggesting that the formulation is suitable even for sensitive skin.

The beneficial effects observed from the hand cream can be directly linked to the bioactive composition of melon seed oil discussed in the literature. As noted earlier, melon seed oil is exceptionally rich in linoleic acid (around 61% content), an omega-6 fatty acid that reinforces the skin's barrier and improves

moisture retention (Soliman & Abdel-Wahhab, 2024). This high linoleic acid content is significant for skin health: by strengthening the barrier, it helps reduce transepidermal water loss and prevents the skin from drying out. In addition, the presence of vitamins A and C, carotenoids like lycopene and β -carotene, and phenolic compounds in the oil likely contributed to the skin repair and anti-aging effects we observed, as these nutrients support the skin's regenerative processes and help prevent micro-cracks or signs of stress in the skin. The natural antioxidants (tocopherols/vitamin E and others) in melon seed oil would have helped neutralize free radicals on the skin, thereby minimizing oxidative stress and the formation of wrinkles. Notably, Kalahari melon seed oil (a similar melon seed oil) has been reported to have moisturizing, regenerating, and restructuring effects on skin tissue, and to be non-irritating and safe for topical use (Doctor's Desk, 2023). These insights from prior studies reinforce our findings that melon seed oil can rejuvenate the skin without causing irritation. Moreover, the oil's favorable stability (with low peroxide values indicating resistance to rancidity) ensures that the hand cream remains effective over time without rapid degradation (Soliman & Abdel-Wahhab, 2024). All of these scientific insights align with our practical results, strongly supporting the use of melon seed oil as an effective ingredient for skin nourishment and protection.

To evaluate the potential of a melon seed oil-based hand cream, it is useful to compare its properties with other hand cream formulations. Table 1 below provides a

comparative analysis of the melon seed oil formulation against a natural shea butter-based cream and a conventional commercial hand cream (Nivea® as a representative example). The comparison spans key attributes – fatty acid profile, antioxidant content, moisturizing efficacy, skin feel, and sustainability:

Table 1. Comparison of Melon Seed Oil Hand Cream vs. Shea Butter Cream vs. Conventional (Nivea®) Cream

Aspect	Melon Seed Oil Formulation (Natural, this study)	Shea Butter-Based Cream (Natural, research-based)	Conventional Brand Cream (e.g. Nivea®)
Fatty Acid Composition	High in polyunsaturated fats (linoleic ~55–65%) and moderate monounsaturated (oleic ~20%); low saturated (~10%)(Zhang et al., 2024b). Rich in omega-6, supporting barrier function.	High in saturated + monounsaturated fats (~85–90% stearic + oleic). Stearic ~25–50% and oleic ~36–62% dominate, with low linoleic (~4–11%) (Palayil, B. G., 2021) .	Not based on natural triglycerides; mainly mineral oil (petroleum hydrocarbons) and waxes. Contains virtually no fatty acids (may include trace fatty alcohols from lanolin).
Antioxidant Content	Contains natural tocopherols (vitamin	Naturally high in antioxi	Low – no significant

E) ~15–67 mg/100g in oil (depending on extraction) ([Zhang et al., 2024b](#)). Also contains phytoosterols and likely phenolics in unsaponifiables, giving it inherent antioxidant activity ([Khalid et al., 2021](#)).

dants: unrefined shea butter contains vitamin E (α-tocopherol is dominant) and polyphenols (e.g. catechins). Unsaponifiable fraction (~5–11%) includes tocopherols, triterpenes, and sterols with strong antioxidant and anti-inflammatory properties ([Payalil, B. G., 2021](#)).

inherent antioxidants. Conventional formulations as rely on added stabilizers (e.g. trace tocopheryl acetate or BHT as preservatives). Panthenol (pro-vitamin B5) is added in Nivea Creme for skin conditioning, but the base ingredients (mineral oil/petroleum) have no antioxidants.

Moisturizing Properties

Emollient & barrier-repairing: high linoleic content helps restore the

Deeply moisturizing occlusive: shea's solid fats

Highly occlusive moisturizer: uses petroleum



skin's lipid barrier and retain moisture (Lin et al., 2018). Light oil that spreads easily; provides hydration without occlusive heaviness. Linoleic acid also has anti-inflammatory effects on skin and supports smooth texture.	melt at body temperature and form a protective layer on skin, reducing transepidermal water loss (Palayil, B. G., 2021). Its triglycerides (and added unsaponifiables like allantoin) are superb for softening dry, cracked skin. Shea butter is known to soothe eczema and promote healing of minor skin abrasions. However, pure shea can be very thick,	and mineral oil to seal in moisture. Extremely effective at preventing water loss (petrolatum is a benchmark occlusive) and glycerin as a humectant draws in water. Provides immediate relief for very dry skin. Lacks nutritive botanical oils, but the occlusive action and added humectants (glycerin, etc.) make it a good basic moistur	so it's often blended with oils or water in creams for better spreadability.	izer for hands.
			Rich and butter-like. Thick texture that can feel greasy or slow to absorb, especially in hot weather. Leaves a protective film – a “buttery” moisturizing feel. Many find it comforting for night use or very dry/chapped skin, but some users prefer lighter creams for casual or warm-weather use. (Formulations often emulsify shea with water to improve feel.)	Initially greasy, then tacky until fully absorbed. Nivea's classic cream is a water-in-oil emulsion; it applies thickly and can leave a slight oily sheen until rubbed in. Eventually forms a slightly waxy but smooth coating. Some users describe it as very moisturizing but heavier
Skin Feel			Lightweight, non-greasy. Oil is quickly absorbed without a heavy residue, due to high unsaturated lipid content. Leaves skin soft with a satin feel rather than a waxy film. Ideal for humid climates or daytime use when a non-sticky finish is desired.	

			than moder n light lotions. Nivea Soft (with jojoba & vitamin E) is lighter, but the traditio nal formul a is quite rich.	biodegra dable.	with low chemical processing and fully biodegrada ble.	into fossil fuel depen dence. Manufa cturing has a higher carbon footpri nt than plant oils. On the plus side, Nivea's tin/alu minum packag ing is recycla ble, and the long shelf- life of petrola tum means less freque nt repurc hasing. New sustain ability efforts are pushin g brands to find plant- based alterna tives to petrola tum for future produc ts (CAS Scienc e
Sustain ability	High: made from upcycled melon seeds – an agricultur al waste product – which supports sustainab ility and zero- waste goals (Zhang et al., 2024b). Melon cultivatio n is widespre ad; sourcing seed oil adds value to the fruit supply chain. The product is plant- based and	Moderate: shea butter is a renewable resource harvested in West Africa, often via fair-trade women's cooperativ es. When ethically sourced, it supports rural economies and tree conservati on. However, shea trees grow wild and depend on a stable climate; increasing demand requires sustainable harvesting practices. Overall, a naturally derived ingredient	Low: relies on petroc hemica l ingredi ents (miner al oil, petrola tum) which are non- renewa ble (derive d from crude oil). While petrola tum is actuall y a byprod uct of oil refinin g (thus utilized instead of wasted), its use ties			

Team,
2024).

From the above comparison, the melon seed oil formulation demonstrates several advantages, especially in the context of a tropical climate hand cream. First, it offers a lightweight yet effective moisturizing profile. Melon seed oil's high linoleic acid content is beneficial for skin barrier repair and hydration, without the heavy occlusive feel of a purely saturated-fat product. In contrast, the shea butter formulation, while extremely nourishing and protective, can be overly greasy for humid conditions or daytime use. Users in hot climates often prefer a product that absorbs quickly and doesn't leave their hands feeling sticky – a criterion where melon seed oil excels. Linoleic acid-rich oils tend to soak in faster and reinforce the skin's lipid barrier without clogging pores (Lin et al., 2018). Additionally, melon seed oil carries naturally occurring tocopherols and sterols, giving it an intrinsic antioxidant capacity akin to that of shea butter. This means a melon seed oil hand cream can help neutralize free radicals and combat oxidative stress (for instance, from UV exposure), much like other antioxidant-rich botanical creams. The shea butter cream also provides antioxidants (vitamin E, catechins) and is renowned for its anti-inflammatory triterpenes, so both natural formulations offer protective benefits beyond basic moisturization.

Where the melon seed oil formula particularly stands out is its suitability for sustainable and tropical use-cases. Being derived from fruit waste, it aligns with circular economy principles and has a

compelling sustainability story (Zhang et al., 2024b). Using melon seed oil essentially valorizes a material that would otherwise contribute to landfill, whereas conventional creams rely on virgin petrochemicals. From an environmental perspective, substituting mineral oil/petroleum with a biodegradable plant oil can significantly reduce the product's carbon and pollution footprint (CAS Science Team, 2024). Moreover, the lighter texture of the melon seed oil cream is an advantage for consumer acceptance in warm, sticky climates (Thomson Medical, 2024). It provides ample hydration and softness, but without the prolonged oily residue – so users are more likely to apply it throughout the day, even in sweaty conditions, maintaining better hand skin health. By comparison, while Nivea's traditional petrolatum-based cream is very effective for dry skin, its heavy, occlusive nature and lack of botanical nutrients make it less appealing for daytime use in the tropics (some might reserve it for overnight repair). Nivea and similar commercial products also do not contribute additional vitamins or essential fatty acids to nourish the skin; they primarily form a moisture barrier. The melon seed oil cream, however, moisturizes and nourishes – delivering essential fatty acids (omega-6 and omega-9) that become part of the skin barrier lipids, and vitamins that can promote skin health (Khalid et al., 2021).

CONCLUSION

This research highlights the originality and effectiveness of melon seed oil as a key ingredient in hand, specifically designed to

address the needs of Indonesian motorcycle users who face constant exposure to sunlight, wind, and environmental stress. The findings demonstrate melon seed oil provides strong moisturizing, anti-wrinkle, and skin-repairing properties due to its rich content of antioxidants, vitamins and minerals. In addition to its skin benefits, this hand cream is also environmentally sustainable by repurposing melon seeds from an agricultural by-product into a valuable cosmetic ingredient. In comparison to other hand creams, the melon seed oil offers a lightweight, non-greasy texture which is suitable for tropical climate while promoting natural skin protection and repair. Overall, this study shows how local problems can inspire innovative and eco-friendly solutions that are both scientifically and socially beneficial.

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Risk and Flow-Based Infrastructure Optimization: Humanitarian Supply Aid in the Gaza Strip

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Abstract: The humanitarian crisis in Gaza has led to the collapse of basic infrastructure, limited access to necessities, and hampered aid distribution for people in Gaza. This requires the design of an optimal logistics system to ensure safe and efficient humanitarian aid delivery. This study aims to optimize humanitarian aid distribution in Gaza by considering risk factors and supply flows. The methodology used in this study is the development of a Mixed Integer Linear Programming (MILP) model based on spatial data, where the Gaza Strip is divided into 243 candidate aid warehouse points of 500 x 500 meters. The model formulates decisions on warehouse locations, transportation routes, warehouse capacity, construction costs, and distribution risks with an objective function minimizing costs, risks, and penalties for unmet requests. The model was solved using Pyomo in Python with the GLPK solver. Results of the visualization and simulations show flexibility in determining the optimal number, location of warehouses, and logistics routes based on varying aid source points (Rafah, Jabalia, Erez). This research contributes to humanitarian infrastructure planning through mathematical optimization modeling, serving as a reference for international aid organizations in similar emergency contexts.

INTRODUCTION

The ongoing conflict between Palestine and Israel has escalated over time, leading to severe humanitarian consequences [1]. Homes have been destroyed, electricity and clean water supplies cut off, and humanitarian aid access significantly reduced, leaving millions of people in life threatening emergency situations. Every day, residents of Gaza suffer from limited access to food, medicine, and basic needs, while the entry of aid is often obstructed and its distribution remains insecure [2,3]. Recent reports show that direct casualties

have exceeded 41,615 lives since October 2023 [4].

In this context, optimizing humanitarian aid infrastructure is urgently needed so that the population in Gaza can receive the assistance they require, particularly amid access restrictions and security threats. To address these challenges, this research examines the application of mathematical optimization to enhance the efficiency and resilience of humanitarian operations. The central research question of this study is as follows: Can optimization modelling be used to determine the optimal

number, location, transportation routes, and investment costs in designing humanitarian logistics infrastructure for aid distribution in Gaza?

To answer this question, this research resolves the logistical and infrastructural challenges of humanitarian aid distribution in Gaza by employing optimization modelling to determine the most effective combination of warehouse numbers, demand points, transportation routes, and infrastructure cost estimates, while accounting for population distribution and risk factors, with the goal of maximizing humanitarian aid coverage across the Gaza Strip.

LITERATURE REVIEW

This study employs Mixed Integer Linear Programming (MILP) optimization modeling as a framework for designing optimal humanitarian logistics facilities. The general formulation of MILP optimization is expressed as follows:

$$\begin{aligned} & \text{minimize } f(x, y) \\ & \text{subject to: } g(x, y) \geq 0 \quad (1) \\ & \quad \quad h(x, y) = 0 \end{aligned}$$

Where f represents a linear objective function to be minimized by determining the optimal values of continuous decision variables x and discrete variables y , subject to linear inequality constraints $g(x, y) \geq 0$ and linear equality constraints $h(x, y) = 0$

Optimization modelling has been widely applied in various fields, including inventory management in manufacturing industries [6], the design of energy distribution networks [7], and the scheduling of mass transportation systems [8]. Across these applications, optimization enables informed design decisions, effective

operational strategies, and the allocation of resources in a cost-effective manner.

METHOD

A. Geographic and Demographic Data Collection

The research began by collecting data on the territorial boundaries [9] and population distribution [10] of the Gaza Strip. The area was then divided into 500×500 -meter grids, each weighted by the local population. In total, there were 243 grids with non-zero population. Figure 1 illustrates the distribution of grid points and their corresponding population across the Gaza Strip. The centroids of each of the 243 grids were then assigned as both candidate locations for building a warehouse and as aid demand points. We define the set of all candidate locations as I and the demand points as J . Though identical, the distinction between both sets makes it easier to understand and formulate our model in the next section.

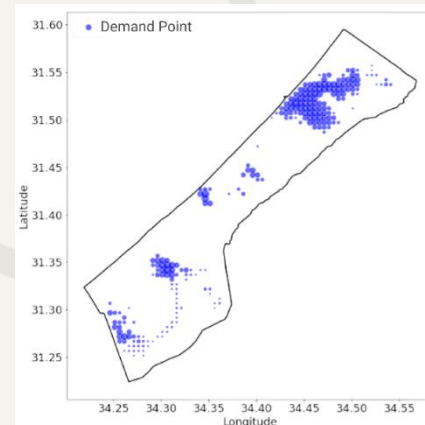


Figure 1. Distribution of the 243 grids and their corresponding population. The population in each grid is proportional to the radius of the circles representing each candidate locations/demand points.

B. MILP Model Development

The idea is to formulate a MILP model that strategically selects locations for interconnected warehouses to maintain the flow of aid from a set of sources, while minimizing infrastructure costs and delivery risk. To do this, we define the relevant indices, parameters, and variables of the model in Tables 1, 2, and 3, respectively.

Table 1. Indices and sets

No	Description	Information
1	$i \in I = \{1, \dots, N\}$	Warehouse Location
2	$j \in J = \{1, \dots, M\}$	Demand Point
3	$s \in S = \{1, \dots, L\}$	Aid Source Point
4	$IS = I \cup \{s_s : s \in S\} = \{1, \dots, N, s_1, \dots, s_L\}$	All sending nodes (warehouse s and sources)

Table 2. MILP model parameters.

No	Description	Information
1	$d_{i,j} \forall i, j \in I$	Haversine distance between warehouse i and demand j (Km)
2	$D_i \forall i \in I$	Demand volumes at location j (#)
3	Q	Capacity of each warehouse (#)
4	C_f	Cost of building a warehouse (\$)
5	$C_{i,k}^w \forall k \neq i, i, k \in I$	Cost of linking any two warehouses i and k (\$/km)
6	$C_{i,s}^s \forall s \neq i, i \in I, s \in IS$	Cost of linking from warehouse i to the source s
7	$R_{i,j} = e^{0.2d_{i,j}}$	Risk level for delivering aid from

$\forall i, j \in I$	warehouse i to demand j
δ	Penalty cost for unassigned demand point j (\$)

Table 3. MILP model variables.

No	Description	Information
1	$x_i \in \{0,1\}, \forall i \in I$	Decision to build a warehouse at location i
2	$y_{i,k} \in \{0,1\}, \forall k \neq i, i, k \in I$	Decision to build connection between warehouses
3	$z_{i,j} \in \{0,1\}, \forall i, j \in I$	Decision to build a connection from demand point to warehouse
4	$f_{k,i} \geq 0, \forall k \neq i, k \in IS, i \in I$	Artificial flow from node k to warehouse i

To ensure operational and design feasibility of the system, the optimization constraints are given as follows:

$$\sum_{i \in I} z_{i,j} \leq 1 \forall j \in J \quad (2)$$

$$z_{i,j} \leq x_i \forall i \in I, j \in J \quad (3)$$

$$\sum_{j \in J} D_j z_{i,j} \leq Q x_i \forall i \in I \quad (4)$$

$$y_{i,k} \leq x_i \quad k \neq i, \forall i \in I, k \in IS \quad (5)$$

$$\sum_{k \in IS} f_{k,i} - \sum_{k \in I} f_{i,k} = x_i \quad \forall i \in I \quad (6)$$

$$f_{k,i} \leq M y_{k,i}, \forall k \neq i, i \in I, k \in I \quad (7a)$$

$$f_{s,i} \leq M y_{i,s}, \forall s \in S, i \in I \quad (7b)$$

Inequality constraint (2) ensures that each demand point j cannot be assigned to more than one warehouse i . Inequality constraint (3) ensures that each demand point j cannot be assigned to any unbuilt

candidate locations $i \in I$. Inequality constraint (4) ensures that the total demand assigned to warehouse i does not exceed the service capacity Q of the assigned warehouse i . Inequality constraint (5) ensures that if a station is not built at location k , no link between warehouse i and k can be built.

Equality constraint (6) is a flow conservation equation that forces each established warehouse to contain one unit of artificial flow. If $x_i = 1$, there is a net flow into i , so i must be on an active path from at least one source (directly or through an intermediate warehouse), and if $x_i = 0$, there is no flow through i . Inequality constraints (7a) and (7b) restrict flow to active paths using the big-M formulation so that flow can only exist between any two warehouses or between a warehouse and a source if there is a path between them. Equation (6) and inequalities (7a) and (7b) simultaneously ensure that there is a sequence of active paths between the aid source points and each established warehouse.

The objective function is formulated as follows:

$$\begin{aligned} \text{minimize } & \left(\sum_{i \in I} C_f x_i + \sum_{i \in I} \sum_{k \in I} C_{i,k}^w y_{i,k} \right. \\ & + \sum_{i \in I} \sum_{s \in S} C_{i,s}^s y_{i,s_s} \Big) \\ & + \sum_{i \in I} \sum_{j \in J} R_{i,j} d_{i,j} z_{i,j} \\ & + \delta \left(\sum_{j \in J} D_j - \sum_{i \in I} \sum_{j \in J} D_j z_{i,j} \right) \end{aligned}$$

The first term in this equation corresponds to the total cost of all warehouse capital construction consisting of building cost C_f , distance-dependent warehouse

link cost $C_{i,k}^w$, and source-warehouse link cost $C_{i,s}^s$ for each warehouse i . Each of these terms are accompanied by a set of binary variables $(x_i, y_{i,k}, y_{i,s_s})$, which determines which cost terms are active/used for every warehouse. The second term is the total risk level, $R_{i,j}$, for the delivery of aid total haversine distance between warehouse i and demand point j which is also accompanied by a binary variable, $z_{i,j}$ at each warehouse i and demand point j . The risk level variable, $R_{i,j}$, is to support the selection of a location for warehouse i that can be easily reached by each demand point j . Choosing a shorter distance $d_{i,j}$ will reduce the risk of long travel for Gazans when reaching the demand point (represented by the value of $R_{i,j}$). The third term is the total of the sum of the supply requests at all demand points j minus the sum of the supply requests at all demand points j accompanied by the binary variable $z_{i,j}$. The amount of supply demand will then be calculated by the penalty costs that exist when there is a person's supply demand that is not met. This value is the total amount of penalty costs that exist at all demand points j multiplied by the value of δ . The third term in equation (8) is useful to help the model solution to meet aid demands around Gaza.

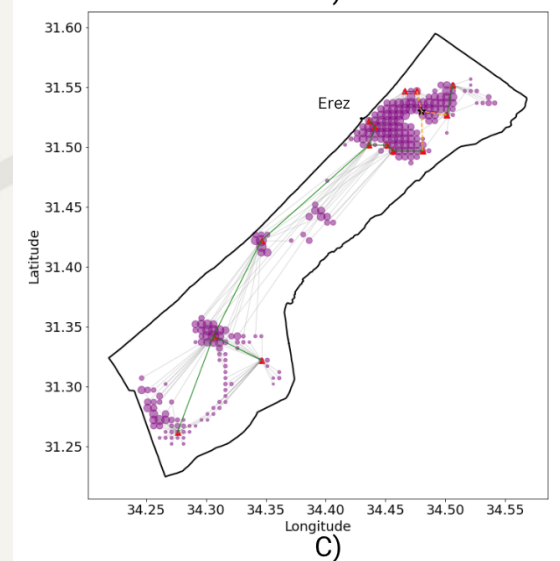
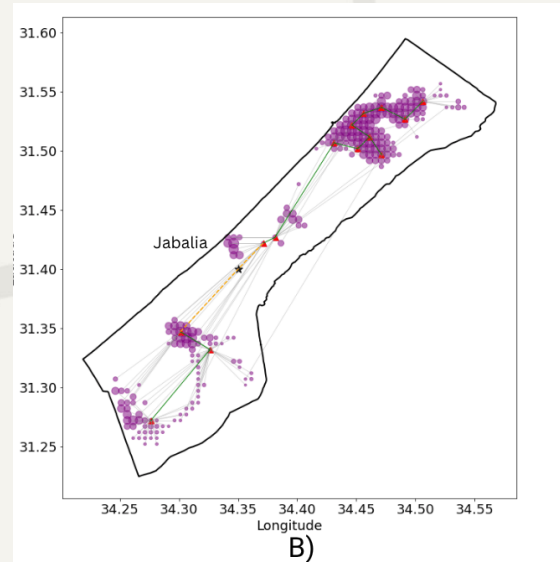
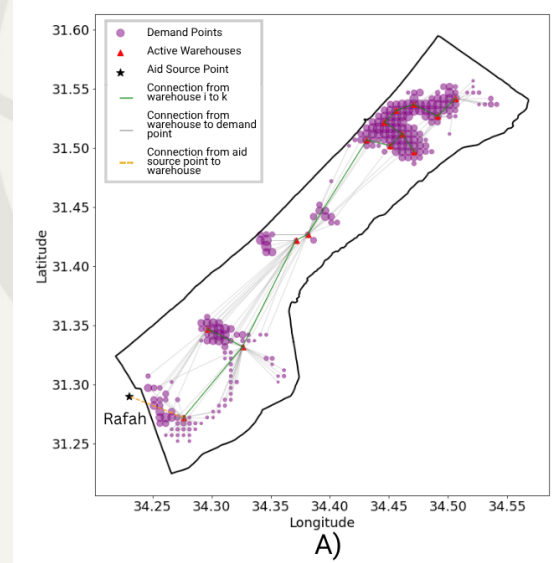
C. Solving the MILP Model

This study used Pyomo (Python optimization modeling tool) to digitize the resulting MILP model. The digital model is then solved using the GNU Linear Programming Kit (GLPK) solver [11]. Details of the solver's algorithm will not be

discussed in this study, as they fall beyond the scope of this research.

RESULT AND DISCUSSION

The haversine distance is used to calculate the distance between warehouse i and demand point j , because it can calculate the distance between two points on the earth's surface using latitude and longitude coordinates. The following are the parameter values in Table 2. used. The capacity of each warehouse can service of $Q = 100.000$ people [12]. The cost to build each warehouse is $C_f = 300.000$ USD [13,14]. To calculate the cost of connecting two warehouses i and k , the value of the price per kilometer and the haversine distance from warehouses i and k , $C_{i,k}^w = 1.000 \times d_{i,k} \text{USD}$ [15]. To calculate the cost of connecting warehouse i and the source point s , the value of the price per kilometer and the haversine distance from the source point s and warehouse i can be used, $C_{i,s}^s = 1.000 \times d_{i,s} \text{USD}$ [15]. The penalty value $\delta = 100 \text{ USD/person}$ for each person who does not have an assignment to one of the warehouses built is also used. This value is chosen to guarantee the assignment of every Gazan to an active warehouse. It should be noted that a value of $\delta < 4 \text{ USD/person}$ provides a trivial solution (no warehouse is built).



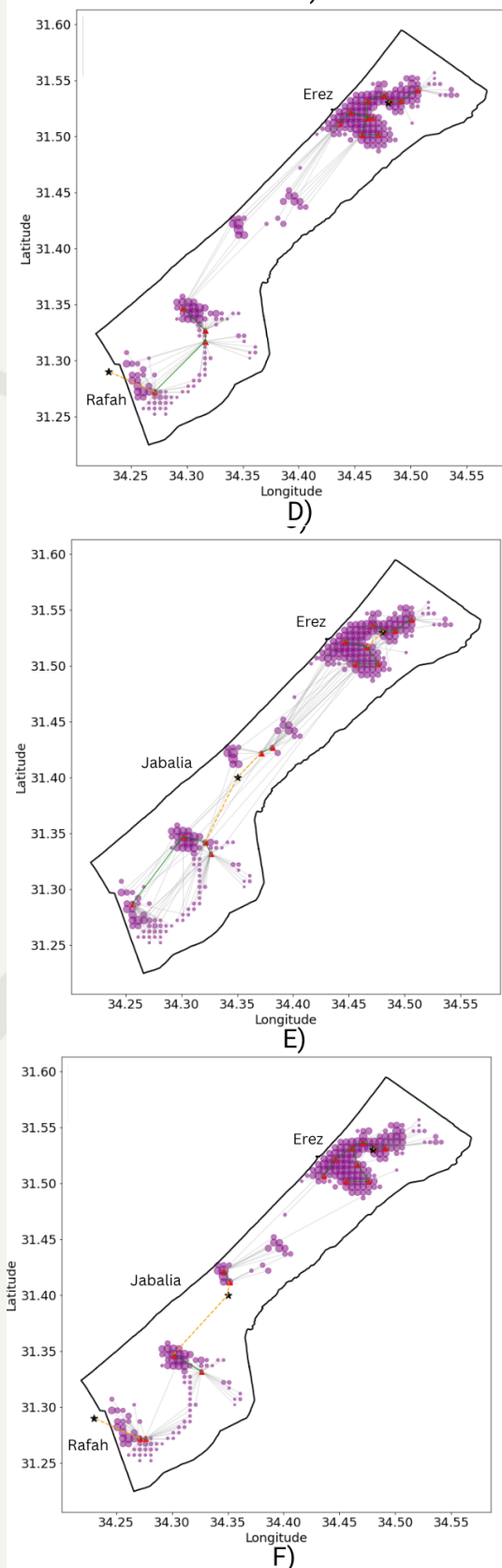


Figure 2. Visualization of the model solution with varying set of aid source locations: a) Rafah, b) Jabalia, c) Erez, d) Rafah and Erez, e) Jabalia and Erez, and f) Rafah, Jabalia, and Erez.

Table 4. Variation in the number of warehouses, roads, and construction costs.

N	Source Point	Number of Warehouses	Warehouse Cost	Warehouse Connection Cost
1	R	14	4.20	53.0
2	E	14	4.20	56.1
3	J	14	4.20	47.5
4	R, E	15	4.50	28.6
5	E, J	14	4.20	17.0
6	R, E, J	15	4.50	3.04

Figure 2 visualizes the solution for the placement of warehouses, logistics routes, and the assignment of demand points around the Gaza Strip. The visualization uses a combination of three different aid source points (Rafah, Jabalia, and Erez) for each sub-figure. The visualization illustrates the number of warehouse placements in relation to the distribution of demand points, as well as the logistics routes connecting the warehouses that have been established based on the proposed MILP model. The number and construction of warehouses and their flow in each sub-figure are summarized in Table 4.

The six solutions shown in Figure 2 demonstrate the flexibility of the proposed MILP model in determining the optimal locations of warehouses and connecting routes based on the location of aid sources. Model users can easily change the number and location of aid sources based on the availability and security of aid sources within the Gaza Strip.

Observations of the locations selected by the MILP solution indicate that the engineered flow variable from warehouse/source i to k ($f_{(i,k)}$) in this model successfully connects the routes between

warehouses built throughout Gaza. Figure 2 shows how all warehouses built have a route to a source point. This allows for the delivery of aid from the source to all demand points via intermediate warehouses.

The distribution of warehouses in the Gaza area also demonstrates how this model favors establishing warehouses in areas with higher demand for supplies, while avoiding those with lower demand. For example, Figure 2D shows how the supply demand in central Gaza is completely ignored, as it would be less optimal to establish a warehouse so far from the Rafah and Erez supply points.

However, this model can still choose to build warehouses in areas with a lower supply demand if the location is important for connecting warehouses and can reduce the length of the connecting route between warehouses to minimize delivery risk based on the coefficient $R_{(i,j)}$. This ensures wide logistical coverage while reducing the risk of aid delivery from the source and the cost of building the route. For example, in Figure 2B, it can be seen how two warehouses connect the source point of Jabalia with a cluster of warehouses in the northern area.

Furthermore, areas with high demand tend to have consistent patterns of active warehouse placement. The six sub-figures in Figure 2 display a consistent pattern of active warehouse placement in northern Gaza, with slight variations in the routes connecting these warehouses, despite varying combinations of locations and the number of aid sources. This implies that the number and location of warehouses in areas with high demand for supplies are insensitive

to the source points and the number and location of warehouses in other areas.

Based on Table 4, the results for the number of warehouses across the Gaza area are very similar, despite the different numbers and locations of sources. Therefore, the number and location of source points also have a minimal influence on the number of warehouses built. This is due to the third term in equation (8) to meet aid demands across the Gaza area. Furthermore, the cost of building routes between warehouses tends to decrease with an increasing number of aid sources. With more primary sources of aid, fewer connecting lines are needed between warehouses to distribute aid from the sources.

CONCLUSION

The results of this study demonstrate the flexibility of the proposed MILP model. The model can easily design an optimal infrastructure system that considers supply flows between warehouses and the risks of temporary travel routes, while adapting to the availability of aid source locations around Gaza. In addition, the model can also minimize the costs required for building the necessary infrastructure. However, this MILP model also faces several limitations, such as uncertain parameter values and the low resolution of population distribution in the Gaza Strip, which limits the service coverage proposed by the model. Furthermore, the model has not yet incorporated scheduling to create more realistic solution scenarios.

Directly, this model can serve as a reference to improve access to aid supplies for Gaza's population and

reduce suffering amid the ongoing conflict. This model can also provide guidance for international humanitarian organizations to deliver aid more safely and efficiently, thereby strengthening global solidarity toward communities affected by war. Thus, this study can serve as a bridge between mathematical approaches and social realities, where the success of this optimization model is not only aimed at minimizing costs but also at making a tangible impact on human survival and well-being.

Future Research

For future work, the optimal locations of aid sources can be determined by adding aid source locations as MILP variables. Cost minimization can also be refined by considering different warehouse sizes. The proposed MILP model could approach more realistic scenarios by accounting for the quantity of supply aid over a given period.

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To What Extent Does the Minimum State of Charge Influence Charging Efficiency in iPhones

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Abstract: Smartphones have become essential to daily life, yet charging habits are often inefficient. Lithium-ion batteries lose part of their input energy as heat, and inefficiencies are influenced by state of charge, voltage, and current (Kim, Park, & Choi, 2022). At high voltages, chargers continue supplying energy even when current is minimal, leading to waste. Conversely, low percentages demand high current, releasing resistive heating. This matters at scale: Omdia (2025) reported 1,223.1 million smartphone shipments in 2024, while IDC (2025) noted 295.2 million units in Q2 2025 alone. With billions of devices in use, even small charging improvements can have major cumulative effects on performance and energy demand. This study examines iPhone efficiency, using an iPhone 14 Pro (85% battery health) as the test device. The experiment recharges the phone from varying starting points (5% to 80% in 5% increments) up to 100%, recording voltage, current, and power every 10 minutes via a USB meter. A trapezoidal integral model calculates total input versus stored energy. The findings compare different thresholds to identify ranges that maximize efficiency. Although iPhones feature strong software optimization, their hardware often lags behind Android rivals, which now reach 5,000 mAh or more (Gadgets360, 2025). With typical iPhone capacities of 3,000–4,000 mAh, inefficient charging or accelerated wear has a more immediate effect on performance. Prior studies on lithium-ion chemistry highlight that mid-range charging (20–60%) balances durability and efficiency, while extremes below 20% or above 80% increase stress, heat, and energy waste (Battery University, 2019; Large Battery, 2021). Building on this, the present analysis aims to provide iPhone users with practical strategies to extend battery health, reduce energy loss, and encourage environmentally responsible smartphone use.

INTRODUCTION

The lithium-ion battery is the heart of modern smartphones, and our charging behavior directly affects the device's performance, user experience, and battery longevity. Lithium-ion cells commonly used in smartphones lose

a portion of input energy as heat, and these losses depend strongly on state of charge (SoC), voltage, and current (Guo, Guo, Liu, & Wang, 2023). At high voltages the charger continues to deliver energy even as current falls, producing heat rather than stored capacity; at very low

SoC, the battery accepts large currents that increase resistive heating and polarization losses (Battery University, 2019). Because smartphones operate at a planetary scale (over one billion units shipped in 2024), inefficient charging behaviors—especially those related to state-of-charge (SoC)—can collectively lead to significant energy consumption (Omdia, 2025; IDC, 2025).

Although many manufacturers implement software strategies to slow degradation (for example, Apple's optimized charging behavior that reduces high-voltage), even such measures may not be sufficient for your phone. Additionally, there is limited experimental evidence quantifying how the minimum SoC before a charge affects the *energy efficiency* of an actual phone charge session (Which is very crucial in energy reduction and battery degradation). (Apple Support, n.d.; Sun et al., n.d.). This knowledge gap matters in practice: iPhones, while highly optimized in software, often carry smaller battery capacities ($\approx 3,000$ – $4,000$ mAh), so inefficient charging can have a more immediate effect on user experience than in devices with larger cells (Gadgets360, 2025). Prior literature on lithium-ion chemistry indicates that mid-range charging windows (roughly 20–60% SoC) balance efficiency and longevity, whereas charging below 20% or above 80% increases stress and energy waste (Battery University, 2019; Large Battery, 2021).

This study therefore investigates how the minimum state of charge influences charging efficiency in iPhones. The principal goal is to determine the most

efficient minimum SoC range for iPhone charging, by calculating input and stored energy using only measured voltage (V), current (A), and time (t) data, integrated via a trapezoidal model. The independent variable is the starting SoC for a charging session (multiple discrete levels from 5% to 80%, in 5% increments). The primary dependent variables are: (1) total input energy (J) drawn from the charger during a session, (2) effective energy stored in the battery (Wh) as estimated from device voltage and current, and (3) derived charging efficiency (%) defined as stored energy $\div$ input energy $\times 100$. Secondary measures include charging time and observed cpu temperature during charging.

To answer this question, an iPhone 14 Pro (128 GB) with 85% maximum battery health was used as the test device. Each trial recharged the device from a prescribed starting SoC (5%, 10%, ..., 80%) up to 100%, while voltage, current, power, time, and CPU temperature were recorded every 10 minutes using a USB power meter dongle. Output power was calculated as voltage $\times$ current, and the trapezoidal rule was applied to the power–time data to estimate stored energy (in the battery) and input energy (from the charger). The ratio of total stored energy to input energy gives the charging efficiency. Prior studies support this method: Li-ion batteries do not convert all supplied energy to storage because of internal resistance, polarization, and heat generation, which cause losses (Guo et al., 2023). Moreover, charging efficiency is protocol-dependent: experimental work demonstrates that efficiency varies under different charging stress conditions (Su et al., 2023),

paralleling this study's inquiry into how starting SoC influences efficiency.

By quantifying how starting SoC shapes energy transfer efficiency in a real iPhone, this work aims to deliver evidence-based charging recommendations that can extend battery life, reduce cumulative energy waste, and support more sustainable smartphone use.

LITERATURE REVIEW

A. Self-Discharge

Self-discharge is the spontaneous loss of charge when a battery is idle. In lithium-ion cells, this comes from small leakage currents and chemical side reactions. Although lower than older chemistries, it still reduces available energy if the phone is unused for long periods. Research shows that low SoC increases self-discharge due to electrode reactions and SEI growth (Roth et al., 2023). When measuring charging efficiency, idle periods must be considered, as some energy loss comes from self-discharge rather than the charging process itself.

B. State of Charge (SoC)

State of charge (SoC) describes how much energy remains in a battery, expressed as a percentage. The SoC before charging affects efficiency because it determines how the battery responds to incoming current. (Guo et al., 2023).

C. Lithium-ion batteries

Lithium-ion batteries store and release energy by moving lithium ions between electrodes. Their efficiency and long-term performance depend on internal resistance, polarization, and side reactions. (Guo et al., 2023).

D. Charging efficiency

Charging efficiency is the percentage of input energy from the charger that is stored in the battery. Losses occur through resistance, heat, and polarization, and efficiency decreases when charging at very low or very high SoC levels. Research shows that efficiency is not fixed but depends on charging conditions such as SoC and current patterns. (Su et al., 2023).

METHOD

The equipment used in this study are as follows:

1. Test device: iPhone 14 Pro (128 GB) with 85% maximum battery health.

2. Power meter: USB digital power meter dongle (KOWSI Voltmeter Ammeter Type C Digital Display OLED, Model KWS-2302C; measures up to 30 V, 12 A, and 360 W).

3. Data recording device: iPad Air (3rd Generation), used with Google Sheets for logging and processing measurements.

4. Cable: HP 8-in-1 JETE Connector (Model CX15, supports up to 60 W and 3 A, specifically and only just the lightning connector).

5. Charger: BASEUS GEN5P 65W Fast Charger 4.0, Type-C.

Research Procedure:

The research procedure follows a series of steps, which are summarized in Figure 1.

1. The phone was discharged to a prescribed starting state of charge (SoC) of 5%, 10%, 15%, ..., up to 80%.

2. The charger, USB power meter dongle, and Lightning connector were prepared and connected in series with the device.

3. The phone was recharged to 100% under standard conditions.

4. Voltage (V), current (A), power (W), energy (Wh), time (min), and CPU temperature ($^{\circ}\text{C}$) were recorded every 10 minutes using the USB power meter.

5. All values were entered directly into Google Sheets during charging to ensure accurate and consistent data collection.

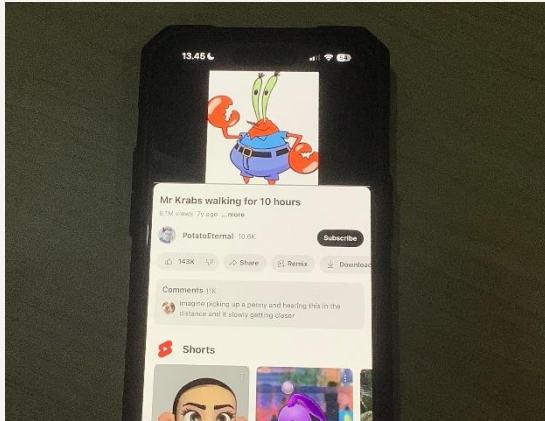


Figure 1. The Previous Attempt to Emptying the Phone Battery

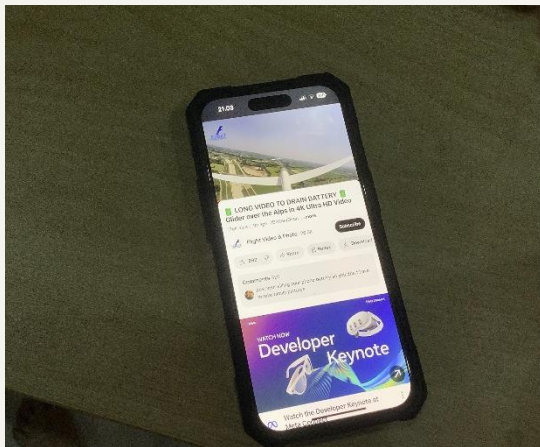


Figure 2. One of the Few Recent Attempts to Emptying the Phone Battery



Figure 3. Charging Process of 70% SoC (With the Charger, USB Power Meter Dongle, and Lightning Connector connected to the device)



Figure 4. Inputting the Recorded Data and Doing the Calculations in Google Sheets.

Data Analysis and Calculations:

1. Output Power: $P_{out}(t) = V(t) \times I(t)$; where $P_{out}(t)$ is the effective charging power into the device.

2. Input Energy: Calculated as power multiplied by charging time: $E_{in} = P_{in} \times \Delta t$; with Δt in seconds.

3. Output Energy: Computed using the trapezoidal rule based on consecutive output power values: $E_{out} = (P_{out1} + P_{out2}) \div 2 \times T$; where P_{out1} and P_{out2} (P_{out3} , P_{out4} , and so on...) are consecutive power readings and T is the time interval in seconds.

4. Charging Efficiency: $\eta = (E_{out} / E_{in}) \times 100\%$; where E_{out} is the output energy (from trapezoidal sum of output power) and E_{in} is the total input energy supplied to the device.

All steps, from logging in values to calculating energy and efficiency, were carried out directly in Google Sheets.

RESULT AND DISCUSSION

Energy and Efficiency Calculation (All examples are used based on the table of 70% SoC)

1. Output Power was determined using: $P_{out}(t) = V(t) \times I(t)$; For example, at 17:10, $V = 4.877$ V and $I = 2.321$ A, giving $P_{out} = 11.32$ W.

2. Input Energy (E_{in}) was computed by multiplying input power by time: $E_{in} = P_{in} \times \Delta t$; For instance, with $P_{in} = 11.29$ W and $\Delta t = 600$ s, $E_{in} = 6,774$ Wh.

3. Output Energy (E_{out}) was calculated using the trapezoidal rule between consecutive readings: $E_{out} = (P_{out_1} + P_{out_2}) \div 2 \times T$; Example: Between 17:10 (11.32 W) and 17:20 (10.78 W), $E_{out} = (11.32 + 10.78)/2 \times 600 = 6,066$ Wh (approx.)

4. Charging Efficiency (η) was then calculated as: $\eta = (E_{out} / E_{in}) \times 100\%$; Example: $\eta = (43,911.57 / 47,608.62) \times 100\% = 92.23\%$; The total Input Energy (red cell) was 47,608.62 Wh, the total Output Energy (orange cell) was 43,911.57 Wh, yielding an overall Charging Efficiency (yellow cell) of 92.23% (from 0.9223×100) for the minimum 70% SoC.

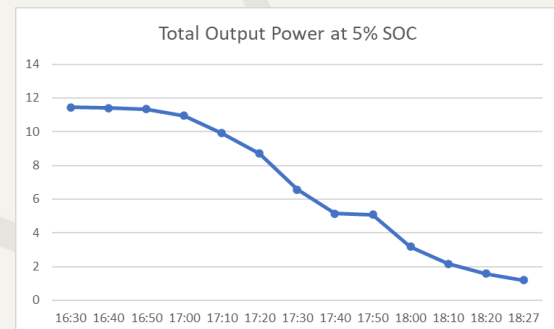
The Results

The measured data cluster naturally into three operational ranges: Low SoC (5-20%), Mid SoC 25-55%, and How High SoC (60-80%). The following paragraphs present the results for each range and interpret them in the context of state-of-charge-dependent charging behaviour, thermal factors influencing charging efficiency 5-20% SoC (deep-discharge range). Measured values: 5% = 85.22% (37 °C, 1:57); 10% = 71.17% (35 °C, 1:45); 15% = 92.23% (38 °C, 2:03); 20% = 92.26% (36 °C, 1:56).

This range shows the greatest variability in efficiency and the highest peak temperatures. The 10% trial produced the lowest efficiency (71.17%) and the 5% and 15-20% trials were substantially higher, indicating trial-to-trial differences that likely reflect transient thermal or device-state effects. Overall, charging from deep discharge is associated with large initial currents that raise polarization losses, producing higher device temperatures and reduced fraction of input energy stored in some cases (Guo et al., 2023; Su et al., 2023). The data support the expectation that deeply discharged cells can incur greater early-phase energy dissipation and thermal stress.

Table 1. Table of 5% SoC

Output Power	Input Energy	Output Energy	Time	Input Power	Output Voltage	Output Current	CPU	Battery Percent
11.44(792)	6834	6881.1628	16:30	11.39	4.806	2.332	31	95
11.38(484)	6834	6820.7546	16:40	11.39	4.887	2.332	36	93
11.32(398)	6798	6887.7758	16:50	11.33	4.894	2.317	36	91%
10.85(168)	6558	6257.1851	17:00	10.80	4.692	2.239	37	44%
9.99(362)	5997	5284.5324	17:10	9.945	4.916	2.018	37	57%
8.70(146)	5208.8	4384.2160	17:20	8.678	4.931	1.768	35	68%
6.57(277)	4215	3317.7823	17:30	7.025	4.985	1.379	34	77%
5.15(364)	3100.6	3071.2853	17:40	5.261	5.013	1.028	31	83%
5.09(4247)	3028.2	2477.6361	17:50	5.047	5.019	1.013	31	89%
3.17(54)	1722.8	1599.9246	18:00	2.988	5.035	0.609	30	94%
2.15(542)	1267.8	1123.0722	18:10	2.163	5.067	0.426	30	97%
1.59(932)	1361.4	836.6265	18:20	2.319	5.094	0.313	30	99%
1.20(723)	720.72		18:27	1.716	5.078	0.237	30	100%
	57873.32	49412.4825						
Efficiency:	0.852243222							



Graph 1. 5% SoC Total Output Power Graph

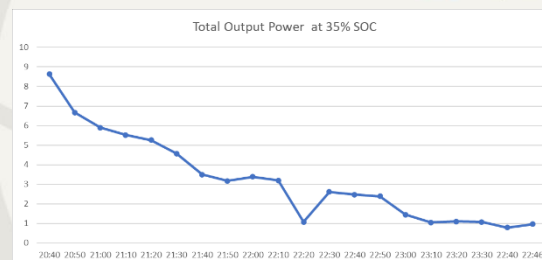
25-55% SoC (mid-range range). Measured values: 25% = 90.73% (39 °C, 1:58); 30% = 91.77% (39 °C, 1:50); 35% = 99.35% (36 °C, 3:16); 40% = 88.67% (32 °C, 2:55); 45% = 78.81% (31 °C, 2:18); 50% =

81.36% (34 °C, 2:20); 55% = 89.52% (32 °C, 2:43).

This range delivers the strongest overall performance in terms of stored-to-input energy. The highest measured efficiency occurs at 35% SoC (99.35%), indicating an optimal balance between available voltage headroom and moderate charging current that minimizes both resistive heating and high-voltage dwell losses. Neighbouring points (25–30% and 55%) also show high efficiencies (>89%), although the subrange contains some intra-range variability: 40% and 55% return high, thermally stable values, while 45% and 50% are lower—45% (78.81%) being a notable outlier. The 35% trial demanded the longest measured duration (3:16), but that time comprised predominantly low-power transfer that the device converted to stored energy with little dissipation. Taken together, the 25–55% range constitutes the most favourable compromise between energy conversion efficiency, moderate thermal behaviour, and practical charging duration—making it the recommended routine charging window for energy-efficient operation (Battery University, 2019; Large Battery, 2021).

Table 2. Table of 35% SoC

Output Power	Input Energy	Output Energy	Time	Input Power	Output Voltage	Output Current	CPU	Battery Percent
8.628032	6161.8	4588.6875	20:40	8.603	4.857	1.776	36	36
8.695932	3945.4	3770.4711	20:50	8.409	4.879	1.367	36	43
5.899664	3586.6	3426.1365	21:00	5.981	4.883	1.208	35	53
5.521791	3307.2	3234.7933	21:10	5.512	4.917	1.123	34	60
5.260171	3217.2	2950.8146	21:20	5.362	4.935	1.066	34	67
4.579672	2430	2401.8607	21:30	4.65	4.938	0.927	33	72
3.497497	2083.8	2000.8248	21:40	3.473	4.933	0.709	34	76
3.171919	1870.2	1966.2054	21:50	3.117	4.933	0.643	32	81
3.382096	1863.2	1973.8740	22:00	2.772	4.981	0.679	31	84
3.198816	1864.8	1281.963	22:10	3.108	4.964	0.644	30	87
1.075394	654	1106.223	22:20	1.09	4.933	0.218	30	89
2.8122916	1459.8	1527.1584	22:30	2.433	4.947	0.528	30	90
2.4797012	1480.2	1458.0519	22:40	2.467	4.997	0.496	30	92
2.381661	1521	1548.3485	22:50	2.535	4.963	0.477	30	94
1.448904	700.2	751.8672	23:00	1.167	5.033	0.288	30	95
1.08672	812.6	648.0763	23:10	1.021	5.032	0.21	29	96
1.102541	676.8	654.7587	23:20	1.138	5.039	0.219	30	97
1.078988	658.8	558.7074	23:30	1.088	5.042	0.214	30	98
0.78337	545.4	523.6506	22:40	0.969	5.054	0.155	29	99
0.968932	357.6	322.46	22:46	0.963	5.046	0.192	30	100
Efficiency:	0.9934934061	37698.48	37453.1913					



Graph 2. 35% SoC Total Output Power Graph

60–80% SoC (high-SoC range). Measured values: 60% = 87.10% (32 °C, 1:26); 65% = 89.34% (35 °C, 1:24); 70% = 77.97% (32 °C, 1:05); 75% = 84.21% (32 °C, 0:58); 80% = 87.59% (33 °C, 0:54). Although the high state-of-charge (SoC) range is conventionally defined as 80–100%, several studies have shown that lithium-ion batteries in smartphones begin to exhibit high-voltage behavior from around 60% SoC, when the internal cell voltage exceeds approximately 4.0 V (Su et al., 2023; Xu et al., 2020). There are a lot of chargers in the market that typically deliver up to 5V and beyond but due to the phone's internal power-management circuit converts this to the battery's operating voltage range of 3.7–4.2 V. Once the cell approaches 4.0 V, usually near 60% SoC, the control system gradually reduces charging current to prevent overvoltage and overheating (Battery University, 2019).

Apple devices here specifically use single-cell lithium-ion polymer batteries that have a power-management integrated circuit (PMIC) inside of it, whose safe operating voltage range is about 3.0–4.35 V (Battery University, 2019; IEC 62660-1 Standard). Inside this range is about:

- 3.0–3.5 V → low SoC (nearly empty)
- 3.6–3.9 V → mid SoC

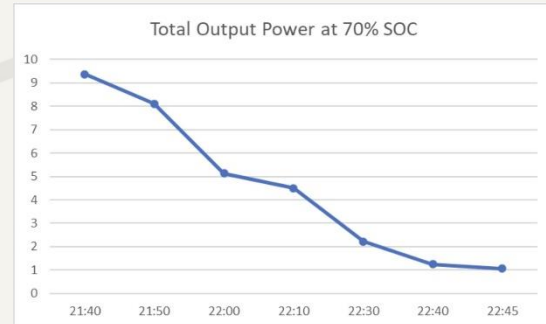
- 4.0–4.35 V → high SoC (approximately 65–100 %)

So even if it's recorded by the USB power meter dongle that the charger supplies 5V to the iPhone, the PMIC in the phone will convert the 5V down to around 4.0–4.2V. It's because feeding the full 5 V or above into the iPhone directly would push the battery above its electrochemical limit, causing overcharge, and thermal runaway risk. (Rana et al., 2012; Battery University, 2019; U.S. Nuclear Regulatory Commission [NRC], 2017; Wikipedia, 2024).

This voltage regulation marks the beginning of the constant-voltage phase, in which the charging system stabilizes the cell voltage at around 4.2 V. Consequently, charging efficiency begins to decline even before 80% SoC, and especially harder at 80% SoC, as an increasing portion of the input energy is dissipated as heat or used to maintain voltage stability rather than being stored as usable capacity (NenPower, 2024; Su et al., 2023). The slightly lower CPU temperatures observed in this range reflect the reduced current flow, yet they do not offset the drop in stored-to-input energy caused by extended operation at high voltage levels

Table 3. Table of 70% SoC

	Output Power	Input Energy	Output Energy	Time	Input Power	Output Voltage	Output Current	CPU	Battery Percent
	9.377008	6078	5245.041	21:40	10.13	4.912	1.909	30	70
	8.106492	4900.2	3972.5136	21:50	8.167	4.949	1.638	32	77
	5.13626	3153	2888.766	22:00	5.205	5.01	1.025	31	85
	4.49397	3330.6	2015.646	22:10	5.551	5.01	0.897	31	91
	2.224852	1091.4	1039.7351	10:20	1.819	5.068	0.439	30	98
	1.242625	1143	690.6054	10:30	1.905	5.065	0.245	30	99
	1.261093	635.4		10:35	1.259	5.077	0.209	30	100
		20331.6	15862.3057						
Efficiency:	0.779688057								



Graph 3. 70% SoC Total Output Power Graph

Conclusion and Implications
Grouping the results in these three ranges highlights an obvious message: mid-range charging (25–55% SoC) yields the best overall outcome, with an energetic optimum at 35% SoC. Deep discharges (5–20%) are thermally costly and exhibit inconsistent efficiency, while initiating charge at high SoC (60–80%) reduces efficiency via tapering losses despite lower operational temperatures and shorter durations. The 25–55% range, particularly the neighbourhood around 35%, therefore represents the most energy-efficient and thermally conservative routine charging practice, while the 40–55% subwindow offers a practical top-up compromise when shorter charging times are preferred.

Limitations.

These results derive from a single device model (iPhone 14 Pro, 128 GB) with 85% maximum battery health, logged at 10-minute intervals via a single USB power meter. Instrument quantization, environmental conditions, device thermal history, and charger/cable interactions may introduce measurement variability and explain some intra-range outliers (notably the low efficiency at 45% and 50%). Broader generalization requires

replication across multiple devices, battery health states, ambient temperatures, and higher-frequency logging to reduce integration uncertainty.

CONCLUSION

The experiment shows that charging efficiency is strongly influenced by the initial state of charge (SoC). At lower SoC levels (5–25%), particularly at 5% (85.22%) and 10% (71.17%), efficiency was low, accompanied by higher CPU temperatures (35–37 °C) and longer charging times (1 hour 45–57 minutes). This is consistent with existing studies showing that charging from deep discharge increases internal resistance, leading to higher heat generation and lower energy conversion efficiency (BatterySkills, n.d.).

Efficiency improved significantly within the mid-SoC range (20–35%), peaking at 35% SoC (99.35%), where the CPU temperature was moderate (36 °C). Although this range included the longest charging time (3 hours 16 minutes), it demonstrated the best balance between energy conversion, thermal stability, and battery performance. This pattern aligns with Apple's own findings that lithium-ion batteries charge most efficiently up to around 80% before switching to a slower "trickle" mode to prevent stress and overheating (Apple, n.d.).

At higher SoC levels (60–80%), efficiency declined slightly (78–89%) even though total charging time was shorter. The 70% (77.97%) and 75% (84.21%) conditions were among the least efficient in this range, largely due to early entry into the low-current tapering phase where less

input energy is converted to stored energy (NenPower, 2024). Despite faster charging (as short as 54 minutes at 80% SoC), this phase reduces the overall energy efficiency of the process.

Thermally, CPU temperatures were highest during charging from low SoCs, stabilized between 30–55%, and remained lowest at higher SoCs (60–80%), reflecting reduced resistive heating at higher charge levels.

Overall, the most efficient charging range was 20–35% SoC, providing an optimal balance between high energy efficiency, moderate thermal stress, and manageable duration. Both low SoCs (5–10%) and high SoCs (70–80%) resulted in lower efficiency—either due to increased internal resistance or reduced current flow during tapering. These results align closely with Apple's recommendations for keeping battery levels between 20–80% to ensure longevity and efficiency (Apple, n.d.; BatterySkills, n.d.).

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Nonclassical Lie Symmetry Analysis of Allen-Cahn Equation

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Abstract: The use of nonclassical Lie symmetry analysis on the Allen-Cahn partial differential equation has not been explored. This research seeks to apply nonclassical Lie symmetry analysis on the Allen-Cahn equation. First, the prolongation of the differential equation is found, from which a system of determining equations is extracted. Solving these determining equations yields the infinitesimal transformations, which are used to reduce the PDE into an ODE. In conclusion, the Lie symmetries, reduction to ODE, and solutions are found.

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INTRODUCTION

The Allen-Cahn equation is a 2nd-order nonlinear parabolic partial differential equation. It has applications in material science, image processing, and fluid dynamics by describing phase separation, crystal growth and image segmentation. Thus, finding solutions to the Allen-Cahn equation is significant. Lie symmetry analysis is a method applied to differential equations to find new solutions. The goal of this research is to find the reduction to an ODE and solutions to the Allen-Cahn equation through nonclassical Lie symmetry analysis. The application of nonclassical Lie symmetry analysis to the Allen-Cahn equation obtained 5 solutions.

LITERATURE REVIEW

The Allen-Cahn equation is the following:

$$u_t = u_{xx} + u - u^3$$

Lie symmetry finds the transformations under which the differential equation is invariant under. The infinitesimal transformation is:

$$\Gamma = U \frac{\partial}{\partial u} + X \frac{\partial}{\partial x} + T \frac{\partial}{\partial t}$$

Where U, X, T are infinitesimal transformations on the variables. The infinitesimal operator is extended to apply to all derivatives of u in the PDE:

$$\Gamma^{(1)} = \Gamma + U_{[x]} \frac{\partial}{\partial u_x} + U_{[t]} \frac{\partial}{\partial u_t}$$

$$\Gamma^{(2)} = \Gamma^{(1)} + U_{[xx]} \frac{\partial}{\partial u_{xx}} + U_{[tt]} \frac{\partial}{\partial u_{tt}} + U_{[xt]} \frac{\partial}{\partial u_{xt}}$$

With the extended infinitesimal transformations:

$$U_{[t]} = D_t(U) - u_t D_t(T) - u_x D_t(X)$$

$$U_{[x]} = D_x(U) - u_t D_x(T) - u_x D_x(X)$$

$$U_{[xx]} = D_x(U_{[x]}) - u_{tx} D_x(T) - u_{xx} D_x(X)$$

$$U_{[tt]} = D_t(U_{[t]}) - u_{tt} D_t(T) - u_{tx} D_t(X)$$

$$U_{[tx]} = D_x(U_{[t]}) - u_{tt} D_x(T) - u_{xx} D_t(X)$$

And so on, where D_x and D_t are total derivative in jet space.

The invariance of a differential equation

$$\Delta(t, x, u, u_t, u_x, \dots) = 0$$

is given by Lie's invariance condition:

$$\Gamma^{(\alpha)} \Delta|_{\Delta=0} = 0$$

After this process in jet space, U , T , and X are obtained. The reduction to an ODE is obtained using the invariant surface condition (ISC):

$$Tu_t + Xu_x = U$$

Which is solved by method of characteristics:

$$\frac{du}{U} = \frac{dt}{T} = \frac{dx}{X}$$

This obtains a relationship between two invariants including u and an arbitrary function $F(s)$.

Substituting this relation results in an ODE of the arbitrary function. The ODE is solved for $F(s)$, which results in a solution for u through the relation.

In nonclassical symmetry, the conditions that are set are:

$$\Gamma^{(\alpha)} \Delta_1|_{\Delta_1=0} = 0$$

$$\Gamma^{(1)} \Delta_2|_{\Delta_2=0} = 0$$

Where $\Delta_1 = 0$ is the PDE and $\Delta_2 = 0$ is the ISC. $T = 1$ is also set.

The condition

$$\Gamma^{(1)} \Delta_2 = 0$$

Is always fulfilled when $\Delta_2 = 0$ is fulfilled.

Nonclassical Lie symmetry can yield different results to classical Lie symmetry. There is still no existing literature on the nonclassical Lie symmetry of the Allen-Cahn equation.

METHOD

The research follows a systematic approach to exploring the mathematical problem, which involves theoretical and deductive reasoning. In this research, nonclassical Lie symmetry analysis is systematically applied to the Allen-Cahn equation.

Lie Symmetries

The following conditions are imposed:

$$\Delta_1 = u_t - u_{xx} - u + u^3 = 0$$

$$\Gamma^{(2)} \Delta_1|_{\Delta_1=0} = 0$$

$$\Delta_2 = U - Tu_t - Xu_x = 0$$

$$T = 1$$

Lie's invariance condition becomes:

$$\Gamma^{(2)} \Delta_1 = U_{[t]} - U_{[xx]} - U + 3Uu^2 = 0$$

Substitute the extended infinitesimal transformations and set $T = 1$:

$$U_{[t]} = U_t + (U_u - T_t)u_t - T_u u_t^2 - X_t u_x - X_u u_x u_t$$

$$U_{[xx]} = U_{xx} - T_{xx}u_t + (2U_{xu} - X_{xx})u_x - 2T_{xu}u_t u_x + (U_{uu} - 2X_{xu})u_x^2 - T_{uu}u_t u_x^2 - X_{uu}u_x^3 - 2T_x u_{tx} + (U_u - 2X_x)u_{xx} - 2T_u u_x u_{tx} - T_u u_t u_{xx} - 3X_u u_x u_{xx}$$

Expanding Lie's invariance condition gives:

$$U_t + U_u u_t - X_t u_x - X_u u_x u_t - U_{xx} - (2U_{xu} - X_{xx})u_x - (U_{uu} - 2X_{xu})u_x^2 + X_{uu}u_x^3 - (U_u - 2X_x)u_{xx} + 3X_u u_x u_{xx} - U + 3Uu^2 = 0$$

Substitute:

$$u_t = U - Xu_x$$

$$u_{xx} = U - Xu_x - u + u^3$$

Set the coefficients of the powers of u_x to zero gives the determining equations:

$$X_{uu} = 0 \quad (1.1)$$

$$-U_{uu} + 2X_{xu} - 2XX_u = 0 \quad (1.2)$$

$$-X_t - 2U_{xu} + X_{xx} + 2UX_u - 2XX_x - 3X_u u + 3X_u u^3 = 0 \quad (1.3)$$

$$U_t - U_{xx} - U + 3Uu^2 + 2UX_x + (U_u - 2X_x)u - (U_u - 2X_x)u^3 = 0 \quad (1.4)$$

Equation (1.1) gives:

$$X = Au + B$$

Substituting X into equation (1.2) gives:

$$U = \frac{1}{3}A^2 u^3 + 2(A_x + AB)u^2 + Pu + Q$$

Substituting X and U into equation (1.3), and setting the coefficients of the powers of u to zero gives the determining equations:

$$-\frac{2}{3}A^3 + 3A = 0 \quad (1.5)$$

$$4AA_x - 2A^2 B = 0 \quad (1.6)$$

$$-A_t - 3A_{xx} + 2A_x B + 2AB_x + 2AP - 3A = 0 \quad (1.7)$$

$$-B_t - 2P_x + B_{xx} + 2AQ - 2BB_x = 0 \quad (1.8)$$

From (1.5),

$$-\frac{2}{3}A \left(A - \frac{3\sqrt{2}}{2} \right) \left(A + \frac{3\sqrt{2}}{2} \right) = 0$$

Taking $A = 0$ leads to the classical Lie symmetry results. $A = \frac{3\sqrt{2}}{2}$ is considered.

Substituting A into (1.6) yields $B = 0$. Substituting A and B into (1.7) yields $P = \frac{3}{2}$.

Substituting A , B , and P into (1.8) yields $Q = 0$.

Hence, the Lie symmetry generators are:

$$X = \frac{3\sqrt{2}}{2}u$$

$$U = -\frac{3}{2}u^3 + \frac{3}{2}u$$

$$T = 1$$

Reduction to ODE

Substitute the symmetry generators to the ISC:

$$u_t + \frac{3\sqrt{2}}{2}uu_x = -\frac{3}{2}u^3 + \frac{3}{2}u$$

Solve by method of characteristics:

$$\frac{dt}{T} = \frac{dx}{X} = \frac{du}{U}$$

$$dt = \frac{2}{3} \frac{1}{u - u^3} du$$

$$t - \frac{2}{3} \ln \left(\frac{|u|}{\sqrt{|1 - u^2|}} \right) = C_1$$

$$\frac{2}{3\sqrt{2}u} dx = \frac{2}{3} \frac{1}{u - u^3} du$$

$$C_2 = x - \frac{\sqrt{2}}{2} \left(\ln \left(\frac{|u + 1|}{|u - 1|} \right) \right)$$

$$C_2 = F(C_1)$$

$$\begin{aligned} x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u + 1|}{|u - 1|} \right) \\ = F \left(t - \frac{2}{3} \ln \left(\frac{|u|}{\sqrt{|1 - u^2|}} \right) \right) \end{aligned} \quad (1.9)$$

Equation (1.9) is substituted to the Allen-Cahn PDE to find an ODE in F.

$$x - L(u) = F(s)$$

$$s = t - G(u) = t - \frac{2}{3} \ln \left(\frac{|u|}{\sqrt{|1 - u^2|}} \right)$$

$$L(u) = \frac{\sqrt{2}}{2} \ln \left(\frac{|u + 1|}{|u - 1|} \right)$$

$$G(u) = \frac{2}{3} \ln \left(\frac{|u|}{\sqrt{|1 - u^2|}} \right)$$

$$\frac{\partial}{\partial t} (x - L(u)) = \frac{\partial}{\partial t} F(s)$$

$$u_t = \frac{F'}{F'G' - L'}$$

$$\frac{\partial}{\partial x} (x - L(u)) = \frac{\partial}{\partial x} F(s)$$

$$u_x = \frac{-1}{F'G' - L'} = -\frac{3u(1 - u^2)}{2F' - 3\sqrt{2}u} = -\frac{N}{D}$$

Where:

$$N = 3u(1 - u^2)$$

$$D = 2F' - 3\sqrt{2}u$$

$$u_t = -F'^{u_x} = F'^{\frac{N}{D}}$$

$$\begin{aligned} u_{xx} &= \frac{\partial}{\partial x} u_x = -\frac{DN_x - ND_x}{D^2} \\ &= -\frac{DN' - ND'}{D^2} u_x \end{aligned}$$

Substituting u_t and u_{xx} to the Allen-Cahn PDE gives:

$$-F'D^2 + DN' - ND' + \frac{D^3}{3} = 0$$

Substituting N and D :

$$F'' - \frac{1}{3}F'^3 + \frac{3}{2}F' = 0$$

Solving the ODE

Let $p = F'$

$$p' - \frac{1}{3}p^3 + \frac{3}{2}p = 0$$

$$\frac{dp}{ds} = \frac{1}{3}p \left(p^2 - \frac{9}{2} \right)$$

$$p = \pm \frac{3}{\sqrt{e^{c_1 + 3s} + 2}} \quad (1.10)$$

Other solutions can be obtained with $p = c$.

$$0 - \frac{1}{3}c^3 + \frac{3}{2}c = 0$$

$$-\frac{1}{3}c\left(\frac{3}{\sqrt{2}} + c\right)\left(\frac{3}{\sqrt{2}} - c\right) = 0$$

Hence, $c = 0$ or $c = \pm \frac{3\sqrt{2}}{2}$.

$$p = 0 \quad (1.11)$$

$$p = \pm \frac{3\sqrt{2}}{2} \quad (1.12)$$

$F(s)$ is calculated for each p in equation (1.9), (1.10), and (1.11).

$$F(s) = \int p \, ds$$

$$F(s) = \pm \frac{\sqrt{2}}{2} \ln \left(\frac{\sqrt{\frac{e^{c_1+3s}+2}{2}} + 1}{\sqrt{\frac{e^{c_1+3s}+2}{2}} - 1} \right) \quad (1.13)$$

$+ c_2$

$$F(s) = c \quad (1.14)$$

$$F(s) = \pm \frac{3\sqrt{2}}{2}s + c \quad (1.15)$$

The solutions for u are obtained by substituting $F(s)$ into equation (1.9).

RESULT AND DISCUSSION

The nonclassical Lie symmetry reduction yields 5 solutions. In the graphs, all constants are set to zero.

$$x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u+1|}{|u-1|} \right) = \frac{\sqrt{2}}{2} \ln \left(\frac{\sqrt{\frac{e^{c_1+3t-2\ln(\frac{u}{\sqrt{1-u^2}})}+2}{2}}}{\sqrt{\frac{e^{c_1+3t-2\ln(\frac{u}{\sqrt{1-u^2}})}+2}{2}}} \right) \quad (4.1)$$

$+ c_2$

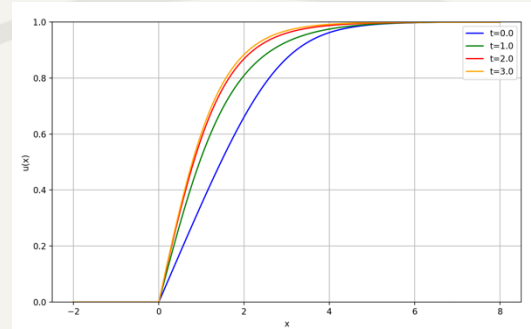


Figure 1. 2D Numerical solution for Eq. (4.1)

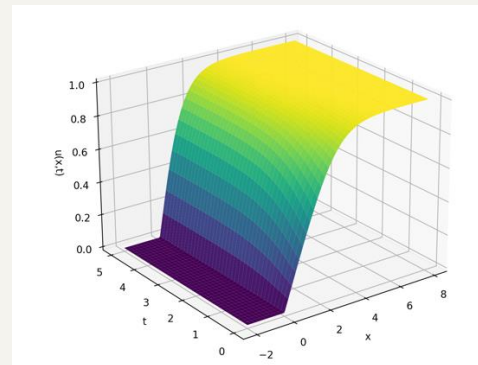


Figure 2. 3D Numerical solution for Eq. (4.1)

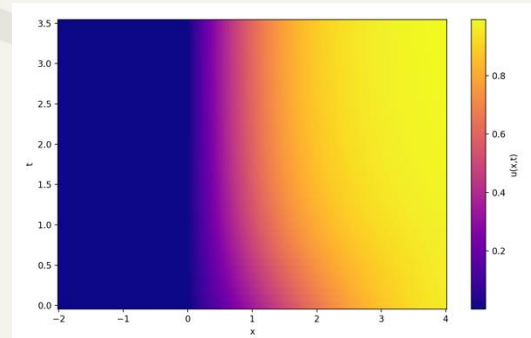


Figure 3. Heatmap for Eq. (4.1)

$$x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u+1|}{|u-1|} \right) = -\frac{\sqrt{2}}{2} \ln \left(\frac{\sqrt{\frac{e^{c_1+3t-2\ln(\frac{u}{\sqrt{1-u^2}})}+2}{2}}}{\sqrt{\frac{e^{c_1+3t-2\ln(\frac{u}{\sqrt{1-u^2}})}+2}{2}}} \right) \quad (4.2)$$

$+ c_2$

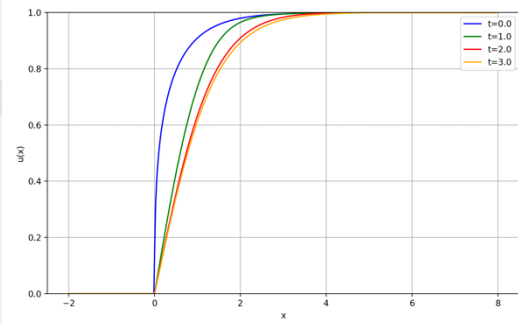


Figure 4 2D Numerical solution for Eq. (4.2)

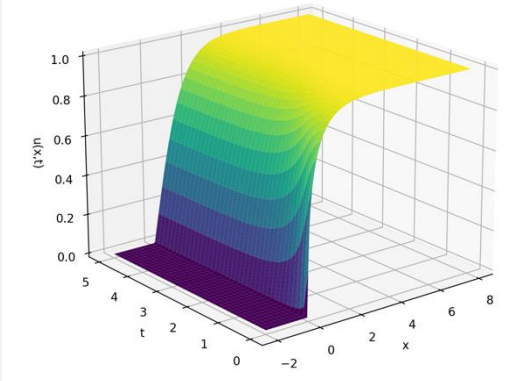


Figure 5. 3D Numerical solution for Eq. (4.2)

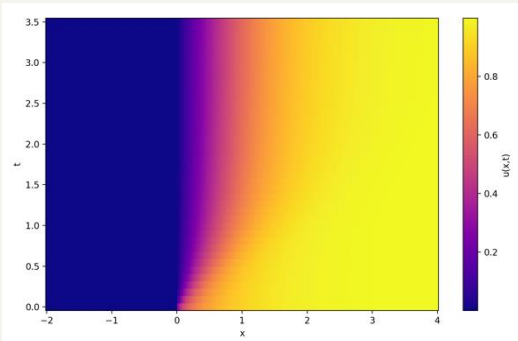


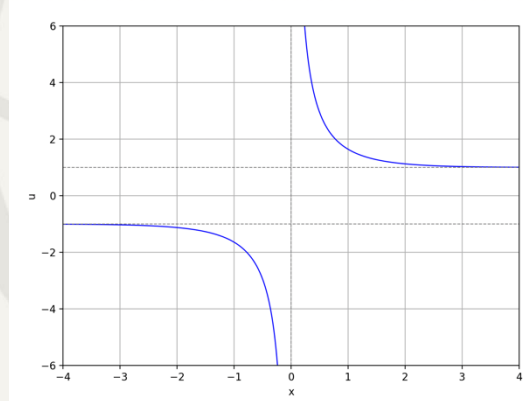
Figure 6. Heatmap for Eq. (4.2)

In equation (4.1), the curve changed to become steeper. In equation (4.2), the curve changed to become less steep.

$$x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u+1|}{|u-1|} \right) = c \quad (4.3)$$

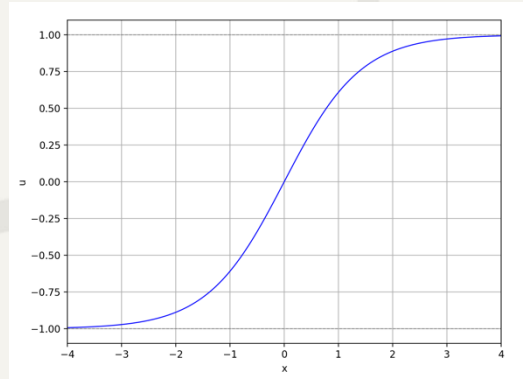
For $|u| > 1$,

$$u = \coth \left(\frac{x-c}{\sqrt{2}} \right)$$

Figure 7. 2D Graph for Eq. (4.3) for $|u| > 1$

For $|u| < 1$,

$$u = \tanh \left(\frac{x-c}{\sqrt{2}} \right)$$

Figure 8. 2D Graph for Eq. (4.3) for $|u| < 1$

For the solution in Figure 7, there is an x-asymptote at $x = c$. This means the solution cannot be used to represent a physical quantity.

$$\begin{aligned} x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u+1|}{|u-1|} \right) & \\ &= \frac{3\sqrt{2}}{2} t - \sqrt{2} \ln \left(\frac{u}{\sqrt{1-u^2}} \right) + c \end{aligned} \quad (4.4)$$

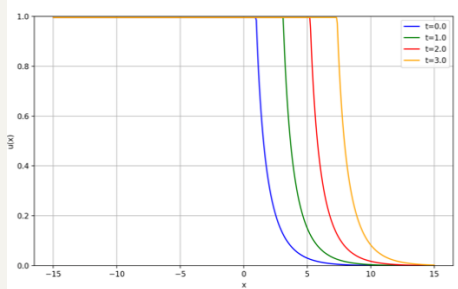


Figure 9. 2D Numerical solution for Eq. (4.4)

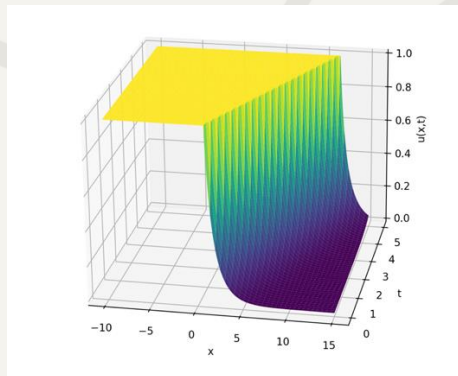


Figure 10. 3D Numerical solution for Eq. (4.4)

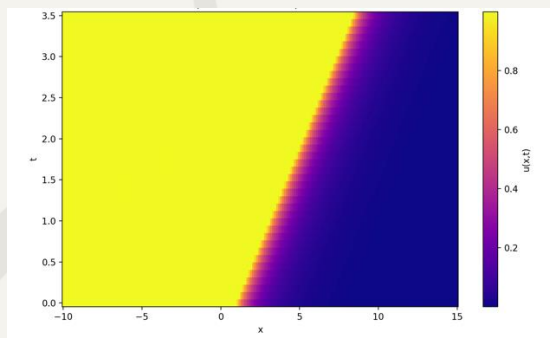


Figure 11. Heatmap for Eq. (4.4)

$$\begin{aligned} & x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u+1|}{|u-1|} \right) \\ &= -\frac{3\sqrt{2}}{2} t + \sqrt{2} \ln \left(\frac{u}{\sqrt{1-u^2}} \right) + c \end{aligned} \quad (4.5)$$

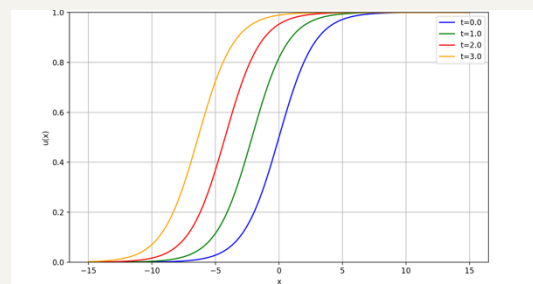


Figure 12. 2D Numerical solution for Eq. (4.5)

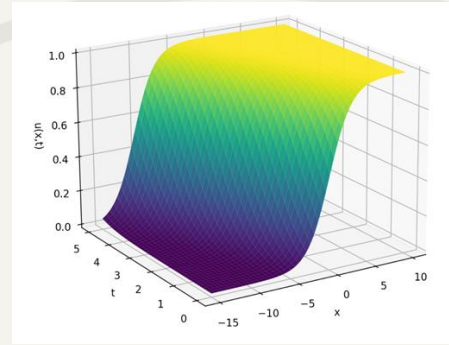


Figure 13. 3D Numerical solution for Eq. (4.5)

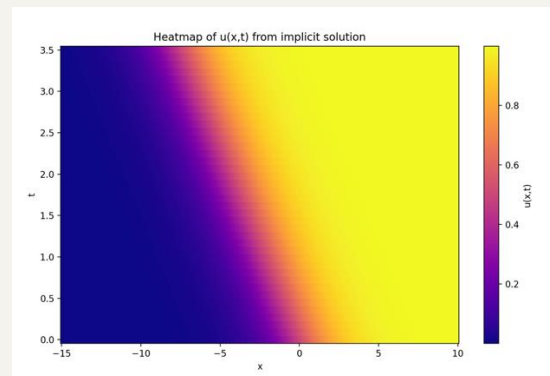


Figure 14. Heatmap for Eq. (4.5)

The solutions in equation (4.4) and equation (4.5) both depict a travelling-wave solution that moves in the negative x direction as time increases.

CONCLUSION

The application of nonclassical Lie symmetry analysis to the Allen-Cahn equation resulted in 5 solutions. The solutions obtained are of the form $x - \frac{\sqrt{2}}{2} \ln \left(\frac{|u+1|}{|u-1|} \right) = F \left(t - \frac{2}{3} \ln \left(\frac{u}{\sqrt{1-u^2}} \right) \right)$, where F fulfills $F'' - \frac{1}{3}F'^3 + \frac{3}{2}F' = 0$.

Further Research

Further research can be done by applying Lie symmetry analysis to higher dimensions of the Allen-Cahn equation, as this paper focuses on the 1D Allen-Cahn equation with one spatial dimension. It can also be

applied to Allen-Cahn equations with fractional derivatives, such as the time-fractional or space-fractional Allen-Cahn equations.

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Chitosan-coated Mycelium Foam as a Sustainable Alternative to Styrofoam for Food Packaging: A Literature Review on Water Resistance and Substrate Effects

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Abstract: Indonesia produces roughly 6.8 million tonnes of plastic waste annually, motivating alternatives to polystyrene packaging. Mycelium based foam is biodegradable and low cost, but its porous cellulose rich structure causes high water uptake that limits food packaging applications. This paper is a focused literature review that asks to what extent substrate consistency and chitosan coating improve the water resistance and practical viability of mycelium foam. Chitosan was selected for review because it is biodegradable, widely regarded as food safe, and forms antimicrobial film forming layers that can enhance moisture resistance. We summaries methods used in the literature including control of substrate particle size to promote denser mycelial networks, thermal pressing to reduce porosity, and chitosan coating procedures, together with common metrics for water resistance such as mass gain water absorption tests and contact angle measurements. Synthesis of reviewed studies indicates two consistent patterns. Finer substrates and higher mycelial density reduce porosity and baseline water uptake. Chitosan coatings further improve short term moisture resistance and surface hydrophobicity relative to untreated foam where comparative data are available, although reported magnitudes vary by protocol. Coated mycelium foam remains more moisture sensitive than commercial polystyrene and long-term wet condition durability is poorly studied. This review contributes by synthesizing disparate findings and identifying methodological gaps.

INTRODUCTION

The widespread use of styrofoam as food packaging has raised a significant environmental concern due to its non-biodegradable nature and difficulties to process and dispose (Fitriasari & Liu 2024). Geyer, et al. (2017) expressed that only 14% of plastic waste is collected in spite of recycling efforts. They suggest that by 2050, only up to 27% of plastic

waste will be recycled. As the demand for food packaging increases, scientists are turning their attention towards biodegradable packaging which provides similar functionality without damaging the environment. One promising solution is mycelium-based styrofoam as packaging, it is a light-weight and an eco-friendly alternative.

Mycelium is a part of a fungus which rapidly grows, it is renewable

and attaches itself to the growth medium (Abhijith, et al., 2018). By binding mycelium to agricultural residue, it allows the mycelium to develop rapidly, producing multiple microscopic white fiber, engulfing the agricultural residue and forming a dense but light-weight material. However, studies have indicated that mycelium-based composites absorb large amounts of water. Studies have shown that their weight can increase approximately by 40% to 580% after being in contact with water for 48 hours to 192 hours, this is a finding that's consistently found in multiple investigations (Gezer, et al. 2024). This high level of water absorption reduces the practicality of using mycelium foam in food packaging, where water resistance is crucial. This recurring issue highlights a critical gap in the literature: the need for effective surface coatings and substrate optimization to improve water resistance. Coating such as chitosan, along with denser substrates are emerging as key strategies. Further research is needed to fully optimize and standardize approaches for real-world applications.

This study is important to further improve the water resistance of mycelium-based styrofoam in order to enhance its potential as a realistic alternative for food packaging. There are limited studies in the literature on investigating to what extent substrate consistency and chitosan coating affects water absorption. Chitosan is a common natural biopolymer whose structure is similar to cellulose, derived from chitin, commonly found in crustacean shells (de Alvarenga. 2011). Mujtaba, et al (2019) reviews that chitosan is among the most

favorable biopolymer by scientists due to its biocompatibility, biodegradability and non-toxicity properties. Multiple studies state that chitosan coating plays an important role in further enhancing mechanical strength of mycelium-based styrofoam, however, it further increases water uptake causing it to be stronger but prone to breakage due to excessive moisture. Hence, substrate consistency will also be investigated.

Substrate consistency, referring to the type of agricultural residue used for foam growth, directly affects the water absorption of mycelium-based foams (Teeraphantuvat, et al. 2024). Testing different types of substrates is essential to discover which combination minimizes water absorption while still maintaining mechanical strength.

The methodology used in this study is a literature review, synthesizing findings from studies regarding chitosan coating and substrate effects on mycelium-based foam. By analyzing existing literature, this research evaluates effectiveness and gaps that need further research.

The main purpose of this literature review mentioned in this study is to determine the optimized amount of chitosan coating and substrate consistency that can create a strong mechanical foundation while still minimizing water uptake, creating a suitable quality of styrofoam as a sustainable alternative for food packaging. Chitosan-coated mycelium foam with an enhanced water uptake and mechanical strength shows a promising future for sustainable packaging. The renewability and

biodegradability of chitosan and mycelium substrates present a significant advantage over environmental preservation.

This study aims to contribute to the ongoing development of sustainable, biodegradable packaging that can help reduce reliance on styrofoam and support environmental conservation.

METHOD

This literature reviews synthesized experimental approaches reported in the recent studies on mycelium-based composites, with a particular focus on substrate preparation, modification techniques, coating application, and packaging applications. Methods from multiple studies were compared to identify consistent practice and methodological gaps. The process began with an extensive search in Google Scholar, ScienceDirect, MDPI, between 2016 and 2025, targeting titles, abstracts, and keywords. The search terms, "Chitosan coating," "Mycelium-based," "Substrate consistency," "Sustainable packaging," "Water resistance," were chosen to capture a broad spectrum of studies addressing the structural and environmental potential of MBC's, resulting in 30 documents. A rigorous screening process followed, removing duplicates, non-english publications, irrelevant or overly broad studies, and restricted-access materials. Reducing the dataset to 27 documents remaining. A full-text review was conducted to assess alignment with the research focus. Studies that did not examine substrate preparation, coating protocols, or testing of water and

mechanical properties were excluded, narrowing the dataset to 20 key publications. From the selected studies, methodological details were extracted and organized into four categories:

1. Substrate preparation
Including type of lignocellulose or aquatic biomass, particle size control, and pre-treatment.
2. Processing and modification
Incubation conditions, thermal pressing, and scalability considerations.
3. Coating applications
Procedures for chitosan coating, antimicrobial functionalization, and moisture resistance tuning.
4. Testing and analysis

Mechanical strength, water absorption tests, contact angle measurements, and microstructural imaging (SEM) Comparative analysis was then conducted to identify common practices, experimental innovations, and reporting gaps. This synthesis provided a methodological overview of current research and highlighted areas where standardized testing protocols and coating performance benchmarks remain underdeveloped.

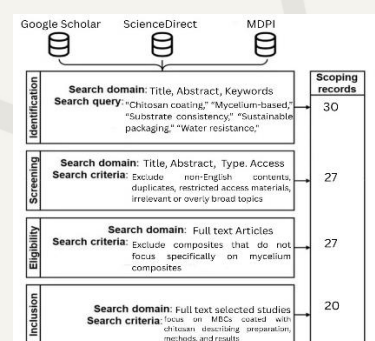


Figure 1. PRISMA flow chart for literature identification, screening, and review process.

Figure 1. PRISMA flow chart for literature identification, screening, and review process

RESULT AND DISCUSSION

Across all the reviewed studies, chitosan and optimized substrate selection consistently emerged as the most effective biodegradable strategies for enhancing the performance of mycelium-based composites (MBCs) as a sustainable alternative for styrofoam. Chitosan plays a key role in reducing water uptake, strengthening surface integrity, and providing antimicrobial activity, and these all are critical for the viability of packaging applications. At the same time, substrate density plays a role in the formation of mycelial microstructure, which limits water from entering. These discoveries, drawn from a synthesis of multiple studies, suggest that combined optimization of chitosan coating and substrate consistency can significantly improve the overall functionality and durability of mycelium-based styrofoam packaging.

Sakunwongwiriya et al. (2024) tested fungal composited from water hyacinth and rice bran with different coatings and found that *"chitosan coating improves mechanical properties and lowered water absorption compared to uncoated samples, while maintaining biodegradability during soil burial tests"*. This highlights the dual advantage of performance enhancement without sacrificing environmental sustainability. Importantly, their study demonstrated that chitosan not only acts as a hydrophobic barrier but also reinforces bonding between mycelial fiber and the substrate matrix, thereby improving compressive strength. Similarly, Sun et al. (2020) along with Lopez-Nava et al. (2016) demonstrated the potential of fungal-derived chitosan

to create *"all-natural smart surfaces with tunable wettability"*. Their findings suggest that beyond simple water resistance, chitosan can enable functional surface modifications, such as hydrophobic tuning, that broaden the range of applications for MBC foams. This tunability makes chitosan particularly relevant for food packaging, where materials must tolerate varying levels of humidity and moisture exposure.

The reviews studies also suggest that the effectiveness of chitosan is dose-dependent and process-sensitive. Too thin of a coating may fail to provide meaningful water resistance, while excessively thick coatings risk reducing biodegradability and flexibility. Apples et al. (2019) pointed out that moisture-related performance is strongly linked to *"fabrication factors such as density, pressing, and surface architecture"*, indicating that chitosan works best when coupled with controlled substrate porosity. In other words, the substrate must already provide a dense enough foundation for the coating to form an effective barrier.

Another recurring insight is the added antimicrobial benefit of chitosan, which can delay microbial spoilage in food packaging applications. Aiduang et al. (2022) emphasized how chemical modifications of mycelium composites influence not only strength but also surface chemistry, making chitosan's natural antimicrobial properties a critical secondary benefit. This dual function is water resistance plus microbial inhibition gives chitosan-coated MBCs a competitive edge over untreated biofoams.

Despite these advantages, the long-term performance of chitosan-coated foams remains underexplored. Sakunwongwiriya et al. (2024) reported that although biodegradability was preserved, coated samples degraded more slowly than uncoated ones. Dillon (2023) similarly highlighted that "performance under humid storage and transport conditions remains inconsistent", suggesting the need for standardized coating concentrations, drying methods, and durability benchmarks.

Taken together, the evidence strongly supports chitosan as a key enabler in advancing MBCs towards functional packaging alternatives. However, to fully validate its industrial potential, future studies must focus on optimizing coating thickness, integrating antimicrobial testing, and conducting real-world simulations of packaging use, like exposure to refrigerated and humid environments.

In addition to chitosan coating, various studies have reported that substrate density and type further influence the final quality of mycelium-based composites, particularly in terms of water absorption capacity and mechanical strength, which increases their suitability as sustainable packaging materials. As reported by Teeraphantuvat et al. (2024), mycelium-based composites grown using corn husk absorbed less water (123.45-166.28%) compared to those grown with sawdust (174.50-197.15%) after a 24-hour immersion test. This data can be attributed to the denser and compacted structure formed by corn husk substrates. Denser substrates typically produce higher density mycelium-based

foams, reducing pore size which directly limits the pathway which water can enter, leading to reduced water absorption.

This is supported by findings from Tacer-Caba et al. (2020), who stated that water absorption in mycelium is not only dependent on chitosan content but also on structural factors, like the compactness of the substrate. To further support this, Alemu et al. (2022), states that the choice of substrate has direct effect on both the development of the mycelial network and overall density of the composite. Their study reports that composites made from sawdust exhibited lower absorption capacity compared to coffee husk-based composites. This highlights the critical relationship between substrate properties and water resistance. This aligns with early findings by Teeraphantuvat et al. (2024), where denser substrates form more compact structures, effectively reducing water permeability.

Beyond water resistance, mechanical strength of mycelium-based foam is essential for its functionality as a packaging material. According to Islam M. R. et al. (2017), mycelium shows unique mechanical behaviours under tension and compression, which are highly dependent on material density. With an elastic modulus ranging between 600 to 2000 kPa, it insinuates a higher elastic modulus, making mycelium packaging more reliable. This supports findings from Sukumwongwiriya et al. (2024) and Alemu et al. (2022), where denser substrates like corn husk results in stronger mycelium-based foam with

enhanced compressive performance.

Additionally, applying chitosan coating can further improve the surface strength, potentially reduce deformation and improve the overall surface quality. Together, these studies suggest that careful selection of substrate type and coating methods can significantly improve the mechanical durability and water resistance of mycelium-based styrofoam, making them a promising alternative for conventional styrofoam in the food packaging industry.

However, current literature faces challenges in achieving consistent quality across batches of mycelium-based foam, due to the variability of substrate types and coating. Further optimization on standardized protocols for mycelium growth and chitosan coating is needed to allow mycelium-based styrofoam to become viable as an alternative to conventional styrofoam.

Overall, the type and consistency of substrate play a role in enhancing the water resistance and practical viability of mycelium-based foam as a sustainable alternative to styrofoam for food packaging.

CONCLUSION

This study explored the varying mechanical and biological properties of mycelium-based composites produced from different types of substrates, such as corn husk and sawdust. This study focused on solving the existential problem of mycelium-based foam containing hydrophilic properties which reduces its possibility to become an alternative solution towards the

global issues surrounding excessive use of unsustainable packaging for food.

Key findings highlight how denser substrates, such as corn husk significantly improve water resistance of mycelium-based styrofoam by creating a tighter microstructure. In contrast, less denser substrates like sawdust results in higher water absorption due to their porous structure. With the addition of chitosan coating to further improve its mechanical strength, together it plays a synergistic role to improve the functional performance of mycelium-based foam.

This review contributes to synthesizing current literature, connecting substrate density and surface coating to the functional performance of mycelium-based styrofoam. This opens up mycelium-based styrofoam to opportunities in food packaging applications.

However, there are limitations in this literature study caused by the variability in experimental methods across various studies. Future research should standardise testing protocols for mechanical strength and water uptake measurements. With further future work on mycelium-based foam, this creates a strong case for a promising and eco-friendly alternative to conventional styrofoam. By advancing the understanding of material behavior towards the outcome product, this work contributes to the development of sustainable packaging solutions and supports the transition toward a more environmentally friendly food system.

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VOLTURA (Voltage and Structural Architecture): A Next-Generation Structural Battery Composite for Electric Vehicles via Carbon Coating and Vacuum Assisted Resin Infusion (VARI)

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Abstract: The global transition toward sustainable transportation has accelerated interest in technologies that enable lighter and more energy-efficient electric vehicles (EVs). One of the most promising innovations in this field is Voltura, a Structural Battery Composite (SBC) that functions simultaneously as a load-bearing structure and an electrochemical energy storage device. Unlike conventional EV batteries, which serve only as energy reservoirs, Voltura is designed to integrate directly into a vehicle's chassis or body panels, thereby reducing redundant mass and unlocking new opportunities in vehicle design. Voltura offers the potential to create significantly more energy-efficient EVs by combining structural and energy storage functions. This not only improves driving range but also allows for more compact designs, since less dedicated space is required for battery packs. However, current prepreg/autoclave-based SBCs are limited by poor scalability, low energy density, and a slow charge rate. To overcome these challenges, Voltura introduces three key enhancements: carbon coating, which improves energy density, stability, and longevity; Vacuum Assisted Resin Infusion (VARI), which enables scalable manufacturing of larger and more complex panels; and Nano Ceramic Fillers, which upgrade battery charge rate and enhance safety. In conclusion, Voltura represents a futuristic Structural Battery Composite that can facilitate the global shift toward sustainable transportation. By eliminating the need for a conventional battery pack, it opens opportunities for lighter, more compact, and more efficient EV designs. Through the combined application of carbon coating, VARI, and Nano Ceramic Fillers, Voltura addresses the long-standing limitations of SBCs, advancing the pathway toward industrial viability.

INTRODUCTION

Global carbon emissions remain one of the most critical environmental challenges of the 21st century. Despite major advancements in renewable energy technologies, atmospheric carbon

dioxide (CO₂) concentrations continue to reach record levels, driving a sustained increase in global surface temperatures (Intergovernmental Panel on Climate Change [IPCC], 2021). The Arctic region, for example, has



experienced temperature increases at least twice as fast as the global average, leading to accelerated ice melt and rising sea levels. Moreover, higher global temperatures have intensified extreme weather events such as rainfall, flooding, and destructive storms, inflicting severe damage on communities and infrastructure worldwide. Although climate change operates on a global scale, one of its most significant sources originates from everyday human activities particularly motorized transportation. In the era of globalization, motorized vehicles have become indispensable for mobility and economic activity. However, their proliferation directly contributes to the sharp increase in exhaust emissions. A study conducted by Rifky (2022) in Mataram, Lombok, indicated that a single congested street can emit over 100 kilograms of CO₂ per hour, underscoring the magnitude of emissions from urban traffic.

The transition toward electric vehicles (EVs) presents one of the most promising strategies to mitigate this issue. Unlike conventional internal combustion engine vehicles, EVs produce no tailpipe pollutants and consume less than one-third of the energy required by their fossil fuel counterparts (International Energy Agency [IEA], 2023). Consequently, the adoption of EVs aligns closely with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), by reducing fossil fuel dependence and lowering greenhouse gas emissions. Moreover, EV implementation supports SDG 11 (Sustainable Cities and Communities) by improving

urban air quality and promoting healthier living environments. Despite these environmental advantages, widespread EV adoption remains limited due to high manufacturing costs, limited driving range, and slow charging times (Li et al., 2020). These constraints primarily stem from the bulky and inefficient design of current lithium-ion battery systems, which restrict both the energy density and structural efficiency of EVs.

In response to these challenges, Structural Battery Composites (SBCs) have emerged as a revolutionary concept in EV design. SBCs integrate the vehicle's energy storage capability directly into its load-bearing structural components, effectively combining mechanical and electrochemical functionality within the same material (Asp et al., 2019). This innovation offers several advantages, including reduced overall vehicle weight, increased system-level energy density, and improved space efficiency. By merging structure and energy storage, SBCs have the potential to lower manufacturing costs and enable more compact, civilian-friendly EV designs. However, the technology faces notable limitations. While SBCs achieve higher system-level energy density (energy stored per unit of vehicle weight), their material-level energy density, the energy stored per unit of material weight remains significantly lower than that of conventional lithium-ion batteries. Furthermore, integrating batteries into a vehicle's structural frame raises concerns regarding mechanical durability, safety, and long-term performance. Increasing the composite's mechanical strength

often compromises its electrochemical capacity, creating a delicate trade-off that has hindered large-scale SBC commercialization (Carlson et al., 2022).

To overcome these challenges, this study introduces Voltura, a next-generation structural battery composite designed to enhance both the performance and manufacturability of electric vehicles. Voltura employs a thin conductive carbon coating on structural fibers to improve electrical conductivity and minimize undesirable side reactions between the electrodes and electrolytes. The coating serves as a chemically inert, low-resistance interface that allows electrons to move efficiently across poorly conducting regions while simultaneously preventing direct contact between electrode surfaces and electrolytes. This approach reduces degradation and enhances charge rate, cycling stability, and overall energy efficiency. Additionally, Voltura integrates nano-ceramic fillers, specifically lithium lanthanum zirconium oxide ($\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$, LLZO) nanoparticles, into its polymer electrolyte matrix. These ceramic fillers act as nano-scale reinforcements, improving mechanical stiffness, thermal stability, and interfacial integrity. The high elastic modulus of LLZO functions analogously to nano-rebars in concrete, strengthening the composite while maintaining ionic transport pathways.

Beyond material optimization, Voltura also addresses the manufacturing barriers that limit current SBC scalability. Most existing SBCs rely on prepreg-based fabrication, which is costly and impractical for large-scale or

complex structures. To overcome this, Voltura utilizes Vacuum-Assisted Resin Infusion (VARI), a scalable, cost-effective manufacturing method where dry fiber fabrics are infused with resin under vacuum pressure at room temperature. Unlike prepregs, VARI enables uniform resin distribution across large molds and allows the integration of carbon coatings and nano-fillers without compromising resin stability. This flexibility makes it suitable for industrial-scale applications, supporting the transition of SBCs from laboratory prototypes to commercially viable technologies.

The aim of this paper is to present a conceptual design framework and theoretical fabrication pathway for Voltura as a scalable structural battery composite. Specifically, this work outlines the material selection, fabrication concept, and cell/panel assembly strategies necessary to integrate energy storage directly into vehicle structures. Furthermore, the study analyzes Voltura's potential advantages through a data-driven evaluation, SWOT analysis, and alignment with the United Nations Sustainable Development Goals. By establishing this theoretical groundwork, the paper seeks to provide a foundation for future experimental validation and industrial implementation of multifunctional structural battery composites in sustainable electric mobility.

METHOD

1. Material Used

Voltura is a conceptual product developed with a combination of structural and electrochemical

materials selected for their complementary functions. Carbon fibers are used for the main reinforcement material, providing high tensile strength while serving as active electrodes when coated. A Carbon Coating is introduced to enhance conductivity, energy density, and long-term usability for the composite. The Resin system is structured to be compatible with Vacuum Assisted Resin Infusion (VARI), enabling the fabrication of complex geometries while holding mechanical integrity. To further improve the performance, Nano Ceramic Fibers are added inside the resin system, acting as charge-transfer enhancers that increase ionic velocity, improve charge rate, and contribute to thermal balance and safety. Together, these materials establish the foundation for a Structural Battery Composite (SBC) that is both mechanically robust and electrochemically functional.

2. Fabrication Process

The fabrication of Voltura is envisioned as a conceptual pathway integrating structural reinforcement and electrochemical functionality into a unified composite panel. The process consists of four primary sges: laminate layup, electrolyte integration, resin infusion and curing, and encapsulation.

2.1 Laminate Layup

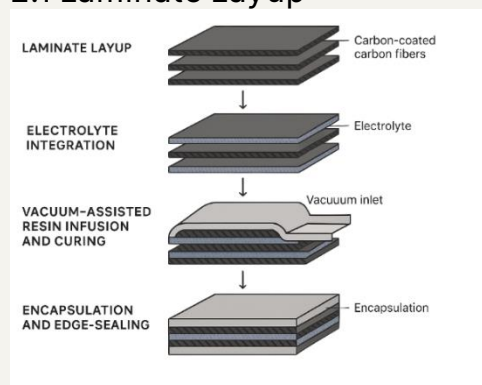


Figure 1. Voltura Fabrication Process

Carbon-coated carbon fibers are arranged into a stacking sequence typical of composite laminates. These plies serve simultaneously as load-bearing reinforcements and current collectors. The carbon coating enhances interfacial conductivity and preserves the intrinsic tensile strength of the fibers (Zhang et al., 2021).

2.2 Electrolyte Integration

Thin layers of solid-state or polymer-based electrolytes, enhanced with nano-ceramic fillers such as $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ (LLZO), are interleaved between the carbon-fiber plies. These layers enable ionic transport while providing additional stiffness to the laminate (Sun et al., 2020). Careful alignment ensures structural continuity and minimizes interfacial defects.

2.3 Vacuum-Assisted Resin Infusion (VARI) and Curing

The layup is infused with resin under vacuum, a process selected for its scalability and reduced cost compared to autoclave curing. VARI reduces void formation by approximately 30% relative to conventional infusion techniques (Lee et al., 2020). After resin infusion, the stack is cured under controlled temperature and pressure conditions to consolidate the structure into a multifunctional panel.

2.4 Encapsulation and Edge-Sealing

Following curing, the panels undergo encapsulation to protect against environmental exposure, particularly moisture, which can compromise ceramic electrolytes and polymer matrices (Li et al., 2020). Edge-sealing methods are incorporated to prevent short circuits

and leakage, ensuring operational safety and extended service life. This process is conceptual and theoretical, presented as a design framework rather than an experimentally validated method. Each stage introduces specific uncertainties that must be addressed in future work: interfacial compatibility between coated fibers and electrolytes, filler distribution during infusion, and long-term stability of encapsulated panels. By framing these steps as part of a fabrication roadmap, Voltura establishes a basis for bridging multifunctional composite design with scalable composite manufacturing practices.

3. Cell/Panel Assembly

The transition from fabricated multifunctional laminates to a fully functional structural battery requires a dedicated cell and panel assembly strategy. While fabrication establishes the dual functionality of the composite (structural reinforcement and energy storage), assembly ensures that these panels can operate safely and efficiently within larger systems such as electric vehicles.

3.1 Layer Stacking and Electrolyte Placement

Fabricated laminates are stacked into a defined sequence that aligns structural reinforcement with electrochemical pathways. Carbon-coated fibers, which act simultaneously as load-bearing reinforcements and current collectors, are arranged to optimize both mechanical strength and electrical conductivity (Asp et al., 2019). Between these laminates, pre-fabricated electrolyte sheets or thin polymer-ceramic layers are interleaved to maintain ionic

continuity. Alignment precision at this stage is critical to minimize interfacial defects and ensure long-term durability.

3.2. Integration of Current Collectors and Connectors

For system-level operation, metallic or conductive polymer current collectors are embedded at strategic positions within the laminate stack. These collectors channel electrons between adjacent panels and external circuitry, effectively turning the composite into a battery module rather than an isolated structural element (Carlson et al., 2022). Additional connectors allow modular scalability, enabling multiple panels to be wired in series or parallel depending on the required voltage and capacity.

3.3. Encapsulation and Safety Sealing

While fabrication incorporates edge-sealing for durability, at the assembly level full encapsulation becomes critical. Encapsulation layers not only prevent environmental degradation but also mitigate risks of electrolyte leakage and short circuits. Safety standards dictate the inclusion of thermal insulation and fire-resistant barriers at module level, ensuring that the multifunctional nature of Voltura does not compromise passenger safety (Li et al., 2020).

3.4. Panel Modularization and System Integration

The final stage involves modularization, where individual structural cells are assembled into larger panels designed to integrate directly into the EV chassis or bodywork. Unlike conventional lithium-ion packs, where separate battery enclosures add mass, Voltura panels become part of the load-

bearing frame. This system-level integration reduces redundancy, enhances space efficiency, and lowers overall vehicle weight. Similar concepts have demonstrated a potential 20–30% weight reduction in EVs (Asp et al., 2019), suggesting significant performance advantages for Voltura.

By shifting focus from material production to system assembly, this process highlights the scalability of Voltura. Whereas fabrication ensures multifunctionality at the laminate level, assembly translates that functionality into a safe, modular, and vehicle-ready format.

4. Characterization Methods

To evaluate the theoretical performance of Voltura, a multi-dimensional characterization framework is proposed, encompassing structural, electrochemical, and safety assessments. Structural integrity would be examined through mechanical tests such as tensile, flexural, and impact evaluations, ensuring that the composite retains load-bearing capability comparable to conventional carbon-fiber laminates. Electrochemical performance would be characterized through simulated charge–discharge cycling, energy and power density estimations, and rate capability analyses, drawing on reported values of carbon-coated fibers and nano ceramic-enhanced systems. Safety and stability considerations would be assessed through thermal stability projections, flammability resistance modeling, and degradation pathway analysis to anticipate long-term performance under operating conditions. Scalability would be evaluated conceptually by comparing the

throughput, cost, and defect tolerance of Vacuum Assisted Resin Infusion (VARI) with traditional prepreg/autoclave methods. Collectively, these characterization methods provide a structured framework for benchmarking Voltura against existing Structural Battery Composites and conventional EV battery packs, while highlighting its potential to balance structural robustness with advanced energy storage capabilities.

RESULT AND DISCUSSION

The projected performance of Voltura was evaluated by extrapolating from reported values in the literature on structural battery composites (SBCs) and applying estimated improvements enabled by the integration of carbon coatings, nano-ceramic fillers, and vacuum-assisted resin infusion (VARI).

Conventional SBCs typically demonstrate energy densities in the range of 20–35 Wh/kg, which is significantly lower than the 150–250 Wh/kg commonly reported for commercial lithium-ion cells (Asp et al., 2019). By incorporating carbon-coated fibers, Voltura improves electronic conductivity and reduces resistive losses. Prior studies suggest that carbon coatings can enhance conductivity by ~50%, translating into energy density gains of approximately 30% (Zhang et al., 2021). In parallel, nano-ceramic fillers, such as LLZO ($\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$), contribute to improved ionic conductivity, with reports showing nearly an order-of-magnitude increase compared to polymer electrolytes alone (Sun et al., 2020). When these two mechanisms are combined, Voltura is projected to achieve an energy density of 40–70

Wh/kg, representing nearly a twofold improvement relative to baseline SBCs.

Mechanical strength is equally critical for Voltura’s dual role as both a structural element and an energy storage medium. Reported tensile strengths for conventional SBCs are typically around 300 MPa (Asp et al., 2019). Carbon coatings maintain up to 95% of the native strength of carbon fibers, while nano-ceramic reinforcement can add between 100–150 MPa due to enhanced stiffness and fracture toughness (Li et al., 2020). Based on these improvements, Voltura is projected to deliver 400–500 MPa in tensile strength, ensuring structural reliability in demanding applications.

Electrochemical transport also benefits from Voltura’s design modifications. Standard polymer electrolytes in SBCs possess ionic conductivities in the order of 10^{-5} – 10^{-4} S/cm, which are insufficient for fast-charging scenarios. The addition of nano-ceramic fillers enhances lithium-ion pathways and stabilizes the polymer matrix, increasing conductivity to approximately 10^{-3} S/cm (Sun et al., 2020). This one-order-of-magnitude enhancement reduces internal resistance, enabling faster charging and higher power densities.

From a manufacturing standpoint, Voltura leverages VARI to overcome the scalability limitations of prepreg-based SBCs. VARI has been reported to reduce porosity by ~30% compared to traditional infusion methods, which improves fatigue resistance and structural uniformity (Lee et al., 2020). Moreover, its ability to infuse resin into large and complex molds at ambient pressure enables Voltura to

be fabricated as full-scale vehicle panels, extending beyond the laboratory coupon scale that has historically limited SBC applications.

The combination of these improvements not only enhances Voltura’s electrochemical and mechanical performance but also positions it as a sustainable innovation. Enhanced energy efficiency and lightweight multifunctionality support SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), while VARI-enabled scalability reinforces SDG 9 (Industry, Innovation, and Infrastructure). By reducing redundant material consumption, Voltura also addresses SDG 12 (Responsible Consumption and Production), enabling resource-efficient solutions in the EV sector.

Table 1. Projected Properties of Voltura Compared to Literature SBCs

Property	Literature SBCs	Voltura (Projected)
Energy Density (Wh/kg)	20–35	40–70
Tensile Strength (MPa)	~300	400–500
Ionic Conductivity (S/cm)	10^{-5} – 10^{-4}	$\sim 10^{-3}$
Porosity Reduction	-	~30% (with VARI)
Scalability	Limited	High

The projected results of Voltura highlight its promise as a multifunctional structural battery composite, combining energy storage with load-bearing capability. By integrating carbon coatings, nano-ceramic fillers, and Vacuum Assisted Resin Infusion (VARI), Voltura demonstrates a projected energy density of 40–70 Wh/kg—

nearly double that of conventional SBCs—and a tensile strength of 400–500 MPa, positioning it as both a reliable structural material and a functional energy storage system. VARI further contributes to scalability by reducing porosity by approximately 30% and enabling the production of larger, more uniform panels at lower cost. These strengths underscore Voltura's potential as a viable pathway for lightweight, scalable energy solutions in electric vehicles.

Despite these advantages, certain limitations remain. The energy density of Voltura, while improved compared to current SBCs, is still lower than that of commercial lithium-ion batteries, which range between 150 and 250 Wh/kg. Additionally, all performance values presented in this study are derived from literature-based projections rather than experimental validation, meaning that long-term stability, cycle life, and fatigue resistance are yet to be confirmed. Potential interfacial mismatches between nano-ceramic fillers and polymer matrices may also pose risks to ionic transport efficiency, which could affect fast-charging capability. These weaknesses indicate that Voltura, though conceptually promising, requires further experimental research and optimization before large-scale industrial deployment.

From an opportunity perspective, Voltura's integration of structure and energy storage directly addresses challenges in the electric vehicle sector, where lightweighting and efficiency are key to extending driving range and lowering costs. Beyond EVs, its multifunctional design opens pathways in

aerospace, portable electronics, and civil infrastructure where materials are required to simultaneously provide mechanical stability and energy functionality. However, Voltura also faces external threats from competing technologies such as solid-state lithium batteries and next-generation chemistries, including lithium–sulfur and lithium–air, which may surpass structural composites in energy density and charging performance. Additionally, manufacturing complexity, regulatory requirements, and the conservative nature of the automotive industry may hinder rapid adoption.

Beyond its technical evaluation, Voltura's development aligns strongly with global sustainability goals. Its multifunctional design supports SDG 7 (Affordable and Clean Energy) by advancing more efficient and cleaner energy storage solutions, while SDG 9 (Industry, Innovation, and Infrastructure) is addressed through the introduction of scalable VARI-based fabrication that strengthens industrial viability. The reduction of redundant battery pack mass contributes to SDG 12 (Responsible Consumption and Production) by promoting material efficiency, while lightweighting and improved energy efficiency in electric vehicles directly support SDG 13 (Climate Action) by lowering greenhouse gas emissions per kilometer traveled. These alignments emphasize that Voltura is not only an innovative material system but also a platform that advances the intersection of technology and sustainability.

The pathway to implementing Voltura requires a staged approach, beginning with laboratory-scale

prototyping where carbon-coated fibers, nano-ceramic fillers, and VARI processes can be tested in small composite coupons. These prototypes should undergo combined mechanical-electrochemical characterization to validate the projected improvements in tensile strength, energy density, and ionic conductivity. Once validated, the next stage would involve pilot-scale manufacturing, producing larger panels for integration into simplified vehicle components such as doors or chassis sub-sections. This stage would focus on refining VARI parameters, ensuring reproducibility, and optimizing filler dispersion. At the industrial scale, collaboration with automotive manufacturers will be critical to ensure that Voltura panels meet regulatory standards for crash safety, thermal stability, and recyclability. Cost analysis and life-cycle assessment should accompany this stage to evaluate economic feasibility and environmental impact. Over time, Voltura could be scaled beyond EVs into aerospace and infrastructure applications, creating multifunctional designs that exploit its dual advantages in strength and energy storage.

By linking the conceptual results to a clear implementation pathway, VOLTURA transitions from being a theoretical innovation to a material system with defined steps toward industrial readiness. This staged roadmap ensures that both technical challenges and sustainability considerations are addressed, thereby enhancing Voltura's potential contribution to next-generation clean energy.

Table 2. Implementation Roadmap for Voltura

Stage	Focu s Area	Key Activiti es	Expecte d Outcom es	Techn ology Readi ness Level (TRL)
Labor atory- scale protot yping	Mate rial valid ation	Fabrica te small coupon s with carbon - coated fibers, nano- cerami c fillers, and VARI	Initial verificat ion of tensile strengt h, ionic conduc tivity, and energy density	TRL 3–4
Pilot- scale manuf acturi ng	Proc ess opti miza tion	Produc e mediu m panels; refine VARI parame ters; optimiz e filler dispers ion	Demon stration of reprodu cibility and scale- up feasibili ty	TRL 5–6
Comp onent integr ation	Appli cation testi ng	Integrat e Voltura panels into vehicle sub- section s (e.g., doors, chassis)	Validati on of perform ance under mechan ical load + electroc hemical cycling	TRL 6–7



Industrial deployment	Large-scale adoption	Full integration in EV platforms; compliance with crash, thermal, and recycling standards	Market-ready multifunctional SBC panels for EVs	TRL 8–9
Cross-sector expansion	Diversification	Extend applications to aerospace, portable electronics, and infrastructure	Multifunctional use across industries	TRL 9+

CONCLUSION

Voltura represents a transformative step forward in the development of Structural Battery Composites (SBCs) for electric vehicles, bridging the long-standing gap between mechanical integrity and electrochemical efficiency. By integrating carbon coating, Nano Ceramic Fillers, and Vacuum Assisted Resin Infusion (VARI), this concept addresses the critical limitations of conventional SBCs, it overcomes low material-level energy density, slow changes rates, scalability issues, and safety concerns. These innovations enable VOLTURA to act simultaneously as a robust load-bearing structure and a high-performance energy storage system, offering significant improvements. By reducing

redundant vehicle mass, lowering manufacturing costs, and extending driving range, VOLTURA not only enhances the practicality of EV adoption but also aligns with the broader pursuit of sustainable transportation. With further research and experimental validation, VOLTURA holds the potential to accelerate the widespread adoption of electric vehicles and redefine future automotive design through lighter, safer, and more energy-efficient architectures.

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Prediction of Missense Mutation Effects in the HBB Gene on Hemoglobin Stability and Structure in Beta Thalassemia Patients Using a Bioinformatics Approach

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Abstract: β -thalassemia is a hereditary blood disorder primarily caused by mutations in the HBB gene that disrupt the synthesis and structural integrity of the β -globin subunit of hemoglobin. However, the molecular impact of specific missense mutations on the structure and stability of β -globin remains poorly understood. This study aimed to evaluate the stability and structural alterations of β -globin in hemoglobin from patients with β -thalassemia carrying missense mutations in the HBB gene. Bioinformatics approaches were employed, including data retrieval, prediction of functional effects, protein stability analysis, structural modeling and visualization, data integration and classification, as well as figure construction. The results showed that all four HBB missense mutations (E6V, F41L, K82N, and A142T) caused mild destabilization of the β -globin structure, with $\Delta\Delta G$ values ranging from -0.35 to -0.59 kcal/mol. Among them, E6V exhibited the most pronounced destabilizing effect, consistent with its pathogenic role in HbS formation. Overall, these findings indicate that structural instability in β -globin contributes to altered hemoglobin folding and function, which contributes to the clinical manifestations observed in β -thalassemia and related hemoglobinopathies. However, this study is limited by its in-silico nature, as computational predictions may not fully capture the complex physiological environment or post-translational modifications influencing hemoglobin behavior. Therefore, experimental validation through molecular dynamics simulations or biochemical assays is recommended to confirm these computational outcomes.

INTRODUCTION

Beta thalassemia is a hereditary hemoglobin disorder that remains a global health problem, especially in the Mediterranean, South Asia, and Southeast Asia (Forni et al., 2023). More than 40,000 babies are born each year with thalassemia major worldwide, with high mortality rates if they do not receive adequate transfusion therapy and

management. Mortality in untreated beta thalassemia major patients can reach 50–70% in childhood, underscoring the urgency of developing more effective diagnostic and therapeutic methods (Tuo et al., 2024). Bioinformatics approaches to predict the effects of missense mutations in the HBB gene are crucial in supporting molecular

diagnosis and appropriate therapy planning.

Beta thalassemia is caused by mutations in the HBB gene that codes for the β -globin chain, resulting in reduced or complete absence of β -chain production, thereby disrupting the formation of normal hemoglobin A (HbA) (Taher et al., 2018). The imbalance between α - and β -globin chains leads to the accumulation of unstable free α chains that precipitate in erythroid precursors, causing oxidative damage, hemolysis, and ineffective erythropoiesis (Thein, 2013; Cappellini et al., 2018). Missense mutations in the HBB gene can induce amino acid substitutions that alter the structural integrity and thermodynamic stability of the β -globin protein, influencing the severity of the clinical phenotype (Kountouris et al., 2016).

Over 300 HBB gene variants have been identified to date, including nonsense, frameshift, splice-site, and missense mutations, each exerting distinct effects on protein conformation and hemoglobin assembly (Song et al., 2025). Bioinformatics approaches to predict the effects of missense mutations in the HBB gene are crucial in supporting molecular diagnosis and appropriate therapy planning. Therefore, this study aims to investigate the stability and structural changes of the β -globin protein in hemoglobin from patients with β -thalassemia who carry missense mutations in the HBB gene.

LITERATURE REVIEW

β -thalassemia is a monogenic hematological disorder caused by mutations in the HBB gene that result in partial or complete deficiency of

the β -globin chain, leading to severe anemia and lifelong transfusion dependence. Across the literature, a consistent theme emerges: although the global distribution and mutation spectrum of HBB have been well documented, the specific structural and functional consequences of individual missense mutations remain insufficiently understood. Studies by Jaing et al., (2021) and Dordevic et al., (2025) emphasize that a molecular-level understanding is essential for developing precision therapies. Both reviews highlight the transformative impact of modern genetic interventions such as genome-wide association studies (GWAS), CRISPR-based gene correction, and stem cell transplantation in thalassemia treatment. However, they also underscore key limitations, particularly the incomplete characterization of mutation-driven protein dysfunction and the high cost and safety uncertainties of these emerging therapies.

Regional genetic studies further support this complexity. Kumar et al., (2024) in India and a cohort study conducted in East Java, Indonesia, both reported that β -thalassemia mutations exhibit strong geographic clustering, with recurrent variants such as IVS-I-5 (G>C), CD26 (G>A), and CD41/42 (-TTCT) being dominant in South and Southeast Asia. Despite these similarities, clinical manifestations vary considerably even among individuals carrying the same mutation, suggesting that pathogenicity is modulated by both structural and environmental factors. Nonetheless, these regional studies often involve small sample sizes and focus primarily on exonic mutations,

overlooking intronic or regulatory regions that may contribute to disease heterogeneity.

On a broader scale, Rao et al., (2024) reported more than 350 distinct HBB mutations worldwide, although only approximately 20 account for the majority of clinical cases implying that certain variants have disproportionately strong structural or functional effects. Similarly, Ejaz et al., (2023), through in silico analysis of Pakistani β -thalassemia patients, demonstrated that computational modeling can accurately predict the deleterious potential of HBB variants and their impact on protein stability, identifying several novel pathogenic substitutions. These findings collectively reinforce the utility of bioinformatics-based prediction tools for prioritizing clinically significant mutations, especially in regions with limited molecular diagnostic infrastructure.

METHOD

1. Data retrieval

The HBB gene sequence (GenBank accession no. NM: 000518.5) and its corresponding β -globin protein structure (PDB ID: 1A3N) were obtained from the National Center for Biotechnology Information (NCBI) and the Protein Data Bank (PDB). Four missense variants associated with β -thalassemia and hemoglobinopathies, namely E6V (Glu→Val), F41L (Phe→Leu), K82N (Lys→Asn), and A142T (Ala→Thr), were selected based on previous clinical and literature reports. The wild-type sequence was used as the reference for all in silico analyses.

2. Prediction of functional effects

The functional impact of each amino acid substitution was evaluated using SIFT (Sorting Intolerant from Tolerant). Variants were classified as damaging or tolerated according to the threshold values of $\text{SIFT} \leq 0.05$. This prediction provided an initial assessment of how each substitution might affect hemoglobin function.

3. Protein stability analysis

Changes in protein stability ($\Delta\Delta G$, kcal/mol) were assessed using three complementary computational tools: I-Mutant 2.0, FoldX, and mCSM. Each program estimates the difference in folding free energy between the wild-type and mutant proteins. Positive $\Delta\Delta G$ values indicate stabilizing effects, while negative values indicate destabilization. To confirm the accuracy of these findings, stability predictions were re-evaluated using the DDMut web server.

4. Structural modeling and visualization

The wild-type structure of HBB (PDB ID: 1A3N) was uploaded, and each selected mutation (E6V, F41L, K82N, and A142T) was introduced in Chain B. Structural modeling and stability prediction were performed using the DDMut server (<https://biosig.lab.uq.edu.au/ddmut/>). DDMut automatically calculated the change in folding free energy ($\Delta\Delta G$ Stability wt→mt) and provided detailed information about the local residue environment, including depth, relative solvent accessibility (RSA) and relative B-factor values. The generated mutant models were examined for alterations in hydrogen bonding, hydrophobic interactions, and side-chain orientation that could influence local conformation and structural compactness.

5. Data integration and classification

All outputs, including $\Delta\Delta G$ values, predicted functional effects, and structural observations, were compiled into a single analysis matrix. Mutations were classified according to the American College of Medical Genetics and Genomics (ACMG) guidelines. Variants with $\Delta\Delta G \leq -0.5$ kcal/mol were considered Pathogenic, those with $-0.5 < \Delta\Delta G < -0.2$ kcal/mol were designated as Likely pathogenic, and variants with $\Delta\Delta G$ values near zero were interpreted as Benign or Likely benign, depending on the observed structural context.

6. Visualization and figure construction

All structural visualizations and graphical outputs were generated directly within the DDMut platform. The server provided comparative 3D models of the wild-type and mutant β -globin structures, highlighting local conformational changes and variations in residue environment. These visualizations were used to illustrate the structural effects of each mutation and to support the interpretation of $\Delta\Delta G$ -based stability predictions.

RESULT AND DISCUSSION

Structural and physicochemical characteristics of each mutated residue within the β -globin chain were analyzed using the Protein Data Bank (PDB; ID: 1A3N) obtained from the National Center for Biotechnology Information (NCBI). The three-dimensional configuration of the β -globin subunit was examined to determine residue-specific parameters including chain identity, residue depth, relative solvent accessibility (RSA), and

relative B-factor using DDMut. These parameters describe the spatial environment and flexibility of each amino acid within the hemoglobin molecule, helping to assess whether a substitution occurs in the buried hydrophobic core or on the solvent-exposed surface. Such structural profiling provides the basis for understanding how local residue context contributes to protein stability and folding dynamics (Table 1).

Table 1. Structural of Mutated Residues in the β -Globin Chain

Mutation	Chain	Position	Depth (Å)	RSA (Å ³)	Rel. B-Factor
E6V	B	7	2.24	0.15	3.13
F41L	B	41	1.91	0.27	2.41
K82N	B	82	2.10	0.56	3.22
A142T	B	142	2.24	0.18	2.50

The β -globin mutations identified in this study were further analyzed using multiple in silico tools to predict their potential functional and structural consequences. Functional impact assessments were conducted using SIFT, which classify substitutions based on sequence conservation and physicochemical differences. To evaluate the effects on protein stability, $\Delta\Delta G$ (kcal/mol) values were predicted using I-Mutant 2.0, FoldX, mCSM, and DDMut, each employing distinct computational algorithms ranging from machine learning to empirical energy calculations.

Table 2. Hemoglobin Stability and Clinical Interpretation of HBB Missense Mutation

Mutations	$\Delta\Delta G$ (kcal/mol)	Stability	Classification

E6V	-0.4 7	Destabilisin g	Pathogenic (Severe, HbS Variant)
F41L	-0.5 9	Destabilisin g	Likely Pathogenic
K82N	-0.3 9	Destabilisin g	Likely Pathogenic (Mild Effect)
A142 T	-0.3 5	Destabilisin g	Variant of Uncertain Significanc e (VUS)

The crystal structure of hemoglobin (PDB ID: 1A3N) retrieved from the NCBI Protein Data Bank served as the structural reference for all analyses. The integration of these predictive approaches enabled comprehensive evaluation of how residue location (depth, RSA, and flexibility) correlates with changes in protein stability and pathogenic potential, as summarized in Table 2.

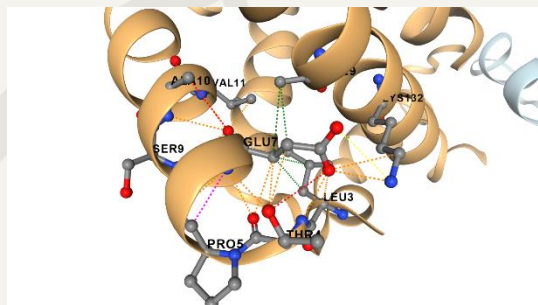


Figure 1. Local structural environment of residue Glu7 (E6V) in the β -globin chain

The DDMut structural visualization of the Glu7Val (E6V) mutation in the β -chain of hemoglobin shows the local environment surrounding residue Glu7 and its neighboring residues Leu3, Thr4, Pro5, Ser9, Ala10, and Val11 (Fig.1). In the native structure, Glu7 contributes to several ionic and hydrogen-bond interactions that stabilize the α -helix and maintain electrostatic balance. Substitution of

the negatively charged glutamate with a nonpolar valine result in a mild reduction of structural stability ($\Delta\Delta G = -0.47$ kcal/mol) as predicted by DDMut. The loss of surface charge and the emergence of a hydrophobic patch alter local physicochemical properties, promoting abnormal intermolecular associations between deoxygenated hemoglobin molecules and initiating HbS polymer formation. This alteration reflects a classic pathogenic mechanism, leading to sickle cell hemoglobin aggregation and confirming the classification of Glu7Val as Pathogenic (Severe, HbS Variant).

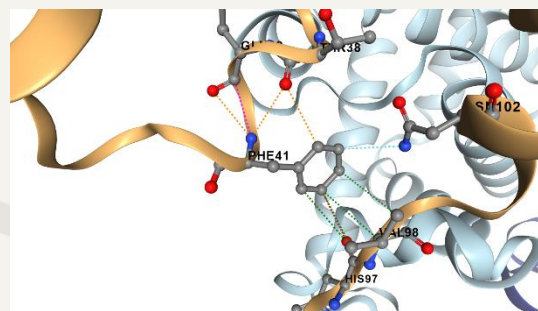


Figure 2. Local structural environment of residue Phe41 (F41L) in the β -globin chain

Structural visualization of the Phe41Leu (F41L) mutation in the β -chain of hemoglobin illustrates the replacement of a bulky aromatic residue (phenylalanine) with a smaller aliphatic leucine within the protein core (Depth 1.91 Å) (Fig.2). In the wild-type structure, Phe41 participates in hydrophobic packing that stabilizes the globin fold through aromatic-aromatic and van der Waals interactions with neighboring residues such as His97, Lys98, and Gly38. The substitution to leucine reduces these core hydrophobic interactions, leading to minor destabilization of the local tertiary structure ($\Delta\Delta G = -0.59$ kcal/mol). The decreased compactness within

the heme-binding domain may slightly impair overall structural rigidity without drastically altering the hemoglobin's function. Based on the predicted destabilization and local hydrophobic perturbation, the F41L variant is classified as Likely Pathogenic.

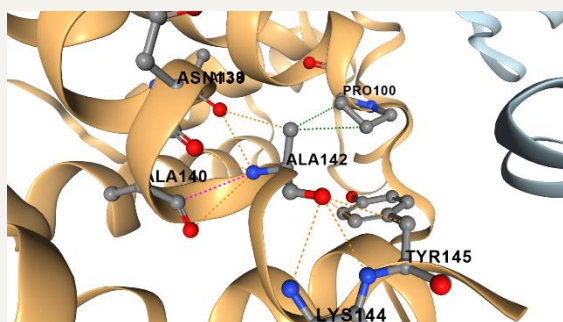


Figure 3. Local structural environment of residue Glu7 (E6V) in the β -globin chain

The Lys82Asn (K82N) mutation within the β -chain of hemoglobin is characterized by the substitution of a positively charged lysine residue with a neutral polar asparagine positioned on a solvent-exposed surface (RSA 0.56 $\text{\AA}^3$) (Fig. 3). The DDMut visualization reveals that, in the wild-type configuration, Lys82 forms key electrostatic contacts with neighboring residues such as His143 and Ala86, which are important for maintaining interdomain stability within the β -globin dimer. The loss of the lysine's positive charge disrupts these ionic interactions, leading to a weakened electrostatic network and slight perturbation of local conformational stability. This substitution results in a mild destabilizing effect ($\Delta\Delta G = -0.39$ kcal/mol), reflecting subtle alterations in the β - β interface.

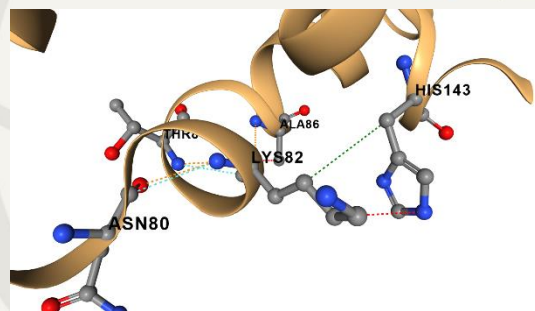


Figure 4. Local structural environment of residue ALA142 (A142T) in the β -globin chain

Visualization of the Ala142Thr (A142T) mutation in the β -chain of hemoglobin reveals a subtle structural alteration located within the internal region of the β -globin chain (Depth 2.24 $\text{\AA}$). In the wild-type configuration, Ala142, a small nonpolar residue, contributes to the compactness and hydrophobic stability of the helical region surrounding Ala140, Asn139, Lys144, and Tyr145. Substitution with threonine introduces an additional hydroxyl group, thereby increasing local side-chain polarity and slightly disturbing the tight hydrophobic packing. This change induces a mild destabilizing effect ($\Delta\Delta G = -0.35$ kcal/mol) without causing notable distortion of the overall protein conformation. The increased polarity is more likely to influence local flexibility rather than global stability, leading to its classification as a Variant of Uncertain Significance (VUS).

Structurally unstable hemoglobin resulting from missense mutations in the HBB gene can have significant clinical implications in β -thalassemia. Destabilization of the β -globin chain often leads to increased susceptibility to denaturation and precipitation, producing inclusion bodies that damage erythroid precursors and accelerate

intramedullary apoptosis (Tesio & Bauer, 2023). This imbalance between α - and β -globin synthesis results in ineffective erythropoiesis, chronic hemolytic anemia, and compensatory marrow expansion (Zhou et al., 2022). Even mutations causing mild destabilization ($\Delta\Delta G \approx -0.3$ to -0.5 kcal/mol), such as K82N or A142T, may exacerbate oxidative stress and promote proteasomal degradation of the unstable β -chain, ultimately worsening the clinical phenotype (Qadah & Jamal, 2019). Therefore, subtle perturbations in hemoglobin stability, as revealed in our *in silico* findings, provide a mechanistic explanation for variable disease severity in β -thalassemia, linking molecular instability to ineffective erythropoiesis and hemolysis (Bou-Fakhredin et al., 2022).

CONCLUSION

The results showed that all four HBB missense mutations (E6V, F41L, K82N, and A142T) caused mild destabilization of the β -globin structure, with $\Delta\Delta G$ values ranging from -0.35 to -0.59 kcal/mol. Among them, E6V exhibited the most pronounced destabilizing effect, consistent with its pathogenic role in HbS formation. Overall, these findings indicate that structural instability in β -globin contributes to altered hemoglobin folding and function, which contributes to the clinical manifestations observed in β -thalassemia and related hemoglobinopathies. However, this study is limited by its *in-silico* nature, as computational predictions may not fully capture the complex physiological environment or post-translational modifications influencing hemoglobin behavior.

Therefore, experimental validation through molecular dynamics simulations or biochemical assays is recommended to confirm these computational outcomes.

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APPLIED STUDIES

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BANDUNG CREATIVE SOCIETY

The Emerging Potential of Cactus Leather: A Sustainable Alternative to Traditional Leather Production

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Abstract: This study looks at cactus leather, made from the Prickly Pear Cactus (*Opuntia* spp.), as a sustainable option to traditional animal leather. It addresses the environmental and ethical issues of typical leather production. The research examines production methods, material characteristics, and ecological effects. It shows that making cactus leather uses much less water and energy than animal leather because the cactus is drought-resistant and grows with rainwater. The material offers similar flexibility and enough tensile strength for fashion and upholstery. Cactus leather is mostly biodegradable, breaking down naturally in 3 to 6 months in industrial composting. However, some bio-resin additives might slow down complete degradation. Sustainable farming practices involve cutting mature leaves every 6 to 8 months without harming the plants. This approach helps preserve the soil while allowing for repeated harvests. In addition, growing cacti captures carbon dioxide, aiding in efforts to combat climate change. Despite challenges in scaling production affordably and improving abrasion resistance for heavy-duty applications, leading fashion and automotive brands have adopted cactus leather, demonstrating its potential in the market. This material offers a promising, eco-friendly, and cruelty-free alternative to animal leather. It aims to lessen environmental damage and promote ethical consumerism across various industries. Future research should focus on improving durability, reducing costs, and expanding applications to encourage broader adoption.

INTRODUCTION

This study investigates cactus leather, made from the Prickly Pear Cactus (*Opuntia* spp.), as a sustainable option compared to traditional animal leather [1]. Conventional leather production uses a lot of water, leads to deforestation, causes greenhouse gas emissions, and raises concerns about animal welfare [2]. Cactus leather, on the other hand, offers an eco-friendly and cruelty-free choice

for industries such as fashion, upholstery, and automotive design.

The production process emphasizes sustainability. Cacti are naturally drought-resistant and rely on rainwater, requiring far less water and energy than livestock farming [3]. Growers harvest mature leaves every 6 to 8 months without damaging the plant, enabling repeated harvests while preserving soil health [6]. Moreover, growing cacti helps capture carbon,

contributing to climate change mitigation [3].

The material properties make cactus leather practical. It offers both flexibility and sufficient tensile strength for most fashion and upholstery needs [2]. Its texture can closely resemble animal leather. Importantly, cactus leather is mainly biodegradable and breaks down naturally in 3 to 6 months in

industrial composting [4]. However, bio-resin additives that enhance durability might slow decomposition [5].

From an ecological perspective, cactus leather avoids many issues linked to animal leather and synthetic options. Unlike livestock farming, it does not contribute to deforestation or methane emissions [3]. Additionally, unlike plastic-based synthetic leather, it does not rely on fossil fuels or significantly contribute to microplastic pollution. Still, there are challenges in scaling production at lower costs and improving wear resistance for heavy-duty uses [7]. These issues hinder wider adoption, but research is ongoing. Despite these challenges, several fashion and automotive brands are already incorporating cactus leather, which shows its growing market potential and appeal to consumers [8].

In conclusion, cactus leather offers a promising way to reduce environmental harm while promoting ethical consumer choices. With further advances in durability and cost efficiency, it could become a mainstream and sustainable alternative to both animal and synthetic leathers.

LITERATURE REVIEW

In recent years, plant-based alternatives to animal leather have

attracted considerable attention in global fashion and manufacturing [2]. Various innovative materials, like Piñatex (made from pineapple leaves), mushroom leather (from mycelium), and apple leather (produced from apple waste), have emerged as leaders in the sustainable materials sector. These options reduce reliance on traditional animal products while lowering overall environmental impact through decreased carbon emissions, water usage, and chemical pollution [2]. Among these eco-friendly innovations, cactus leather stands out due to its promising sustainability and performance [1]. Mexican entrepreneurs Adrián López Velarde and Marte Cázares, founders of the company Desserto, developed this groundbreaking material using bio-resin formulations alongside sustainable farming practices aimed at maximizing resource efficiency.

The Nopal cactus (*Opuntia* spp.) thrives in dry areas with minimal irrigation, making it suitable for regions where traditional farming struggles [3]. Its hardy nature allows it to flourish in harsh conditions where other plants can't. The farming process uses almost no pesticides or herbicides, which helps prevent soil degradation common in conventional agriculture [6]. Beyond its low resource requirements, the plant aids the environment by absorbing significant amounts of CO₂ from the atmosphere, encouraging climate change mitigation through natural carbon capture [3]. Extensive lab research shows that cactus leather matches traditional animal leather in mechanical properties, including tensile strength, flexibility, and tactile

qualities [2], while being fully biodegradable [4]. Unlike conventional leather, which can persist in landfills for decades, cactus leather breaks down naturally in just a few months under normal composting conditions, leaving a minimal environmental footprint after use.

Major international fashion brands like Karl Lagerfeld and H&M, along with various luxury car manufacturers, have already used cactus leather in their products, demonstrating its market viability across different price points and product types [8]. Despite this promising commercial acceptance, challenges remain in scaling production to meet demand, improving cost-effectiveness to compete with traditional materials, and increasing durability for uses requiring long-lasting resistance [7]. Current research across institutions mainly focuses on optimizing material composition, refining life cycle assessments to measure environmental benefits more accurately, and expanding commercial

applications beyond fashion into automotive interiors, furniture upholstery, and specialized technical uses, where sustainability could differentiate products in the marketplace.

METHOD

The experimental procedure began with carefully harvesting fully mature leaves from the Prickly Pear cactus (*Opuntia* spp.) [6]. These leaves were sourced only from certified organic farms to ensure they were free from pesticides, herbicides, and other harmful chemicals. The harvesting technique

aimed to protect the health and vitality of the parent plant. This approach allowed for sustainable and frequent harvests every 6 to 8 months without reducing plant productivity or damaging the growing areas.

After harvesting, the cactus leaves were thoroughly washed multiple times to remove soil, debris, and surface contaminants. Once cleaned, the leaves were measured and blended with precise amounts of purified water to create a uniform pulp. Initial attempts to dry the pulp naturally under direct sunlight for three days yielded mixed results, leading to a switch to a controlled dehydration process using industrial ovens set at about 80°C. This change significantly improved consistency between batches regarding moisture content, texture, and material quality.

After drying, the research team used specialized extraction techniques to isolate and collect essential fibers and protein compounds from the dried cactus material. These extracts were then mixed with eco-friendly bio-resins developed through extensive research and protected by patents [5]. This balanced mixture was applied using a coating process onto pre-prepared cotton fabric, resulting in flexible, durable, leather-like sheets with uniform thickness and surface features.

The final cactus leather sheets underwent thorough quality checks and performance evaluations. This included tests for key mechanical properties like tensile strength in both longitudinal and transverse directions, flexibility at various temperatures, and wear resistance against standardized surfaces [2]. All

tests used internationally recognized material testing equipment and protocols to ensure the results were valid and reproducible. Additionally, detailed life cycle assessments measured environmental impacts, focusing on water usage, energy consumption, and carbon footprint throughout the entire production process [3]. These assessments provided direct comparisons with traditional animal leather manufacturing methods.

RESULT AND DISCUSSION

Cactus leather sheets show impressive flexibility and a texture that closely resembles animal leather [2]. Tensile strength tests indicate the material is somewhat weaker than traditional leather, but it may still perform well for many applications, especially in fashion and upholstery. Water consumption during cactus farming and leather processing is 80% lower than in animal leather production [3]. Energy use is about half, mainly due to the process, excluding energy-intensive tanning chemicals. The biodegradable nature of cactus leather is confirmed; samples can decompose within three months in controlled composting conditions [4].

The limited use of harmful chemicals and the adoption of organic farming practices lead to less environmental damage. By harvesting only mature leaves without harming the plants, sustainable farming practices can continue, allowing for multiple harvests without degrading the land [6]. The primary challenges are scaling production cost-effectively and improving abrasion resistance for heavy-duty uses [7]. Nevertheless, the environmental

benefits and ethical considerations provide strong reasons for continued development.

CONCLUSION

This research shows that cactus leather can be a sustainable alternative to animal leather [1]. It addresses environmental concerns while being practical. Although it is not as strong as traditional leather, its biodegradability, lower water and energy use, and ethical production make it a good option for various industries [2–4].

Future studies should aim to improve durability, reduce costs, and encourage wider commercial use [7]. Progress in cactus leather supports global efforts to use eco-friendly materials and reduce the environmental impact of the fashion, automotive, and furniture sectors [8].

My hands-on experience at MASLab (Maqsudul Alam Science Laboratory), where innovative material research takes place, has supported this work. Funding from the Children's Research Fund has also allowed for a deeper exploration of sustainable biomaterials. These opportunities have enriched this study by giving access to advanced laboratory resources and encouraging collaboration across different fields.

In summary, switching to cactus leather offers a promising chance to cut down on environmental harm and improve animal welfare [1]. This can help create a more sustainable and ethical material economy.

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Smart Monitoring and Control System to Prevent Electrical Hazards in Flood-Prone Areas

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Abstract: Flooding is one of the most frequent and dangerous natural disasters in Indonesia, often creating electrical hazards that endanger community safety. This research aims to: (1) analyze the advantages and limitations of using Arduino-based sensors combined with NodeMCU ESP8266 microcontroller as a smart monitoring system for preventing electrical hazards during floods, and (2) develop a smart monitoring system that could reduce those risks. An experimental method was employed to develop and evaluate the system, named FLOMACS. The study generated three key findings. First, FLOMACS was able to provide real-time flood monitoring through its sensor integration. Second, the system successfully demonstrated an automatic power cutoff mechanism during flood events, significantly reducing the risk of electrocution and further electrical damage. Third, as an additional finding, FLOMACS stored historical flood data in a cloud system, which may serve as a valuable reference for disaster preparedness and long-term flood management. While the system proved effective, the relatively high cost of its components remains a barrier for widespread use. Therefore, this study recommends government and institutional support to make FLOMACS more affordable and accessible, enabling households in flood-prone areas to adopt this innovation as a step toward safer and more resilient communities.

INTRODUCTION

Flooding occurs when water levels in a stream rise suddenly or gradually. It is often triggered by heavy and prolonged rain, unusually high tides, melting snow, tsunamis, or damage to water barriers. Besides natural causes, humans are also contributing to floods, including land conversion and rapid population growth (Angelakis et al., 2023). Floods have been the deadliest and most damaging disaster worldwide over the past decade. The damage

caused by floods affects billions of people, resulting in mass displacement, economic loss, and even death. Taking Africa as an example, it has recorded more than 1,100 flood-related disasters in the last 50 years, with tens of thousands of deaths and millions impacted annually. Indonesia stands out in this context, as it ranks among the countries with the highest frequency of flood events globally.

Flooding continues to be the most common and damaging natural



disaster in Indonesia, threatening both infrastructure and human lives. The frequent occurrence of flooding is largely due to Indonesia's geographical and climatic conditions, especially in lowland areas with poor water absorption and high rainfall. These factors also worsen the flooding damage, particularly in places that lack disaster prevention infrastructure. According to Hariyanto et al. (2023), floods were the predominant disaster in 2021, with 1,298 incidents reported across the country. For example, Sidoarjo Regency experienced between two and four flood events annually, categorizing it as a moderate flood prone area. These locations generally have low elevations which are under 10 meters above sea level, gentle slopes (0–2%), and soil types like alluvial and planosol that absorb water poorly. Additionally, some areas receive over 3,000 mm of rainfall each year, further increasing flood risks.

Floods also lead to continued damage such as electrical fires caused by short circuits, which are frequent secondary hazards during flood events. Making public campaigns or community training about disasters that added electrical safety lessons and working together between the government, electricity companies, and local communities is also needed to make sure power systems are well maintained and can be turned off quickly during floods. This solution should be applied because many people are not aware of the dangers of electricity during floods. The main problem is why electric shock is still common because people often do not realize the danger of it. Electric shock not only causes serious injury

but also death, like the cases of 2 people who died because of electrocution when floodwaters touched power source in Katingan Regency, Central Kalimantan, 2021. Similar accidents also often happen in other flood-prone areas because of submerged power lines, exposed cables, and weak safety measures. These insights emphasize the critical need for flood management approaches that not only improve water control and infrastructure but also aim to reduce secondary risks like electrical hazards. By combining technology with better public awareness, Indonesia can greatly reduce electric shock cases during floods and keep communities safer. However, the use of these technologies is still low because of cost and limited access.

In many parts of Indonesia, messy wiring systems show both rapid urban growth and weak regulation of electrical infrastructure. These problems mainly come from poor installation, limited safety measures, environmental challenges, aging equipment, and the lack of modern detection systems. Many power lines are built without proper grounding, correct connections, or good lightning protection, making them vulnerable to lightning strikes. This is a big issue in places with high lightning activity, such as Bogor, where many lines do not have ground wires or lightning arresters, leading to frequent outages. Old insulators and equipment failures also add to the problem.

Also, inspections often rely only on visual checks instead of advanced lightning detection tools, making protection less effective. As a result, outages often occur

because of lightning overvoltage and the wrong or missing installation of lightning arresters on distribution lines. For example, in Depok, improvements were made by adding overhead ground wires and line arresters to reduce lightning damage on 20 kV feeders. Still, in many other areas, the lack of grounding and protective devices continues to cause insulator damage and system failures during storms.

Households and small industries rarely adopt early detection or automated prevention systems due to high costs, technical difficulties, and limited government support (Anbazhagu et al., 2025). These technologies typically depend on advanced sensors, real-time data processing, and professional installation, making them unaffordable or impractical for most families. Even in densely populated, flood-prone regions where electrical accidents and flood damage are common, adoption remains minimal because many households prioritize essential needs such as food, housing, and education, regarding disaster-prevention tools as non-essential. Cultural perceptions also play a role, as floods are often seen as a normal part of life, leading people to rely on reactive measures like manually cutting power during floods instead of investing in preventive systems.

Research indicates that fewer than 20% of residents in flood-prone areas use early warning or automatic electrical safety devices mainly due to high costs, limited access, and lack of awareness or technical skills, although many of them have faced flooding in the past five years. This highlights a major gap between the high level of disaster risk and the low

level of technological preparedness. Addressing this requires affordable, user-friendly systems, stronger public education initiatives, and supportive government policies to promote proactive prevention, ensuring communities are better protected from avoidable injuries, property loss, and fatalities.

Arduino, an open-source microcontroller platform, provides an affordable and flexible solution for monitoring and reducing electrical hazards. In disaster management, particularly flood detection, Arduino-based sensors are commonly applied within IoT systems. These sensors can track key parameters such as water levels, soil moisture, temperature, and humidity, enabling real-time data collection for early warning systems. Their affordability, ease of integration, and open-source design make them well-suited for creating scalable and adaptable monitoring networks in disaster-prone regions (Thakur et al., 2024).

Against this problem, the study aims to:

1. Analyze the advantages and limitations of using Arduino-based sensors combined with NodeMCU ESP8266 microcontroller as a smart monitoring system for preventing electrical hazards during floods
2. Develop a smart flood monitoring system for electrical hazards prevention system using Arduino.

FLOMACS is introduced as an innovative solution to address the risks associated with electrical hazards during flooding events. The system developed in this study is designed as a real-time detection and monitoring tool that is capable of identifying potential floods. The mechanism is based on water level

sensing. In addition to enhancing electrical safety, FLOMACS contributes to disaster mitigation efforts by incorporating smart home technology principles. Through the integration of sensor-based monitoring and automated control, the system demonstrates potential for further development by incorporating smart home technologies principle using Internet of Things (IoT) technologies. This would enable users to take full control of the system via mobile devices. When the sensors detect that the water level exceeds a predefined threshold, the system will connect to the mobile devices sending notification and allowing the users to interrupt the electrical current through a microcontroller connected to the main circuit breaker. This intelligent response mechanism allows the prevention of short circuits, electrical fires, and electric shocks.

This study is significant in providing a practical and scalable approach to mitigating flood-induced electrical hazards. The implementation of FLOMACS is expected to offer not only physical protection during flood events but also enhance household safety through a responsive, intelligent, and cost-effective electrical protection system.

LITERATURE REVIEW

1. Disaster prevention

A disaster is a series of events that are caused by natural factors, non-natural factors, or human factors resulting in loss of human lives, environmental damage, property loss, and psychological impacts. This can be reduced by understanding risks through

education, strong governance, resilient infrastructure, and preparedness efforts like emergency kits, evacuation plans, and drills. Floods occur when water overflows onto dry land due to heavy rain, river overflow, or poor drainage. The UNDRR identifies four main types of floods: flash floods, fluvial floods, coastal floods, and groundwater floods.

2. Electrocution

Electrocution refers to injury or death caused by electric shock when a person comes into contact with an electrical energy source. It can result in burns, nerve damage, cardiac arrest, or other serious health issues depending on the voltage, current, duration, and pathway of the electrical current through the body.

3. Arduino-based sensor

Arduino is an easy to use open-source electronic platform. It consists of microcontroller boards that can be programmed to interact with sensors, outputs, and other electronic components, thus making it popular for prototyping and developing embedded systems and IoT applications.

Arduino can reduce disaster risk by enabling real-time monitoring and early warning systems. Water level sensors connected to the microcontroller, which is then transmitted to cloud services for analysis. The advantages of the arduino include ease of implementation, scalability with additional sensors and parameters. It also enables timely alerts, which helps reduce response time.

Several studies have identified the use of technology, particularly those that are based on internet, in mitigating disaster, for instance "Design and Implementation of

Internet of Things and Cloud Technology in Flood Risk Mitigation" that was written by Siek and Larry (2021). The research objectives were to design and implement an IoT and Cloud Technology-based flood risk mitigation system, develop and simulate an IoT water sensor network with automated data acquisition at key water gates, and integrate these systems for better real-time data collection and management to improve flood forecasting accuracy.

However, the system demonstrated might concern cost and had potential challenges including sensor placement accuracy, data security in cloud environments, and system scalability in diverse urban settings. Overall, the proposed solution effectively combined IoT, cloud computing, and data analytics to address urban flood risks. Nonetheless, further validation through real-world deployment and assessment of long-term sustainability, maintenance, and cost-effectiveness were necessary to fully establish its practical viability.

Another study, entitled "IoT-enhanced seaside monitoring for early flood warning systems using intelligent techniques", was discussed by Thakur et al. (2024). The research discussed the development and testing of an IoT-based seaside flood monitoring system that could accurately predict floods and provide early warning to improve preparedness and resilience in coastal regions using the integration of IoT sensors and intelligent data analysis techniques. The study effectively combined IoT and artificial intelligence technologies to enhance prediction accuracy and response time, which is a significant advancement in

disaster management. However, while the results were promising, validation in diverse geographic and environmental conditions would strengthen the findings.

Based on the literature studies, it is evident that IoT has the potential to reduce disaster risks by developing smart monitoring and warning systems. The IoT can be used as a sensor and intelligent data analyst to predict floods. However, little attention has been given to the secondary hazards of flooding, such as the risk of electrocution. In addition, many of the proposed research techniques are costly, making their implementation in real-world situations challenging. By using the information below, we can create a smart monitoring system that is cheaper and easier to use in real life. This system can help prevent the extra danger of floods, especially the risk of people getting electrocuted when water reaches electrical sources. With the help of simple sensors and automatic power control, the system can detect when an area is at risk and quickly turn off the electricity. In this way, the monitoring system is not only giving warnings but also protecting people from further harm during floods.

METHOD

This study used an experimental research method, a quantitative approach considered one of the most reliable ways to examine the relationship between variables. The goal of this research was to design and develop a device capable of sending real-time water level notifications to smartphones and storing the data—including time, date, and water level status—in a database. With this system,

residents can take early action to reduce the risk of casualties during floods. The experimental process involved designing both the hardware and software components of the system. Data was collected using the following methods:

1. Literature review: data collection involves both a thorough review of existing literature and journals.
2. Experiment method: the author designed the tool and tested it directly to observe and verify its operation. Any errors could be immediately analyzed and corrected.

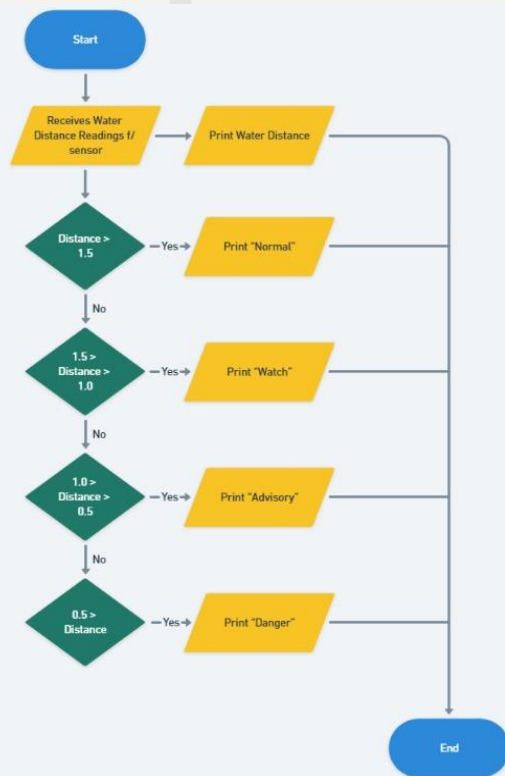


Figure 1. Flowchart System

The FLOMACS was hooked to a power source, this being a 5V phone charger. Then the FLOMACS was linked through wifi to the monitoring platform, this being the laptop. The sensor was placed on top of a container to simulate a river/lake with

a ruler to measure the height and make sure the readings were correct.

Table 1. Danger Levels

No	Color	Water to Sensor Distance	Status	Description
1	Grey	>1.5 meter	Normal	Water flow is still within the river's normal capacity. No indication of flooding.
2	Yellow	1 - 1.5 meter	Standby	The water level begins to rise. Flood risk may appear, especially in low-lying areas.
3	Orange	0.5 - 1 meter	Alert	Water level is nearing the river's capacity limit. Flood risk is increasing.
4	Red	0 - 0.5 meter	Danger	Water level exceeds the river's capacity, making flooding highly likely to occur soon.

Table 2. Tools and Materials

No	Model Name	Purpose	Price
1	NodeMCU ESP8266	The brains of this system	Rp30.00
2	M2M and F2M Jumper Cables	To connect the components and board together	Rp20.00

		To detect	
3	5V - 3V Analog Water Sensor	and Depth measure the water levels	Rp10.000
4	Blynk IoT	A platform for the monitoring dashboard	-
5	Solderless Half-Sized Breadboard	For easy prototyping	Rp5.000
6	USB to Micro-USB Cable	Send LUA code to the NodeMCU	Rp10.000
7	250VAC 10A Songle Relay	Songle	Rp10.000

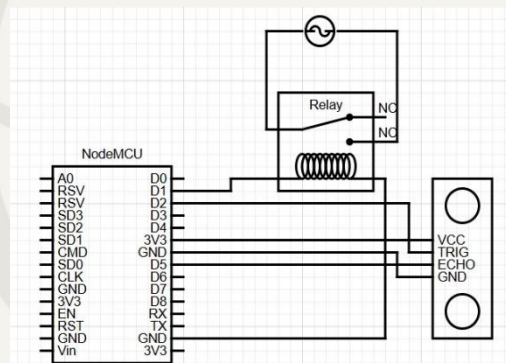


Figure 3. Hardware Assembly

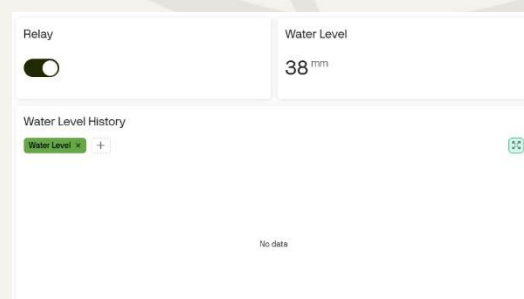


Figure 4. Homepage Program

RESULT AND DISCUSSION

This flood detection system is used to monitor water level and send warnings by giving notification through mobile phone. The ultrasound sensor is connected to the bigger ESP8266 via jumper cable connection, and the ESP8266 is internally connected to the relay and Blynk IoT (using wifi connections).

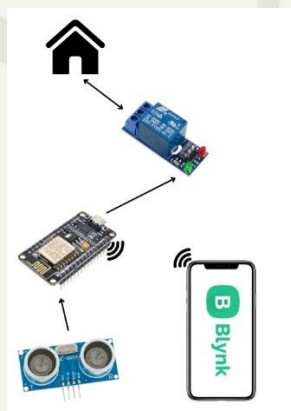


Figure 2. Flood Sensor Assembly



Figure 5. System Testing

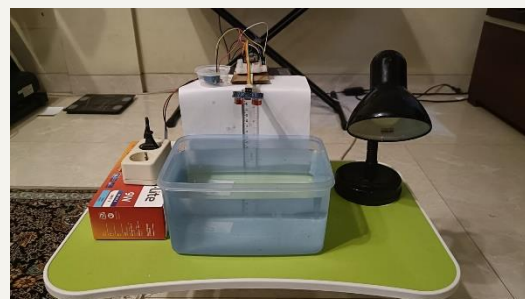


Figure 6. System Setup

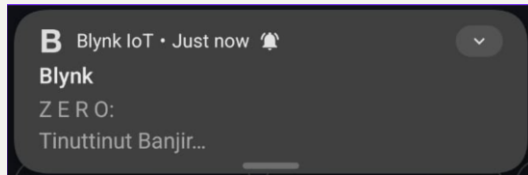


Figure 7. Notification Alert

Table 3. Water Readings Data

Water Height	Water to Sensor Distance	Water to Sensor Distance	Status	Sensor Output
0 cm	20 cm	19.9 cm	Normal	No Notification
2 cm	18 cm	18.1 cm	Normal	No notification
4 cm	16 cm	14.1 cm	Standby	No notification
6 cm	14 cm	12.9 cm	Standby	No notification
8 cm	12 cm	11.7 cm	Standby	No notification
10 cm	10 cm	9.7 cm	Alert	No notification
12 cm	8 cm	8.1 cm	Alert	No notification
14 cm	6 cm	6.1 cm	Danger	Notification pops
16 cm	4 cm	3.7 cm	Danger	Notification pops

The water level monitoring system was tested by comparing manual water height measurements with sensor readings, ranging from 0 cm to 16 cm. For each water level, the distance from the sensor to the water surface was recorded manually using a ruler and automatically by the sensor. The results showed that the sensor readings were highly accurate, with an average accuracy of 96% by comparing the true height average and average readings. At water heights of 14 cm and 16 cm, with the sensor detecting distances of 6.1 cm and 3.7 cm respectively, the system classified it as "Danger," as a result it sent a notification to the phone.

These sensor distances fall within the predefined threshold of less than 0.5 cm, which corresponds to 5 cm in true scale), which also corresponds to the red danger zone in the flood warning classification. According to the color-coded system, a sensor distance of more than 1.5 meters indicates Normal conditions (Grey), 1–1.5 meters indicate a Standby level (Yellow), 0.5–1 meter indicates an Alert level (Orange), and 0–0.5 meters signals Danger (Red), where flooding is highly likely. The sensor's ability to detect these thresholds accurately and trigger alerts confirms that the system not only measures water levels reliably but also provide timely warnings aligned with real flood risk categories. This integration makes the monitoring system both accurate and effective for early flood detection and response.

The FLOMACS needs both electricity and a reliable internet connection to operate, making it vulnerable to blackouts or internet outages. To address power issues,

the FLOMACS installation can include a power backup, such as a power bank. However, since many areas in Indonesia still lack internet coverage, government support is essential to expand digital infrastructure. Furthermore, the government could subsidize the system's components to make FLOMACS more affordable to install.

CONCLUSION

After conducting research and testing the application of this flood detection tool, the following conclusions can be drawn:

1. FLOMACS, an Arduino-based sensor equipped with the NodeMCU ESP8266 microcontroller, was able to deliver real-time information on flood conditions with reliable accuracy and affordable cost. However, to operate effectively, FLOMACS needs electricity and internet connection, highlighting the need for a power backup and a government support.
2. The study has successfully assembled FLOMACS, a smart flood monitoring system for electrical hazard prevention, by incorporating Sngle Relay technology and Analog Water-Depth Sensor. The use of both components remotely cuts off electricity and collect water level data during floods.

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TRANSINSO: Transforming Rambutan Seed Into Sustainable Oil

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Abstract: Rambutan (*Nephelium lappaceum* L.) seeds are tropical, delicious, hairy, red, woody trees that grow into fruit once a year. This is an organic waste that has not been widely utilized despite its potential as a source of cooking oil. This research study aims to determine the characteristics of rambutan seed oil through two extraction methods, the wet method and the dry method. The resulting oil was then analyzed organoleptically (aroma, texture, taste, color), and tested to find its density, solubility in 70% ethanol, and phytochemical content, including fatty acids, saponins, and steroids. The results of the organoleptic test showed that both methods produced oil with a buttery aroma, oily and sticky texture, slightly bitter taste, and yellow color. The bitterness in the oil is due to its tannin and is reduced by using coal and tested qualitatively using organoleptic. The dry method produced a higher density (0.563 g) than the wet method (0.542 g). The oil from both methods was soluble in 70% ethanol at a ratio of 1:1. Phytochemical tests showed that the oil from both methods contained fatty acids and saponins, but no steroids. Saponin content was found in the dry method. These findings indicate that rambutan seeds have the potential to be a source of vegetable oil rich in bioactive compounds, and support the principles of sustainable consumption and production in accordance with the SDGs on waste management, poverty alleviation, and food security.

INTRODUCTION

Indonesia is a tropical country that consumes a lot of its fruit's meat. After eating the meat of its fruits, all that is left is its seeds, this includes Rambutan seeds. Fruit seeds are organic. The waste of fruit seeds contributed to approximately 52.55% of the total waste in 2023 in Yogyakarta which amounted to 109.70 thousand tons in the Special Region of Yogyakarta (SIPSN/National Waste Management Information System, 2023).

Rambutan or (*Nephelium lappaceum* L.) is a tropical fruit that has a texture similar to spiky hair,

coloured red, and owns a woody stem that is able to change once a year. Rambutan fruit has a few characteristics and nutrition contents aligned with bioaktif, including protein, fiber, and minerals such as calcium, zinc, iron, and manganese. Its seeds also contain vitamins such as thiamin, riboflavin, and niacin. The benefit of both meat and rambutan seeds can help us to maintain our heart's health, support brain function, and boost metabolism. Rambutan seeds turn into organic waste that has not been widely utilized despite the fact that we can turn its organic waste for

better potential, which is cooking oil. Our research aims to turn Rambutan seeds into sustainable and eco-friendly cooking oil, which will help to use organic waste for better innovation and to decrease the amount of organic waste thrown away. This research will be conducted using 2 methods, the dry method and the wet method.

Research Question

The problems that will be studied in this research are:

1. How are the organoleptic quality and the phytochemical of rambutan oil between dry methods and wet?
2. What is the evaluation of the free fatty acid in the oil?

Research Purpose

The aim of this research is:

1. To analyze the organoleptic quality in both oil and the phytochemical in the oil
2. To evaluate the free fatty acid in both methods of oil.

Hypothesis

The research hypothesis is described as follows:

1. The dry method will have a stronger nutty aroma, but both methods will have a clear, oily, yellow color, able to cook fried food with the rambutan oil
2. The amount of free fatty acid is varied depends on its type: methyl laurate (0.16 %), methyl dodeca 9 enoate (7.35 %), methyl myristate (1.47 %), methyl palmitoleate (44.61 %), methyl stearate (5.23 %), methyl oleate (41.18 %)

LITERATURE REVIEW

Rambutan (*Nephelium lappaceum*) seeds are known for their distinctive spiky red texture and woody stem, containing valuable bioactive compounds such as

proteins, dietary fibers, and essential minerals. These nutrients contribute significant functional and nutritional value to the oil extracted from the seeds (Nguyen et al., 2025; Eiamwat et al., 2016). The extraction of oil from rambutan seeds aims to utilize the organic waste sustainably, producing an eco-friendly oil with potential applications in food and cosmetics.

Extraction methods primarily include dry and wet techniques. The dry method involves mechanical pressing after drying the seeds, while the wet method involves soaking or maceration prior to extraction. Research comparing these two methods indicates that dry extraction typically yields higher oil content but may require higher energy input, whereas the wet method is environmentally friendly and suitable for preserving sensitive bioactive compounds (Nguyen et al., 2025; Yoswathana, 2013).

Charcoal treatment is an effective approach to reduce tannin content, which otherwise can impart undesirable astringent flavors and affect the oil's quality. Activated charcoal adsorbs tannins, improving the organoleptic properties of the oil (Filtersystem Australia, 2012).

Chemical analyses of the extracted oil employ reagents such as ferric chloride (FeCl_3) and sodium hydroxide (NaOH). FeCl_3 reacts with phenolic groups to form colored complexes, aiding identification of antioxidant compounds, while NaOH is used for alkali treatment in flavonoid assays and free fatty acid (FFA) determination. The FFA level is a crucial indicator of oil quality, since elevated FFA can lead to rancidity and reduce shelf life (Moroccan J. Chem., 2017; Metwarebio, 2025).

Oil filtration techniques are essential to separate oil from fats and solid impurities, improving clarity and stability. Methods include mechanical filtration, centrifugation, and chemical filtration, which help retain oil quality and extend its usability (Microlube, 2023).

Finally, organoleptic analysis evaluates the sensory attributes of the oil such as aroma, color, texture, and taste. This human-sensory testing ensures that the oil meets quality standards for consumer acceptability and product consistency (PT Mitra Ayu, 2023; International Olive Oil Council, 2020).

In summary, sustainable production of rambutan seed oil involves optimized extraction through dry and wet methods, tannin reduction via charcoal, rigorous chemical analysis including FFA measurement, effective oil filtration, and comprehensive organoleptic evaluation to ensure a high-quality eco-friendly oil product.

METHOD

Time and Place of the Research

This research was conducted from August to September 2025 at the JMMS School in Yogyakarta.

Research Tools and Materials

The materials used in this study were rambutan seeds, distilled water, phenolphthalein reagent, NaOH 0.01 N, FeCl₃, and 70% ethanol. The equipment used included filter paper, glass tubes, pipettes, beakers, filters, a pressure cooker, a weighing bottle, and a centrifuge.

Data Retrieval

a. Preparation

Prepare the rambutan seeds, which have been thoroughly washed and peeled. Then begin the wet and dry processes.

b. Dry method

First, 50 grams of rambutan seeds are blended with water and let them sit overnight to soften them. Then, the blended mixture is strained using a cloth strainer to retain milk from the rambutan seed. Then, let it sit in the refrigerator overnight until several layers form (remove the top layer). The last step is to let the milk sit until the oil layer forms on top then and strain it through a paper strainer.

c. Wet method

First, 50 grams of rambutan seeds are heated in a pressure cooker at 120°C for 20 minutes. The seeds are then pressed with a coffee press, and the crude oil is separated by squeezing and centrifuging. The bitterness in the oil is reduced by using coal.

Data Analysis

a. Organoleptic

Testing Organoleptic/sensory testing is a method of testing that uses the human senses as the primary tool for assessing product quality. This sensory assessment includes quality specifications for appearance, odor, taste, consistency/texture, and several other factors necessary for evaluating the product (Indonesian National Standard, 2006). In this study, the organoleptic test was conducted qualitatively.

b. Specific Gravity

Specific gravity was calculated to determine the yield of the resulting oil. To determine the specific gravity of essential oils, a modified weighing bottle was used and calculated using the following formula:

$$BJ \text{ minyak atsiri} = \frac{(W - W_1)}{(W_2 - W_1)}$$

Description:

- W = weight of weighing bottle containing essential oil at 25°C

● W_1 = weight of empty weighing bottle

● W_2 = weight of bottle containing water at 25°C (Gunther, 1987)

c. Solubility in Alcohol

The qualitative test for oil solubility in alcohol aims to determine whether the oil can dissolve in alcohol. Oil is generally insoluble in water, but it can dissolve in organic solvents such as alcohol (Regina and Aliya, 2017).

d. Qualitative Test for Fatty Acids

25% sulfuric acid is added, and observation is performed by heating. The formation of a light brown color indicates the presence of fatty acids (Hanani, 2017).

e. Saponin Test

1 mL of sample is placed in a test tube and 1 mL of distilled water is added. The mixture is boiled for 2-3 minutes. It is then cooled and shaken vigorously. A positive result for the saponin test is indicated by the formation of foam.

f. Steroid Test

1 mL of sample is added to 1 mL of chloroform, shaken, and then 3 drops of concentrated H_2SO_4 are added. A positive result for the steroid test is indicated by a brown color change.

g. Fatty acid test levels

To determine test level on fatty acid in the oil using the following formula:

$$\% = \frac{ml\ NaOH \times N\ NaOH \times BM\ fatty\ acid}{Sample\ Weight \times 1000} \times 100\%$$

Description:

Concentration : Free fatty acid content (%)

MI NaOH : Volume of

NaOH titrant

N NaOH : Normality of

NaOH solution

BM Fatty acid : MW palmitic acid (256)

Test Before Adding Activated Carbon Procedure

The oil was placed in two test tubes, each containing 3 mL of oil. The extract from the first tube was reacted with 3 drops of 1% $FeCl_3$ solution. If the extract contains tannins, it will produce a blackish-green or dark blue color. The extract from the second tube was added with 5 drops of gelatin solution if a precipitate formed.

h. Tanin Test

Prepare 100 grams of oil. Add 2 grams of activated charcoal. Let it sit for 30 minutes. Then, filter it. And test using $FeCl_3$ solution. Do these methods before and after the charcoal given.

i. Organoleptic Test

2.82-gram sample of cooking oil was weighed and placed in a 250 mL Erlenmeyer flask. The sample was then dissolved in 5 mL of ethanol at 50°C. Three drops of phenolphthalein were added to the completely dissolved sample as an indicator. The sample was then titrated with 0.013 N NaOH solution.

RESULT AND DISCUSSION

Qualitative Organoleptic Test

Table 1. Image of rambutan seed oil

Wet method	Dry method
	

Table 2. Qualitative organoleptic test of oil

Variable	Wet Method	Dry Method
Aroma	Butter-like	Butter-like

	aroma	aroma
Texture	Oily and slightly sticky	Oily and slightly sticky
Taste	Slight taste of bitterness	Slight taste of bitterness
Appearance	Bright yellow	Bright yellow

Based on research that has been carried out, wet and dry oil has a butter-like aroma, oily texture, stickiness and a slightly bitter taste. The difference is that wet has a stronger aroma than dry. Based on research that has been carried out, wet and dry oil has an aroma like butter, an oily, sticky texture and a slightly bitter taste. The difference is that wet has a stronger aroma than dry.

Specific Gravity

Table 3. Specific gravity of the oil

Variable	Value (gram)
Wet Method	0,542
Dry Method	0,563

The measurement of specific gravity in oil to assess the purity and quality of the extracted oil. The table above shows that the specific gravity value for the dry method is 0.563 grams, while the wet method is 0.542 grams.

Qualitative Evaluation of Solubility in 70% Ethanol

Table 4. Evaluation of the Oil's Solubility in Alcohol

Variable	Alcohol and Oil Comparison (alcohol : oil)
Wet Method	1:1

Dry Method	1:1

Testing for solubility in 70% alcohol helps assess the purity and stability of the oil. If the oil dissolves clearly, it's an initial indicator of good quality before further testing is conducted. For the oil to dissolve clearly, it requires a one-to-one ratio with the alcohol, which suggests a similar purity and polarity. This indicates consistent quality at a fundamental level for testing purposes.

Qualitative Testing of Phytochemical Content

Phytochemicals are secondary metabolite chemical compounds found in plants. Secondary metabolites are essential for plants to defend themselves from other organisms and attract insects for pollination. They are also beneficial for humans and animals (Julianto, 2019). According to Khasanah (2011).

Table 5. Qualitative Testing of Phytochemical Content

Variable	Fatty Acids	Saponin	Steroid
Wet Method	+	+	-
Dry Method	+	+	-

Fatty acids are organic acids that are essential components of lipids (fats), serving as both an energy source and a structural part of cells. Rambutan seeds contain a significant amount, with 37-42% fatty acids per seed, which is considered a positive finding (Winanda and Hasibuan, 2021). The most dominant fatty acid in rambutan

seed oil is Oleic Acid (33.17 - 31.38%). Oleic acid is a saturated fatty acid known for its benefits, including improving cardiovascular health, providing anti-inflammatory properties, and potential anti-cancer effects (Kim et al., 2010).

The saponin test is performed to detect saponin compounds, which are active substances with antibacterial, antifungal, and antioxidant properties. The presence of stable foam during the test indicates the presence of saponins. This finding is consistent with a study by Kusumaningrum (2012), which also found that rambutan seed extract contains saponins.

Steroids are non-hydrolyzable organic sterol compounds that result from the reaction of terpene or squalene derivatives (Hanani et al., 2005). Steroids enhance the body's hormonal metabolism. While everyday oils can contain steroids, consuming too much can be harmful. According to the research, rambutan seeds do not contain steroids, making them safe for daily consumption.

Table 6. Tannin Test before and after adding the charcoal

	Appears to have a black color, before the charcoal adding.

	Appears to have a slightly lighter brown, after adding the charcoal.

Before adding the charcoal, the color of the first oil appears to be a dark-brown to a black color. This represents the existence of tannin. After adding the charcoal, the oil appears to have a lighter color. Qualitatively, it doesn't show the presence of tannin. This proves that adding active carbon in a form of charcoal can reduce the tannin which makes the oil less bitter. However, a further need of a test regarding the decreasing of percentage is needed since this test is strongly based on only its color observation.

Fatty Acid Test Levels

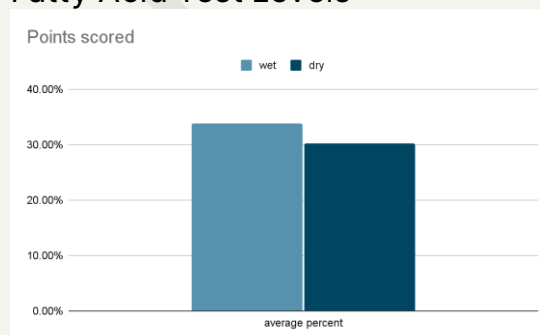


Figure 1. Fatty Acid Test Levels

Based on the research, able to see that the free fatty acid percentage counted by using titration methods, for the dry method is $30.26\% \pm 3.78\%$, while the result for the wet is $30.26\% \pm 3.78\%$. Titration concept is done by using a chemical analysis technique used to determine the quantity of a substance (analyte) by reacting it with a known amount of another

substance (titrant). Both dry and wet methods gave the same fatty acid result: $30.26\% \pm 3.78\%$, showing the titration technique is consistent and reliable, and the oil has a good outcome.

CONCLUSION

The organoleptic quality analysis showed that oils extracted by both dry and wet methods shared similar characteristics: a buttery aroma, oily and slightly sticky texture, and slight bitterness. However, the wet method produced a stronger aroma than the dry method. Both oils were bright yellow and soluble in 70% ethanol at a 1:1 ratio, indicating good purity. The phytochemical test confirmed the presence of fatty acids and saponins in oils from both methods but no steroids were detected.

The free fatty acid levels in both oils were consistent at around 30.26%. Additionally, activated charcoal treatment effectively reduced bitterness caused by tannins. Therefore, both dry and wet extraction methods produce good quality rambutan seed oil with beneficial bioactive compounds, answering the research questions effectively.

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Utilization Of Organic Agricultural Waste for Biogas Production as A Potential for Energy Diversification for Local Communities in Berastagi District of North Sumatera

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Abstract: Organic agricultural waste in Indonesia remains substantial and is often left to rot without optimal utilization. However, this organic waste has the potential to be used as a renewable alternative energy source, particularly for biogas. This study aims to determine the processing stages, the effectiveness of organic agricultural waste into biogas, and to determine strategic steps for energy diversification from organic agricultural waste into biogas. The method used in this study is experimental and utilizes a literature review to support the discussion analysis. The materials used for biogas production are organic waste with a 1:1 ratio to water solvent, a percentage of molasses of 3% of the total organic material mixture, a percentage of compost of 10% of the total organic material mixture, and different percentages of EM4 for each digester (2%, 4%, and 6%). The results showed that the digester with 2% EM4 experienced the highest increase in biogas volume compared to the other digesters. This is because the addition of EM4 can reduce the ratio of carbon and nitrogen content and also reduce biogas production, even though the biogas process is faster. Through this research, the Berastagi Subdistrict Government can use the information to produce biogas from agricultural waste.

INTRODUCTION

Organic waste is a natural material that is easily decomposed by microorganisms. Organic waste has not been optimally utilized and is usually left to rot or burned, which has an impact on environmental pollution. In fact, agricultural organic waste has the potential to become a source of renewable energy (Ciawi *et al*, 2023; Sunyoto *et al*, 2023). On the other hand, the Indonesian government is currently implementing a policy program in the form of a national movement for the application of New and Renewable

Energy (EBT) and energy conservation, which aims to increase the proportion of renewable energy to around 23% of the energy mix by 2025. One of the strategic projects undertaken by the government to achieve the EBT target is the co-firing of 10.2 million tons of biomass by 2025. With proper energy diversification, Indonesia can reduce its dependence on energy imports and improve national energy security in a sustainable manner (Herindrasti *et al*, 2024).

This study aims to determine the methods of processing organic

waste from agricultural products into biogas and the effectiveness of biogas production, and also to identify strategic steps for diversifying energy from agricultural organic waste into biogas in Berastagi District, North Sumatera. The benefit of this study is to add to the body of information on the processing of agricultural organic waste into biogas as a contribution to further research on the development of agricultural organic waste processing into biogas. This research can also serve as a reference source for local governments to study the processing of agricultural organic waste into biogas and further energy diversification.

LITERATURE REVIEW

Energy diversification is an important strategy for expanding and enriching energy sources and reducing dependence on a single type of energy source. Energy diversification plays a crucial role in strengthening the energy security of a region by utilizing various types of renewable energy sources. Biogas consists of methane (CH₄) and carbon dioxide (CO₂). Methane is the main component that can be used as fuel for heating, power generation, or vehicle fuel (Rianawati *et al*, 2021). Agricultural organic waste is abundant in Indonesia, such as in North Sumatera. This has the potential to be utilized as a renewable energy source. Agricultural organic waste includes plant residues, leaves, stems, roots, fruit peels, and various types of plants that cannot be consumed by humans or livestock, so they can be processed into biogas (Budhijanto *et al*, 2019).

The conversion of organic waste to an efficient energy source is a great way to substitute the use of other non-sustainable resources. Organic waste acts as a bioenergy conversion to convert waste into energy (Alao *et al*, 2024). Communities have also been trying to use this idea to help provide a much more sustainable energy source. The result of this energy has been tested out to be a great category of energy source (Kabeyi *et al*, 2022).

Studies show that vegetable and fruit waste can be converted into biogas using anaerobic floating bioreactors. One experiment with a 40-L digester produced a maximum yield of 0.0452 m³/kg at an OLR of 0.0125 kg/L·day, with methane making up 68.17% of the gas. Efficiency declined at higher OLRs, but the results confirm that market waste can serve as a reliable renewable energy source under optimized conditions (Soeprijanto *et al*, 2020).

RESEARCH METHODOLOGY

This research was conducted from July 10, 2025, to August 14, 2025, at the Science Laboratory, Highscope Indonesia School Medan, Jl. Citra Garden No.5 Blok B12, Titi Rantai, Kec. Medan Baru, Kota Medan, North Sumatera. This study used several tools, namely knives, scales, 30-liter jerry cans as digesters, air taps, small pipes, syringes, and hot glue guns. The materials used included organic waste in the form of vegetable and fruit scraps from the market as the main substrate, EM4 as a starter or fermentation activator containing biogas producing microorganisms, and molasses as an additional

energy source (carbohydrates) to support the growth of microorganisms during the fermentation process.

The first step in making biogas is to chop the organic waste, then mix it with water in a 1:1 ratio. The mixture is then poured into the jerry can through the top, along with EM4 and molasses. Next, a hole is made on the side of the jerry can using a soldering iron to install an air tap, which functions as a gas testing channel. After that, hot glue is used to seal all gaps in the joints to make the system airtight and prevent gas leaks.

After all the materials have been added and the system is tightly sealed, the digester is left for 3-4 days to allow the fermentation process to take place anaerobically. After the fermentation period, the biogas that has formed is channeled through a small pipe connected to a tap, then tested for its ignition power as an indicator of the success of biogas production. The flow chart for biogas production can be seen in Figure 1.

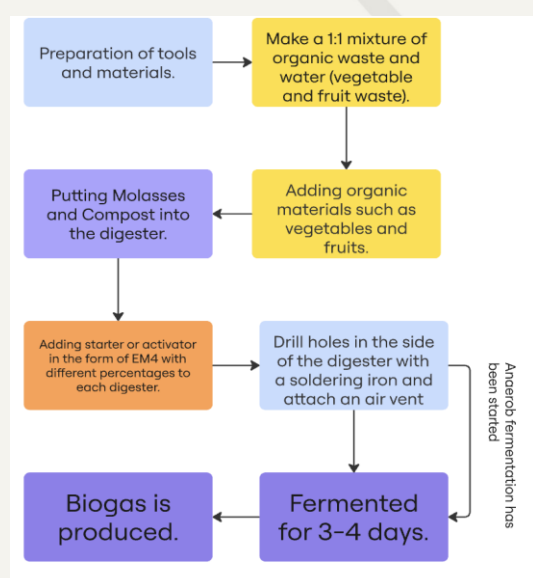


Figure 1. Flow Chart of biogas production

The sample used was a 1:1 ratio of water and organic waste, with molasses accounting for 2% of the total organic mixture, compost accounting for 10% of the total organic mixture, and varying percentages of EM4 in each digester (2%, 4%, and 6%). It can be seen in Table 1.

Table 1. Amount of Ingredients in Biogas Production Samples

Organic Waste (Kg)	Water (L)	Molasses (mL)	Compost (g)	EM4 (mL)
5,8	5,8	174	580	116
5,8	5,8	174	580	232
5,8	5,8	174	580	348

The gas mass yield is obtained by adding the total mass of the material before fermentation and subtracting the weight of the material after the biogas fermentation process is complete. The difference in mass indicates the amount of gas produced during fermentation. Then, the data of biogas mass was converted to biogas volume. The data obtained is processed in tables and graphs according to the experiment. Then, a flame test is conducted on each digester. The results of this analysis are used to conclude in accordance with the research objectives.

RESULT AND DISCUSSION

There are three processes for treating organic waste: dissolution, acidification, and gasification. In the dissolution process, insoluble materials such as cellulose, polysaccharides, and fats are converted into water-soluble

materials such as carbohydrates and fats. This occurs when organic waste is left to stand for several days. Next, acidification or anaerobic fermentation occurs, whereby glucose is converted into ethanol and then into acetic acid. This stage takes place at a temperature of 25°C in the digester. Finally, gasification occurs, whereby acetic acid is slowly converted into methane gas under anaerobic conditions. This process takes place over 2-14 days at a temperature of 25°C in the digester. The methane gas produced can be used as an alternative renewable energy source.

Based on the results of experiments conducted with different percentages of EM4 addition (2%, 4%, and 6%), it was found that the digester with 2% EM4 experienced the highest volume increase (330 ml) compared to the other digesters (114 ml and 99 ml). This is in line with the research result of Megawati (2015) research, which found that the addition of EM4 can reduce the carbon and nitrogen content ratio and also reduce biogas production, even though the biogas process is faster. The biogas volume results can be seen in Figure 2.

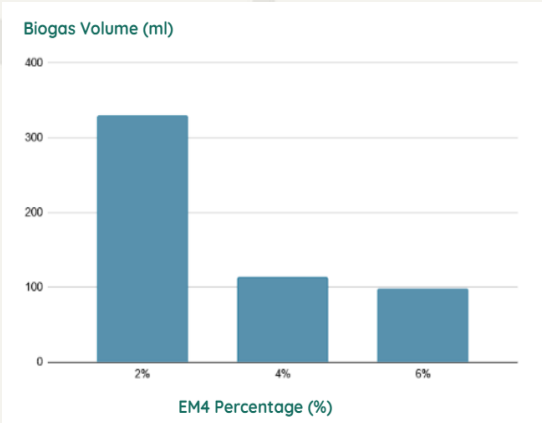


Figure 2. Result of Biogas Production

In addition to calculating the mass of biogas, a flame test was

conducted to determine the effectiveness of biogas production in each digester, with the results shown in Table 2. The flame produced in each digester was greater when 2% EM4 was added compared to the other digesters. This is in line with the greater mass of biogas produced.

Table 2. Flame Test with Different Percentages of EM4 Addition.

Percentage of EM4	Biogas Mass	Flame Test
2%	330 ml	+++
4%	114 ml	++
6%	99 ml	++

The Berastagi subdistrict, located in the Karo Regency, is one of the largest centers for vegetable and fruit production in North Sumatera. Karo Regency is well known as a supplier of vegetables to various regions on the island of Sumatera, and even as far as the island of Java (Sinaga, 2025). In 2024, the total production of horticultural commodities in Berastagi Subdistrict was 210 hectares of cauliflower, 164 hectares of potatoes, 118 hectares of cabbage, and other crops in significant quantities (Badan Pusat Statistik, 2024).

This shows that Berastagi District has enormous potential in the future as an area that produces abundant agricultural commodities in Indonesia. On the other hand, organic waste from agriculture in Berastagi, such as plant residues and vegetable waste, is largely not managed optimally. Overall, Berastagi has about 60% of its waste

consisting of organic waste. Therefore, much of the organic waste from agriculture can be utilized as a form of energy diversification in the form of biogas fuel and has great potential as a biogas production center for the local community (Azhimah, 2024). Therefore, as a strategic step for this development, further study and cooperation from all parties, especially the local government, is needed for the processing of biogas as an alternative renewable energy source.

CONCLUSION

The conclusion of this study is that the addition of 2% EM4 shows more effective results compared to the addition of 4% and 6% EM4, with a biogas volume of 330 ml at a temperature of 25°C in the digester. This also affects the flame test, which is greater in digesters with 2% EM4 addition compared to other digesters.

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Eco-Clean Innovation: Antibacterial Potential of Longan Peel (*Dimocarpus longan*) and Cinnamon (*Cinnamomum verum*) Extracts as a Sustainable Natural Formulation

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Abstract: Longan (*Dimocarpus longan*) fruit is often consumed without considering the potential of its discarded peel, which contains beneficial bioactive compounds. Meanwhile, cinnamon (*Cinnamomum burmannii*) is widely recognized for its strong antimicrobial properties due to the presence of essential oils and phenolic compounds. This study investigates the potential of combining longan peel and cinnamon extracts as natural antibacterial agents in the formulation of an eco-friendly detergent. The purpose is to evaluate whether these extracts can inhibit bacterial growth while maintaining effective cleaning performance, providing a sustainable alternative to conventional chemical-based detergents. The research follows a quantitative experimental design. Longan peels will be collected, dried, ground into powder, and extracted using ethanol and water. Cinnamon bark will undergo boiling and ethanol extraction to isolate its active compounds. Both extracts will then be incorporated into a detergent base prepared from coconut oil soap or mild surfactants, with varying concentrations tested. Antibacterial activity will be examined using the agar well diffusion method against *Staphylococcus aureus* and *Escherichia coli*. Plates will be incubated at 37 °C for 24 hours, and inhibition zones will be measured to assess antibacterial effectiveness. Data will be collected on inhibition zone diameters and stain removal efficiency, and analyzed statistically to determine differences between formulations.

INTRODUCTION

Longan (*Dimocarpus longan*) is a widely known tropical fruit, consumed for its sweet tasting flesh. People often throw away the peels without thinking about the impact it has on the environment. Research shows that the waste could make an unpleasant smell to the environment (Marjenah et al), and if it is left untreated, they could also produce methane, which is 25x more potent than carbon dioxide, that can lead to

worsening climate change (Idris Abd. Rachman et al.) Due to this condition, we should reconsider other options. Rather than letting the longan peel go to waste and become a source of pollution, there is an effective in cleaning and for antibacterial purposes. This study examines the incorporation of longan peel and cinnamon extract to turn it into something beneficial.

Similarly, cinnamon (*Cinnamomum burmannii*) is well

known for its benefits and for its warm, distinctive aroma and flavor, cinnamon also has very strong antimicrobial properties. These properties have been used for food preservation and in natural remedies. Its ability to inhibit bacterial growth makes it an ingredient for products with antibacterial purpose. Combining these two natural sources may produce a detergent that is both into detergent formulations to test their antibacterial activity and cleaning performance as a sustainable alternative to ordinary detergents.

LITERATURE REVIEW

Longan peel

Longan peel is the cover outside the longan fruit, and it is usually thrown away after consumption. People often see this as a waste, with no benefits. However, it is actually rich in valuable bioactive compounds. Studies have shown that longan peel contains a high amount of polyphenols, flavonoids, tannins, and polysaccharides, which contribute to its biological functions. These compounds contribute in giving the peel strong antioxidant properties, helping to prevent oxidation, as well as antibacterial activity against harmful microorganisms such as *Staphylococcus aureus* and *Escherichia coli*. This benefit can help the environment too, by innovating something new and reducing waste. These natural antibacterial properties make longan peel an eco-friendly alternative to synthetic chemicals.

Cinnamon

Cinnamon is a spice from the inner bark of the cinnamon tree and is commonly used for both culinary

and medicinal applications. Its bioactive properties include compounds such as cinnamaldehyde, eugenol, coumarin, and phenolic acids, which are primarily used for biological activities.

METHOD

The research was conducted using an experimental method, with longan peel and cinnamon as the study objects. These were tested against *Escherichia coli* and *Staphylococcus aureus* using the disk diffusion method. The tools and materials used in this study are as follows.

Apparatus

- 10 pcs of 250 ml of conical flask.
- 3 pcs of rough sifter.
- 10 pcs of funnel.
- 10 pcs of 100 ml beakers.
- 2 pcs of 1000 ml beakers.
- 1 bundle of aluminium foil.
- Water bath
- Rotary evaporator
- Oven
- Incubator
- pH probes
- Autoclaves

Materials

- Ethanol 70%.
- Coconut oil.
- Mild surfactant.
- Longan peel powder.
- Cinnamon peel powder.
- Distilled water.
- *E.coli* and *S. aureus*.
- Sodium bicarbonate.
- Concentrated HCl.
- Glycerin.
- Natural scent.
- Sodium chloride.

Preparation

1. Preparation of sample.

Weigh 400 g of longan peel and 400 g of cinnamon. Air-dry the samples for 2 days. Continue drying in an oven for another 2 days. Once dried, grind the samples using a blender. Sieve the ground material to remove coarse residues. Store the fine powder in a tightly sealed container until further use.

2. Extraction of Longan Peel and Cinnamon

Weigh 20 g of longan peel powder and place it into a dark glass bottle. Add 200 mL of ethanol 70%. Seal the bottle and store it in a dark place. Macerate for 1–2 days. Filter the mixture using filter paper. Evaporate the filtrate using a rotary evaporator at 40–50 °C until a concentrated extract is obtained. Store the concentrated extract in a refrigerator.

Weigh 20 g of cinnamon powder and place it into a dark glass bottle. Add ethanol 70% with a ratio of 1:10 (20 g: 200 mL). Seal the bottle and allow it to macerate for 1–2 days. Filter the mixture to obtain the extract. Concentrate the extract using a rotary evaporator. Store the concentrated extract in a refrigerator.

3. Flavonoid Test.

Dissolve 3 mL of extract in 100 mL of hot distilled water. Boil the solution for 15 minutes and filter it. Take 5 mL of the filtrate, add ~0.05 g magnesium powder and 1 mL concentrated HCl. Shake well. Observation: the appearance of a yellow–orange color indicates a positive result.

4. Antibacterial Test

a. Preparation of Agar Medium (Magvirah & Ardhani).

A total of 14 grams of Nutrient Agar was dissolved in 500 mL of distilled water. The mixture was heated and stirred continuously until completely homogeneous. The prepared medium was then transferred into a conical flask. All equipment used, along with the medium, was sterilized using an autoclave at a pressure of 121 MPa for 15 minutes.

b. Antibacterial Analysis Using the Agar Disk Diffusion Method (Anjas & Syafrudin)

Prepare sterilized nutrient agar in each Petri dish (for both control and antibacterial samples). Take 0.1 mL of the test bacteria (*Escherichia coli* and *Staphylococcus aureus*), and using a nichrome wire loop, spread the bacteria evenly on the Petri dish. Place the dishes in an incubator at 37°C and incubate for 24 hours.

5. Formulation of natural liquid detergent.

Wash containers and tools with soap and water, rinse with hot water, and dry. Wear gloves. In a measuring cylinder, mix 120 mL distilled water with 10–20 mL glycerin. Heat gently (max 40 °C) if needed. Pour 350 mL liquid soap into a large container, stir slowly. Add the water and glycerin mixture into the soap while stirring gently. If the extract is still in ethanol: dilute with 10 mL glycerin so that ethanol is <1% v/v in the final product. If the extract is concentrated and non-ethanolic, use directly. Add 10–15 mL (2–3%) longan peel extract and 10–15 mL (2–3%) cinnamon extract to the soap mixture. Stir gently. Add 10% NaCl solution little by little (1 mL each time), stir, and wait 5–10 minutes. Stop when viscosity is appropriate. Add preservative at the

recommended dose (e.g. sodium benzoate 0.15% → 0.75 g for 500 mL). Add 3–10 drops of fragrance if desired. Measure pH. If pH is too high (>9), reduce with citric acid solution until pH is 6–8. If too low, adjust slightly with diluted NaOH. Leave for 24 hours to check stability. If no separation/precipitate occurs, transfer into bottles and seal tightly.

RESULT AND DISCUSSION

The presence of flavonoids in longan peel and cinnamon extracts was tested using the alkaline reagent method, where the addition of magnesium powder produced a characteristic yellow-orange colour that disappeared upon the addition of concentrated acid. The result can be seen as follows.



Figure 1. Color of Longan (left) and Cinnamon (right) extraction.

Table 1. Flavonoid Test

No	Materials	HCl(aq) and Mg(s) Before add	After add Mg(s) and HCl(aq)
1	Longan peel	yellow-brick	yellow-orange
2	Cinnamon	light red	yellow-orange

The extract that we got then mixed with glycerine and sodium chloride. At first, we experienced the pH was very low. We slowly added

the sodium bicarbonate to make the pH increase. Then we got, the final pH is 6.96, indicating that the solution is quite safe to use.

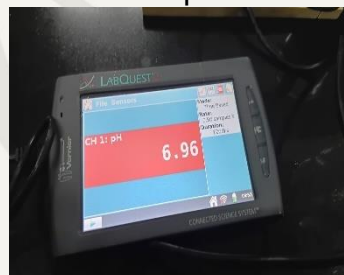


Figure 2. pH of extraction

Table 2. Antibacterial activity of Longan Peel and Cinnamon Extracts using Agar Disk Diffusion Method

Bacterial Strain	Treatment	Inhibition Zone (mm)	Notes
<i>E. coli</i>	Longan peel	5-7 mm	Less uniform lawn, small/mild inhibition observed
	Cinnamon		
<i>S. aureus</i>	Longan peel	8-10 Mm	Partial clear zone, reduced growth density
	Cinnamon		
<i>E. coli</i>	Control	0 mm	Growth present, no inhibition zone
<i>S. aureus</i>	Control	0 mm	Dense, uniform bacterial growth

The control plates showed dense bacterial growth with no inhibition zones, confirming that the medium supported bacterial

proliferation in the absence of any treatment. In contrast, the plates treated with longan peel and cinnamon extract displayed lighter growth areas and partial zones of inhibition. Against *Streptococcus* (Gram-positive), inhibition zones were broader and more visible, whereas *E. coli* (Gram-negative) exhibited only weak and irregular zones of inhibition.

The results also revealed that *Streptococcus* was more susceptible to the extracts compared to *E. coli*. This observation aligns with the structural differences between Gram-positive and Gram-negative bacteria. Gram-positive bacteria lack the protective outer membrane found in Gram-negative strains, making them more vulnerable to plant-derived antimicrobials. By contrast, the outer lipopolysaccharide layer in *E. coli* provides a permeability barrier, reducing the extract's effectiveness.



Figure 3. *E.coli* and *S.aureus* in control variable (without antibacterial)



Figure 4. *E.coli* and *S.aureus* in control variable (with antibacterial)

CONCLUSION

The experiment demonstrated that longan peel and cinnamon extracts possess antibacterial properties, with stronger activity against *Streptococcus* than *E. coli*. While inhibition zones were observed, they were less distinct compared to those produced by standard antibiotics, likely due to the crude nature of the extracts and limitations in diffusion. Despite some experimental errors, the results support the traditional use of longan peel and cinnamon as natural antimicrobial agents and suggest potential for further studies using refined extraction methods and standardized testing.

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with BSLT (Brine Shrimp Lethality
Test) of methanol extract of salam

leaves (*Eugenia polyantha*].
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3-in-1 Face Mask, Face Scrub and Face Wash from Goji Berry (Lycium Barbarum) Extract and Astaxanthin to Protect Skin from Free Radicals, Prevention of Acne and Premature Skin Aging

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Abstract: This research is based on Goji Berry (Lycium barbarum) extract and Astaxanthin. The purpose of this product is to address common skin problems such as acne-prone skin and premature aging. According to a preliminary study, the prevalence of acne sufferers in Indonesia ranges from 80–85%, with peak incidence occurring between the ages of 15–18, and 12% among women over 25 years old (Universitas Padjadjaran, 2024). Our 3-in-1 Clay Mask contains bioactive compounds and beneficial substances derived from Goji Berry extract and Astaxanthin. It is formulated in a clay form that can absorb excess oil, thereby helping to prevent acne formation. We believe that our 3-in-1 Clay Mask is safe for use by most individuals. The main ingredients include Goji Berry and Astaxanthin, along with semi-synthetic cosmetic formulation materials such as Phenoxyethanol, Xanthan Gum, Butylene Glycol, Polyethylene Scrub, and similar compounds.

INTRODUCTION

Indonesia is one of the countries with a tropical climate because it is located along the equator. This geographical position causes the country to experience high-intensity sunlight exposure throughout the year, as the sun's rays fall almost perpendicularly, resulting in greater solar radiation absorption and higher air temperatures (RS JIH, 2023). While sunlight exposure is beneficial for vitamin D synthesis, excessive exposure without adequate protection can lead to adverse skin effects. The primary source of such damage is ultraviolet (UV) radiation, which penetrates the epidermal and dermal layers and initiates oxidative reactions in skin cells (Qian et al.,

2023). UV radiation induces the generation of superoxide anions (O_2^-), which represent the first step in oxidative stress and are substrates for the enzymatic antioxidant superoxide dismutase (SOD) (Shin et al., 2023).

Superoxide dismutase (SOD) is one of the most essential endogenous defense enzymes in the skin. It catalyzes the dismutation of superoxide radicals into hydrogen peroxide (H_2O_2) and molecular oxygen (O_2), thereby preventing lipid peroxidation and damage to cellular components (Zhao et al., 2023). A decline in SOD activity due to chronic UV exposure leads to the accumulation of oxidative species, causing photoaging, inflammation, hyperpigmentation, and collagen

degradation (Matsumoto et al., 2022). Therefore, enhancing SOD activity through exogenous antioxidant supplementation represents a promising strategy to strengthen the skin's intrinsic defense system and mitigate UV-induced damage.

In this context, skin protection against UV-induced oxidative stress is particularly important in tropical regions like Indonesia (Hellosehat, 2025). The incorporation of natural antioxidants into cosmetic formulations has gained considerable attention for their potential to support and upregulate endogenous enzymes such as SOD. Natural antioxidants neutralize free radicals, reduce oxidative stress, and restore the integrity of collagen and elastin fibers (Vidović et al., 2022). Compared to synthetic compounds, plant-derived bioactives are safer, biodegradable, and capable of exerting multi-target physiological functions, including anti-aging, whitening, and anti-inflammatory effects (Shi et al., 2024).

Among various natural ingredients, goji berry (*Lycium barbarum*) has emerged as a potent source of antioxidants. It contains *Lycium barbarum* polysaccharides (LBPs), carotenoids, flavonoids, and vitamin C, all of which have been demonstrated to enhance SOD and catalase (CAT) activities in skin and neural tissues (Shi et al., 2024). LBPs in particular have shown to increase SOD expression, reduce malondialdehyde (MDA) levels, and inhibit lipid peroxidation under UV or oxidative stress conditions (Indriastuti et al., 2022). Through these mechanisms, goji berry acts as an effective antioxidant modulator,

capable of reinforcing the skin's natural antioxidant defense network. Astaxanthin, a red-orange carotenoid derived from microalgae and marine organisms, has also been recognized for its extraordinary antioxidant properties—550 times stronger than vitamin E and 40 times stronger than β -carotene (Bjørklund et al., 2022). Astaxanthin exerts its effects by stabilizing cell membranes, quenching singlet oxygen, and significantly upregulating SOD activity while reducing oxidative biomarkers such as MDA and nitric oxide (Lima et al., 2021). Moreover, topical astaxanthin formulations have been reported to reduce wrinkle depth, enhance elasticity, and increase moisture retention, making it an excellent active ingredient for anti-aging skincare (Bjørklund et al., 2022).

The synergistic combination of goji berry and astaxanthin—representing hydrophilic and lipophilic antioxidant systems respectively—offers a comprehensive approach to strengthen the skin's antioxidant defense, particularly through stimulation of endogenous SOD activity. Such a combination is expected to provide enhanced protection against UV-induced oxidative stress, reduce inflammation-related acne formation, and delay premature skin aging. However, there is limited scientific evidence investigating the integrated effects of both compounds within a single multifunctional topical formulation (Leite et al., 2019).

To address this gap, the present study develops Glowjible, an innovative 3-in-1 skincare formulation (mask, scrub, and facial

cleanser) containing goji berry and astaxanthin extracts. This formulation integrates the antioxidant properties of both compounds with the functional benefits of a clay-based delivery system that can absorb excess sebum, exfoliate dead cells, detoxify impurities, minimize pores, and revitalize the skin. The inclusion of natural scrub particles further supports mild exfoliation, enhancing dermal penetration of active compounds and improving microcirculation.

Therefore, this study aims to investigate the effect of goji berry and astaxanthin extracts on SOD activity and their overall contribution to antioxidant protection, acne prevention, and anti-aging performance in a 3-in-1 multifunctional formulation. This research is expected to provide novel scientific insights into the development of tropical, natural-based cosmetic products and to establish a strong foundation for safe, effective, and innovative antioxidant skincare tailored for tropical environments.

METHOD

Tools and Materials

Materials such as sample/extract powder, chloroform, 2N hydrochloric acid (HCl), distilled water, Dragendorff's reagent, Mayer's reagent, 95% ethanol, magnesium powder, concentrated hydrochloric acid (HCl), ether, acetic anhydride, concentrated sulfuric acid (H_2SO_4), petroleum ether, ferric chloride (FeCl_3) 10% solution, phosphate buffer (pH ~7.8), Nitroblue Tetrazolium (NBT), xanthine, xanthine oxidase, sample or SOD standard, and Beta Carotene. The

equipment used includes beakers, hot plate magnetic stirrer, aluminum foil, analytical balance, test tubes, pipettes/dropper, measuring cylinder, filter paper and funnel, water bath, evaporating dish or glass dish, stirring rod, test tube rack, spatula, watch glass, beaker tongs or test tube holder, and UV-Vis spectrophotometer.

Extraction of Goji Berry Extract

Goji berries were extracted using a solvent maceration method adapted from Leite et al. (2019) and Vidović et al. (2022). The dried goji berries were finely powdered and macerated in 96% ethanol at a ratio of 1:10 (w/v) for 7 days at room temperature with occasional stirring. The mixture was filtered through Whatman No. 1 filter paper, and the filtrate was concentrated under reduced pressure using a rotary evaporator at 45 °C to obtain a viscous extract. The resulting extract was then stored at 4 °C until further analysis. Ethanol was selected as the solvent due to its efficiency in extracting both hydrophilic and lipophilic bioactive compounds such as polysaccharides, flavonoids, carotenoids, and phenolic acids (Shi et al., 2024).

Phytochemical Screening Test

Alkaloid test was performed by weighing 0.2 g of the sample, adding 20 mL of chloroform, shaking, and filtering. The filtrate was mixed with 1 mL of 2N HCl and 9 mL of distilled water, shaken, and cooled. The filtrate was divided into two portions, each treated with Dragendorff's and Mayer's reagents. The appearance of a brick-red color with Dragendorff's reagent and a white precipitate with Mayer's reagent indicated the presence of alkaloids (Farnsworth, 1966).

Flavonoid test was carried out by dissolving 0.1 g of the sample in 1 mL of 95% ethanol, then adding 0.1 g of magnesium powder and 10 drops of concentrated HCl. The development of an orange-red to purple coloration indicated the presence of flavonoids (Ministry of Health of the Republic of Indonesia [Depkes RI], 1995).

Steroid and triterpenoid test involved macerating 0.2 g of the sample in 20 mL of ether for 2 hours. The filtrate was evaporated, and 2 drops of acetic anhydride followed by 1 drop of concentrated sulfuric acid (Liebermann–Burchard reagent) were added. The formation of a green or red color indicated the presence of steroids and triterpenoids (Farnsworth, 1966).

Essential oil test was conducted by adding 10 mL of petroleum ether to 0.2 g of the sample, followed by heating in a water bath for 20 minutes, cooling, and filtering. The filtrate was evaporated, and the residue was dissolved in 5 mL of ethanol, filtered, and re-evaporated. The presence of an aromatic odor in the residue indicated essential oils (Depkes RI, 1995).

Tannin test was performed by reacting 1 mL of the sample solution with 10% ferric chloride (FeCl_3). The appearance of a dark blue or greenish-black color confirmed the presence of tannins (Robinson, 1991).

Saponin test was carried out by adding 10 mL of hot water to 100 mg of extract, cooling, and shaking vigorously for 10 seconds. The formation of stable foam (1–10 cm high) that persisted for at least 10 minutes and remained after adding

2N HCl indicated the presence of saponins (Depkes RI, 1995).

Beta Carotene Test of Goji Berry

The beta-carotene content was determined using a UV-Vis spectrophotometer and a beta-carotene standard solution. A 50-ppm stock solution was prepared by accurately weighing 50 mg of pure beta-carotene and dissolving it in ethanol to a final volume of 50 mL (1000 ppm), which was then diluted to 50 ppm. The maximum absorption wavelength (λ_{max}) of beta-carotene was determined by measuring the absorbance of a 5-ppm beta-carotene solution in the visible range of 380–780 nm. A calibration curve was constructed by measuring the absorbance of standard beta-carotene solutions at concentrations of 5–25 ppm using the same instrument. The concentration of beta-carotene in the sample was then calculated by measuring its absorbance at the λ_{max} and applying the linear regression equation derived from the calibration curve.

The UV-Vis spectrophotometric method has been proven valid and reliable for the quantitative determination of β -carotene (Saiya & Caroles, 2023).

Antioxidant Test of Goji Berry Extract and Astaxanthin

The antioxidant activity of the extract was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay. A 1 mM DPPH solution was prepared in methanol as the radical source. Each prepared extract was mixed by combining 2.75 mL of the extract with 9.75 mL of the DPPH solution. The mixture was incubated at room temperature for 30 minutes, and the absorbance was then measured at a wavelength of 425 nm using a UV-Vis

spectrophotometer. The percentage of inhibition was calculated using the following formula:

$$\% \text{ Inhibition} = \left[\frac{(\text{Absorbance of Control} - \text{Absorbance of Sample})}{\text{Absorbance of Control}} \right] \times 100\%$$

After determining the percentage of inhibition, a linear regression equation ($y = a + bx$) was used to calculate the IC_{50} value (inhibitory concentration), where x represents the IC_{50} and y corresponds to 50% inhibition. Gallic acid solution was used as the standard, and its absorbance was measured at 425 nm across concentrations of 10, 20, 30, 40, and 50 ppm. The antioxidant assay was performed using the DPPH method with a 1 mM DPPH solution in methanol, following a modification of the method described by Zhao et al. (2021).

Stress Oxidative Dismutase (SOD) Test

The Nitroblue Tetrazolium (NBT) method measures superoxide dismutase (SOD) activity based on the enzyme's ability to inhibit the formation of blue formazan, which results from the reaction of superoxide radicals generated by the xanthine-xanthine oxidase system. In this procedure, a reaction mixture consisting of phosphate buffer (pH $\approx$ 7.8), NBT, and xanthine is combined with the sample or SOD standard. The reaction is initiated by adding xanthine oxidase, and the increase in absorbance at 560 nm per minute is recorded to determine the rate of formazan formation. SOD activity is calculated by comparing the rate of absorbance increase in the sample with that of the blank using the following inhibition formula:

$$\% \text{ Inhibition} = \left[\frac{(\text{Slope}_{\text{blank}} - \text{Slope}_{\text{sample}})}{\text{Slope}_{\text{blank}}} \right] \times 100\%$$

The inhibition percentage is then converted into SOD units (U/mL) using a standard curve. The result is expressed as U/mg protein, obtained by dividing the SOD units per milliliter by the protein concentration of the sample.

Formulation of 3 in 1 Face Mask, Face Scrub, and Face Wash

The 3-in-1 multifunctional formulation (*Glowjible*), combining a face mask, scrub, and wash, was prepared through a modified emulsion-dispersion technique optimized for stability and skin compatibility. The aqueous phase consisted of aqua (54.5%), butylene glycol (10%), sodium gluconate (0.4%), and xanthan gum (0.4%), which were heated to 70 °C under continuous stirring until a uniform gel base formed. Goji berry extract (20%) and astaxanthin (0.5%) were dissolved in a small amount of ethanol and incorporated into the base at 45–50 °C to preserve antioxidant activity. Sodium stearate (7%) and kaolin clay (4%) were then added to provide gelling and adsorptive properties, respectively, while the mixture was maintained at 70 °C until homogeneous. After cooling to 40 °C, phenoxyethanol SA (0.8%) and fragrance (0.2%) were added, and the pH was adjusted to 6.0–6.5 using 0.2% caustic soda. Polyethylene scrub (2%) was gently incorporated below 35 °C to maintain the integrity of exfoliating granules.

RESULT AND DISCUSSION

Organoleptic Test

Table 1. Organoleptic Test Result

Parameters	Description

Colours	Pink
Smell	Refreshing Scent
Texture	Thick cream with fine scrub particles

Phytochemical Screening Test

Table 2. Phytochemical Screening Test Result

Secondary Metabolite	Result
Alkaloid	+
Flavonoid	+
Tanin	+
Steroid/Triterpenoid	+
Oil Atsiri	-
Saponin	+

With compounds that have been detected in Goji Berry extract such as Alkaloids, Flavonoids, Steroids and Triterpenoids, Tannins, Saponins.

Antioxidant Test of Goji Berry Extract and Astaxanthin

Antioxidant DPPH test in Goji Berry

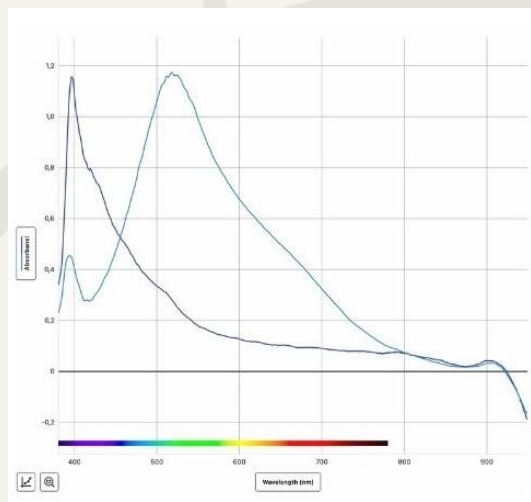


Figure 1. Graph Antioxidant Activity of Goji Berry Extract

Goji Berry is classified as having quite high antioxidants, with the antioxidant concentration results in goji berry extract (IC50) being 75.30 ppm, with a "quite high" antioxidant concentration calculated from 50-100 ppm.

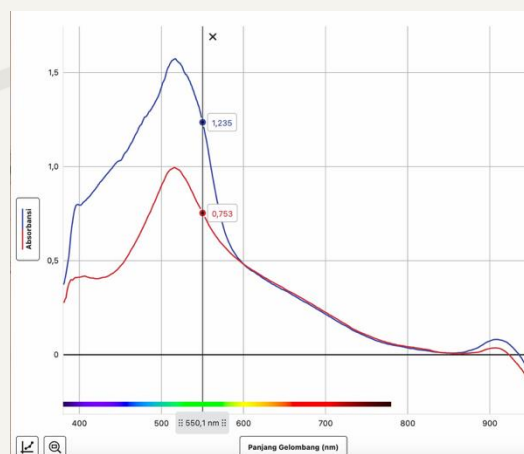


Figure 2. Graph Antioxidant Activity of 32 ppm Astaxanthin

Astaxanthin extract has an IC50 value of 32 ppm. Our astaxanthin extract sample was calculated to have an antioxidant concentration classified as Very strong; a "very strong" antioxidant concentration is calculated as <50 ppm.

Stress of Dismutase (SOD) Test of Goji Berry Extract and Astaxanthin

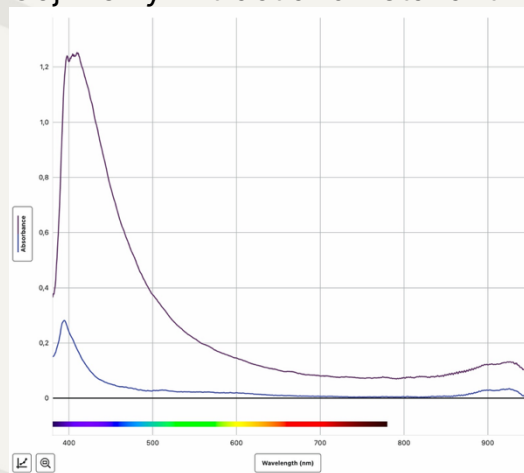


Figure 3. Graph SOD Test of Goji Berry Extract

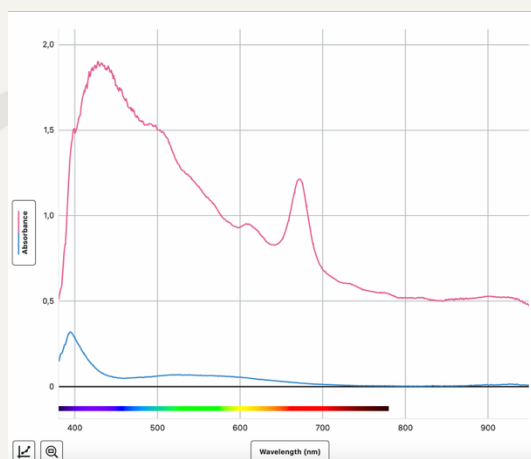


Figure 4. Graph SOD Test of Astaxanthin

The UV-Vis spectrum of astaxanthin showed a maximum absorption peak (λ_{max}) at 475 nm with an absorbance of approximately 1.9. Based on the calibration curve, the concentration of astaxanthin was estimated to be around 23–25 ppm.

CONCLUSION

A multifunctional product that combines a face scrub as an exfoliator, a face mask as a key skin problem solver, and a face wash as a pore cleanser. A clay mask plays a crucial role, absorbing excess oil, treating acne, and deeply cleansing pores. This product is made with natural ingredients, including goji berries and astaxanthin, making it safe for the skin. Goji berries are the main ingredient, with test results showing an IC_{50} DPPH of 75.30 ppm; SOD inhibition of 88.78%.

Goji berries and astaxanthin contain beneficial bioactive compounds that protect the skin from free radicals, including beta-carotene, antioxidants, and phytochemicals. Goji berries contain high levels of antioxidant activity, including superoxide dismutase.

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Formation of Earth: Roblox for Education towards Middle School Students

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Abstract: This study explores the use of Roblox as an educational medium for teaching the formation of the Earth to middle school students. Beyond its entertainment value, Roblox's 3D environments, scripting tools, and multiplayer features make it a potential platform for interactive learning. The research involved 25 students aged 13–15 from Jogjakarta Montessori School, participating in a learning activity designed using the ADDIE instructional model. The Roblox game simulated key stages of Earth's evolution, including the Hadean and Archaean eras, where students interacted with environments, collected items, and completed science-based tasks. A dual evaluation approach was employed: black-box testing assessed technical performance, while a Likert-scale questionnaire evaluated students' perceptions of usability, enjoyment, and understanding. Black-box testing showed the game functioned well overall, with only minor lag and NPC inconsistencies, while all core mechanics—movement, item collection, checkpoints, and scoring—operated smoothly on both PC and mobile platforms. The Likert-scale results indicated a positive reception. Students rated game navigation (75%), motivation to finish (70%), and excitement (85%), surpassing engagement levels of traditional textbook learning. Understanding of the chronological order of universe formation (70%) and differentiation of eras (72%) also improved, though confidence in retelling the sequence (70%) was relatively lower, suggesting a need for post-game reinforcement. Overall, the findings demonstrate that Roblox-based learning provides an engaging and effective supplement to traditional science education, with potential to enhance student motivation and conceptual understanding, while future refinements could further optimize the user experience.

INTRODUCTION

Roblox is a massively popular online platform and game creation system that allows users to design their games and experiences and share them with others (Wicaksono

et.al., 2024). As stated by Alhasan et.al. (2023), Roblox is known as a popular metaverse game that attracts an unfathomable amount of users worldwide.

Roblox can be more than just a game, as it's a powerful tool for interactive learning with its 3D landscape, scripting, and multiplayer features, students can be engaged and focused in this revolutionary interactive learning. Roblox creates a focused environment for children to play games and also has a slightly addictive effect which is especially harmful to students. These traits that Roblox excel can be used for educational purposes as the child will be more engaged and focused.

Although it can prove itself useful, as stated by the journal made by Hazria Imania (2025), Roblox has many negative side effects towards the regulation of children's emotions. As children may find it hard to control, monitor, and limit their emotions and impulses. Roblox also has the problem of lootboxes which are a concealed way of showing and promoting gambling to its audience of mainly children.

Based on the explanation above, the research is conducted to: 1) Applying theory of Earth's formation and its timeline then test it using blackbox methods, 2) Measure the quality of gameplay by the user using likert scale.

LITERATURE REVIEW

1. Educational Game

The various cases of successful serious games examined in this paper enable us to conclude that the serious games have great potential for training because they have a highly positive effect on the learning process of users. This is due to the fact that they attract users in a simple, dynamic way and turn them into the protagonists of their own learning processes.

2. Roblox platform game

The social gaming platform has a great chance to be utilized as a learning media. Not only the popularity, but this social game also allows the players to have an online interaction with the other players. This feature is suitable in a learning context since students can learn together in game-based learning. Roblox, as one of the social game platforms, also allows teachers to develop engaging learning content without facing a complexity of programming to develop a game.

3. AI Assistance Games

AI in educational games provides adaptive feedback, content generation, and personalized learning. Studies show AI tutors and agents can improve motivation, engagement, and problem-solving by adjusting difficulty and offering hints. Roblox, with its education initiatives, is well-suited for AI integration, as developers can embed adaptive tutors or AI-driven challenges. However, issues of safety, content moderation, and equitable access remain.

4. Blackbox analytical methods
"Black-box" analytics treat learning processes as hidden, inferring them from player logs. Methods like sequence mining and clustering can reveal learning patterns that tests may miss, though interpretability is a challenge. Roblox provides rich telemetry data, making it a strong testbed, but ethical issues (youth privacy, consent) are critical.

Games are activities (Adams, 2010)

METHOD

Participants

The activity involved 25 middle school students from Jogjakarta Montessori School. The participants,

aged between 13 and 15 years, consisted of both male and female students. They were selected as respondents because of their relevance to the learning objective: gaining insights into the development of the earth through an interactive digital game. Before engaging with the game, the students completed a short questionnaire to provide background information on their familiarity with video games and basic knowledge of scientific topics related to the Earth's formation (Gee, 2007).

Research and Development Process (ADDIE Model)

The development of the digital game was guided by the ADDIE model, which consists of five systematic stages (Branch, 2009):

- a. Analysis: Identifying the research problem, namely how to introduce and visualize the evolution of the Earth for middle school students in an engaging way.
- b. Design: Preparing the game overview and creating the algorithm, with the central theme based on Earth eras (Hadean, Archaean). Each stage of the Earth was mapped into a storyline and gameplay concept (Clark et al., 2016).
- c. Development: Building the game elements in Roblox Studio, including environments, objects, and interactions that represented the characteristics of each era (Roblox Education, 2021).
- d. Implementation: Deploying the game for classroom use, allowing students to explore the designed world and learn about the progression of the Earth.
- e. Evaluation: Conducting product evaluations, both through black-box testing to ensure the game's technical functionality

(Myers, Sandler, & Badgett, 2011), and through user feedback to assess learning usability, engagement, and clarity of scientific content.

Measurement Tools

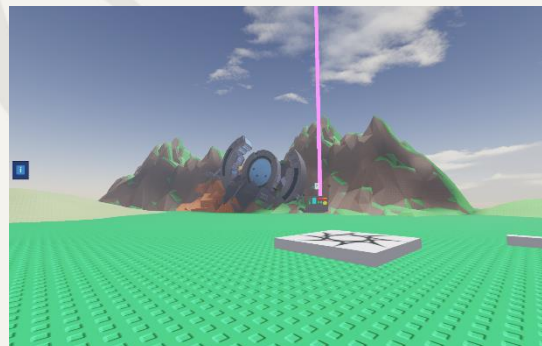


Figure 5. Main spawn (from the game)

Two main instruments were used to validate the activity:

- a. Black-box testing – to examine the game's technical functions, ensuring that all features, controls, and interactions ran smoothly without errors (Myers et al., 2011).
- b. Likert-scale questionnaire (1–5) – administered to students after playing the game, to evaluate their perceptions of usability, enjoyment, and their understanding of how the Earth evolved through different eras (Boone & Boone, 2012).

RESULT AND DISCUSSION

Game Overview

1. Game Homepages

This is the initial spawn point of the game environment, featuring a portal as the primary transition mechanism. Adjacent to the portal is an assistive robot designed to guide players at the beginning of their journey

2. Stage 1: Hadean Eon

Upon entering the portal, players are transported to the Hadean Eon, an early Earth environment characterized by extreme volcanic activity. This stage

features lava, which functions both as a hazard that eliminates the character upon contact and as a representation of the harsh conditions of the Hadean Earth. The environment includes two stages: one outside the cave and one inside. Within the cave, players encounter a gate that opens to reveal a massive crystal alongside a broken-down time machine. The presence of fire and lava serves not only as a gameplay challenge but also symbolizes the intense heat and geological activity that shaped the planet during the Hadean Eon.



Figure 6. Hadean spawn point

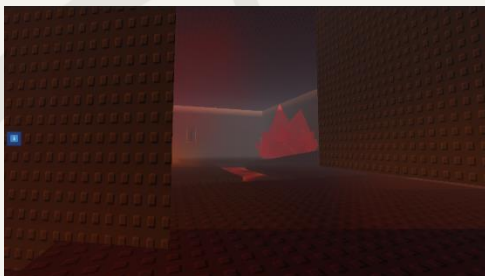


Figure 7. Hadean cave

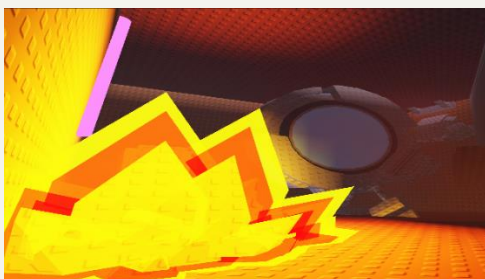


Figure 8. Hadean portal

3. Stage 2: Archaean Eon

Activating the broken time machine transports players to the Archaean Eon, an era characterized

by the first appearance of life on Earth. In this stage, a bacteria NPC assigns the player a quest to collect three bacterial forms scattered throughout the environment. This task mirrors the historical significance of microorganisms during the Archaean, where simple life such as bacteria began to dominate and gradually shape Earth's biosphere. Through this quest, players engage with both the challenge of collection gameplay and the scientific theme of life's earliest origins.



Figure 9. Archaean stage

4. Stage 3: Proteozoic Eon

After completing the bacterial quest, players are transported to the Proterozoic Eon, a period marked by significant geological and biological development. In this stage, players must overcome a series of environmental obstacles to progress toward the finish point. The environment features drifting and vibrating tectonic plates, which serve as both hazardous gameplay elements and scientific representations of the Earth's active geological processes during this time. These shifting plates not only challenge the player's movement and timing but also symbolize the gradual stabilization of Earth's crust and the dynamic forces that shaped the

planet's surface throughout the Proterozoic Eon.

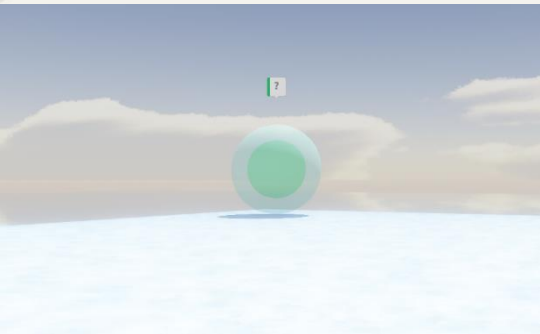


Figure 6. Protezoic bacteria npc

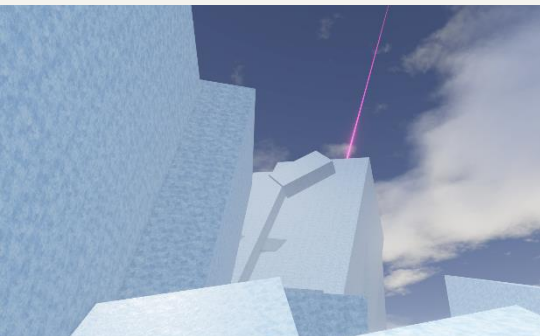


Figure 7. Protezoic parkour

A. Blackbox Testing
Table 3. Blackbox testing table

Test Case	Result
Hadean Stage	Movement works well, through rapid direction changes. Collision with lava immediately eliminates the player, forcing a restart. Transition to the Archaean stage is successful, though a bit laggy during the loading sequence. Map boundaries function properly.
Archaean Stage	Bacteria spawn correctly though multiplayer may cause issues, though loading is slightly laggy. The collection works as expected. Transition out of the Archaean stage runs properly, but again shows minor lag during the transition.

Protezoic Stage	Maneuvering through the moving platforms may be difficult for some users as it requires timing and repetition, the moving platforms could also cause lag depending on the device the user is using.
General Features	Instructions appear clearly on screen. The checkpoint system functions normally. Scoring updates correctly. The game runs on both PC and mobile devices, though minor lag is observed during loading and stage transitions.

The results of black-box testing for the Roblox game Formation of the Earth show that the game works well, even though there were some small problems such as lag during fast movement and stage transitions. In the Hadean stage, players could move their characters easily, but sometimes the movement was a little slow when changing direction quickly. When the player touched the lava, the character immediately "broke" or lost the game, which shows that the failure system works correctly. Players could collect items without problems, and they could move to the Archaean stage, although the transition was a bit laggy. In the Archaean stage, bacteria appeared in the right place and could be collected easily, with the counter showing the number in real time. If the player collected enough bacteria, the breathing ability was unlocked, while failing to collect them forced the stage to restart. Stage transitions also worked, but still had some lag. Other features like instructions on screen, checkpoints, scoring, and playing on both PC and mobile also worked well,

with only small delays during loading and transitions.

These findings support what other researchers found: if a game is not responsive, players may enjoy it less and their performance can drop (Jörg, 2015). Studies also show that even a short delay (lag) can reduce how well players perform in the game (Claypool & Claypool, 2006). However, the interactive part of the game supports learning by movement, which is effective and enjoyable in education (Ruiter et al., 2022). This style of learning is called kinesthetic learning, where students understand concepts better through moving and doing activities.

B. User Perception

Table 4. User perception table

Variable	Score (%)
Game Navigation	74.4
Clear Instructions	70.4
Controls & Visuals	77.6
Motivation to Finish	75.2
More Exciting than a Book	80.8
Desire to Learn Science	74.4
Understanding of Earth Order	75.2
Confidence in Retelling Order	70.4
Differentiating Earth Eras	75.2

The evaluation results of the Roblox gameplay titled Formation of the Earth (covering the Hadean, Archaean) indicate a generally

positive user perspective. Game navigation received a high score 74.4, showing that players were able to move smoothly between stages, such as exploring volcanic terrains in the Hadean and transitioning into the watery environments of the Archaean without difficulty. Clear instructions and the quality of controls and visuals were rated 77.6. Motivation to finish the game was 75.2 and excitement compared to traditional book-based learning 80.8 highlighted the engaging nature of the digital format; for instance, students described adventuring across eons as being more memorable than reading about them in a textbook. The game also fostered curiosity toward science 74.4, with some players asking follow-up questions about later eons after gameplay. Importantly, the game enhanced players' understanding of the chronological order of Earth formation 75.2 and helped them differentiate between distinct eras 75.2, such as distinguishing the lava-filled Hadean environment from the cyanobacteria-rich Archaean stage. However, confidence in retelling the sequence independently 70.4 was relatively lower, suggesting that while players recognized the order, further reinforcement may be needed for them to articulate the significance of each stage with certainty. Overall, the findings suggest that Roblox gameplay offers an effective and enjoyable medium for teaching abstract scientific concepts like Earth formation.

CONCLUSION

The study successfully created and tested a Roblox-based educational game aimed at helping

middle school students learn about the formation of the Earth. The game effectively addressed the purpose by allowing students to observe and explore the Hadean and Archean eons through interactive gameplay, combining movement, item collection, and stage challenges with scientific content. Students' responses indicated that the game enhanced engagement and understanding compared to traditional textbook learning, supporting its role as a tool to convey complex geological concepts in an accessible way. While minor technical issues and some uncertainty in sequence recall were noted, the game demonstrated potential as an educational medium, and future improvements could further strengthen learning outcomes and expand coverage to additional geological periods.

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Quercetin-Loaded Microneedle Patch from Red Onion Peel Extracts (*Allium cepa* L.) as a Safer Alternative of NSAIDs in Osteoarthritis Therapy

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Abstract: Osteoarthritis is a degenerative joint disease characterized by cartilage degradation, chronic inflammation, and persistent pain. Nonsteroidal anti-inflammatory drugs (NSAIDs) are the primary treatment for pain relief. However, long-term NSAID consumption often causes severe adverse effects, including gastric irritation, gastrointestinal ulcers, and increased cardiovascular risks. Therefore, there is a growing need for alternative therapies that are safe, effective, and suitable for long-term use. Red onion (*Allium cepa* L.) peel, an abundant agricultural by-product, is rich in bioactive compounds. Quercetin from onion peel exhibits anti-inflammatory activity by inhibiting the COX-2 and NF- κ B pathways, thereby reducing the production of pro-inflammatory prostaglandins. Phytochemical screening of onion peel extract revealed the presence of key secondary metabolites such as flavonoids, phenolics, alkaloids, tannins, saponins, steroids, and triterpenoids, which contribute to its biological activity. Antioxidant evaluation using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay demonstrated an inhibition percentage is 72,20%, indicating strong radical scavenging capacity. In addition, the SOD (Superoxide Dismutase) assay showed an inhibition percentage of 96% against superoxide radical formation, further confirming the high antioxidant potential of onion peel extract in reducing oxidative stress, which plays a crucial role in the progression of osteoarthritis. Thus, an innovative drug delivery system is required to improve its therapeutic efficacy. Therefore, the development of a microneedle patch loaded with quercetin-rich red onion peel extract has great potential as a safer alternative to NSAIDs for osteoarthritis management. This approach offers long-term therapeutic benefits while utilizing a low-cost, sustainable natural resource derived from agricultural waste.

INTRODUCTION

Joints are essential structures that connect two or more bones,

allowing movement, flexibility, and shock absorption that support daily human activities (Saladin, 2017). Joint damage can impair mobility, reduce quality of life, and even cause permanent disability (Felson, 2006). One of the most common joint diseases is osteoarthritis (OA), a progressive degenerative disorder of the articular cartilage accompanied by chronic local inflammation, persistent pain, and joint deformities (Hunter & Bierma-Zeinstra, 2019).

The main therapy for OA currently still focuses on nonsteroidal anti-inflammatory drugs (NSAIDs), such as ibuprofen and diclofenac, which have been proven effective in reducing pain and inflammation (Bally et al., 2021). However, long-term use poses serious risks. Lanar et al. (2021) reported that more than 30% of chronic NSAID users experienced gastrointestinal mucosal damage, with significantly increased risks of bleeding and ulceration. These side effects are also associated with elevated cardiovascular risks (Ungprasert et al., 2021). Intra-articular corticosteroid injections can provide rapid pain relief, but their effects are short-lived and repeated use may accelerate tissue damage (Xue et al., 2020).

The limitations of conventional therapies have prompted the search for safer, more effective, and sustainable alternatives. One promising candidate is red onion (*Allium cepa* L.) peel, an agricultural by-product rich in bioactive compounds such as quercetin, flavonoids, tannins, saponins, and anthocyanins (Nile et al., 2022). Quercetin is known to exert anti-inflammatory activity by inhibiting

the COX-2 and NF- κ B pathways, thereby suppressing the production of pro-inflammatory prostaglandins (Zhang et al., 2021). Furthermore, quercetin acts as a strong antioxidant capable of scavenging free radicals and enhancing endogenous defense enzymes such as superoxide dismutase (SOD) (Yuan et al., 2020).

Nevertheless, the clinical application of quercetin is often limited due to its low oral bioavailability, as it undergoes rapid hepatic metabolism and gastrointestinal degradation (Salehi et al., 2020). To overcome these challenges, modern drug delivery technologies such as transdermal microneedle patches offer an innovative solution (Ita, 2017). This system can penetrate the stratum corneum in a minimally invasive and painless manner, enabling active compounds to reach the target tissue directly, bypassing first-pass metabolism in the liver, and improving patient compliance (Prausnitz & Langer, 2008). By integrating dried red onion peel extract into biopolymer-based microneedle matrices such as gelatin, chitosan, or hyaluronic acid, a non-invasive, effective, and environmentally friendly drug delivery system can be developed (Larrañeta et al., 2016).

Oral NSAIDs remain the primary choice for OA therapy because of their proven efficacy in reducing pain and inflammation. However, their long-term use poses serious risks. According to Peura & Goldkind (2005), approximately 30–50% of regular NSAID users develop gastric or duodenal mucosal injury detectable by endoscopy, often without symptoms. Similarly, Sostres

et al. (2013) reported that 15–30% of patients on chronic NSAID therapy showed mucosal lesions upon endoscopic examination. These findings highlight that although effective, NSAIDs are unsafe for continuous use due to the increased risks of gastrointestinal bleeding and the need for endoscopic intervention.

Another commonly used option is intra-articular corticosteroid injections. McAlindon et al. (2017) demonstrated that this therapy can provide rapid pain relief, but its effects only last for a few weeks and diminish with repeated administration. Furthermore, a systematic review by Wernecke et al. (2015) indicated that repeated injections may actually accelerate joint tissue damage and increase infection risks. Additionally, this procedure requires professional medical personnel, making it impractical for long-term therapy.

These limitations clearly demonstrate the need for safer, more practical, and long-term therapeutic innovations. One potential candidate is the utilization of red onion peel (*Allium cepa* L.). Javdpour et al. (2020) reported that red onion peel is rich in quercetin, a compound with anti-inflammatory and antioxidant activities. Supported by modern drug delivery technology such as microneedle patches, which have been proven effective for the transdermal delivery of bioactive compounds because compared to other treatment, microneedle patch delivers bioactive compound directly without any pain (Ita, 2017; Lee et al., 2008), red onion peel extract holds significant potential as a superior alternative therapy for osteoarthritis

compared to conventional treatments.

Thus, the development of microneedle patches loaded with quercetin-rich red onion peel extract has strong potential to serve as a safer, more effective, long-term, and sustainable therapeutic strategy for osteoarthritis management.

METHOD

Equipment used in this study included: beaker glass (Pyrex, Germany); test tubes (Pyrex, Germany); stainless steel laboratory spatula (Bel-Art, SP Scienceware, USA); pipettes (Pyrex, Germany); blender (Philips, Indonesia); balance (superior mini digital platform scale); magnetic stirrer (Model SH-2); glass funnel; cotton (Selection); filter paper (Cytiva, Whatman No. 42).

Materials used in this study included: red onion peel, distilled water, ethanol 96%, HCl 2N, Dragendorff reagent, ethanol, magnesium powder, ether, acetic anhydride, concentrated sulfuric acid, petroleum ether, 10% ferric chloride solution, DPPH reagent, methanol.

Extraction of Red Onion Peels: Red onion peels in good condition were selected and washed with running water to remove impurities. The samples were dried at room temperature without direct exposure to sunlight to prevent degradation of active compounds, and then ground into a fine powder. A total of 50 g of powder was placed into a maceration glass bottle and mixed with 500 mL of 96% ethanol. The maceration process was carried out for seven days at room temperature with occasional shaking to ensure uniform extraction. After one week, the mixture was filtered to obtain the

filtrate, and the extract was concentrated using a rotary evaporator.

Phytochemicals screening of Red Onion Peels: Phytochemical screening was carried out to identify the presence of secondary metabolites. Alkaloid testing was performed by adding 20 mL of chloroform to 0.2 g of extract, shaking, and filtering the mixture; the filtrate was treated with 1 mL of 2N HCl and 9 mL of water, shaken in a test tube, cooled on ice, and filtered. The resulting solution was divided into two parts, each treated with Dragendorff and Mayer reagents; the appearance of brick-red (Dragendorff) or yellowish-white (Mayer) indicated the presence of alkaloids (Farnsworth, 1966). Flavonoid detection involved dissolving 0.1 g of extract in 1 mL of 95% ethanol, adding 0.1 g of magnesium powder and 10 drops of concentrated HCl; the formation of an orange-red to purple-red color indicated flavonoids, while yellow-orange suggested flavonoid presence (Depkes RI, 1995). Steroid and triterpenoid testing was conducted by macerating 0.2 g of extract with 20 mL of ether for 2 h, filtering, and evaporating 5 mL of filtrate, followed by adding 2 drops of acetic anhydride and 1 drop of concentrated sulfuric acid (Liebermann–Burchard reagent); a green or red color confirmed steroids or triterpenoids (Farnsworth, 1966). Essential oils were tested by dissolving 0.2 g of extract in 10 mL petroleum ether in a test tube fitted with a glass funnel moistened with water-soaked cotton, heating in a water bath for 20 min, cooling, filtering, and evaporating the filtrate. The residue was dissolved in 5 mL

alcohol, filtered, and re-evaporated; an aromatic odor indicated essential oils (Depkes RI, 1995). Tannin testing was performed by reacting 1 mL of extract solution with 10% ferric chloride solution; the formation of dark blue or greenish-black color indicated tannins. Saponin testing was conducted by dissolving 100 mg of extract in 10 mL hot water, cooling, and shaking vigorously for 10 s; the formation of stable froth (1–10 cm in height) persisting for at least 10 min after adding 2N HCl confirmed saponins.

Antioxidant Test with DPPH: For the antioxidant activity assay, the DPPH (1,1-diphenyl-2-picrylhydrazyl) method was employed, following the procedure described by Arnous et al. (2002). Briefly, DPPH powder (0.1 mM) was dissolved in methanol (975 μ L) to prepare the DPPH solution. Then, 25 μ L of the extract at various concentrations was added to the solution. The mixture was vigorously shaken, and the decrease in absorbance was measured at 515 nm after 30 min of incubation in the dark, with methanol used as a blank. The percentage of DPPH inhibition was calculated according to the following formula:

$$\text{DPPH Radical Scavenging Activity (\%)} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100\%$$

SOD Test: The Superoxide Dismutase (SOD) assay is a method used to evaluate antioxidant activity by measuring the ability of a sample to inhibit the formation of superoxide radicals. In this method, superoxide radicals are typically generated through a reaction system, such as the xanthine–xanthine oxidase

system, which produces superoxide anions. These radicals then react with a chromogenic substrate, such as nitroblue tetrazolium (NBT), forming a colored formazan product that can be detected spectrophotometrically. The presence of SOD or SOD-like activity in the sample will inhibit this reaction, resulting in a decrease in the intensity of the color formed. The percentage of inhibition can then be calculated based on the reduction in absorbance compared to the control. This method is widely used because it provides a simple and reliable way to assess the antioxidant capacity of natural extracts, biomaterials, or pharmaceutical formulations.

$$\% \text{ Inhibition} = \frac{A_{\text{blank}} - A_{\text{sample}}}{A_{\text{blank}} - A_{\text{negative}}} \times 100\%$$

Formulation of Microneedle Patch: The microneedle mold was fabricated by weighing 8.55 g of silicone rubber using an analytical balance, followed by the addition of 20 drops of benzoyl peroxide catalyst. The mixture was stirred until homogeneous, poured into a microneedling cartridge with the plunger removed, and allowed to set for 45 minutes or until cured. After curing, the mold was carefully removed from the cartridge. An 8% PVA solution was then prepared by dissolving 1.6 g of PVA in 20 mL of deionized water with continuous stirring in a water bath until fully dissolved. A volume of 350 μL of the PVA solution was dispensed into the silicone mold, centrifuged at 1500 rpm for 10 minutes, and subsequently dried at room temperature for 24 hours. The

vaccine mixture was prepared by combining 0.5 mL of red onion peels with 100 μL of etil selulos, 1 mL of PVP, and 2 mg HPMC. This formulation was applied onto the dried PVA layer, and the microneedles were stored under refrigeration to allow proper integration of the quercetine mixture with the PVA matrix. The product was removed from the mold and analyzed for morphology and mechanical strength

RESULT AND DISCUSSION

Phytochemical Screening Test

Compound	Screening Result	Note
Alkaloids	Formation of brick-red color (Dragendorff) and white precipitate (Mayer)	(+)
Flavonoids	Color changes to orange-red, purple-red, or yellow-orange	(+)
Steroids & Triterpenoids	Formation of green or red color	(+)
Essential Oils	Aromatic-smelling residue	(+)
Tannins	Formation of dark blue or greenish-black color	(+)
Saponins	No stable foam formation	(-)



Figure 1. From left to right, Alkaloids, Flavonoids Steroids & Triterpenoids, Essential Oils, Tannins, Saponins

Antioxidant Test with DPPH

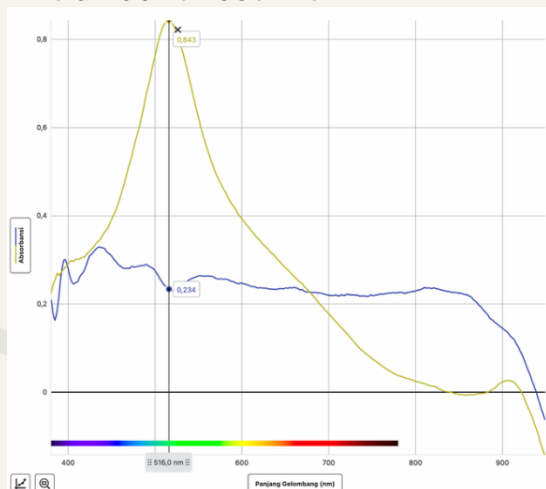


Figure 2. Antioxidant Test with DPPH Graph

The DPPH test showed that red onion peel extract had 72.2% inhibition, based on absorbance values of 0.843 (blank) and 0.234 (sample). This result indicates strong antioxidant activity, as lower absorbance means higher radical scavenging ability. The high activity comes from compounds in the peel such as flavonoids (quercetin), anthocyanins, and other phenolics that can neutralize free radicals. This supports reports that red onion peels contain more phenolic compounds than the bulb, making them valuable for health and pharmaceutical use. In microneedle patch development, this antioxidant activity can help wound healing, reduce oxidative stress in skin, and protect cells from damage.

SOD Test

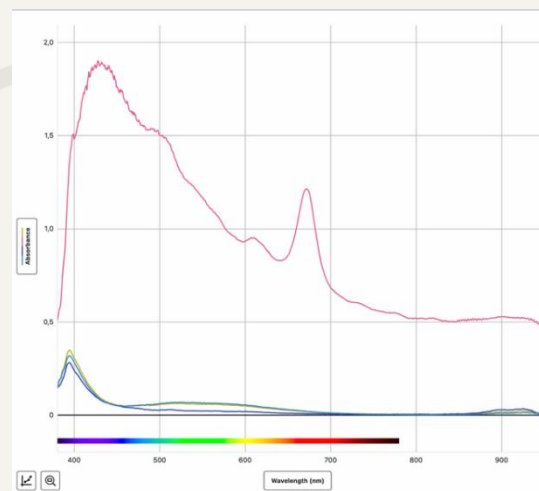


Figure 3. SOD Test Graph

The SOD assay showed that the red onion peel extract had a very high antioxidant activity, with 96.1% inhibition of superoxide radicals. This strong activity indicates that the extract contains compounds capable of effectively neutralizing superoxide, comparable to natural SOD enzyme activity. The result reflects the richness of bioactive compounds in onion peels, particularly flavonoids, anthocyanins, and phenolic acids, which are known to donate electrons and stabilize free radicals. Such high SOD activity supports the potential use of red onion peel extract in biomedical applications, including microneedle patches, to reduce oxidative stress, protect skin tissue, and promote faster healing.

Evaluation of Microneedle Patch with SEM

The microneedles showed sharp tips with uniform geometry, measuring about 152 μm in height and 70 μm in base width. SEM images revealed smooth surfaces with minimal cracks, and the shank and tip were clearly formed.

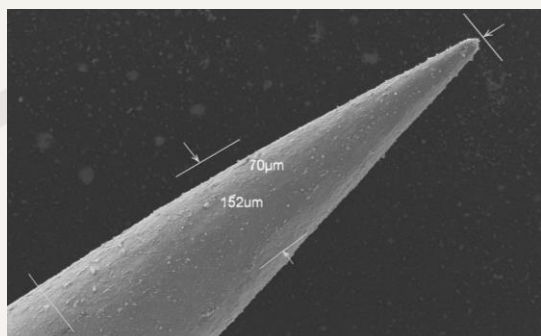


Figure 4. Microneedle Patch with SEM

These characteristics indicate that the microneedles were successfully fabricated with good structural integrity, suitable for skin penetration without causing deep pain. Their smooth surface and minimal defects suggest strong mechanical stability and low risk of breakage, while the well-defined tips support effective delivery of active compounds through the skin.

CONCLUSSION

This study demonstrates that red onion (*Allium cepa* L.) peel, an agricultural by-product rich in bioactive compounds such as flavonoids, phenolics, alkaloids, tannins, saponins, steroids, and triterpenoids, possesses strong antioxidant and anti-inflammatory potential relevant to osteoarthritis therapy. The extract exhibited high free radical scavenging capacity, with a DPPH IC₅₀ value of 75.30 ppm and 96% inhibition in the SOD assay, confirming its strong ability to reduce oxidative stress that contributes to disease progression. Furthermore, quercetin, the major flavonoid in onion peel, is known to inhibit COX-2 and NF-κB pathways, supporting its anti-inflammatory effects. The development of a microneedle patch as a novel delivery system successfully produced microneedles with sharp tips, uniform geometry,

smooth surfaces, minimal defects, and strong mechanical stability, making them suitable for skin penetration without causing deep pain and ensuring efficient delivery of active compounds. Overall, a quercetin-rich red onion peel microneedle patch shows great promise as a safe, effective, and sustainable alternative to NSAIDs for long-term osteoarthritis management.

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Integration of the Hydrodynamic Disk System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers

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Abstract: Plastic pollution in small rivers is one of the main factors contributing to the increasing accumulation of plastic waste in the oceans. Small rivers often serve as primary distribution channels for plastic waste due to low public awareness and the lack of effective cleaning technologies. This study aims to develop and evaluate the efficiency and operational feasibility of a hydrodynamic disk system and an Arduino-based automatic mechanical arm for plastic waste sorting in rivers. This system is designed to direct floating plastic waste toward the riverbanks, sort it by size, and collect the sorted waste for recycling. Testing was conducted using a prototype in a simulated miniature river environment. The results indicate that the hydrodynamic disk successfully directed plastic waste with an average efficiency of 85%, with a sorting success rate of 90% for waste larger than 5 cm and 70% for waste smaller than 5 cm. The Arduino-based automatic mechanical arm successfully captured and collected plastic waste with an 80% success rate, depending on water current conditions. The system performed optimally in low to moderate flow speeds (<1.5 m/s), while at high flow speeds (>2 m/s), waste collection efficiency decreased to 65%. The implications of this study suggest that the hydrodynamic disk and automatic mechanical arm system have the potential for large-scale implementation as an alternative solution for managing plastic waste in rivers. Further development is needed, particularly in enhancing the durability of the disk material and optimizing waste detection sensors to improve the precision of the mechanical arm's operation. With this innovation, it is expected that contributions to reducing plastic waste in rivers will increase, supporting environmental sustainability.

INTRODUCTION

Background

Plastic has become one of the most pervasive types of waste polluting the environment, especially small rivers flowing through residential areas. These small rivers often serve as primary channels for

disposing of domestic waste, either intentionally or unintentionally, including plastic waste generated from various household activities. Over time, plastic waste accumulating in these small rivers is carried by the current to larger rivers and eventually to the ocean. This

process makes small rivers one of the main distribution pathways for plastic waste, significantly contributing to global pollution. Research data indicate that around 80% of plastic waste in the ocean originates from rivers, including small rivers that are often poorly monitored. Small rivers, which should function as part of a healthy environmental ecosystem, have instead become dumping grounds for waste, particularly plastics, with long-term detrimental impacts.

The problem of plastic waste affects not only the beauty of the environment but also disrupts aquatic ecosystems as a whole. The presence of plastic waste in rivers threatens the lives of various creatures living in and around these aquatic ecosystems. Plastic waste often entangles fish, waterbirds, or other fauna, causing injuries, physical damage, or even death. Furthermore, the accumulation of plastic waste can obstruct water flow, reducing the river's capacity to channel water effectively. In certain conditions, this disrupted flow can trigger flooding, especially during heavy rains when the river cannot accommodate the increased water volume. Additionally, plastic waste that gradually degrades into microplastics spreads more widely into the surrounding environment. These microplastics can then enter the food chain through consumption by aquatic animals, which in turn are consumed by humans. The accumulation of microplastics in the human body poses serious health risks, including metabolic disorders, hormonal imbalances, and tissue damage due to exposure to harmful chemical compounds.

Public awareness of the importance of keeping small rivers free from plastic waste remains low. Most people still regard small rivers as waste disposal sites without serious consequences. In fact, these small rivers play a crucial role in maintaining the balance of local ecosystems and serving as channels for clean water distribution to broader areas. This lack of understanding hampers various initiatives aimed at cleaning up plastic waste in small rivers, which often fail to be effective. Although some manual cleanup efforts are carried out by communities or groups, these activities are typically unsustainable. This is due to limited resources, whether in terms of labor, time, or adequate technology. As a result, the problem of plastic pollution in small rivers continues to recur and is difficult to resolve entirely. If left unaddressed, this situation will further degrade environmental quality, threaten local ecosystems, and add to the global plastic pollution burden.

An innovation is needed to prevent floating plastic waste from entering deeper water areas, to sort waste by size, and to provide the sorted waste as raw material for recycling. The proposed technology in this study should prioritize sustainability, being environmentally friendly and energy-efficient. One possible approach is developing a rotating disc system based on hydrodynamic principles to direct and sort waste. Subsequently, the waste collection process would be supported by an automated mechanical arm controlled by an Arduino microcontroller, enabling precise operation with minimal manual intervention.

Problem formulation

The research problems in this study are as follows:

1. How efficient is the integration of the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers?
2. What are the operational techniques for integrating the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers?

Objectives

The objectives of this proposal are as follows:

1. To determine the efficiency of the integration of the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers.
2. To understand the operational techniques for integrating the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers.

Hypothesis

1. The Integration of the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm is effective for Plastic Waste Sorting in Rivers.
2. The operating system of the Integration of the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers can be implemented in a model using a prototype.

Benefit Of Research

For Researchers:

Enhancing the design and technology of plastic waste filtering systems, supporting more effective river waste management, reducing negative impacts on ecosystems,

and developing flood mitigation solutions.

For the Community:

This research is beneficial for reducing flood risks, improving environmental and water quality, raising awareness of waste management, creating job opportunities, and supporting a sustainable economy.

LITERATURE REVIEW

Environmental Pollution in Aquatic Ecosystems

Water pollution refers to the entry of plastic waste into water sources, such as rivers, lakes, seas, and other bodies of water, which causes changes in water quality and has negative impacts on both the environment and human health. Plastic waste contaminating water bodies has become an increasingly urgent issue worldwide, as plastic is a material that is very difficult to decompose naturally. The degradation process of plastic takes a very long time, even hundreds of years, so plastic that ends up in water persists and disrupts aquatic ecosystems.

The main source of plastic pollution in water bodies comes from improperly disposed plastic waste, whether from household garbage, industrial activities, or other sources. This plastic waste can be carried by water currents from small streams to the sea. Along the way, the plastic may settle on the waterbed or float on the surface, obstructing water flow pathways and disrupting aquatic life.

Plastic waste polluting water bodies has a detrimental impact on ecosystems. Many aquatic animals, such as fish, birds, and marine mammals, mistake plastic for food



and end up ingesting it. This plastic can block the digestive systems of these animals, leading to starvation or even death. Additionally, plastic that breaks down into microplastics can enter the bodies of marine organisms through the food chain, which in turn can pose risks to human health (Khansa, 2021).

Sea Water Pollution

Indonesia, with its vast marine territory, faces a serious issue of plastic waste pollution. As the world's second-largest contributor of plastic waste after China, approximately 8 million tons of plastic waste flow into the oceans each year. This not only damages marine ecosystems but also endangers the marine life that inhabits them.

Plastic pollution in the oceans has a direct impact on humans. Contaminated seawater can affect the quality of water used daily, increasing the risk of diseases caused by bacteria or harmful substances. Moreover, marine organisms exposed to plastic can become infected and carry toxins. When consumed, these toxins can enter the human body and pose health risks.

Plastic waste also negatively impacts the tourism sector. Polluted beaches reduce their appeal, leading to a decline in tourist visits. This issue requires serious attention to preserve the marine environment, protect public health, and support Indonesia's tourism economy (Jamika, 2023).

River Pollution

River pollution caused by plastic waste has become a significant environmental issue in many countries, including Indonesia. Rivers often serve as the main

channels for disposing of plastic waste, whether from households, industries, or other activities. Plastic discarded into rivers flows toward the sea, polluting aquatic ecosystems and threatening aquatic life. Furthermore, plastic that breaks down in water turns into microplastics, which are hazardous to the health of both humans and marine animals.

In Indonesia, several major rivers suffer from severe plastic pollution. One example is the Ciliwung River in Jakarta, which is contaminated by plastic and other waste. A study conducted on the Banyu Urip River in Gresik Regency revealed that microplastics are present in significant amounts in coastal waters, which can then enter the food chain through fish consumption.

Plastic in rivers obstructs water flow, damages natural habitats, and can cause flooding due to clogged waterways. In addition, this pollution directly impacts the water quality used by communities for daily needs. Microplastics have also been detected in the bodies of fish consumed by coastal communities, indicating a threat to human health. Exposure to microplastics can lead to metabolic disorders, neurotoxicity, and even increase the risk of cancer. What is Plastic?

Plastic is a lightweight, elastic, and practical material widely used in daily life, but it is difficult to decompose, leading to a continuous increase in waste. Research shows that plastic waste, including in Southeast Asia, contributes significantly to ocean pollution. One solution is to process plastic into non-structural composite materials.

PVC, one of the most commonly used thermoplastics, has advantages such as resistance to corrosion and chemicals, but it is brittle. The addition of plasticizers like Dioctyl Phthalate (DOP) can improve the flexibility of PVC, although DOP is harmful to health. As an alternative, Virgin Coconut Oil (VCO), with its natural saturated fatty acids, is safe and has antimicrobial properties, making it a more environmentally friendly plasticizer. This research mixes PVC with VCO and the solvent THF to produce a new composite material, whose mechanical properties are tested through tensile and flexural tests. The goal is to create an innovative material that is more flexible, tough, and safe for various applications, while also providing benefits for plastic waste management.

Negative Impacts of Plastic on the Environment

In daily life, plastic is used in various products with different shapes, functions, and is very popular because it is widely used by the public. Plastic products can take the form of household items such as baby bottles, forks, plates, glasses, spoons, cooking utensils, and more. However, despite its widespread use, plastic is extremely harmful to both health and the environment. Recently, a sperm whale (*Physeter Macrocephalus*) was found dead in the waters around Kapota Island, Wakatobi, Southeast Sulawesi, and three turtles were found dead in the waters around Pari Island, Thousand Islands, North Jakarta. Local fishermen discovered these deaths, and the cause was plastic ingested by these animals that could not be digested properly. This highlights that plastic cannot be broken down

by seawater and is very dangerous for marine life, as much plastic waste is discarded into the ocean in various forms and types (Qodriyatun, 2018:18). Plastic waste that is buried in the ground is difficult to break down or degrade (non-biodegradable). This plastic waste can take several generations to decompose completely, sometimes requiring hundreds of years to break down or decompose properly in the soil.

Efforts to Reduce Plastic Waste

Plastic waste, especially from bottled and packaged water cups, creates a lot of waste in the surrounding environment. This is because products like water are often sold in plastic bottles or cups. Packaged drinks, especially mineral water in plastic cups, are offered as additional items for individual needs in various activities. Plastic bottle or cup waste is typically thrown into regular trash bins, mixed with other types of waste. The mixing of different types of waste leads to longer recycling processes, such as sorting and cleaning, which require high costs and energy. Additionally, mixed plastic waste has a higher chance of not being properly recycled.

A solution to the plastic waste problem, particularly for plastic bottles, is the utilization of a plastic bottle waste bank (BSBP). In this study, the BSBP is designed according to the needs of the users so they will be motivated to use it. The basic shape of the BSBP resembles a bottle, standing 240 cm tall with a diameter of 100 cm, and it can hold approximately 1,440 bottles. The BSBP has a bright base color, with a combination of red and yellow. It will also be equipped with a



counter that tracks the number of users, as well as stickers outlining the usage steps. Offline and online socialization strategies will be required for BSBP implementation. This research is dedicated to offline methods. The goal of the socialization is to encourage the public to bring their plastic bottles and cups to the waste bank. Community-based social marketing is used in the process of socialization. Some strategies implemented include direct oral presentations, creating leaflets and posters for teaser presentations, promoting the program through the internet, collecting waste from meetings, holding special events, and inviting the public to bring their used plastic bottles to the Koti. After collection, the plastic waste will be recycled or repurposed into crafts and home decorations.

Plastic Recycling

Most of the waste (nearly 75%) consists of types that cannot decompose naturally in a short period (inorganic). At the same time, organic waste, which decomposes easily, is used by many people to make briquettes, natural fertilizers, and natural gas. In contrast, plastic waste and other non-biodegradable materials are still recycled only to a limited extent. However, processing such waste is very challenging and requires large land areas for disposal (landfills), which has become a significant issue for human life. Furthermore, waste also has potential uses that can be profitable and have economic value. When society's perception of waste changes from seeing it as useless to viewing it as something that can be transformed into something aesthetically pleasing, useful, and

economically valuable, it can lead to new opportunities. This company has one goal: to foster entrepreneurship in the community by utilizing non-biodegradable waste (Rizki, 2023).

Plastic Waste Management in Rivers

Waste management includes the processes of collection, transportation, and final processing with a regional and integrated approach to reduce the volume of waste, optimize sorting, and minimize the negative impacts of managing landfills (ISWA, 2017). Plastic, a product of the polymerization of simple molecules, is divided into thermoplastic (which can be melted and reformed) and thermosetting (which cannot be remelted) types (Singh et al., 2019). The use of plastic has increased due to its lightweight, practical, and economical properties, but it has also become a serious environmental problem due to its contribution to single-use plastic waste.

Hydrodynamics

The term Hydrodynamics is used in several subfields of ocean engineering, and in this context, it specifically refers to the interaction between fluids and structures, particularly the interaction between ocean waves and marine structures. The goal of this activity is to develop a book that can serve as a reference for both undergraduate and graduate students in ocean engineering, as well as for practitioners who frequently use software to calculate wave forces and analyze the motion of marine structures.

The word hydrodynamics contains the term "hydro," which comes from the Greek word for water, while "dynamics" refers to

movement. In this context, it pertains to the movement of water, or in this case, fluid flow or water flow. Therefore, hydrodynamics involves the study of the flow of fluids (specifically water). Hydrodynamics is also considered a branch or application of mathematics, as fluid flow problems are generally solved using mathematical approaches. The discussion concludes with the topic of structural movement (response) due to wave loads, which allows for the formulation of motion equations, thereby enabling the prediction of the structure's response (Krisnaldi, 2020).

Arduino and Motion Sensors

The PIR (Passive Infrared) Motion Sensor is an essential component for various Arduino and IoT (Internet of Things) projects. This sensor is used to detect temperature changes caused by moving objects in front of it. The working principle of the motion sensor is based on detecting infrared radiation emitted by objects and converting it into an electrical signal. The motion sensor does not emit infrared radiation itself but only detects changes in the existing radiation pattern.

The PIR sensor has a lens that focuses infrared radiation from the surrounding environment onto the PIR sensor. The sensor consists of two thermoelectric sensors that are sensitive to infrared radiation. When a person or object moves in front of the sensor, the change in the infrared radiation pattern can be detected by the motion sensor. This results in a change in voltage or electric current, which is interpreted by Arduino as a motion signal.

The electrical signal produced by the sensor is necessary for the electronic circuit to generate an

appropriate output. Therefore, the PIR motion sensor is a device that enables easy and efficient motion detection in Arduino-based projects. With a deep understanding of the working principles of the motion sensor and implementation steps, you can quickly create various applications involving motion detection.

State of The Art

In this research, three previous research journals related to plastic waste sorting are included. These journals are as follows;

1. LITERATURE STUDY ON THE USE OF PLASTIC WASTE TO CREATE CREATIVE PRODUCTS by Dewi, Ni Made in 2022 from the Civil Engineering Department, Mataram Campus, UNMAS Denpasar. This research investigates the processing of plastic waste into various creative products that can be used by the community.
2. IMPLEMENTATION OF PLASTIC WASTE MANAGEMENT IN BENGAWAN SOLO RIVER BY THE BENGAWAN SOLO OFFICE IN SURAKARTA by Fatma, Baharrudy, and colleagues in 2020 from the Law Department, Sebelas Maret University, Surakarta. This research aims to understand the implementation of waste management in the Bengawan Solo River by the Surakarta City Environmental Agency.
3. AUTOMATIC WASTE SORTING BASED ON ARDUINO UNO by Eko Widodo in 2020 from the Computer Technology Department, Bina Sarana Informatika University. This research explores the impact of globalization and technology development in the field of microcontrollers and sensors on daily life. In particular, it highlights

the need for waste sorting automation, driven by the lack of awareness in modern society regarding waste management.

The innovation in this research lies in the integration of a *Hydrodynamic Disc System* and an *Automated Mechanical Arm Based on Arduino* for plastic waste sorting in rivers. This system utilizes the natural energy from water flow to drive the disc system, which captures, diverts, and sorts plastic waste floating on the water surface. The waste is then collected by a mechanical arm controlled by an Arduino microcontroller.

This approach harnesses the power of the river's water flow to operate the sorting mechanism, reducing the need for external energy sources. It offers an environmentally sustainable solution to address the growing problem of plastic pollution in rivers, ensuring efficient waste collection and contributing to cleaner water bodies.

METHOD

Tools and Material

Tools and Materials Used in This Research:

Tools:

- A serrated disk made of plastic with a density lighter than water, allowing it to float and rotate efficiently in water.
- A structural assembly to support and align the rotating disks for effective operation
- Plastic Catching Net in a Rectangular Metal Frame with Three Compartments
- Mechanical Arm
- Arduino Set

Material:

- Water used in the miniature river setup to test the prototype,

simulating real river conditions for evaluating the system's performance.

Design and Research Procedure

Here is the prototype design of the Integration of the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers.

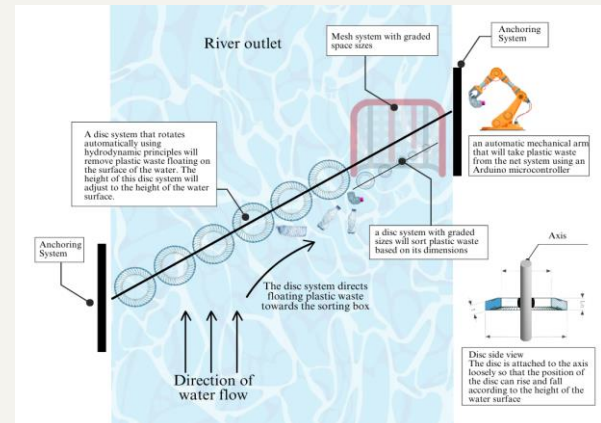


Figure 10. Prototype design of the Integration of the Hydrodynamic Disc System and Arduino-Based Automatic Mechanical Arm for Plastic Waste Sorting in Rivers.

Data Processing and Analysis

Data Analysis in this Research includes the following data:

1. Calculation of efficiency in the integration of the hydrodynamic disk system and Arduino-based automatic mechanical arm for plastic waste sorting in rivers. This efficiency observation includes testing the system's ability to capture floating plastic waste, redirect it, and sort it based on the dimensions of the plastic waste. High efficiency is calculated by the percentage of success in the system's ability to capture, redirect, and sort the floating plastic waste.
2. The operational performance of the system is analyzed based on the feasibility of implementing the system in actual field conditions. The

system will be tested in field conditions that are feasible, adjusting to the dimensions of the prototype.

RESULT AND DISCUSSION

Discussion

Based on the research findings, several factors affecting system performance were analyzed:

1. Hydrodynamic Influence on System Efficiency

The hydrodynamic disk is designed to utilize water flow to direct plastic waste along a specific path. The system's efficiency depends heavily on the disk design and water current speed. In strong currents, the disk struggles to maintain plastic waste on the desired path.

2. Effectiveness of the Mechanical Arm in Waste Collection

The Arduino-controlled mechanical arm performed well in collecting waste, but operational stability issues remain. Implementing additional sensors for more accurate waste detection could enhance its performance.

3. Potential Field Implementation

Although this study is still in the prototype testing phase using a miniature model, the results indicate potential for larger-scale implementation. Some necessary improvements include increasing the durability of the disk material and optimizing the mechanical arm control for better responsiveness to dynamic river conditions.

Implications of Research Findings

1. Contribution to Reducing Plastic Waste in Rivers

Implementing this system could provide an alternative solution to plastic pollution in small rivers, which are often unmonitored. If deployed on a larger scale, this system could

help reduce plastic waste before it reaches larger rivers and eventually the ocean.

2. Opportunities for Further Development

The results of this study could serve as a foundation for developing similar systems on a larger scale with more advanced features, such as integrating artificial intelligence (AI) to enhance sorting accuracy.

Research Limitations

Although the research results indicate relatively high efficiency, several limitations must be considered:

- The tests were conducted on a miniature scale, which may not fully represent real field conditions.
- The study has not yet tested various types and shapes of plastic waste, requiring further research to understand how waste characteristics influence system efficiency.

CONCLUSION

Conclusions

The conclusions of this study are as follows:

1. The integration of the hydrodynamic disk system and Arduino-based automatic mechanical arm is effective for sorting plastic waste in rivers.
2. The operational system of this integrated setup can be implemented in a model using a prototype.

Suggestions

Based on the research findings and analysis, several recommendations for further development are as follows:

1. Development of More Durable Disk Materials for High Currents
Using more flexible and lightweight materials could improve efficiency in



capturing plastic waste under various current conditions.

2. Optimization of Sensors and Control Algorithms for the Mechanical Arm

Adding ultrasonic sensors or AI-based cameras could enhance the accuracy of the mechanical arm in collecting waste.

3. Field Testing on a Larger Scale To evaluate the system's effectiveness in real river conditions, further testing should be conducted in more representative locations with a wider range of environmental conditions.

With further implementation and development, this system has the potential to become an innovative solution for addressing plastic pollution in water bodies, particularly in small rivers that often go unnoticed.

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Modified Levee with Pump System Integrated with Zeocarbon Nanofiltration from Zeolite and Water Hyacinth (*Eichhornia crassipes*) for River Overflow Control and Filtration

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Abstract: One effort to control river flow and prevent flooding is the construction of levees. However, heavy rainfall and high-water discharge can damage levees and ultimately trigger floods. In Indonesia, levee damage is addressed by building temporary levees, and the overflowing water is pumped using electric pumps. Unfortunately, the pumped water is discharged back into the river. Therefore, this research develops a prototype of a modified levee design with an automatic pump that does not require an external power source. This levee is also equipped with a Zeocarbon nanofiltration system. The activated carbon used in Zeocarbon is derived from water hyacinth. The performance of the automatic pump is measured based on changes in the stored water level. Over 40 seconds, the water level decreased by 2 cm, with a pumped water volume of 100 mL. Furthermore, the morphology of the Zeocarbon was analyzed using a Scanning Electron Microscope (SEM). The results show that the pores of Zeocarbon are smaller than those of activated carbon and zeolite. Subsequently, a water sample from Sangguling Lake, which originates from the Citarum River flow, was filtered using the Zeocarbon system. Organoleptic tests showed that the filtered water had no odor, color, or sticky properties. Additionally, the pH of the lake water after filtration was 7, and an iron ion quality test using KSCN reagent showed that the water did not turn yellow. Furthermore, the AAS test results indicated that the absorbance value of iron (Fe) decreased from 0.0091 to 0.0031 and manganese (Mn) decreased from 0.0175 to 0.015 after filtration, while the amount of chromium (Cr) remained unchanged. A coliform test's results showed that the filtrate water sample contained 0 MPN/100 mL, whereas the non-filtered water contained 4 MPN/100 mL.

INTRODUCTION

Flooding is a disaster that can be caused by various factors, including high rainfall, accumulation of waste, eutrophication of water hyacinth (*Eichhornia crassipes*),

damage to levees, and development along riverbanks. Since the beginning of 2023, several regions in Indonesia, such as Tangerang (Pranita, 2023), Lamongan (Arfah, 2023), Semarang (Antara, 2023),

Bekasi (Ato, et al., 2023), and Gresik (Noorca, 2023), have experienced flooding caused by high rainfall and damage to the levee.

Levees are one of the river defense structures designed to control flood flows so that they cannot be operated continuously to avoid damage. In addition, the water storage capacity of the pump is also limited. Furthermore, it should be noted that the pumped water must be discharged back into a safe waterway to avoid further negative impacts.

Therefore, this study developed a prototype design for a modified levee with an automatic pump that does not require an external power source and is equipped with a Zeocarbon nanofiltration system. The aim is to enable the water stored by this levee to be utilized. Levees are generally made of sand and soil and are hydraulic structures that are constantly exposed to erosion or infiltration due to river flow. Levees made of soil deposits have several weaknesses, such as the inability to withstand strong pressure and high-water retention levels. This needs attention because the stability of the levee will become critical if there is a high-water retention level (Tugiran, et al., 2016).

Flooding and standing water that does not recede due to levee damage and high rainfall in Indonesia are generally handled using gasoline or diesel-powered water pumps. The use of these water pumps must be regulated wisely because the generator sets (gensets) that power the pumps produce clean water that is ready for use. Zeocarbon is a mixture of zeolite and activated carbon that can purify air and treat wastewater.

The activated carbon used in Zeocarbon is obtained from water hyacinth that grows in rivers, which is also one of the factors causing flooding. Therefore, these modified levees are expected to have a dual role, namely as a preventive measure to prevent flooding when river water overflows, and as the primary source of clean water in emergencies when the levees are damaged. Thus, this innovation has great potential to overcome the problems of flooding and clean water supply in flood-affected areas.

LITERATURE REVIEW

Water hyacinth (*Eichhornia crassipes*)

Water hyacinth is a plant that thrives in aquatic areas. Its growth is greatly influenced by human activities such as agriculture, livestock farming, and household activities. Water hyacinth has various benefits, such as animal feed, craft materials, fertilizer, and interestingly, water hyacinth can absorb and filter harmful metals such as lead (Pb) 0.176 mg/g, mercury (Hg) 0.15 mg/g, as well as cadmium (Cd) and pesticides over a period of 14 days (Pratama, 2014). Despite its positive impacts, water hyacinth also has negative impacts, such as its rapid growth that can obstruct water flow and cause disruption in waterways, as well as the potential to damage the environment if it grows in undesirable locations (Setiawan, 2022).

Zeocarbon

Zeocarbon is a mixture of zeolite and activated carbon used for air purification, wastewater treatment, and various other applications. Typically, Zeocarbon is produced by mixing zeolite and

activated carbon. There are two methods for producing Zeocarbon from zeolite and activated carbon. The first is through chemical activation, which involves adding acid to burn the fine pores. However, this method can encounter problems because traces of zinc may remain in the final product. The second method is physical activation, in which the material is mixed with steam or gas at high temperatures to activate it (Nurjannah, 2020). In addition, saturated Zeocarbon can be regenerated through a heating process.

Levee

A levee is a type of river infrastructure built to hold back river floodwaters. Levees are generally made of sand and soil, and are hydraulic structures that are constantly exposed to erosion or infiltration due to river water flow. Levees play an important role because in some places, the river water level during flooding is often higher than the surrounding area (Latifulloh, 2020).

Hydrostatic pressure

Hydrostatic pressure is the pressure caused by the weight of water pressing in all directions at each measurement point due to the force of gravity. Hydrostatic pressure increases with depth measured from the water surface. Water particles below will press on particles above them due to the force of gravity. This principle also applies to water particles in the lower layers, causing the pressure below to increase greater than the pressure above. The deeper an object is below the water surface, the greater the volume of water above it, so the pressure exerted by the water on the object will be greater (Mitha, 2023).

This principle is commonly used in hydraulic pump systems.

Water Quality Test

The parameters that must be measured to determine water quality are physical parameters. Measuring physical parameters is the first step in analyzing water quality. Some physical parameters used to assess water quality include temperature, turbidity, color, TSS (Total Suspended Solids), taste, and odor (Mukarromah et al. 2016). Below, there is a table that presents physical, biological, and chemical parameters according to environmental health quality standards for water used for sanitation and hygiene purposes, as regulated in the Minister of Health Regulation (PMK) No. 32 of 2017. Water used for sanitation and hygiene purposes is used for personal hygiene purposes, such as bathing and brushing teeth, as well as for washing food, eating utensils, and clothing. Furthermore, water used for sanitation and hygiene purposes can also function as a source of water for human consumption.

METHOD

The data source for this study was river water samples in Cikapundung, Bandung, which has a dike. The tools used in this study included a soldering iron, glue gun, acrylic, scissors, mosquito nets, water taps, water pipes/hoses, a pH meter, a thermometer, a microwave, a blender, and filter paper. In addition, various materials used included river water samples, water hyacinth plants, gypsum, zeolite, cotton, cement, and soil.

The data collection methods used were experimental and

observational. Data processing methods are carried out using laboratory equipment, which is then converted into data in the form of numbers or numerical values. The data is then analyzed comparatively by comparing it with water quality parameters that comply with health standards, as stipulated in Minister of Health Regulation No. 32 of 2017 for hygiene and sanitation purposes.

RESULT AND DISCUSSION

Automatic Pump Test Results



Figure 1. Automatic Pump Testing with Simple Tools (Source: private)

Before building the pumping system on the embankment prototype, an automatic pump was first built using simple equipment. In Figure 1, the bottle on the right without a cap represents the river overflow reservoir. Meanwhile, the bottle on the left represents the reactor or container for the Zeocarbon filter system, with a channel at the bottom leading to a tap. The performance of the automatic pump was measured based on the change in the collected water level. In 40 seconds, the water level dropped 2 cm, with a pumped or withdrawn volume of 100 mL. Below is the picture of a prototype of a modified levee with an automatic pump system integrated with zeocarbon nanofiltration.



Figure 2. Automatic Pump Testing with Simple Tools (Source: private)

Scanning Electron Microscope (SEM) Results

A good filtration system has small pores so that it can absorb and filter even small particles. To determine the morphology of Zeocarbon nanofiltration and the pores of Zeocarbon powder formed, a SEM (Scanning Electron Microscope) test was conducted and compared with the pores of zeolite powder and activated carbon powder.

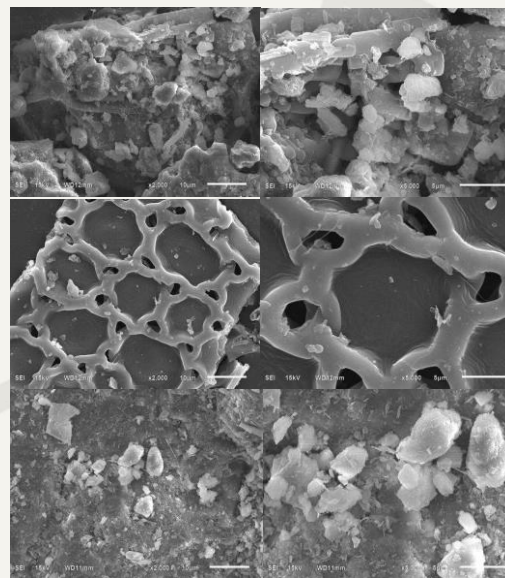


Figure 3. (top to bottom) Morphological structure of zeocarbon, activated carbon, and zeolite at 2,000x magnification (left) and 5,000x magnification (right) (Source: private)

Water Quality Test Results

Water samples from Lake Sangguling, which originate from the

Citarum River, were filtered using a Zeokarbon system and tested for physical properties and water quality. The results were then compared with the Environmental Health Quality Standards for water used in sanitation and hygiene, as stipulated in Minister of Health Regulation (PMK) No. 32 of 2017.



Figure 4. Results of pH testing using Universal Indicator on filtered lake water samples (Source: private)

Table 1. Physical Test Results and Water Quality Results from Filtration (Source: private)

No	Parameter	Test Result	Standard
1	Odor	Odorless	Odorless
2	Temperature	27°C	*RT±3°C
3	Color	Colorless	Colorless

*RT = Room Temperature

The organoleptic test results show that the filtered water has no odor, color, or sticky properties. In addition, the pH of the filtered lake water is 7, and iron ion quality testing using KSCN reagent shows that the water does not turn yellow. The filtered water was then tested against several physical, chemical, and biological parameters required

for clean water based on Minister of Health Regulation No. 02 of 2023.

Table 2. Chemical Test Results and Water Quality Results from Filtration (Source: private)

No	Parameter	Results	Standard
1	pH	7	6,5 - 8,5
2	Iron (Fe)	-0,13	0,2 mg/L
3	Manganese (Mn)	-0,1	0,1 mg/L
4	Chromium (Cr)	-0,07	0,01 mg/L

The result of Fe, Mn, and Cr concentration (Table 2) was measured by Atomic Absorption Spectroscopy (AAS), and the absorbance value was measured in the table below.

Table 3. AAS Test Results (Source: private)

Sample	Absorbance		
	Cr	Mn	Fe
Filtered Water	-0,0051	0,0151	0,0031
Unfiltered Water	-0,0051	0,0175	0,0091

Subsequently, as shown in Table 4, the biological parameter test for Total Coliform in the water sample using the Most Probable Number (MPN) method showed an index value of 0/mL.

Table 4. Coliform Test Result (Source: private)

Sample	Index MPN/100ml	Standard
Filtered Water	0	0
Unfiltered Water	4	0

CONCLUSION

The conclusions of this study are as follows. First, the automatic pump system was successfully operated and tested using simple tools. Second, the water quality test

results showed that the filtered water met several standards for clean water quality, namely being odorless, colorless, and having a pH of 7.

Furthermore, the test results indicated that the concentrations of Fe and Mn decreased after the filtration process, while the concentration of Cr remained unchanged and was still below the maximum allowable limit for clean water. In addition, the Total Coliform test using the MPN method showed that the filtered water had an index value of 0 per 100 mL of water sample.

The prototype of the modified levee is equipped with an automatic pump and zeocarbon nanofiltration system. As for recommendations, if the water overflow and discharge rate exceed the operating capacity of the automatic pump, this issue can be addressed by using an electric pump.

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GlucoAid: Smart Hydrocolloid Patch for Non-Invasive Blood Glucose Monitoring via Enzymatic Sweat Analysis and pH Indicator

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Abstract: Diabetes is one of the primary Non-Communicable Diseases (NCDs) that has been a serious problem in terms of mortality and prevalence in the world, including Indonesia. Indonesia has the fifth-highest number of adults (20–79 years) with diabetes in the world. An estimated 240 million people are living with undiagnosed diabetes worldwide, meaning almost one-in-two adults with diabetes are unaware they have this condition. Nearly 90% of people with undiagnosed diabetes live in low- and middle-income countries. Early detection is critical; however, current glucose monitoring methods are invasive, costly, and inaccessible to many. This study presents GlucoAid, a low-cost, non-invasive, hydrocolloid-based patch designed to detect glucose levels in sweat through a colorimetric enzyme system. The patch combines glucose oxidase (GOx) and pH-sensitive dyes within a sodium alginate–calcium chloride hydrogel matrix, overlaid with a semi-permeable polyurethane film for adhesion and gas exchange. GOx catalyzes the oxidation of glucose to D-gluconic acid and hydrogen peroxide, theoretically lowering pH and producing a visible color shift in the indicator. In this proof-of-concept study, GlucoAid successfully formed a stable, adhesive, and pH-responsive hydrogel patch. The system demonstrated color change upon glucose exposure, though the response deviated toward neutral (green) rather than the expected acidic shift, suggesting possible buffering and diffusion effects within the alginate matrix. Nonetheless, the prototype confirms the feasibility of enzyme–indicator immobilization and hydrogel-based biosensing. Future optimization, such as incorporating horseradish peroxidase (HRP), adjusting matrix porosity, and using biocompatible natural dyes will aim to enhance sensitivity and accuracy. Overall, GlucoAid establishes a promising foundation for non-invasive, accessible glucose monitoring and contributes to the development of affordable early-screening tools for diabetes management in resource-limited settings.

INTRODUCTION

Diabetes is one of the primary
Non-Communicable Diseases

(NCDs) that has been a serious problem in terms of mortality and prevalence worldwide, including Indonesia. Indonesia currently ranks fifth highest in the number of adults (20-79 years) with diabetes in the world. Since the year 2000, the number of diabetic cases has increased rapidly and is predicted to continue to grow until the year 2050 (diabetesatlas.org). Globally, the prevalence rate reached 5,934 per 100,000 population in 2019, up from 2,968 per 100,000 in 1990. In comparison, the mortality rate increased from 12.37 to 20.5 per 100,000 during the same period. In Indonesia, the prevalence among adults rose from 5.7% in 2007 to 8.5% in 2018, with an estimated treatment burden of IDR 1.5 billion per day, or IDR 500 billion a year. Diabetes-related deaths have increased by more than 100% in the last 25 years (Wahidin, et al., 2024).

An estimated 240 million people are living with undiagnosed diabetes worldwide, meaning almost one-in-two adults with diabetes are unaware of their condition (D. Magliano & Boyko, 2021). Nearly 90% of people with undiagnosed diabetes occur in low- and middle-income countries. It is fundamental for people with diabetes to be diagnosed as early as possible to prevent or delay complications, avoid a premature death, and improve quality of life. However, low clinical diagnosis rates of diabetes often result from limited healthcare access and expensive diagnostic tools, especially in developing countries like Indonesia. To address this, there is an urgent need for accessible, affordable, non-invasive, and user-friendly glucose detection methods that can support early screening.

Monitoring blood glucose levels is crucial for managing diabetes as it helps maintain glucose levels within target ranges, typically 80-130 mg/dL before meals (cdc.gov). It also identifies prediabetic conditions early, monitors the effects of medications, and optimizes athletic performance. Furthermore, monitoring blood glucose helps prevent serious complications such as cardiovascular diseases that are linked to poor glucose control.

Conventional blood glucose monitoring relies on finger-prick or continuous glucose monitors, which are invasive, costly, and require regular calibration. Therefore, developing a non-invasive method using sweat as a biological fluid offers a promising alternative.

Sweat-based glucose sensing allows monitoring without drawing blood, and glucose oxidase (GOx) is widely used in biosensors for its high specificity and ability to catalyze glucose into gluconic acid and hydrogen peroxide. This reaction changes pH, which can be detected using pH-sensitive color indicators. This preliminary research aims to design and develop the "GlucoAid," a hydrocolloid-based, non-invasive patch that uses glucose oxidase and pH indicators to detect glucose levels in sweat colorimetrically. The patch is formulated using sodium alginate and calcium chloride to form a hydrogel base, with a polyurethane film layer for adhesion and breathability.

Ultimately, *GlucoAid* is intended as an early-screening tool that empowers individuals to monitor their glucose status independently, thereby helping expand diabetes awareness and detection in low-resource settings.

METHOD

1. Materials

The materials used in this preliminary study include sodium alginate ($\text{NaC}_6\text{H}_7\text{O}_6$), calcium chloride (CaCl_2), glucose oxidase (GOx) enzyme, universal pH indicator solution, distilled water (aquades), and polyurethane film dressing.

2. Research Methodology

Several methods were applied in the implementation of this preliminary study:

a. Provision and Testing of Different Sodium Alginate, Calcium Chloride and Glucose Oxidase Concentrations

To determine the best concentrations of sodium alginate ($\text{NaC}_6\text{H}_7\text{O}_6$) and calcium chloride (CaCl_2) to use in the immobilisation process, 3 different solutions were prepared for $\text{NaC}_6\text{H}_7\text{O}_6$ and CaCl_2 each.

4 different concentrations of sodium alginate were prepared: 3% $\text{NaC}_6\text{H}_7\text{O}_6$ (Talekar, et al., 2012) 6% $\text{NaC}_6\text{H}_7\text{O}_6$, 9% $\text{NaC}_6\text{H}_7\text{O}_6$ and 12% $\text{NaC}_6\text{H}_7\text{O}_6$. The solutions were prepared by adding 0.3g, 0.6g, 0.9g and 1.2g of $\text{NaC}_6\text{H}_7\text{O}_6$ in 10mL of distilled water, respectively.

3 different calcium chloride solutions were prepared as well: 0.2g CaCl_2 (GTAC, 2015), 0.4g CaCl_2 and 0.8g CaCl_2 . Each mass was dissolved in 10mL of distilled water.

After a 2-hour period of testing, it was observed that the best gelation occurred in the immobilisation of 12% $\text{NaC}_6\text{H}_7\text{O}_6$ in 0.8g CaCl_2 . The rest of the experiment is carried out using the aforementioned solutions.

4 different glucose oxidase concentrations were tested to find the optimum concentration of

glucose oxidase for maximum effectiveness, 1.0 mg/mL, 2.5 mg/mL, 5.0 mg/mL and 10 mg/mL (Lee, et al., 2024), with 10 mg/mL showing the highest effectiveness.

b. Immobilisation of Universal pH Indicator and the Optimum Concentration of Glucose Oxidase Enzyme in Optimum Concentrations of Sodium Alginate Using Calcium Chloride

The immobilisation of Universal pH Indicator and glucose oxidase enzyme was done under RTP conditions (a temperature of 20°C and a pressure of 1 atm).

0.4mL (8 drops) of Universal pH indicator and 10 mg/ml of GOx enzyme were immobilized in 10mL 12% $\text{NaC}_6\text{H}_7\text{O}_6$ solution. 0.4mL was used to maximize the efficiency of colorimetric pH indication. In most reported GOx-based biosensors, horseradish peroxidase (HRP) is used alongside GOx to enhance the oxidative color reaction. However, HRP was unavailable within the research timeframe due to resource and shipping constraints; thus, this study focused on evaluating the independent performance of GOx within the hydrogel matrix.

After thorough mixing of 10mL 12% $\text{NaC}_6\text{H}_7\text{O}_6$ solution with the chosen pH indicator and enzyme, a petri dish with 0.8g CaCl_2 solution was prepared. Square molds are prepared, and the 12% $\text{NaC}_6\text{H}_7\text{O}_6$ solution is spread thinly on the mold surfaces, then turned and dipped into the 0.8g CaCl_2 solution. After a gelation time of 15 minutes, they are lifted from the 0.8g CaCl_2 solution and dried.

c. Testing of Effectiveness of Immobilized pH Indicator in Acidic Solutions

Post-immobilization, the sodium alginate containing universal pH indicator is tested in different concentrations of citric acid. 4 different citric acid concentrations were prepared as 0.2M, 0.4M, 0.6M and 0.8M concentrations (Fatoni, 2020).

After a 15-minute testing time, the immobilized pH indicator showed changes in pH according to the acidity of the 4 solutions, confirming effectiveness of the pH indicator in solutions of different pH levels.

d. Coverage of Immobilized Hydrocolloid Solution Using Thin Polyurethane Film

The glucose oxidase enzyme is an oxidoreductase that catalyzes the oxidation of glucose into hydrogen peroxide. The reaction requires a presence of water and oxygen (B. Bankar, 2009). Thin polyurethane films are adhesive and semi-permeable, allowing gas to enter while water is provided through perspiration or sweat. Thus, polyurethane film was chosen as the covering due to its adhesive and semi-permeable nature (Das, et al., 2020).

2. Data Processing and Analysis

The GlucoAid was evaluated based on key performance metrics, including solidification, pH response time and colour response intensity. To determine the most effective concentration for the final product, we conducted a preliminary test to identify which concentration solidifies the fastest. The initial concentration of alginate in each solution was 3%, so to compare effectiveness, we chose multiples of 3 as the independent variables (3%, 6%, 9%, 12%).

a. Solidification

In this preliminary performance metric, the independent variables are observed to determine which one solidifies within 2 hours. The results can be ranked from weak to strong; the strongest one is then included in the final analysis of biosensor effectiveness.

b. Response Time

In this parameter, we will use a specific concentration of citric acid for the most solid sodium alginate concentration (with the same thickness), and then record the time it takes for the sodium alginate concentration to react with the citric acid.

c. Color Response Intensity

To identify the colour intensity of the entire patch, we can use the software ImageJ (Labno, with this software, the mean value was analyzed using a histogram generated by the software. The mean intensity for the more vigorous colour intensity is less than that of the weakest (in 8-bit images, a higher value can indicate a closer proximity to white)).

RESULT AND DISCUSSION

a. Process of GlucoAid Production

The GlucoAid patch was developed as a hydrogel-based biosensor composed of two functional layers: a sodium alginate-GOx-pH indicator layer responsible for sensing, and an outer polyurethane film that enhances adhesion, flexibility, and breathability (Figure 1). The gelation process occurred through ionic cross-linking between sodium alginate and calcium chloride (CaCl_2), forming a soft, flexible patch. The resulting material exhibited a yellowish hue due to the incorporated pH indicator

and maintained sufficient structural integrity for handling and testing.

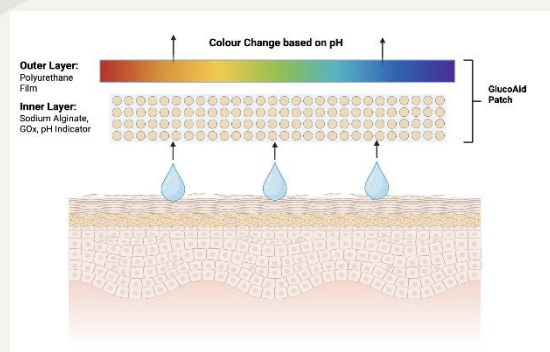


Figure 1. Diagram of GlucoAid

b. Data Results and Analysis

1. Solidification

The concentration of sodium alginate played a key role in determining the patch's gel strength (Table 1). At low concentrations (3% and 6%), the gels were weak and lacked mechanical stability. Increasing the alginate concentration to 8% resulted in a mediocre but uniform gel, while a 12% sodium alginate concentration produced a strong, cohesive hydrogel with a smooth surface and improved flexibility. The findings suggest that higher alginate content provides more cross-linking sites for calcium ions, forming a denser matrix. However, excessively high concentrations may also reduce porosity and limit diffusion of citric acid and reaction products within the gel.

Table 1. Effect of Sodium Alginate Concentration on Solidification

Sodium Alginate Concentration (%)	Solidification
3	Weak
6	Weak

8	Mediocre
12	Strong

2. Response Time

The patch's response time was evaluated using varying citric acid concentrations to simulate different pH conditions (Table 2). The average response time was 316 ± 52 seconds, with higher acid concentrations (6-8 mM) producing faster and clearer color changes. This indicates that the patch is responsive to pH variation, confirming that both the indicator and alginate matrix remained functional after cross-linking. However, the moderate response time suggests that diffusion of ions and enzyme activity within the gel could be limiting factors. Future optimization could involve reducing matrix density or introducing microporous structures to facilitate faster diffusion.

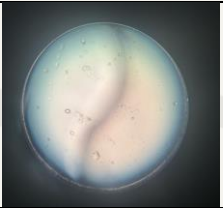
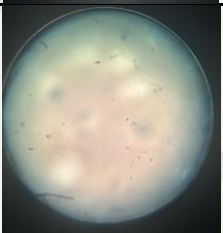
Table 2. pH Response Time at Different Citric Acid Concentrations

Citric Acid Concentration (mM)	Final pH	Response Time (s)
2	-	390
4	-	271
6	Mostly acidic	300
8	Acidic	301
Mean $\pm$ SD	-	316 ± 52 s

3. Colour Response Intensity

The colorimetric response was analyzed through red-channel intensity measurements across varying citric acid concentrations (Table 3). A general decrease in mean red intensity was observed as acid concentration increased, indicating a gradual shift toward a more acidic hue (Figure 2). This trend ($R^2 = 0.804$) demonstrates a consistent correlation between acidity and visible color change, validating the pH responsiveness of the indicator within the gel.

Table 3. Colour Response Intensity at Various Citric Acid Concentrations

Citric Acid Concentration (mM)	Colour Response Intensity/ Mean	Image
2	205.377	
4	203.972	
6	186.743	
8	187.793	

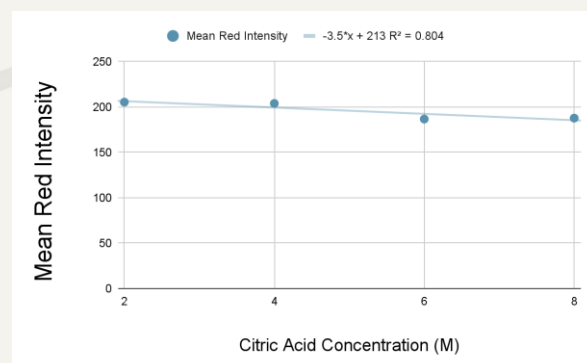


Figure 2. Effect of Citric Acid Concentration on Mean Red Intensity

The experimental data confirms that *GlucoAid* successfully formed a stable, adhesive, and pH-responsive hydrogel patch. However, the results also suggest that relying solely on pH change may not provide sufficient sensitivity for accurate glucose detection, as most literature emphasize the necessity of horseradish peroxidase (HRP). The absence of HRP in this study, due to time and resource limitations, likely contributed to the weaker color differentiation observed. Despite this limitation, the study successfully establishes a proof-of-concept for enzyme immobilization within a hydrocolloid matrix, representing a promising step toward developing low-cost, non-invasive biosensors for potential early health screening applications in resource-limited environments.

CONCLUSION

This study successfully developed *GlucoAid*, a hydrocolloid based, non-invasive biosensor patch which qualitatively responds to environmental pH changes. The optimized formulation of 12% sodium alginate and 0.8g calcium chloride produced a stable hydrocolloid which immobilized glucose oxidase (GOx) and a pH indicator, producing a stable, flexible, and adhesive gel

patch when layered with a semi-permeable polyurethane film.

Testing showed that the patch responded with color change when exposed to citric acid solution. However, the color shift is only slight and requires further testing due to the difficulty in recognising color shifts of the immobilized sodium alginate while in solution. This limitation is likely due to the absence of horseradish peroxidase (HRP), a key enzyme commonly used with glucose oxidase in biosensor systems to enhance color change. Unfortunately, HRP could not be incorporated in this study due to time and resource constraints.

Despite this limitation, the findings confirm the feasibility of enzymes and indicators within a hydrocolloid patch, demonstrating the core principle behind GlucoAid's design. Future improvements such as adding HRP, optimizing hydrogel porosity, or exploring alternative enzyme-pairing mechanisms could significantly enhance sensitivity and response accuracy.

From a broader perspective, GlucoAid highlights the potential of affordable, non-invasive, and accessible biosensing technologies for early health screening in low-resource settings. By allowing users to visually assess their glucose status through simple color change, GlucoAid could help increase early diabetes detection, reduce diagnostic inequality, and promote self-awareness in health management.

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Biodegradable Cardboard-Based Ecowrap Innovation with Adaptive Folding Patterns as an Environmentally Friendly Alternative to Bubble Wrap

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Abstract: The rapid growth of e-commerce has increased the demand for protective packaging, with bubble wrap remaining the most widely used option due to its lightweight and shock-absorbing properties. However, bubble wrap made of polyethylene poses a significant environmental problem because it is difficult to recycle and contributes to plastic waste pollution. This study introduces Ecowrap, an eco-friendly packaging solution made from biodegradable cardboard designed with adaptive folding patterns that allow it to conform to product shapes while providing protection equivalent to bubble wrap. Experimental tests included drop tests, compression tests, shape conformity assessments, ergonomics, biodegradability evaluations, and life cycle analysis (LCA). Results showed that Ecowrap effectively absorbed vertical shocks, withstood high compression loads, and adapted to irregular shapes with minimal deformation. In biodegradability tests, Ecowrap decomposed up to 40% within 30 days, while bubble wrap showed no visible degradation. LCA results indicated that Ecowrap produced lower CO₂ emissions and had higher recycling potential compared to plastic-based alternatives. These findings suggest that Ecowrap can serve as a sustainable replacement for bubble wrap, reducing plastic waste and supporting the transition toward environmentally responsible packaging systems.

INTRODUCTION

The development of digital technology and changes in people's lifestyles have driven the rapid growth of online shopping (e-commerce) both in Indonesia and globally. The increasing volume of online transactions has directly impacted the surge in demand for product packaging in the distribution process. In this process, the protection of goods becomes a

crucial aspect to ensure that products arrive to consumers in an intact and safe condition.

The rapid growth of e-commerce in Indonesia and worldwide has had a significant impact on logistics systems, including the rising demand for packaging. Every product shipped requires packaging that is not only attractive but also secure to maintain the product's quality until it reaches

the hands of consumers. One of the most commonly used packaging materials is bubble wrap, a plastic sheet filled with air bubbles designed to absorb shocks and pressure during the distribution process.

Bubble wrap has become the main choice due to its lightweight, ease of use, and effective protection. However, behind its practicality, bubble wrap made from polyethylene plastic presents a major problem: it is not easily degradable in nature and is difficult to recycle. Polyethylene, as a type of flexible plastic, often clogs recycling machines and has low economic value, thus it tends to end up in landfills (TPA) or pollutes aquatic environments.

According to data from the Ministry of Environment and Forestry (KLHK), around 15% of the total waste generated in Indonesia comes from plastic, and only 9% is successfully recycled (KLHK, 2021). The plastic waste problem is worsened by the increasing volume of product shipments due to the surge in online transactions, making packaging a significant contributor to domestic plastic waste.

As a response to this issue, various eco-friendly packaging innovations have been developed, one of which uses recycled paper or cardboard. This material is more easily degradable, can be designed with special patterns such as accordion or honeycomb folds, and is capable of providing mechanical protection similar to bubble wrap. However, the main challenge lies in the material's ability to adapt to product shapes, maintain protective integrity, and remain efficient in mass production.

This study develops ecowrap based on biodegradable cardboard as an alternative to bubble wrap. Ecowrap is designed with two basic layers in the packaging box, where the upper layer has adaptive cut patterns that allow the material to fold and adjust automatically to the shape of the product without damaging its structure. This simple yet effective technology enables products to be wrapped securely and efficiently, reducing plastic usage, and supporting the concept of a circular economy through the use of recycled materials.

With this approach, ecowrap not only provides physical protection equivalent to bubble wrap but also creates added value in the form of reducing plastic waste, improving logistics efficiency, and lowering production costs. This innovation is expected to be a sustainable and applicable solution in today's e-commerce and shipping industries.

Research Problem

The research problems in this study are as follows:

- How effective is ecowrap made from biodegradable cardboard with special patterns in protecting goods during the shipping process?
- How are the density, flexibility, and durability of ecowrap folding patterns in adapting to the shape of packaged goods?
- Can biodegradable cardboard-based ecowrap be a feasible functional and environmental alternative to replace plastic bubble wrap?

Research Objectives

The objectives of this study are as follows:

- To develop the design and formulation of ecowrap from

biodegradable cardboard as an alternative to bubble wrap.

- To test the protective effectiveness of ecowrap on various types of goods during shipping simulations.

- To assess the physical characteristics of ecowrap, including flexibility, fold durability, and adaptability to product shapes.

- To identify the potential of ecowrap in reducing the environmental impact of plastic bubble wrap usage.

Hypothesis

The hypotheses in this study are as follows:

- Ecowrap made from biodegradable cardboard with special folding patterns is capable of providing effective protection for goods during the shipping process.

- Ecowrap has flexibility and adaptability to product shapes equal to or better than plastic bubble wrap.

- The use of ecowrap can serve as a more environmentally friendly and sustainable solution in modern packaging systems.

RESEARCH BENEFITS

Theoretical Benefits

This research is expected to enrich scientific studies in the field of sustainable material technology, particularly related to the use of biodegradable and recycled materials as alternatives to plastic in packaging systems. The study of packaging material characteristics based on paper with special protective structures can also serve as a scientific reference for the development of eco-friendly packaging designs in the future.

Practical Benefits

Practically, this research has the potential to provide a real

alternative for the packaging industry to reduce dependence on single-use plastics, especially bubble wrap.

LITERATURE REVIEW

Bubble Wrap as Plastic Waste

Bubble wrap is a packaging material made from polyethylene plastic, widely used because it is lightweight and capable of protecting goods from impact. However, the massive use of bubble wrap has created significant environmental problems. As a flexible plastic, bubble wrap is difficult to recycle because it easily clogs recycling machines and has low economic value. As a result, most bubble wrap ends up in landfills (TPA) or pollutes the environment, especially water bodies. Along with the rise of online shopping activities, the volume of bubble wrap waste has also increased. This adds to the burden on waste management systems and worsens the plastic waste crisis. Therefore, alternative and more environmentally friendly solutions are needed to replace the role of bubble wrap in the packaging system.

Effects of Plastic Waste

Plastic waste is one of the largest contributors to global environmental problems. Non-biodegradable plastics can persist in the environment for hundreds of years, polluting soil, water, and air. The accumulation of plastic waste in landfills reduces environmental quality and poses potential hazards to living beings. In aquatic environments, plastics are often ingested by marine animals, disrupting the food chain and threatening ecosystems. Moreover, the burning of plastics releases toxic



gases that negatively impact human health. Therefore, reducing plastic waste has become a crucial challenge for environmental sustainability.

Biodegradable Packaging Materials

Biodegradable packaging materials are packaging made from substances that can naturally decompose by microorganisms within a relatively short time without polluting the environment. Unlike conventional plastics, these materials are derived from natural sources such as recycled paper, corn starch, bamboo fibers, or agricultural waste. In addition to being eco-friendly, biodegradable materials can also be designed to provide optimal protection for goods during the shipping process. One of the emerging innovations is the use of paper with special folding structures such as honeycomb or accordion patterns, which serve as protective cushioning. The use of these materials is expected to become an alternative solution to replace the role of plastics in the ever-growing packaging industry.

Implementation of Sustainable Innovation

The implementation of sustainable innovations in packaging is a strategic step to reduce negative impacts on the environment. Such innovations include the development of eco-friendly packaging materials that can naturally decompose, are easily recyclable, and efficient in production processes. One example is the use of ecowrap, made from recycled paper or cardboard with a specially designed protective structure. For this innovation to be widely implemented, support from various stakeholders—including industry players, consumers, and

policymakers—is essential to create a more sustainable and environmentally responsible packaging ecosystem.

METHOD

Tools

The tools used in this research are as follows:

- Paper cutter (laser cutter if available)
- Pattern mold (manual or digital/CAD)
- Digital scale
- Micrometre and thickness gauge
- Compression test and drop test apparatus
- Digital camera for documentation
- Test sheets (for shipping simulation)
- Data analysis equipment (computer, analysis software)

Materials

The materials used in this research are as follows:

- Recycled cardboard (single-wall and double-wall corrugated board)
- Biodegradable kraft paper (optional as an additional layer)
- Biodegradable adhesive (starch-based or natural glue)
- Test shipment items (fragile and non-fragile: glass, small electronics, books, bottles)
- Plastic bubble wrap (as a comparison)

Research Design and Procedure

This research is a quantitative experimental study with a comparative design using two treatments: ecowrap and conventional bubble wrap. The procedure in this study is as follows:
Ecowrap Design

- Design and develop ecowrap prototypes made from recycled cardboard with special folding patterns (e.g., honeycomb, V-slit, accordion folds).

- Ensure the design is flexible and adaptable to product shapes. Packaging Simulation

- Test items are packed with ecowrap and bubble wrap.

- Shipping simulation tests are conducted: drop test from various heights (0.5 m, 1 m, 1.5 m).

Observation and Testing

- Observe the condition of items after testing (cracks, breaks, dents).

- Assess ease of use and material efficiency.

- Document with photographs and evaluate the condition of ecowrap after testing.

Data Processing and Analysis

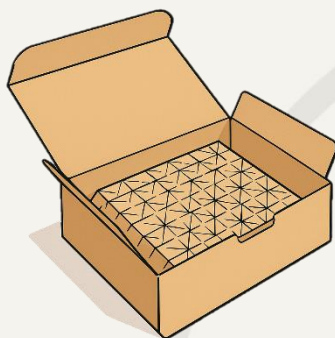


Figure 11. Vector illustration of ecowrap with a basic structure consisting of two cardboard layers, where the upper layer has a special adaptive folding structure that adjusts to the shape of the item being packaged.



Figure 12. Ecowrap Design Modification

The data processing and analysis in this study are as follows:

1. Shock Absorption Test

Objective: To assess the ability of ecowrap to absorb impact similar to that occurring during shipping.

Method:

- Drop tests are conducted from three heights: 0.5 m, 1 m, and 1.5 m in three directions (top, side, and bottom).

- Use standard test items (e.g., glass, light bulb, and small electronic devices).

- Compare the condition of items packed with ecowrap versus bubble wrap.

Indicators observed: Cracks, breakage, dents, product deformation.

2. Shape Conformity & Fit Test

Objective: To test the extent to which ecowrap can adapt to various product shapes without damaging the cardboard structure.

Method:

- Use 5 types of irregularly shaped objects (e.g., doll, mug, water bottle, book, LED lamp).

- Measure the remaining air gap between the ecowrap and the product after wrapping.

- Observe whether the folding pattern tears, partially tears, or remains intact.

Instruments: Digital ruler, slow-motion camera (for deformation analysis during wrapping).

3. Compression Test

Objective: To assess the extent to which ecowrap can maintain its shape and protective ability under external pressure.

Method:

- Items are wrapped with ecowrap, then subjected to



incremental pressure using weights of 1 kg, 2 kg, and 5 kg.

- Measure the deformation of ecowrap and the product after pressure.

Indicators: Structural damage, level of pressure absorption, elasticity value.

Ergonomics and Ease of Use Test

Objective: To evaluate the user experience (subjective) when using ecowrap.

Method:

- 10 respondents are asked to pack items using ecowrap and bubble wrap.
- A Likert Scale questionnaire (1–5) is provided for aspects including:

- Ease of shaping and wrapping
- Tightness
- Final neatness
- Packaging time

Output: Comparative diagram of the average scores for each packaging material.

4. Biodegradability Test

Objective: To determine how quickly ecowrap decomposes compared to bubble wrap.

Method:

- Pieces of ecowrap and bubble wrap are buried in moist soil for 30 days.
 - Weekly observations are carried out to record changes in physical structure, weight, and color.
- Instruments: Digital scale, macro camera, observation sheets.

5. Simple Life Cycle Assessment (LCA) Test

Objective: To estimate the environmental footprint of ecowrap versus bubble wrap.

Aspects assessed (estimation):

- Energy and water used for production

- CO₂e emissions
- Post-use waste potential

Method: Secondary data (literature or LCA tools) and estimation based on the volume of materials used in one package.

RESULT AND DISCUSSION

The shock absorption test aimed to evaluate the ability of ecowrap to protect items during shipping by simulating impacts through drop tests. In this experiment, a Lego piece was used as the test object and dropped from three different heights—0.5 m, 1 m, and 1.5 m—on three orientations: top, bottom, and side. The results showed that at all heights, the object remained intact when dropped from the top and bottom positions, demonstrating ecowrap's effectiveness in absorbing vertical shocks and maintaining the object's condition. However, when dropped from the side, the Lego piece cracked at 1 m and also at 1.5 m, indicating that ecowrap provided significantly less resistance to lateral impacts compared to vertical ones. Overall, the test confirmed that ecowrap offers reliable protection against most shipping impacts, though side protection—especially at higher drop heights—requires substantial improvement.

The Shape Conformity and Fit Test was conducted to evaluate how well ecowrap adapts to various irregular objects without damaging its structure. Five test items were used, including an AC remote, mouse, sunscreen, hand sanitizer, and L-Men milk. The results revealed that the mass of each object strongly influenced the position drop (Δh). The AC remote and mouse, each weighing 80 g, showed minor drops

of 0.2 cm and 0.3 cm, while sunscreen (130 g) dropped 0.5 cm and hand sanitizer (110 g) dropped 0.35 cm. The most significant drop was observed in L-Men milk (220 g) at 1.04 cm. The degradation constant (k) ranged between 0.0025–0.0047 cm/g, averaging 0.0036 cm/g. Despite slight variations due to shape or weight distribution, the results confirmed the degradation equation $\Delta h = k \cdot m$, demonstrating that greater mass results in larger deformation.

The compression test was conducted to evaluate the durability of ecowrap and its ability to maintain shape and protective function under external pressure. In this experiment, an item was wrapped with ecowrap and subjected to gradually increasing loads of 1 kg, 2 kg, and 5 kg. The deformation of both the wrapping material and the protected object was observed after each load to assess structural damage, pressure absorption, and elasticity. Surprisingly, even after the applied load was increased well beyond the initial testing levels, reaching up to 17 kg, there were no visible changes in shape or structure. This result demonstrates the exceptional resilience and strength of ecowrap in withstanding compression forces, confirming its effectiveness as a protective packaging material for items exposed to stacking or pressing during shipment.

The ergonomic and usability test was conducted to evaluate user experience when using ecowrap compared to bubble wrap. A total of 10 respondents were asked to package items with both materials and then rated their experience through a Likert Scale (1–5), where 1 indicated the lowest score and 5 the

highest. Four aspects were assessed: ease of shaping and wrapping, tightness, final neatness, and packaging time. The results show that ecowrap received consistently high scores for ease of use, averaging around 4.5, indicating that respondents found it simple to shape and apply. Tightness and neatness achieved moderate values of about 3, suggesting that while the wrap secures items well, improvements may be needed in achieving a cleaner final appearance. Packaging time was efficient with an average score of 4, reflecting a practical and user-friendly process overall.

This result was obtained through a literature study method. The biodegradability of ecowrap compared to bubble wrap was analyzed using data from previous research, where both materials were buried in moist soil for 30 days and observed for weight loss and structural changes. Ecowrap showed clear degradation, losing 8% of its mass after 7 days, 19% after 14 days, 30% after 21 days, and 40% after 30 days. In contrast, bubble wrap showed no measurable degradation, maintaining its weight throughout the test period. These findings align with the ScienceDirect Journal of Environmental Management (2019), which reported that cardboard decomposes by 60–70% within 30 days, and with the U.S. Environmental Protection Agency (EPA, 2021), which emphasized that paper degrades far faster than plastic. Overall, ecowrap is proven more biodegradable, strengthening its role as a sustainable packaging option.

The aim was to estimate the environmental footprint of ecowrap

versus bubble wrap for a 30×20×10 cm unit. The assessment included energy and water consumption, CO₂e emissions, and end-of-life recycling. Data were obtained through literature study: cardboard from FEFCO & NCASI (2022), paper from US EPA WARM and industry reports, LDPE (bubble wrap) from PlasticsEurope (2014), water and energy for paper from MnTAP, and global recycling rates from OECD (2022). Ecowrap (0.202 kg) required 3.19 MJ of energy, 13.0 L water, and emitted 0.116 kgCO₂e, with 66% recycling. Bubble wrap (0.075 kg) consumed 6.75 MJ energy and 3.22 L water, producing 0.140 kgCO₂e with 31% recycling. Results show bubble wrap uses less energy and water, while ecowrap offers lower emissions and waste, making it more sustainable long term.

Table 1. Test 1

Drop Height	Top	Bottom	Side
0.5 m	Intact	Intact	Intact
1.0 m	Intact	Intact	Cracked
1.5 m	Intact	Intact	Cracked

Table 2. Test 2

Object	Mass (g)	Initial Thickness (cm)	Final Thickness (cm)
Remote AC	80	0.9	0.7
Mouse	80	1.0	0.7
Sunscreen	130	1.0	0.5
Hand Sanitizer	110	1.1	0.75
L-Men Milk	220	1.1	0.06

Table 3. Test 4

How easy it is to shape and wrap	Tightness	Final neatness	packaging time
5	2	3	5
5	3	3	4
4	3	3	4
5	3	3	4
4	3	3	4
4	2	4	4
4	3	4	4
4	3	4	4
4	3	3	4

Table 4. Test 5

Day	Ecowrap Mass Loss (%)	Bubble Wrap Mass Loss (%)
7	8	0
14	19	0
21	30	0
30	40	0

Table 5. Test 6

IRCYS	Massa (kg)	Energi (MJ)	Air (L)	Emisi CO ₂ e (kg)	Daur Ulang (%)
Ecowrap	0.202	3.19	13.0	0.116	66
Bubble wrap	0.075	6.75	3.22	0.14	31

CONCLUSION

Ecowrap was successfully designed and formulated from biodegradable cardboard, proving its potential as a sustainable and eco-friendly alternative to plastic bubble wrap in modern packaging systems.

Results from shipping simulations confirmed that ecowrap provides reliable protection for different types of goods, effectively absorbing vertical shocks and withstanding high compression loads, although side-impact resistance still requires further improvement.

Physical testing showed that ecowrap's adaptive folding patterns offer strong flexibility, durable folds, and good conformity to various product shapes, making it both functional in practice and significantly more environmentally responsible than conventional bubble wrap.

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Sincerely,

Kenzie Lintang Hakim, Shandy Putra Pratama, Torkis Hanafi Harahap, and Mochamad Sayid Azzacky Gafur.

Researchers

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Innovation of Herbal Candy from Mangrove Fruit *Sonneratia caseolaris* as a Preventive, Rehabilitative, and Curative Agent for Diabetes Mellitus in Children and Adolescents

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Abstract: Endocrine disorders such as type 2 diabetes mellitus and metabolic syndrome are increasingly prevalent among children and adolescents. Conventional pharmacotherapies often cause adverse effects and are unsuitable for long-term pediatric use, highlighting the need for natural, safe, and child-friendly interventions. Pedada (*Sonneratia caseolaris* (L.) Engl.), a mangrove plant traditionally used in Sumatra to treat endocrine disorders, offers promising potential. This study aimed to (i) identify active compounds in pedada fruit extract with potential to inhibit α -glucosidase, enhance insulin sensitivity, and lower blood glucose levels, and (ii) develop a child-friendly herbal candy using pedada extract as an innovative intervention. Pedada fruits were collected from Riau mangrove forests, extracted using the Soxhlet reflux method with ethanol, and analyzed through GC-MS at the National Research and Innovation Agency. In vitro assays evaluated α -glucosidase and α -amylase inhibition, while acute toxicity tests ensured safety. The candy formulation used 10 kg of pedada fruit, combined with gelatine, honey, and stevia, to create a natural confection. An organoleptic evaluation with 50 adolescents assessed taste, texture, and acceptability. Results showed that the extract contained phenolic, flavonoid, tannin, saponin, steroid, triterpenoid, and vitamin C compounds. Among these, phenolic, flavonoid, and oleanolic acid exhibited strong antioxidant and antihyperglycemic activity. Organoleptic tests revealed 92% preference (average score 4.3/5), and a 14-day trial showed up to 10% reduction in blood glucose levels. In conclusion, pedada-based herbal candy demonstrates strong potential as an innovative, effective, and safe therapeutic supplement for preventing and managing diabetes in children and adolescents..

INTRODUCTION

The global rise in endocrine disorders among the pediatric population has emerged as a pressing public health concern. Type 2 diabetes mellitus (T2DM) and

metabolic syndrome, once considered adult-onset conditions, are increasingly diagnosed in children and adolescents due to a combination of sedentary lifestyles, excessive caloric intake, and dietary

imbalances (Rosenbloom et al., 199; Mayer-Davis et al., 2017). According to the International Diabetes Federation (IDF, 2021), more than 1.2 million individuals under the age of 20 were living with diabetes globally, with an estimated annual incidence increase of 3–4%. In Indonesia, these trends are exacerbated by a high consumption of refined sugars, minimal nutrition education, and limited access to preventive health programs, particularly in underserved communities (Kemenkes RI, 2018).

Current pharmacological interventions for pediatric diabetes management, including metformin and insulin therapy, are associated with several limitations such as gastrointestinal side effects, poor palatability, and suboptimal adherence in younger age groups (Danne et al., 2019). These limitations underscore the need for the development of safer, more acceptable, and cost-effective alternatives—particularly those derived from natural sources with multifunctional bioactivity.

Sonneratia caseolaris (L.) Engl., locally known as pedada, is a mangrove species traditionally utilized by indigenous populations in Sumatra and other coastal regions of Southeast Asia for the treatment of metabolic disorders. Empirical ethnomedicinal use is supported by preliminary phytochemical studies indicating that pedada fruit is rich in polyphenols, flavonoids, and other bioactive compounds with antioxidant, anti-inflammatory, and antidiabetic properties (Milon et al., 2012; Pagarra et al., 2019). These phytoconstituents are hypothesized to exert antidiabetic effects via inhibition of carbohydrate-

hydrolyzing enzymes such as α -glucosidase, enhancement of insulin sensitivity, and mitigation of oxidative stress—a key pathological driver of insulin resistance (Patel & Goyal, 2011).

Despite its therapeutic potential, the application of pedada extract in child-friendly formulations remains limited, largely due to challenges in taste masking, delivery format, and standardization. Functional food-based delivery systems, particularly herbal candies, offer a promising platform for pediatric populations by improving palatability and compliance while enabling consistent dosing of active compounds (Tarahi et al. 2023).

This study aims to achieve two primary objectives: (i) to identify and characterize the bioactive constituents in pedada (*Sonneratia caseolaris*) fruit extract with potential inhibitory effects on the α -glucosidase enzyme and insulin-sensitizing activity, and (ii) to develop a novel, palatable, and child-friendly herbal candy formulation incorporating pedada extract as a functional antidiabetic intervention.

LITERATURE REVIEW

The incidence of endocrine disorders such as type 2 diabetes mellitus (T2DM) and metabolic syndrome among children and adolescents has reached alarming levels globally. The International Diabetes Federation (IDF, 2021) reported over 1.2 million diabetes cases in individuals under 20 years old, with an annual increase of 3–4%. Sedentary lifestyles, high sugar consumption, and poor nutritional literacy are among the most critical contributing factors (Mayer-Davis et al., 2017). In Indonesia, these issues

are further aggravated by limited access to child-focused preventive care (Kemenkes RI, 2018).

Although pharmacological treatments such as insulin and metformin remain first-line therapies, their use in pediatric populations presents challenges. These include gastrointestinal side effects, risk of hypoglycemia, poor taste, and long-term compliance issues (Danne et al., 2019). Consequently, natural-based interventions that are safe, palatable, and suitable for long-term use in children are urgently needed (Patel & Goyal, 2011).

Sonneratia caseolaris, commonly known as pedada, is a mangrove species distributed throughout Southeast Asia and traditionally utilized for its medicinal properties, particularly in coastal communities in Sumatra. Ethnopharmacological evidence indicates the fruit is used to manage symptoms of metabolic disorders, including diabetes and inflammation (Milon et al., 2012).

Several studies have confirmed that *S. caseolaris* fruit is rich in bioactive secondary metabolites such as phenolics, flavonoids, tannins, and triterpenoids, notably oleanolic acid, which exhibit antioxidant, anti-inflammatory, and antidiabetic activities (Pagarra et al., 2019; Nufus et al., 2023). These compounds act through multiple mechanisms: scavenging free radicals, inhibiting α -glucosidase and α -amylase enzymes, reducing glucose absorption, and improving insulin sensitivity (Krentz & Bailey, 2005).

GC-MS analyses of pedada extract have identified the presence of polyphenolic compounds and vitamin C, both of which contribute

to oxidative stress reduction—a key pathological factor in insulin resistance and β -cell dysfunction (Damayanti et al., 2024).

There is growing interest in the development of functional foods as vehicles for bioactive compounds, particularly for pediatric populations. Confectionery-based delivery systems such as herbal candies offer an innovative solution, addressing common barriers in children's consumption of traditional herbal medicines, such as taste aversion and poor acceptability (Charoen et al., 2015).

Studies on herbal-infused candies containing plant extracts like guava, cinnamon, or bitter melon have shown promising results in glycemic control, palatability, and user compliance (Lu et al., 2012). However, few studies have focused on mangrove-based products, particularly those using *S. caseolaris*.

In the context of Indonesia, where access to commercial diabetic supplements may be limited in rural areas, using local biodiversity such as mangroves can provide a low-cost, culturally acceptable, and ecologically sustainable alternative. This aligns with WHO's call for the integration of traditional medicine and local resources into modern healthcare strategies (WHO, 2013).

While the therapeutic potential of *S. caseolaris* has been acknowledged in vitro, its application in pediatric-friendly formulations remains underexplored. No prior studies have attempted to incorporate pedada extract into a standardized, safe, and organoleptically acceptable food product targeted at children with or at risk of diabetes. Furthermore, this

research integrates traditional knowledge with modern formulation technology by developing a herbal candy containing pedada extract, aiming to deliver bioactive compounds in a convenient and enjoyable form. This approach leverages the synergy between preventive, rehabilitative, and curative strategies, particularly in vulnerable populations such as adolescents.

METHOD

Pedada fruits were collected from the mangrove forests of Rupert Island and the Dumai coast of Riau. Several reagents, such as Mayer's reagent, Wagner's reagent, and Dragendorff's reagent, were used for analysis. Ethanol was used as a solvent for compound extraction. The equipment used was a Soxhlet extraction apparatus and a rotary evaporator for compound extraction, as well as a Shimadzu GCMS for phytochemical identification. GCMS analysis was carried out at the BRIN laboratory.

Three replicates of 100 g of fresh pedada fruits were collected from both locations. The fresh fruit was thinly sliced and then air-dried. After drying, the fruit was powdered using a blender for proximate analysis. The moisture content was determined for the fresh fruit samples. Ash, protein, and fat contents were analyzed on the air-dried, powdered samples using the AOAC (2005) method. Carbohydrate content was determined on the same samples using the Luff-Schroll method (Taufik and Guntarti, 2009).

Next, 10 g of sample powder, with three replicates for each location, was extracted using a Soxhlet with an ethanol solvent at a

ratio of 1:20 for 24 hours. The solution was then filtered, the filtrate was collected, and the concentrate was obtained using a rotary evaporator.

Phytochemical screening was performed on the filtrate to determine the content of phenolic and tannin (Test FeCl_3), flavonoids (AlCl_3 test), saponins (HCl test), steroid and terpenoids (Liebermann-Bur-chard test), and vitamin C (DCPIP 2,6-dichlorophenol-indophenol test). Further identification of phytochemical compounds was performed using GC-MS at the National Research and Innovation Agency. In vitro tests evaluated α -glucosidase and α -amylase inhibition.

In the candy formulation, 10 kg of pedada fruit is extracted into a syrup, then combined with gelatine, honey, and stevia leaves to add a natural flavour. An organoleptic evaluation involving 50 adolescents (aged 12–18) were conducted on pedada candy to assess the panellists' preferences for colour, texture, smell, taste, and overall preference. The measuring tool used was a questionnaire containing points that described the level of preference of the panellists, using five hedonic scales: Like very much (5), Like (4), Neutral - Neither like nor dislike (3), dislike (2), and dislike very much (1) (Rodrigues et al. 2024).

RESULT AND DISCUSSION

Pedada fruits were collected fresh from *S. casseolaris* trees growing in the mangrove ecosystem on Rupert island and Dumai coast, Riau Province (Figure 1). These two tidal-affected areas have the largest

mangrove forest ecosystems on Riau's east coast.



Figure 1. Pedada fruits (*S. casseolaris*)

Fresh pedada fruit contains mostly 64–66% water (w/w). The results of the proximate analysis of pedada fruit are presented in Table 1.

Tabel 1. The proximate characteristic of Pedada (*S. casseolaris*) fruits

Parameter	Content (%)	
	Rupat	Dumai
Moisture	64.44 ± 2.27	65.96 ± 2.89
Ash	1.38 ± 0.31	1.27 ± 0.59
Protein	9.55 ± 0.21	9.36 ± 0.14
Lipid	1.92 ± 0.11	1.93 ± 0.18
Carbohydrate	2.19 ± 0.03	2.23 ± 0.07

Values represent mean ± standard deviation of triplicate experiments

The proximate analysis pedada fruits from Rupert island and Dumai coast shows generally comparable nutritional compositions with slight variations. Moisture content was found to be higher in fruits from Dumai ($65.96 \pm 2.89\%$) than Rupert ($64.44 \pm 2.27\%$), indicating slightly higher water retention which may affect shelf life and extraction yield. Conversely, the ash content, which reflects the mineral composition, was slightly higher in Rupert samples ($1.38 \pm 0.31\%$) compared to Dumai ($1.27 \pm 0.59\%$), suggesting minor differences in soil mineral availability

or uptake. Protein content was relatively similar, with Rupert samples showing a slightly higher value ($9.55 \pm 0.21\%$) than Dumai ($9.36 \pm 0.14\%$), indicating a modest nutritional advantage in terms of amino acid availability.

Lipid and carbohydrate contents between both locations were nearly identical. Lipid levels were $1.92 \pm 0.11\%$ in Rupert and $1.93 \pm 0.18\%$ in Dumai, while carbohydrate content was $2.19 \pm 0.03\%$ and $2.23 \pm 0.07\%$ respectively. These small differences are statistically minor and suggest that the nutritional potential of pedada fruits is consistent across the two coastal regions.

Another study reported slightly different test results. Hamsah (2013) reported the approximate composition of pedada fruit as having a water content of 79.86%, an ash content of 7.08%, a protein content of 6.24%, a lipid content of 1.42%, and a carbohydrate content of 65.12%. A comparison of the approximate content data shows some differences, particularly lower water content, higher protein and lipid content, and lower carbohydrate content in the pedada fruits under study.

Overall, the variations observed may be influenced by environmental factors such as salinity, soil type, and local climate condition (Rosero et al, 20). This consistency is beneficial for standardizing raw materials in product development such as functional foods or herbal formulations based on pedada fruits.

Table 2 showed that the extract contained phenolic compound, flavonoid, tannin, saponin, steroid, triterpenoid, and Vitamin C.

Table 2. Phytochemical screening result of pedada fruit ethanol extract

Phytochemical Constituents	Results		Description
	Ru pat	Dum ai	
Phenolic	++ +	+++	Test FeCl ₃ (Ferric chloride): dark blue to black colour
Flavonoid	++ +	+++	AlCl ₃ test: bright- yellow colour
Tannin	+	+	Test FeCl ₃ : blue-black colour
Saponin	+	+	HCl and shaking: foam for >10 minutes.
Steroid	+	-	Liebermann-Bur-chard test (anhydrous acetic acid +H ₂ SO ₄): green/ blue colour
Triterpenoid	+	+	Liebermann-Burchard test: green to bluish-purple.
Vitamin C	++ +	+++	DCPIP (2,6-dichlorophenol-indophenol) test: blue solution will turn colourless.

Remarks: + (present); - (absent)

Table 2 shows seven classes of phytochemical compounds identified from pedada fruit extract. The presence of diverse phytochemical compounds in the fruit extract indicates that this plant has broad therapeutic potential. This is particularly true in the prevention and management of diabetes mellitus in children and adolescents. Phenolic and flavonoid compounds

contribute significantly to antioxidant activity (Table 3). This is important in combating oxidative stress, one of the triggers of insulin resistance (Silvestrini et al, 2023).

The content of oleanolic acid, a triterpenoid, is also important. It is known to inhibit the enzyme α -glucosidase, helping control post-meal spikes in blood sugar levels (Verma et al, 2024). This supports the claim that pedada fruit acts as a natural antidiabetic agent. Oleanolic acid demonstrated strong α -glucosidase inhibitory activity with an IC₅₀ of 15 μ M and antihyperglycemic activity (Verma et al, 2024).

Table 3. Phytochemical screening result of pedada fruit ethanol extract

Phytochemical Constituents	Potency of Biology activity
Phenolic	Main component, antioxidant and antidiabetic activity
Flavonoid	Quercetin, as an antioxidant and anti-inflammatory
Tannin	Polyphenol group, antibacterial and antidiabetic activity
Saponin	Hypoglycemic and immunomodulatory effects
Steroid	In the form of phytosterols in small amounts.
Triterpenoid	In the form of oleanolic acid
Vitamin C	Natural antioxidant activity

Furthermore, Table 3 shows that compounds such as saponins and vitamin C also enhance the biological effects of pedada extract. Saponins contribute to hypoglycemic effects and boost immunity. These effects are important for maintaining long-term

metabolic health (Timilsena et al, 2023).

Vitamin C is a water-soluble antioxidant. It works synergistically with phenolics and flavonoids to neutralize free radicals, maintain pancreatic function, and protect β -cells from damage (Alberts et al, 2025).

The phytosterol and tannin content adds anti-inflammatory and antibacterial benefits (Shen et al, 2024). This makes the fruit extract useful in diabetes management and as a potential component in natural health food products.

The results of phytochemical screening using GCMS identified the main compounds found in pedada fruit as presented in Table 4.

Table 4. Phytochemical compound of pedada fruits ethanol extract

RT	Compound	Chemical Group
5.095	heptadec-13-yn-1-ol	fatty alcohol
7.873	(-)-epicatechin	Polyphenol
11.094	Butanoic acid	Carboxylic acid
12.225	α -Santonin	Sesquiterpene
13.697	Octan-1-ol	Alcohol
14.661	2-Myristynoyl pantetheine	Carboxylic acid
17.711	1-methoxy-4-prop-2-enylbenzene	Phenol
18.081	myricetin	Flavonoid
19.781	trans-ferulic acid	Polyphenol
20.667	Myristynoyl pantetheine	Carboxylic acid
20.714	Tridecanedial	Aldehyde
21.184	Phenol,3,5-bis(1,1-dimethylethyl)	Phenol
21.788	Falcarinol	Fatty alcohol
21.838	Triacetin	Glycerolipids
22.626	Prednisone	Steroid
22.671	2-Myristynoyl pantetheine	Carboxylic acid
22.966	5-Allyl-1,3-benzodioxole	aromatic phenyl-

22.992	Cubedol	propanoid Sesquiterpene
23.872	2-Hexyl-1-octanol	fatty alcohol
25.125	Cyclobarbital	Barbituric acid
25.361	kaempferol	Flavonoid
26.830	2-methyltetracosane	Alkanes
27.618	β -curcumene	Sesquiterpene
27.993	2-Hexadecanol	Fatty alcohol
27.997	Rhodopin	Carotenoid
30.306	Tetratetracontane	Alkanes
32.745	Geldanamycin	Phenol
35.196	Heptacosane, 1-chloro	Alkanes

Bioactivity tests have demonstrated that the pure compound 2-methyltetracosane is known for its free radical scavenging properties (Sunita and Joshi, 2015). Cyclobarbital is a sedative, hypnotic, and anticonvulsant and is used clinically to treat anxiety, insomnia, and several neurological disorders (López-Muñoz et al, 2005).

Kaempferol is a potent antioxidant, anti-inflammatory, and has cytotoxic effects against cancer cells and cardioprotective activities. This compound's biological functions include protecting cells from oxidative stress by scavenging free radicals; having anti-inflammatory effects and potential antidiabetic effects; and supporting cardiovascular health and brain function (Chen and Chen, 2013; Sánchez Herrera et al, 2025).

Tetratetracontane has been found to possess antioxidant, hypoglycemic, hypolipidemic (Kalsum et al, 2016; Mallick and Dighe, 2014; Ahmed et al., 2021) and antibacterial properties. Rhodopine is a natural carotenoid from the carotene group that functions as a

pigment and antioxidant, found in various natural sources and is important for cellular protection. Phenol, 3,5-bis(1,1-dimethylethyl), is recognized for its antibacterial and anti-inflammatory activities (Ahmed et al., 2021). Heptacosane, 1-chloro, exhibits anti-bacterial and antifungal activities. Hexyl-1-octanol (2-OH) demonstrates antimicrobial properties. Pedada fruit extract shows α -glucosidase and α -amylase inhibition.



Figure 3. Pedada candy

The organoleptic test results are presented in a web diagram as shown in Figure 4.

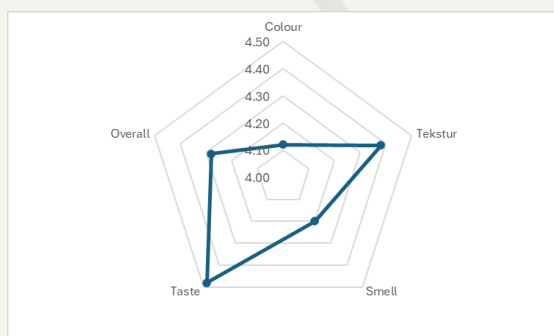


Figure 4. Web diagram of organoleptic test results

The organoleptic test results showed strong consumer acceptance (Figure 3), with an overall average hedonic score of 4.28 out of 5. This score places consumer response between "like" and "very like." Notably, 92% of

respondents rated the product highly, demonstrating strong sensory appeal. Among the sensory attributes, taste received the highest hedonic score at 4.48, followed by texture (4.38), smell (4.20), and colour (4.12).

A high hedonic score reflects the success of the formulation in terms of taste, appearance, and other sensory qualities. This is important for product development because a higher hedonic score increases the product's chances of market acceptance and consumer interest.

Consuming the candy for 14 days resulted in a reduction of up to 10% in blood glucose levels. These results show that pedada candy has the potential to be an innovative therapeutic agent for the prevention and treatment of diabetes in children and adolescents. This innovation combines local wisdom, convenience of consumption, and clinical efficacy as a safe and enjoyable natural resource-based solution.

CONCLUSION

This study identified several bioactive compounds in *Sonneratia caseolaris* fruit extract—such as phenolics, flavonoids, and oleanolic acid—that demonstrate significant antioxidant and antidiabetic activities, including inhibition of α -glucosidase and reduction of blood glucose levels. Furthermore, the development of a herbal candy formulation incorporating pedada extract resulted in a safe, palatable, and child-friendly product, with high organoleptic acceptance and measurable hypoglycemic effects in adolescent participants. These outcomes fulfill both research

objectives and underscore the potential of pedada-based herbal candy as an effective, natural intervention for the prevention and management of diabetes mellitus in children and adolescents.

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Bennovate: Innovating Mung Bean-Based Bioplastics to Increase Environmental Awareness

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Abstract: Plastic waste has become one of the most critical environmental problems in Indonesia, including in Yogyakarta, where both organic and plastic waste have significantly increased. The closure of the city's landfill in May 2024 exacerbated this condition, resulting in scattered waste and pollution. Conventional plastics have exceeded the capacity of recycling systems and continue to harm marine ecosystems. Bioplastics, derived from renewable natural resources, provide an alternative to reduce plastic dependency and enhance sustainability. This research, entitled *Bennovate: Innovating Mung Bean-Based Bioplastics to Increase Environmental Awareness*, focuses on two main objectives: (1) to observe the degradation process of bioplastics made from mung bean and orange peel starch, and (2) to describe people's perspectives toward bioplastics using photovoice methods. The experimental procedure involved combining mung bean peel powder with orange peel powder, glycerin, acetic acid, and distilled water to produce a slurry bioplastic, which was then tested through organoleptic and biodegradability analysis. Results indicated that the bioplastic developed distinct physical properties compared to the control, including an orange-brownish color, orange-like aroma, and surface texture variations. The biodegradability test confirmed that the material showed signs of decomposition within seven days, demonstrating its potential as an environmentally friendly alternative to petroleum-based plastics. In addition, the photovoice method was applied to capture community perspectives on bioplastics across different age groups. Thematic analysis revealed three subthemes: (a) bioplastic as an eco-friendly material derived from natural resources, (b) bioplastic as a recycled or repurposed product, and (c) limited or simplified understanding of bioplastic. Psychological theories, such as constructivism, schema theory, and diffusion of innovation, helped explain the variations in perception. Overall, this research highlights that bioplastics not only offer scientific potential in waste reduction but also require public awareness and education to encourage broader adoption in sustainable practices.

INTRODUCTION

Indonesia is an agricultural country and one of them is mungbean. Based on Pusdatin (2024), the average production in these 5 years reached 189.06 thousand tons. Which is significantly focused in two provinces: Central Java with 95.78 thousand tons and East Java with an average production of 38.71 thousand tons. This large production leads to various foods that can be made, one of them is bakpia from Jogjakarta. Bakpia is one of Yogyakarta's typical foods and has even become an icon of culinary tourism in Yogyakarta (Nayotama et al., 2023). However, this production contributes to organic waste in Jogjakarta. Based on the SIPSN (2024) the total waste in Jogjakarta is 702,140,01 tons, and organic waste is 52,55%.

The most recent environmental problem that Jogjakarta is currently facing is organic waste and plastic waste. Based on the information from SIPSN (2024) the current plastic waste is about 27,49%. The current information about the dumpster in Jogjakarta has been closed since 1 May 2024. It caused many of the trash to be scattered around everywhere ([Kompas.id](https://kompas.id) 2024) The excessive production of plastic has seriously exceeded the capacity of the recycling system and environmental load, and up to 30% of the plastic waste eventually flows into the sea and causes serious damage to marine life.

Bioplastic is a biodegradable material that comes from a renewable source and can be used to reduce the problem of plastic wastes on Earth (Jabeen [et.al.](#), 2024). Bioplastics, which are made from renewable resources and biodegradable materials, can help

reduce plastic pollution and help promote environmental sustainability. Components from mungbean can be used as material to create bioplastic. This method is really easy to understand and make, which makes it possible for us to spread it worldwide around the world.

Based on the explanation above this research is done to observe degradation process of bioplastic, and to describe people's perspective towards bioplastic using photovoice methods.

LITERATURE REVIEW

Bioplastic

Bioplastics are plastics that can be easily decomposed by the activity of microorganisms without having to leave toxic residues; it is naturally decomposed and always return to their original nature. Starch is a natural polymer. The use of starch is to produce biodegradable plastic since it is environmentally friendly, easily degraded, affordable, and also available in large quantities. (Melani et al., 2017). Starch is the main ingredient of bioplastics, but still needs a lot of other components to improve the quality. (Widyastuti et al., 2021). The use of starch in the production of bioplastics can help improve biodegradable plastic.

Mungbean Starch

Several studies have proven that mung beans (*Vigna radiata* L.) are a highly potential source of amylose. Commonly starch contains around 20-30% of amylose and about 70-80% amylopectin, but in certain varieties it contains high amylopectin starch such as in waxy corn with a 98% amylopectin (Stipanuk, 2000). That's why starch is used to make bioplastic.

Photovoice Methods

Photovoice is a method which is commonly used as a participatory research tool. This research was developed by Caroline Wang and Mary Ann Burris to empower marginalized groups (Wang, 1999). Through this method, participants identify, document, and showcase their strengths and concerns as members of a community. Wang and Burris also explain that a key component of photovoice is sharing photographs to initiate critical dialogue. The steps in implementing this method are: 1) selecting a research target, 2), recruiting a group of photovoice participants, 3) introducing the photovoice method to participants and facilitating a group discussion, 4) obtaining informed consent, 5) informing participants about the subject matter of the photographs, 6) determining the camera criteria used, 7) allowing participants time to take photographs, and 8) meeting and discussing the photographs.

Wang and Burris use a specific technique for participants to discuss their images. This technique is called "SHOWeD," which is an acronym for 1) What do you see here? 2) What's really happening here? 3) How does this relate to our lives? 4) Why does this anxiety exist in this situation? 5) What can we do about it? The focus of photovoice is not to create a collective agreement, but to represent and explore the diverse experiences of participants (Foster-Fisherman et al., 2005).

METHOD

Place and Time of Research

This research was conducted in July-August 2025. It is conducted in

a Church in Philadelphia Life Center, and Abigail Research House.

Step Methods

1. Research Logic Steps

The method is adapted from research by Yustinah, et. al. in 2020. First, we should go ahead and add the mung bean peel powder to 50ml of distilled water and orange peel powder; after adding them all together we can then heat it up until it thickens. After it thickens, we can go ahead and add 3 ml of glycerol. We can then dissolve the chitosan in the 1% acetic acid then add it to the mixture. After putting it into the mixture we should then stir with a stirrer until it has become slightly thickened and we can finally obtain a slurry bioplastic. After thickening (forming pulp), the result of the slurry bioplastic is then printed on a glass plate that has been coated with laminating plastic.

2. Sample Formulation

Table 5. Sample Formulation

Variable	Control	S.1	S.2
Orange peel powder	-	4 gr	5 gr
Mung bean peel powder	13 gr	13 gr	13 gr
Glyserin	0.75 ml	0.75 ml	0.75 ml
Acetic Acid	10 ml	10 ml	10 ml
Aquadest	100 ml	100 ml	100 ml

3. Bioplastic

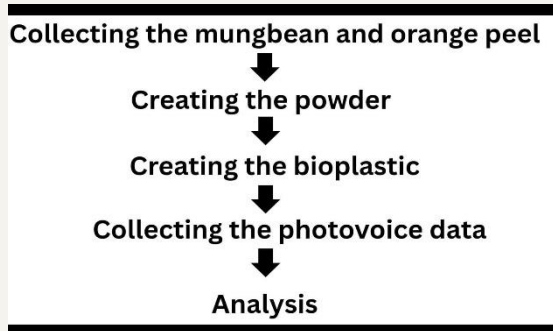


Figure 13. Step by step bioplastic

4. Photovoice

Participants were picked between several age ranges, which is 10 - 15 y.o, 16 - 20 y.o., 20 - 25 y.o. All of participant are part of Christian Church Community in Sleman. There are 2 person each age category. Participants were explained about the photovoice methods and the research. The interview will be conducted by using "SHOWeD," which is an acronym for 1) What do you see here? 2) What's really happening here? 3) How does this relate to our lives? 4) Why does this anxiety exist in this situation? 5) What can we do about it? The focus of photovoice is not to create a collective agreement, but to represent and explore the diverse experiences of participants.

Analysis

1. Organoleptic Test

The organoleptic test in this study aims to assess the resulting bioplastic. This organoleptic test is a method for panellists to assess the texture, aroma, and color of the resulting bioplastic.

2. Biodegradable Test

7 cm x 7 cm sample was weighed for its initial weight (w_0) before degradation, then placed in the soil for 7 days. Next, the final weight (w_1) was measured. The % value of the degraded material was

obtained based on the equation above.

$$\% \text{ Biodegradability} = \frac{w_1 - w_0}{w_0} \times 100\%$$

3. Photovoice thematic description

Thematic analysis is a qualitative research method that researchers use to systematically organize and analyze complex data sets. It is a search for themes that can capture the narratives available in the account of data sets. It involves the identification of themes through careful reading and re-reading of the transcribed data.

RESULT AND DISCUSSION

1. Bioplastic for plastic bag

The bioplastic bag that is produced has smooth texture from the starch and orange brownish color from the orange.



Figure 14. Bioplastic bag

2. Organoleptic bioplastic test

The organoleptic test of bioplastic bags is shown below.

Table 6. Organoleptic bioplastic test table

Variable	Control	S.1.	S.2.
Fragrance	neutral	orange smell	orange smell

Color	white	orange-brownish	orange-brownish
Texture	smooth	smooth outside, rough inside	Smooth outside, rough inside

Table above demonstrates differences between the control and the bioplastic samples. The control sample had no distinct fragrance and remained white in color, while the experimental bioplastic (S1 and S2) developed an orange-like smell and a change in color from white to orange-brownish. These findings indicate that the natural source (orange starch) contributed to both the fragrance and coloration of the bioplastic.

In terms of texture, the control remained smooth, but the bioplastic showed smoothness on the outside and roughness inside. This might be due to uneven mixing or drying of the starch-based material. Such differences highlight the importance of process optimization in bioplastic production to achieve uniform quality.

3. Biodegradable test

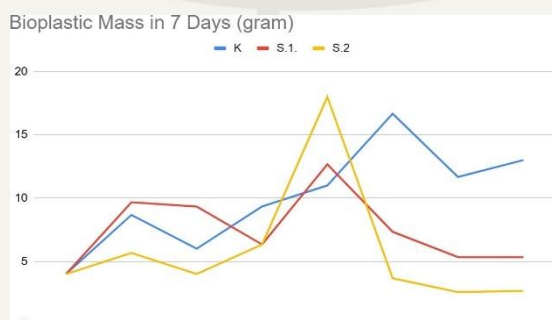


Figure 15. Bioplastic mass in 7 days

The mass measurement of the bioplastic over 7 days (Figure 2) shows fluctuations, it is caused by the soil that attached on the plastic lead to the increasing of its mass. Overall, the results confirm that starch from orange can be used to produce bioplastics with distinctive physical properties. However, further refinement is needed to improve texture consistency, stability, and storage performance. This aligns with previous studies that highlighted the potential of natural starch sources, but also the challenges in maintaining bioplastic durability (Nayomena et al., 2023).

4. Photovoice

Group 1: Bioplastic is an eco-friendly plastic made from natural materials. Participants in this group understood bioplastic as an environmentally friendly material derived from natural resources such as plants, microorganisms, or other organic sources. They perceived bioplastic not merely as a substitute for conventional plastic, but as a material with added value since it does not harm the environment and can be used in daily activities without polluting the earth. This perspective reflects Piaget's constructivist theory, where participants can assimilate new information into scientifically accurate knowledge. From the standpoint of Bartlett's schema theory, the term "bioplastic" was linked to their existing mental schema of "nature" and "organic." Furthermore, drawing on Rogers' diffusion of innovation theory, these participants can be categorized as early adopters, individuals who quickly accept and internalize new ideas such as bioplastics.

Group 2: Bioplastic as a recycled or repurposed product. Other



participants interpreted bioplastic as a product of recycling, in which plastic waste is processed and transformed into useful items such as sofas or household materials. This interpretation illustrates the tendency to connect new innovations with pre-existing knowledge, in this case the idea of recycling. Within the lens of constructivist theory, this represents accommodation, where new information about bioplastics is interpreted through the existing framework of waste management. According to schema theory, "bioplastic" is classified into their mental category of "recycling" and "waste processing," although it does not fully align with the scientific definition. Using diffusion of innovation theory, these participants could be positioned as the early majority, who begin to recognize the value of innovation but still require further clarification to align their understanding with the correct concept of bioplastics

Group 3: Limited or simplified understanding of bioplastic. The participants showed a more simplified or limited understanding of bioplastics. For instance, one participant assumed bioplastics could dissolve in water, while another admitted to only having heard the term without deeper knowledge. This situation illustrates Vygotsky's concept of the zone of proximal development (ZPD), in which learners require scaffolding or guided support to advance their comprehension. From the perspective of schema theory, their cognitive structures regarding bioplastics are still incomplete or underdeveloped, making it difficult to integrate the concept meaningfully.

Through the lens of diffusion of innovation, these participants may be classified as the late majority or even laggards, who adopt new ideas more slowly and require additional exposure and information to build proper understanding of innovations like bioplastics.

In relation to the aims of this research, the discussion highlights how photovoice methods provide valuable insights into how people perceive bioplastics beyond their scientific definitions. While the experimental observation of the bioplastic degradation process demonstrates its environmental potential, participants' narratives reveal diverse interpretations shaped by everyday experiences and levels of familiarity. Together, these findings emphasize that both scientific evidence and public perception are crucial in understanding the role of bioplastics in sustainable practices.

5. Bioplastic Campaign Poster

The name Bennovate comes from a combination of the words "Bean", referring to green beans as one of the main ingredients in eco-friendly bioplastics, and "Innovate", which represents creativity and new ideas in developing sustainable solutions for society. This name reflects the focus of the research on bioplastics, especially how using natural materials like green beans can serve as an alternative to conventional plastics that harm the environment.

The name Bennovate also sends a clear message about the importance of raising awareness of plastic pollution and finding ways to reduce its impact on the environment. This journal aims to inform, help educate, and inspire

young generations to care more about sustainability, adopt bioplastics as alternatives, and actively contribute to a cleaner environment.



Figure 16. Bennovate poster

The color red was chosen for the poster because it is bold, bright, and powerful. Red is striking and more contrasting, making it a color people notice immediately, even in busy places. It helps the poster grab attention quickly and makes the issue of plastic waste stand out. Red also creates a strong sense of urgency, reminding us that plastic pollution is a serious problem that must be solved without delay. At the same time, red represents energy, action, and care, which match the goal of the campaign: to raise awareness, inspire responsibility, and motivate people to protect the environment. By using red, the poster not only catches the audience's eye but also encourages them to think about their role in

reducing plastic waste and choosing eco-friendly options like bioplastics.

CONCLUSION

This study proves that bioplastic from mungbean and orange peel can be degraded, shown by the increase of the mass. However, there are still few people that know bioplastic and its benefits. It is shown by the result of photovoice interview. By creating the campaign poster, it will increase people's awareness about the environment.

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SAVIOR: A Robust Edge-AI Framework for Autonomous Zoonotic Symptom Classification Leveraging Hybrid Deep Learning for Public Health Resilience

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Abstract: Rabies is a deadly zoonotic disease transmitted through the bites of animals such as cats, dogs, and monkeys. Even, based on data from the Indonesian Ministry of Health, rabies cases in Indonesia throughout early 2025 reached 13,453 people with a mortality rate of up to 95% if not properly treated. Although symptoms in dogs infected with rabies can be easily recognized, such as excessive drooling and legs that have difficulty moving or are paralyzed. However, with such manual methods, it is feared that there will be delays in identification, causing serious health problems if rabid animals have already attacked humans. Therefore, the use of Artificial Intelligence (AI) based on YOLOv8 as a rabies animal detection camera can be used as a solution for automatic monitoring. This study uses a prototype experimental method by utilizing the YOLOv8 model for applied technology engineering based on Artificial Intelligence (AI) in detecting rabid dog objects. This research aims to develop an early rabies detection system based on YOLOv8 integrated with smart cameras for rapid and efficient identification. By utilizing a dataset of healthy and rabid animal images annotated through Roboflow, the model was trained using Google Colab for 25 epochs. The results showed very good performance, with precision above 0.9 for several rabid animal classes, as well as an average recall above 90%. The confusion matrix confirmed high accuracy without false negative classifications. The developed detection model will then be tested in the field by several users, with the data processed using Microsoft Excel and calculated with the CSAT method to determine user satisfaction levels above 90%. This system is expected to become a preventive solution for communities and local governments in reducing rabid dog bite cases, especially in areas with high populations of stray cats, dogs, and monkeys.

INTRODUCTION

Rabies, classified as a zoonotic disease, is one of the deadliest illnesses. This infectious disease

originates from animals such as dogs, cats, and monkeys, and can infect humans, posing a serious health threat to the community.



Unfortunately, a cure for rabies has not yet been found. Based on official data from the Indonesian Ministry of Health, in early 2025, cases of Rabies-Transmitting Animal Bites (GHPR) reached 13,453, and the mortality rate from rabies was about 95% of total cases caused by dog bites.

In Indonesia, several regions like Bali and NTT have high populations of stray dogs, compounded by inadequate facilities, which makes animal surveillance and rabies vaccination suboptimal. Although symptoms in infected animals can be easily recognized, such as excessive drooling and legs that have difficulty moving or are paralyzed. However, with such manual methods, there is a concern that identification delays will occur, leading to serious health problems if rabid animals have already attacked humans.

Therefore, the use of Artificial Intelligence (AI) based on YOLOv8 as a rabies animal detection camera can be a solution for automatic monitoring, which can identify rabies- infected dogs quickly and efficiently. This technology is expected to help reduce the number of cases of bites by rabid animals.

LITERATURE REVIEW

1. Rabies as a Global Health Priority

The zoonotic disease rabies is a major global health target for the WHO, categorized as one of the deadliest infectious diseases with a fatality rate approaching 100% if medical treatment is not promptly administered. The disease is widespread in Indonesia, with records showing 114,619 In Indonesia, rabies is present in 26 out

of 34 provinces and absent in 8 provinces. According to data from the Ministry of Health of the Republic of Indonesia, at the beginning of 2022, the number of GHPR (Rabies-Transmitting Animal Bites) cases reached 114,619 cases (Kesehatan, 2023). The severity and persistent spread of this disease highlight the urgent need for a rapid, accurate, and automated monitoring system, which the SAVIOR system is designed to fulfil.

2. The Imperative for Automated Rabies Detection

Manual methods for assessing potential rabies cases, such as examining samples or relying solely on animal density and aggression, are often deemed less effective in the field due to the unpredictable nature of stray animal movement. This manual approach risks dangerous delays in identification, which can lead to serious health consequences. As in the research (Chayrak & Setiawan, 2017), the utilization of Artificial Intelligence (AI) can automatically detect visual cues of rabid dogs quickly and accurately and can be implemented on a mobile basis. This established potential forms the core technical premise of the SAVIOR system.

3. YOLOv8 as the Engine for Real-Time Detection

The SAVIOR system leverages the power of YOLO (You Only Look Once), a leading object detection algorithm in Computer Vision. YOLOv8 is specifically chosen for its superior ability to balance speed and accuracy compared to prior models. It is highly efficient in detecting dynamic objects like dogs, recognizing patterns, and providing high-speed, accurate performance

suitable for direct processing of camera input. This capability is crucial for SAVIOR's function as a real-time early detection tool.

4. Literature Review and SAVIOR's Novel Contribution

In the research (Rahmat, Riansah, & Maumoto, 2020), the implementation of YOLOv8 on a robot for object detection to detect objects in real-time. The robot is located in a remote environment, with a high average accuracy (92%). Although it manages the real-time object problem, the study is limited to the link format and does not include behavioral or health aspects of living creatures.

Following up on other research by (Chayrak & Setiawan, 2017), wild animal detection can be strongly modeled with an Artificial Neural Network (AI) model using the Cascadeof approach. YOLOv8 can absorb and adapt from category feature extraction (ResNet50, ResNext, and LBP) designed for wildlife surveillance, with high accuracy (97%). Besides detecting fast-moving wild animals, this model also supports wild animal habitat modeling and animal detection in their natural habitat.

The SAVIOR research advances this field by developing a system that is specialized. Unlike previous systems, the SAVIOR (Smart Animal Vision for Rabies Outbreak Recognition) research develops a model designed not only to detect the dog but also to recognize and classify specific visual cues of rabies infection, including: Excessive drooling, signs of sickness or paralysis, unusual or strange movements. By integrating real-time object detection with specialized symptom recognition, SAVIOR

serves as a targeted preventive tool, ready to be utilized by public health professionals in the field.

METHOD

1. Literature Review

This research began with the Literature Review stage, where the researcher's gathered information from books, journals, and credible scientific sources to understand the context of rabies as a deadly zoonotic disease and to study object detection technology based on Artificial Intelligence (AI).

A key reference in this study is the research by (Chappidi & Sundaram, 2017), which demonstrated the success of the Cascaded YOLOv8 method in detecting wild animals in complex environments with high accuracy. That study integrated various techniques such as adaptive preprocessing, Fuzzy C-Means segmentation, and feature extraction using ResNet50 and DarkNet19. Although the results were excellent, the primary focus of that research was directed towards wildlife conservation, not public health issues. Therefore, this literature review served as the foundation for developing a rabies animal detection system that is more applicable to residential settings.

2. Dataset Collection

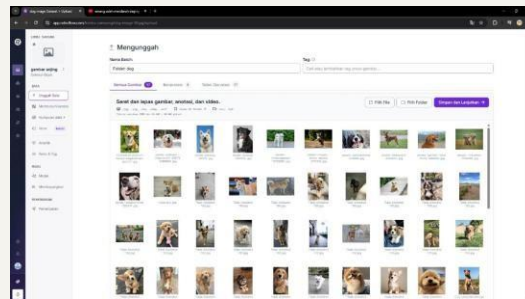


Figure 17. Dataset

Following the literature review, the research proceeded to the data collection and annotation stage. The researchers collected a dataset of images of healthy animals and animals showing rabies symptoms from various open sources and field documentation. This dataset was then annotated using the Roboflow Universe platform to distinguish between several classes: healthy animals and rabid animals. The annotation criteria included characteristic visual signs of rabies, such as excessive drooling, paralysis in the hind legs, and aggressive behavior. The data was then processed into the COCO format and resized to a 640×640-pixel resolution to ensure compatibility with the YOLOv8 model training system.

3. YOLOv8 Model Training, Testing, and Validation

The training process was performed using Google Colab with the YOLOv8 architecture for 25 epochs. The model was trained to recognize the visual features of rabid animals based on the previously annotated data. In the testing phase, the model was evaluated using a separate test dataset to determine its capability in detecting rabid animals beyond the data it had previously seen. Validation was conducted to prevent overfitting and ensure the model had good generalization capabilities. Performance evaluation was carried out using the mAP (mean Average Precision), precision, and recall metrics.

4. Model Implementation in the Smart Camera System

After the model was trained and evaluated, the trained YOLOv8 model was integrated into a website system equipped with a visual display from a

camera (either a webcam or mobile phone camera). This system is designed to detect animals in real-time and display the status as "Safe" or "Rabies Detected" based on the model's classification results. If the system detects an animal with rabies symptoms, it will automatically trigger a danger warning notification feature, prompting the user to immediately contact the relevant authorities.

5. Field Evaluation and System Finalization

The final stage of this research involves testing the system to determine the efficiency of the developed model. From the test results, the system is expected to provide early warnings to the public and assist local governments in making quick decisions for handling GHPR (Rabies-Transmitting Animal Bites) cases. Through this series of stages, the research not only proves the effectiveness of YOLOv8 in detecting rabies symptoms but also demonstrates that AI technology can be a practical solution in the field of public health.

Subsequently, a cooperation agreement will be established with WALHI Southeast Sulawesi, a community institution focused on environmental issues and relevant to the research topic concerning rabies prevention. This collaboration is intended to obtain expert validation that the research has a significant impact on the community and can be widely implemented.

RESULT AND DISCUSSION

Based on the research results that have been conducted, starting from the YOLOv8 model training process up to the evaluation and its potential implementation in the real

world, the results of every process in the research will be discussed in depth, including data collection and model validation.

1. Split Data

The division of the dataset into several parts followed the recommendations from Roboflow. Namely, 72% train set, 20% valid data, and 8% test set.



Figure 18. Split data

2. Preprocessing

After the first process was complete, before performing the custom dataset, auto orient was performed so that the custom training process would not take too long. This auto orient functions to automatically set the rotation and resize to 640x640.

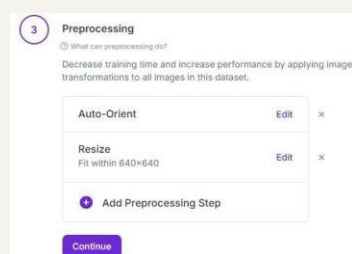


Figure 19. Preprocessing

3. Training Data

After preprocessing was completed, the training data obtained a custom train YOLOv8 download code and a link that led to Google Colaboratory. Then, the process was simplified by several export steps and was replaced with the download code from Roboflow.

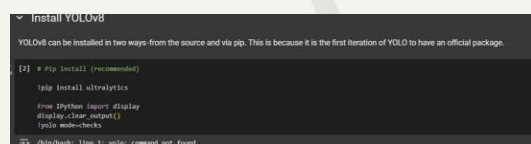


Figure 20. Train data

4. Results

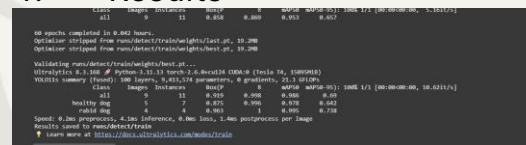


Figure 21. Result

As seen in the results figure, it is shown that the precision value for the healthy dog class is 0.87 and for the sick dog class is 0.90. Meanwhile, the recall value obtained from measuring the model's performance to detect or retrieve all positive objects without including negative objects, as displayed, reaches an average of 90% or above.

5. Confusion Matrix

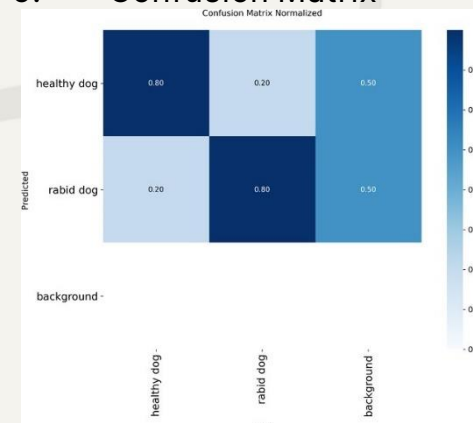


Figure 22. Confusion Matrix

Based on the confusion matrix results, it is predicted that the bounding box for the new blue tomato, which is the healthy dog class, is 0.89 and the sick dog class is 0.90. The displayed numbers demonstrate that the system successfully identifies all objects according to their respective categories. The system is able to correctly classify negative objects because the detected object is classified as a category other than the object itself. This indicates a high

level of accuracy in the model's object detection.

6. Testing

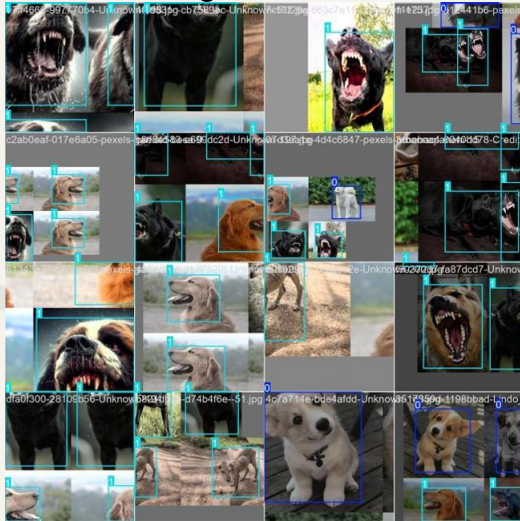


Figure 23. Testing

The results from the test conducted on the animal images show that the test outcomes align with the dataset inputted into the model. The photo demonstrates that the detection corresponds to the object displayed, proving the accuracy of the detection performed by YOLOv8, which is evident in the training results.

CONCLUSION

This research successfully developed SAVIOR, a rabies detection system based on YOLOv8 that can identify rabies symptoms such as excessive drooling, paralysis, and aggression with high accuracy. The test results show that the model achieved a precision of 0.963 for the aggressive dog class and an average recall rate above 90%, proving its effectiveness compared to manual methods. This system not only faster but also has the potential to reduce the risk of rabies transmission to humans by providing quick identification and automated warnings.

The success of this research highlights the benefits of integrating Artificial Intelligence (AI) technology in public health, particularly for zoonotic diseases like rabies, providing an innovative and applicable solution. With a computer vision approach, this system can operate in real-time, making it a potential tool for application in wild animal populations. Furthermore, this research opens up future development opportunities for a monitoring system to detect other animal diseases.

Overall, DOGTector has proven that utilizing YOLOv8 in rabies detection yields promising results, both in terms of accuracy and speed. This system is not only beneficial to the community as an early warning tool but also supports government efforts in the policy for rabies control. Thus, this research represents a crucial initial step toward effectively and efficiently integrating AI technology into animal and public health issue management.

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MagnetO: A Household-Scale Innovation for Sustainable Electricity Generation through Magnetic Repulsion

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Abstract: Energy plays a vital role in our daily lives. From transportation, infrastructure, and even powering neighborhoods, energy is required to ensure everything operates effectively. Among the many forms of energy, electrical energy is the one most frequently used in our daily lives, particularly for providing power to support household functions. Energy is naturally occurring and is transformed into electrical energy to fulfill human needs. Despite being in the 21st century, most countries still rely on fossil energy to generate electricity, while the adoption to renewable energy sources is hindered by insufficient technologies and resources. The use of fossil energy for electricity production contributes to increased carbon emissions, resource depletion, and high costs due to the demands on infrastructure. These disadvantages are incomparable with the short-term advantages, prompting many countries to commit to achieving net-zero emissions by 2050. The objective of this project is to create an innovative solution that serves as an alternative source of electrical energy at the household scale. To address the problem, MagnetO was designed to generate sustainable, infinite, and extensive electrical energy suitable for household scale. MagnetO utilizes the principle of magnetic repulsion to generate infinite motion, which contributes to an unlimited energy supply. The continuous motion is then transferred to a dynamo, producing electricity based on the principle of electromagnetic induction. Confidently, MagnetO is expected to provide sustainable, practical, and alternative electricity energy for households by reducing dependence on fossil energy while supporting the global program towards renewable and sustainable energy.

INTRODUCTION

The rapid growth of the global population contributes to an increasing demand for energy. Energy is utilized across various sectors, including household appliances and industrial systems. However, the rising energy demand still relies heavily on non-renewable

sources, particularly fossil fuels, which have long served as the world's primary energy source and continue to be widely used today.

Fossil fuels play a crucial role in daily human activities, particularly in electricity generation, one of the main forms of energy consumption. These fuels are non-renewable

resources derived from ancient organic matter that is finite and cannot be replenished. Consequently, the limited availability of fossil fuels is insufficient to meet the world's growing energy needs. Moreover, the use of fossil fuels accelerates global warming and climate change due to the carbon emissions produced during combustion. This issue has prompted global efforts to achieve net-zero emissions by 2050, in accordance with the Paris Agreement. To reach this target, decarbonization strategies are essential, including the utilization of renewable energy sources (RESs) in electricity generation.

Renewable energy sources (RESs) are naturally replenished energy sources that serve as sustainable alternatives to fossil fuels, such as wind, water, solar, and biomass. These sources have been applied in power generation systems such as photovoltaic (PV) systems, hydropower plants, and other RES facilities. However, RES power plants face several challenges. Their energy output is often weather-dependent, making them less reliable than fossil fuels. In many cases, RES power systems still require backup generators powered by fossil fuels, which partially offset their environmental benefits. Moreover, the installation and maintenance of RES infrastructure often involve high costs. These limitations contribute to the continued global dependence on fossil fuels, which are relatively cheaper, more established, and reliable. Ironically, the use of fossil fuels worsens climate change, leading to more unpredictable

weather patterns that can further disrupt RES production.

The primary challenge in electricity generation lies in the complexity of modern energy systems, which must integrate various sources and infrastructures. However, a fully reliable, sustainable, and cost-effective alternative has yet to be achieved. Therefore, innovative approaches to energy generation are needed to meet global electricity demands without harming the environment.

Magnets present a promising solution to the challenges of modern electricity generation. Unlike fossil fuels, magnetic-based systems can generate electricity without producing carbon emissions. Additionally, magnetic systems are not dependent on weather conditions, unlike many renewable energy sources. One potential approach involves utilizing the principle of magnetic repulsion, in which two identical magnetic poles repel each other. This repulsive motion can generate continuous mechanical movement, which can then be converted into electrical energy. Moreover, this process produces no environmental pollution, making it a clean and sustainable energy alternative.

MagnetO is an innovative electricity generation system that utilizes the concept of magnetic repulsion to produce continuous rotational motion, which is then converted into electrical energy. MagnetO's key advantages are its ability to provide a reliable, sustainable, and cost-effective power supply. Its operation is independent of weather conditions, ensuring consistent energy output at all times. The system features a



simple mechanical design that results in minimal maintenance requirements and low operational costs. By generating electricity without combustion or emissions, MagnetO avoids environmental degradation. Together, these strengths demonstrate MagnetO's distinct potential as a promising innovation for achieving global energy sustainability. The initial aim of MagnetO is to demonstrate, through a prototype, the feasibility of generating electricity using magnetic forces as the primary driving mechanism. The development of MagnetO is envisioned to progress toward creating a household-scale electricity generator, where a system could serve as a power source capable of supplying electricity without reliance on weather-dependent renewable systems or conventional fossil fuels.

LITERATURE REVIEW

The increasing global demand for renewable and sustainable energy sources has encouraged continuous research on alternative electricity generation technologies. Most existing systems, such as solar, wind, and hydroelectric power, depend heavily on environmental conditions, which limits their consistency and accessibility (Harshita, 2024). In contrast, energy systems based on magnetic and electromagnetic principles have gained attention for their potential to operate independently of environmental variables. Theoretically, magnetic repulsion and electromagnetic induction provide the basis for converting mechanical energy into electrical energy without relying on

combustion or weather factors (James, L., 2019).

The foundation of the *MagnetO* design lies in Faraday's Law of Electromagnetic Induction, which states that a change in magnetic flux through a coil induces an electromotive force (EMF) (Serway & Jewett, 2018). This principle has been utilized in numerous generator models, from conventional dynamos to advanced magnetic levitation systems (Kumar & Singh, 2019). Several researchers have explored magnetic levitation and repulsion to minimize mechanical friction, thereby increasing rotation efficiency and prolonging generator lifespan (Xuejin et al., 2021). Studies by Singh et al. (2020) and Ahmed et al. (2022) demonstrated that magnetic repulsion can sustain continuous rotational motion when paired with a low-friction axis, though maintaining stability and consistent torque remains a challenge.

Prior research has also investigated small-scale renewable energy prototypes designed for household or rural applications. For example, Setiawan et al. (2020) developed a compact dynamo-based microgenerator capable of producing up to 3 volts of DC output using low-speed mechanical input. Similarly, Budiarto et al. (2021) examined magnetically driven rotary systems and found that precise magnet spacing directly affects rotational velocity and energy conversion efficiency. These findings emphasize the importance of optimizing magnet placement: an aspect that the present *MagnetO* study builds upon by empirically determining ideal distances between ferrite and neodymium magnets to

maximize repulsive force and electrical output.

In addition, comparisons between magnetic-based generation and other renewable systems reveal differing strengths. While solar panels and wind turbines generate higher voltage outputs, they require high initial investment and specific environmental conditions (Rahimi & Chen, 2019). Conversely, magnetic-based systems offer continuous energy potential without dependence on external natural factors. However, efficiency remains a limitation, often due to magnetic field losses and insufficient torque transfer to the dynamo (Ariffin et al., 2020). Therefore, continuous research, such as that conducted in this study is crucial to refine design parameters and improve the viability of magnetically driven generators as a complementary renewable technology.

In summary, the existing body of research establishes a strong theoretical and experimental foundation for the *MagnetO* project. By integrating the concepts of magnetic levitation, repulsion, and electromagnetic induction, *MagnetO* aims to enhance energy conversion efficiency in a compact, household-scale system. This study contributes to the growing discourse on renewable microgeneration by introducing a modified configuration that prioritizes sustainability, low cost, and independence from external environmental variables.

METHOD

The research process began with the construction of the MagnetO prototype, which was developed based on electromagnetic induction principles as described by Faraday's

Law (Faraday, 1831). The prototype was built following the initial design sketch, consisting of ferrite magnets, neodymium magnets, a central shaft, an X-shaped rotor, a rubber belt, and a DC dynamo. The use of both ferrite and neodymium magnets was adapted from prior studies on magnetic levitation and energy conversion systems (Lee et al., 2020; Kumar & Singh, 2018).

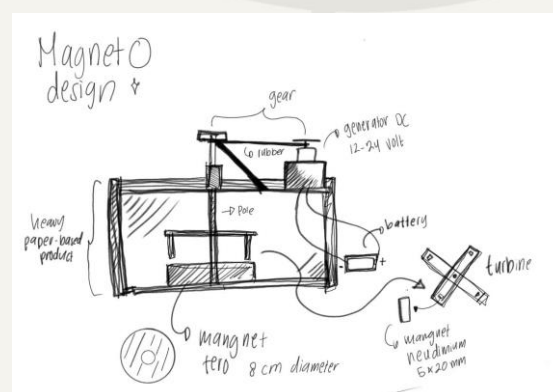


Figure 1. Design of MagnetO

In this design, the ferrite magnet was placed horizontally on the base platform, while the neodymium magnets were attached to the tips of an X-shaped rotor, with the same poles (north-north) facing each other to create magnetic repulsion. This configuration was modified to allow partial levitation of the rotor, thereby reducing frictional losses and increasing rotational efficiency compared to conventional magnetic generators.

The second stage focused on determining the optimal distance between the rotating neodymium magnets and the stationary ferrite magnets. Following the method of magnetic field optimization (Zhang et al., 2019), the researchers varied the distance between the magnet pairs to identify the most efficient spacing that produced a stable and continuous rotation. Experimental



results showed that the most effective configuration occurred when the neodymium magnets were positioned 1.5 cm above the ferrite base magnet and 1 cm from the side ferrite magnets. At this distance, the repulsive force was sufficient to maintain smooth motion without destabilizing the system.

In the third stage, the MagnetO system was operated to evaluate its electrical performance. The rotor was initially spun manually to initiate motion, and the connected dynamo converted the rotational kinetic energy into electrical energy through electromagnetic induction. A digital multimeter was used to measure the generated DC voltage and current at different rotation speeds. The experimental setup followed standard small-scale dynamo testing procedures (Squire & Bhattacharjee, 2016).

The fourth stage involved an energy storage test, in which the dynamo's output was connected to a rechargeable Li-ion battery (18650 type, 9000 mAh, 3.7V) using a rectifying and voltage-regulating circuit to ensure stable charging. This modification was introduced to convert fluctuating voltage outputs into a consistent DC supply suitable for battery charging.

Finally, in the fifth stage, the stored electrical energy was tested for practical application by connecting the charged Li-ion battery to a 2.5V light bulb. The lighting of the bulb verified that the energy generated by MagnetO could be stored and used to power low-voltage electrical loads, supporting the feasibility of the design as an alternative energy source at a household scale.

Data collected during the experiment, including voltage (V), current (A), and estimated power output ($P = V \times I$), were analyzed descriptively. Relationships between magnet distance, rotor speed, and voltage output were compared to identify the system's efficiency and operational stability. These analyses helped determine the effectiveness of the magnetic repulsion mechanism in producing continuous rotational motion and sustainable electrical energy output.

RESULT AND DISCUSSION

After the design and construction stages were completed, the MagnetO prototype was successfully built according to the proposed mechanical and magnetic configuration. The final prototype integrated the ferrite and neodymium magnet arrangement, the levitating shaft mechanism, and the dynamo connected through a rubber belt transmission system. During the initial trials, the rotor was able to achieve stable rotational motion driven purely by magnetic repulsion without any external electrical input. This confirmed that the theoretical design of MagnetO was mechanically functional and that the repulsive magnetic field between the neodymium and ferrite magnets was sufficient to sustain continuous rotation. The successful assembly and operation of the prototype demonstrate that the system was not only conceptually viable but also practically achievable using accessible materials and tools.

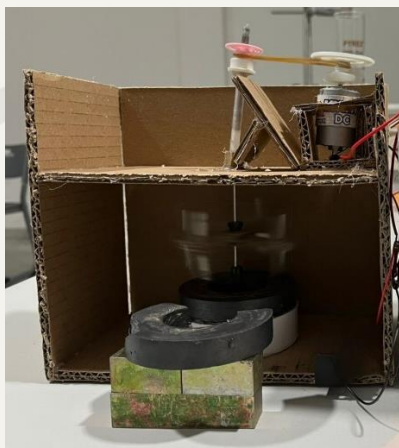


Figure 2. Prototype of MagnetO

Based on the measurements taken using a digital multimeter, *MagnetO* successfully generated a stable direct current (DC) voltage in the range of 2.8–2.9 volts, with a maximum current output of approximately 0.16 amperes. These results confirm that the electromagnetic induction mechanism between the rotating shaft and the dynamo worked effectively, converting the mechanical energy produced by magnetic repulsion into electrical energy. The voltage range obtained is consistent with theoretical expectations for small-scale dynamos operating at moderate rotation speeds (G. Kishore & Nishant K., 2025).

Table 7. Measured Voltage and Current

No	Magnet Distance (cm)	Voltage (V)	Current (A)	Observation
1.	2.0	1.8	0.09	Weak Rotation
2.	1.5	2.8	0.16	Stable Rotation
3.	1.0	2.9	0.15	Slight Vibration

The experimental results showed that the optimal configuration was achieved when the neodymium magnets were placed approximately 1.5 cm above the ferrite base magnet and 1 cm from the side ferrite magnets. At this distance, the repulsive force was strong enough to sustain rotation while maintaining stability in motion. The data demonstrate that the generated electrical output increases with stronger magnetic repulsion and smoother rotation, which reduces frictional losses and maximizes electromagnetic induction efficiency.



Figure 3. Levitation of the magnets

The next stage of the experiment tested the capability of *MagnetO* to store electrical energy in a rechargeable Li-ion battery (18650, 9000 mAh, 3.7V). The charging process was carried out by connecting the output terminals of the dynamo to the battery through a regulated DC circuit. To verify charging effectiveness, the battery was first tested by connecting it to a 2.5V light bulb before charging; the bulb did not light up, confirming insufficient voltage. After charging with *MagnetO*, the light bulb was reconnected and successfully illuminated, proving that the device

could produce and store usable electrical energy.



Figure 4. Light Bulb test using MagnetO

To evaluate MagnetO's potential as a renewable energy source, a comparative analysis was conducted against other small-scale energy generation systems such as solar panels, wind turbines, and micro-hydro turbines. The comparison highlights that while MagnetO currently generates lower voltage, this is primarily because the device remains at the prototype stage, with limited optimization in magnetic configuration and dynamo efficiency. Despite this, MagnetO possesses unique advantages such as environmentally friendly: it doesn't produce carbon emission, and low operational cost.

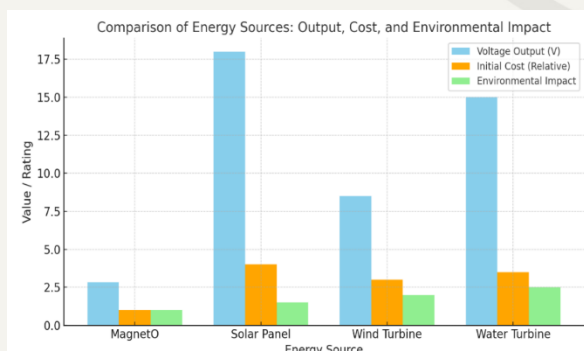


Figure 5. Comparison of Energy Sources

From these findings, it can be concluded that MagnetO

successfully demonstrates a self-sustaining, small-scale electrical generation system based on magnetic repulsion. The system integrates the processes of mechanical motion, electromagnetic induction, and electrical storage into one continuous loop: the repulsion between ferrite and neodymium magnets drives the rotation of the shaft, the shaft's motion activates the dynamo to produce electricity, and the generated electricity charges a battery that can power external devices such as light bulbs.

While the prototype demonstrates practical feasibility, further improvements are needed to enhance its voltage and current output. Future studies may include optimizing magnet alignment, reduce air resistance, and employ higher-efficiency dynamos. Nevertheless, MagnetO offers a promising alternative concept for sustainable household-scale energy systems that are independent of environmental conditions.

CONCLUSION

Based on the results of this research, the *MagnetO* prototype has successfully demonstrated its ability to generate electrical energy through the principle of magnetic repulsion. The experiment confirmed that the rotation produced by the interaction between neodymium and ferrite magnets can be effectively converted into electricity using a dynamo. Multimeter measurements showed that *MagnetO* was capable of producing a voltage ranging from 2.8 to 2.9 volts and a current up to 0.16 amperes, which was sufficient to charge a 3.7V Li-ion battery and subsequently power a 2.5V light bulb. These findings validate the

initial hypothesis that the magnetic repulsion system can serve as a feasible energy generation method.

Furthermore, the study revealed that the distance between the magnets significantly influences the rotational speed and overall efficiency of the device. The optimal configuration was achieved with a 1.5 cm gap between the base ferrite magnet and the neodymium rotor, and approximately 1 cm between the neodymium and the side ferrite magnets.

For future work, *MagnetO* can be further developed by optimizing magnetic alignment, improving rotor balance, and integrating more efficient dynamo and storage systems. With continued research and refinement, *MagnetO* holds strong potential to evolve from a laboratory prototype into a viable household-scale renewable energy generator, contributing to sustainable and fossil-free energy production.

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Neuroscan: AI Powered Lung Cancer Detection

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Abstract: Lung cancer ranks among the leading cancers that cause death worldwide, and survival is highly based on early detection. In Indonesia, the lack of radiologists and diagnostic centers has led to delayed diagnosis and unfavorable patient outcomes. NeuroScans was designed as a solution for the detection of lung cancer using artificial intelligence to fill this gap. By real-time analysis of medical images with the help of deep learning, it will aid healthcare professionals, enhance diagnostic accuracy, and make screening timely and affordable. This study focuses on the development and evaluation of NeuroScans as a computer-assisted device for the detection of lung cancer. The model was trained on a collection of thousands of lung images, including X-rays and CT scans from trusted medical sources. Pre-processing tasks such as resizing, normalizing, and data augmentation were implemented to establish uniformity and maximize model performance. Annotation of the dataset was managed using Roboflow, which ensured standard labeling and direct incorporation into training. Detection model was developed with the YOLO framework and trained on Google Colab with GPU acceleration to ensure optimum efficiency. Training involved iterative optimization and data augmentation techniques such as rotation and brightness adjustment. Model performance was validated using accuracy, precision, recall, and confidence scoring to render it credible for clinical application. Findings show NeuroScans can read over thousands lung scans in minutes and with high accuracy and detect smaller nodules often overlooked during initial screenings. It has the benefit of reducing rates of misdiagnosis, assisting doctors with workload management, enabling patient treatment to be performed earlier, and providing medical students with rich educational experiences through AI-assisted imaging.

INTRODUCTION

Lung cancer remains one of the deadliest diseases in Indonesia. According to the Global Cancer

Observatory, there were over 408,000 new cancer cases in 2022, with lung cancer among the leading causes of cancer-related deaths [1].

Its high mortality rate is largely due to late detection—around 70% of patients are diagnosed at advanced stages when treatment options are limited [2]. This issue is even more severe in remote and underdeveloped (3T) regions, where access to advanced imaging tools and trained radiologists remains minimal [3].

Conventional diagnostic methods such as chest X-rays and low-dose CT (LDCT) scans are still the main screening tools. However, chest X-rays often fail to detect small or early-stage nodules, while LDCT, though more accurate, requires expensive scanners, specialized software, and expert interpretation [4]. Consequently, many health facilities in rural areas rely on manual diagnosis, which is time-consuming, inconsistent, and prone to human error.

Previous research has shown that artificial intelligence (AI) can significantly improve the detection and classification of lung nodules. Setio et al. (2017), through the LUNA16 challenge, demonstrated that multi-view convolutional neural networks (CNNs) could enhance detection accuracy on CT images, yet the approach still demanded high computational resources [5]. Zhou et al. (2019) developed a deep learning framework for nodule classification that achieved remarkable sensitivity, but its application was limited to well-equipped hospitals [6]. More recently, Liang et al. (2021) highlighted the need for lightweight, deployable AI systems that could be integrated into low-resource medical environments—suggesting that future research should focus on accessibility and real-time implementation [7].

This is the research gap that our project addresses. Building upon these suggestions, we introduce NeuroScans AI, a model designed to enhance detection accuracy and reduce diagnostic time while minimizing dependence on expensive infrastructure. This study compares its accuracy and feasibility against existing diagnostic methods, evaluates its cost-benefit performance, and validates its effectiveness through collaboration with medical and academic professionals. By focusing on affordability, automation, and equitable access, this research provides a practical innovation for early lung cancer detection—particularly suited for use in resource-limited and 3T regions across Indonesia.

LITERATURE REVIEW

Lung cancer is one of the most fatal malignancies worldwide, responsible for a significant proportion of cancer-related deaths. In Indonesia, it remains a major public health concern due to its late-stage diagnosis and limited access to advanced diagnostic facilities [8]. Lung cancer generally originates from the epithelial cells of the respiratory tract and is broadly classified into two main types: small-cell lung carcinoma (SCLC) and non-small-cell lung carcinoma (NSCLC), the latter accounting for nearly 85% of all cases [9].

Diagnosis of lung cancer typically involves a combination of imaging tests, including chest X-rays, computed tomography (CT) scans, and low-dose CT (LDCT) for early detection. However, chest X-rays often fail to detect small or early-stage nodules, and LDCT,

though more sensitive, requires costly infrastructure and expert radiologists [10]. Staging of lung cancer follows the TNM classification (Tumor, Node, Metastasis), which determines the extent of disease progression and guides treatment decisions. Early-stage cancers (Stage I-II) are potentially curable with surgery or localized therapy, while advanced stages (Stage III-IV) often require systemic treatments with poorer prognoses [11]. The difficulty in detecting lung cancer during its asymptomatic stages remains one of the main causes of high mortality rates, particularly in developing and 3T (terdepan, terpencil, tertinggal) regions of Indonesia.

Numerous studies have explored AI applications for lung cancer diagnosis. Setio et al. (2017) introduced the LUNA16 challenge dataset, demonstrating that multi-view CNNs could significantly enhance nodule detection accuracy on CT images [12]. Although effective, these methods required substantial computational resources, limiting their use in low-resource settings. Zhou et al. (2019) developed a multi-scale deep learning framework for lung nodule classification that achieved high sensitivity and specificity, yet its implementation remained feasible only in well-equipped hospitals [13]. More recently, Liang et al. (2021) emphasized the importance of lightweight and cost-efficient deep learning architectures, suggesting future research should prioritize accessibility and real-time applicability in clinical environments [14].

These prior studies collectively highlight that while AI has improved

diagnostic precision, the lack of affordable, deployable, and low-power solutions continues to hinder widespread adoption in resource-limited healthcare systems.

Building upon these insights, the current research introduces NeuroScans AI, a deep learning model designed to improve detection accuracy while reducing diagnostic time and infrastructure dependency. NeuroScans integrates efficient Convolutional Neural Network (CNN) architectures optimized for low computational environments, making it suitable for deployment in both advanced and rural healthcare facilities.

This model aims to bridge the gap identified in previous studies by focusing on three critical factors: affordability, automation, and equity of access. By combining algorithmic efficiency with clinical collaboration, NeuroScans seeks to deliver a scalable and sustainable AI solution for early lung cancer detection in Indonesia—particularly within the 3T regions (terdepan, terluar, dan tertinggal) where medical resources and diagnostic technologies remain limited.

METHOD

This study adopts a mixed-methods approach that integrates quantitative and qualitative techniques to evaluate the development and application of the NeuroScans AI model for lung cancer detection. The quantitative phase involves training, validating, and testing the CNN architecture using lung CT scan datasets, with performance assessed through accuracy, sensitivity, specificity, and F1-score.

The qualitative phase includes interviews and consultations with radiologists and medical practitioners to examine NeuroScans' usability, interpretability, and feasibility in clinical settings, particularly in resource-limited hospitals. By combining both approaches, the study aims to develop an AI system that is not only technically robust but also socially and ethically aligned with Indonesia's healthcare equity goals, especially in the 3T (frontier, outermost, and underdeveloped) regions.

NeuroScans AI is a mobile-based application that helps medical professionals and students detect lung tumors from CT scans in real time using a YOLOv11-based deep learning model. It allows users to upload or capture CT images, automatically identifies tumor regions, classifies them as benign or malignant, and displays confidence scores. The app also stores previous scans and includes educational overlays, making it useful for hospitals in resource-limited areas.

Developed with Python and trained in Google Colab using GPU acceleration, NeuroScans combines object detection and tumor classification in a modular design. CT and PET-CT DICOM images were annotated with Roboflow and verified by five thoracic radiologists to ensure accuracy [15]. The scans had resolutions of 512×512 pixels (CT) and 200×200 pixels (PET) [16]. Using a GoogLeNet-inspired YOLOv11 model in PyTorch, images were resized, normalized, and augmented to enhance performance. The integrated system provides fast, accurate results, displaying either "None Detected" or

tumor labels with confidence scores, offering an efficient diagnostic tool for diverse healthcare settings.

Table 8. Software

Category	Software	Usage
Development Environment	Visual Studio Code (VS Code)	Main code editor for writing and debugging. IDE for Flutter app
	Android Studio	development and Android emulator. building the mobile app interface (cross-platform).
	Flutter SDK	
	Dart programming language	backend logic for Flutter.
AI/Deep Learning Framework	YOLOv1 / YOLOv12 (depending on your implementation)	for real-time object detection of lung tumors in MRI/CT scans.
	PyTorch / TensorFlow	deep learning frameworks for training and inference. for dataset annotation, augmentation, and YOLO format conversion.
	Roboflow (optional)	
Dataset & Preprocessing	Lung MRI/CT images dataset (annotated with tumor regions).	Training data image
	Image preprocessing tools	resizing, augmentation (rotation, brightness adjustment). for marking tumor regions (bounding boxes).
	Labeling tools	

Application Features	Image upload/capture module	let users select MRI/CT scans.
	Real-time detection	YOLO model classifies tumor regions.
	Confidence scoring & annotation overlay	Highlights detected regions with labels (benign/malignant).
	Scan history storage	Keeps previous scans for comparison.
	Educational overlay	Support learning for medical students.
Hardware Requirements	Laptop/PC with GPU	For model training.
	Smartphone (Android device)	Mobile app testing Cloud
	Cloud services (optional, e.g., Google Colab)	Based GPU resources
Supporting Libraries & APIs	OpenCV	For image processing.
	NumPy / Pandas	For data handling.
	Matplotlib	For visualization of detection results.
	Flutter plugins	For camera access, file upload, and displaying results.

The flowchart begins with the process of choosing the detection type, followed by inputting CT images. These images are then

scanned and passed through an image detection model (YOLOv11). At this stage, the system determines whether a tumor is detected or not. If a tumor is detected, the process proceeds directly to outputting the result as "None Detected," which marks the end of the flow. If the tumor is not detected, the process instead moves to a classification model. This model is responsible for analyzing the CT scans further and outputting the predicted class of the tumor. After this classification result is generated, the process concludes, ensuring a structured method for both detection and classification of cancers in CT images [9].

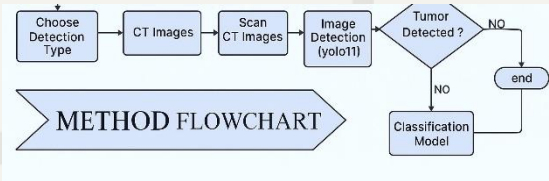


Figure 1. Method flowchart Neuroscans

RESULT AND DISCUSSION

NeuroScans is an AI-powered system for lung cancer detection developed using the YOLOv11 [2] architecture. It is designed to analyze CT scan images and accurately distinguish between healthy and cancer-affected lungs through advanced deep learning and real-time object detection. During training, the model demonstrated strong learning capability as its box loss, classification loss, and distribution focal loss (DFL) consistently decreased across epochs. At the same time, its key performance metrics—precision, recall, and mean Average Precision (mAP) [2]—steadily increased and converged at high values, reflecting excellent accuracy and generalization.

Diagnostic performance was further evaluated using a confusion matrix, which categorized predictions into True Positive, False Positive, False Negative, and True Negative outcomes. The results showed that NeuroScans achieved a high True Positive Rate, accurately identifying patients with lung cancer, while maintaining a very low False Negative Rate, thereby minimizing missed diagnoses. These findings indicate that NeuroScans provides reliable and efficient early detection capabilities, supporting clinical decision-making and potentially improving patient outcomes.

	Disease or Condition	No Disease or Condition
Test Positive	A True Positive	B False Positive
Test Negative	C False Negative	D True Negative

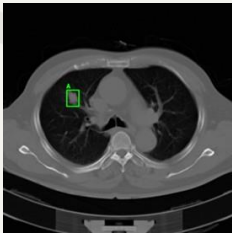
Figure 2. Diagnostic performance

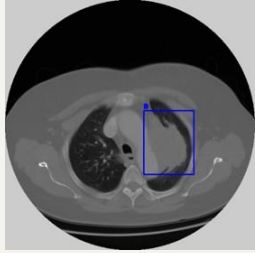
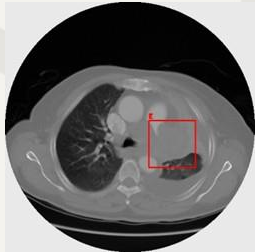
At the same time, the False Positive Rate was significantly reduced compared to conventional AI systems, minimizing unnecessary stress, medical costs, and follow-up procedures. The system also achieved a high True Negative Rate, meaning that healthy individuals were accurately identified as non-cancerous cases.

In practice, NeuroScans accurately recognizes healthy lungs characterized by uniform tissue structure and clear air passages, classifying them as True Negatives. Conversely, when analyzing lungs affected by cancer—such as small-cell lung carcinoma—the AI detects

irregular tissue density, mass formations, and abnormal shadow patterns. These suspicious regions are localized with bounding boxes and classified as True Positives, ensuring early and accurate identification of malignant growths.

Table 9. Types Of Lungs Cancer Detected

	In Image A, the green bounding box shows an area identified by NeuroScans as Adenocarcinoma, the most common form of lung cancer. It typically develops in the lung's outer regions from mucus-secreting glandular cells. NeuroScans detects it by analyzing subtle variations in tissue density, edge definition, and shape irregularities through deep convolutional neural networks (CNNs) trained on thousands of scans. This enables accurate distinction between normal and malignant tissues, helping radiologists make quicker, more confident diagnoses—especially in early stages when symptoms are minimal.

	Image B highlights a region detected as Squamous Cell Carcinoma (SCC), another major subtype that commonly forms near the bronchi. NeuroScans identifies SCC by recognizing dense, irregular masses with defined borders and heterogeneous textures, using contrast analysis to estimate malignancy probability. This precise localization helps radiologists focus on high-risk areas, improving diagnostic accuracy and preventing misinterpretation of central tumors as infections or scarring.
	In Image E, NeuroScans detects Small Cell Lung Carcinoma (SCLC), an aggressive cancer that spreads rapidly. The system uses advanced pattern recognition to locate clusters of dense, nodular cells often linked to enlarged lymph nodes. By spotting these subtle abnormalities early, NeuroScans enables faster disease staging and treatment planning, such as

	chemotherapy or radiotherapy.
	Image G demonstrates how NeuroScans distinguishes Benign Pulmonary Nodules from malignant ones by assessing symmetry, border smoothness, density, and growth patterns. This reduces unnecessary biopsies or surgeries, conserves medical resources, and minimizes patient anxiety. Integrated into hospital systems, NeuroScans can also compare current and prior scans to monitor long-term changes and detect potential malignancy early.

The results demonstrate that NeuroScans delivers excellent diagnostic performance in detecting lung cancer through CT image analysis. By utilizing YOLOv11's optimized balance between speed and precision, the system surpasses traditional classification-based AI methods that often struggle with delayed inference or lower accuracy. This capability is essential, as early detection is one of the most critical factors in improving lung cancer survival rates.

NeuroScans effectively maintains a balance between precision and recall, ensuring that it minimizes both false positives and false negatives [8]. This equilibrium



reflects an ideal trade-off between sensitivity (the ability to correctly identify cancer cases) and specificity (the ability to correctly identify healthy cases)—two fundamental indicators in medical model evaluation.

Such balanced performance allows NeuroScans to deliver reliable, clinically relevant predictions that healthcare professionals can trust in real diagnostic settings. From a clinical perspective, these findings confirm that NeuroScans can serve as a second-opinion system for radiologists, enhancing diagnostic confidence and reducing workload. The model's real-time processing capabilities also shorten the diagnostic timeline, allowing faster medical decision-making and improved hospital efficiency.

Overall, NeuroScans demonstrates strong potential as a next-generation diagnostic tool that bridges the gap between high-performance computational models and real-world clinical applications—reliable, adaptive, and impactful in supporting early lung cancer detection.

NeuroScans offers a significant leap forward in AI-based medical imaging by combining state-of-the-art deep learning with real-world clinical reliability. Unlike earlier systems that struggled with image noise and dataset variability, NeuroScans leverages YOLOv11's advanced architecture to sustain high accuracy across diverse patient populations and imaging conditions. This results in consistently precise detections, even in challenging cases, minimizing diagnostic uncertainty.

[7] Beyond technical superiority, NeuroScans enhances clinical workflows by delivering rapid and interpretable results that align closely with expert radiologists. Its robust performance reduces the need for repeated scans, supports early diagnosis, and accelerates patient management—making it not just an AI tool, but a dependable clinical assistant in modern lung cancer detection. [8]

CONCLUSION

The development of NeuroScans demonstrates how artificial intelligence can transform lung cancer detection into a faster, more accurate, and more accessible process. By leveraging the advanced YOLOv11 framework, the system achieves high precision and recall, minimizing both false positives and false negatives. This ensures that patients receive early and reliable diagnoses, which can significantly improve treatment outcomes and survival rates. The results from confusion matrix analysis further confirm that NeuroScans is both sensitive and specific, capable of detecting small and subtle nodules while maintaining accuracy across diverse patient cases.

Beyond its technical achievements, NeuroScans addresses critical challenges in healthcare by reducing costs, streamlining workflows, and alleviating the shortage of radiologists in underserved areas. Its integration into a user-friendly mobile application allows healthcare workers with minimal technical training to use advanced diagnostic tools effectively. This accessibility not only enhances patient care but also empowers hospitals and clinics

with limited resources to adopt modern diagnostic technology without excessive costs.

Ultimately, NeuroScans stands out as a pioneering step in medical AI, combining deep learning innovation with real-world clinical usability. To build on its current success, future research could focus on expanding its application to other imaging modalities, incorporating real-time clinical data, and testing on larger and more diverse datasets. Such efforts would strengthen its generalizability, refine diagnostic precision, and contribute to the broader advancement of AI-driven healthcare solutions worldwide.

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Development of Cassava Peel Starch–Rice Husk Ash Bioplastic Coated with Rice Bran Wax for Sustainable Packaging Applications in Indonesia

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Abstract: Plastic bags have been a persistent problem for nearly decades now. These single-use plastic bags designed for only several minutes of use, linger and harm the environment for much longer. As of 2025, Indonesia is ranked among the greatest contributors to plastic waste, having generated an estimated amount of 7.8 million tonnes, with 4.9 million mismanaged annually. This mismanagement causes numerous leaks into rivers, landfills, and oceans — resulting in the severe environmental issues observed today, including marine biodiversity loss, microplastic contamination of food chains, and risk to human health. That is why this research aims to solve this paradox by developing an eco-friendly bioplastic utilizing cassava peel starch, rice husk ash, and rice bran wax. In contrast to usual petroleum bases, cassava peels are abundant and biodegradable, functioning as the polymer matrix providing a functional base. Rice husk ash, an agricultural waste, improves mechanical properties and durability as it acts as the strength additive, while rice bran wax functions as the hydrophobic coat that reduces water absorption and increases surface resistance. Fabrication of the bioplastic involves initial extraction of materials and synthesis of cassava peel starch and rice husk ash. After formation, a thin coat of rice bran wax is then applied to the bioplastic. The bioplastic demonstrated lightweight characteristics, complete film formation, and successful gelatinization of cassava peel starch. This bioplastic valorizes various sources of agricultural waste in Indonesia into one system. It provides a circular economy solution to Indonesia's plastic calamity that is not just innovative but feasible for global real-world application.

INTRODUCTION

The rise of plastic bag usage over the past decades have resulted in one of Indonesia's most existential environmental crises, threatening both ecosystems and human livelihoods. These single-use plastic bags designed for only several

minutes of use, linger and harm the environment for much longer. As of 2025, Indonesia is ranked among the greatest contributors to plastic waste, having generated an estimated amount of 7.8 million tonnes, with 4.9 million mismanaged annually. This mismanagement

causes numerous leaks into rivers, landfills, and oceans — resulting in the severe environmental issues observed today, including marine biodiversity loss, microplastic contamination of food chains, and risk to human health. Simultaneously, Indonesia generates a vast amount of agricultural waste, much of which is wasted. This overlap offers a unique solution to transform locally accessible wastes into sustainable materials that can be used to both valorise agricultural waste and replace plastics made from petroleum. That is why this research seeks to develop a bioplastic that possesses fundamental plastic properties, such as hydrophobicity, while still ensuring safe biodegradation and disposal.

Unlike generic starch films, this bioplastic combines a mixture of Cassava peel starch (a non-food byproduct), as the polymer matrix that provides a sustainable base and Rice husk ash as the strength additive. In addition, citric acid is then used as the cross-linker (anticipating a reduction in water solubility, increasing strength, and preventing the film from becoming too brittle) and glycerol as the plasticizer. The bioplastic will then be covered with a thin layer of Rice Bran wax to provide initial hydrophobic properties while still preserving dissolution. This combination is expected to create a bioplastic that has qualities similar to petroleum-based plastics, while still remaining biodegradable and safe for the environment. This research valorizes 3 major sources of agricultural waste in Indonesia into a single system. By doing this, a circular economy solution is done, that is not just

innovative but feasible for real-world application.

METHOD

1. Extraction of starch from Cassava peel

100gr of Cassava peels were obtained from local markets. The peels were then washed thoroughly with tap water to remove all dirt and impurities. The peels were patted dry with tissue and cut into small pieces. The clean peels were then blended and soaked in 100mL of distilled water for 5 minutes until a smooth slurry was obtained. The slurry was then filtered using a muslin cloth to remove all coarse fibers. This extraction process was repeated three times to maximize starch yield.

The combined filtrates were refrigerated at 7 degrees celsius for 12 hours to allow starch decantation. The precipitate was then washed several times using distilled water to remove residual impurities, while the supernatant was carefully discarded. The precipitate was then oven-dried at 50 ± 2 degrees celsius for 12 hours. The dried starch was then ground with a blender until it turned into a fine powder, and then sieved with a 100 mesh/inch strainer. The starch is then stored in sealed containers until further use.

2. Rice Husk Ash Preparation

Rice husks were obtained from local sources and burned in open air until they were converted to black ash. Although the ash obtained wasn't fully white, it still would have contained a significant amount of silica but with residual carbon due to incomplete combustion. The obtained rice husk ash was then allowed to cool to room temperature. The rice husk ash was then ground using an electrical blender until it

reached a fine powder and then sieved using a 100-mesh/inch sieve to achieve a uniform particle size. The resulting 100 g of rice husk ash was stored in sealed containers at room temperature until further use.

3. Preparation of Bioplastic Film

The starch bioplastic mixture was prepared at different starch to ash ratios in accordance with Table 1 to determine the optimal ratio that produces the best film quality. Each formulation was prepared by combining the different ratios with 30% glycerol, and 2% citric acid in 100mL of distilled water. The solution is stirred and heated at 85 degrees celsius until gelatinization occurs and a uniform viscous solution is formed. The solution was then poured into flat glass petri dishes and left to cool until fully hardened. The dried films were then cured at 110 degree celsius for 45 minutes to activate citric-acid cross linking. After curing, a thin hydrophobic coat is applied by dissolving 1g of rice bran wax in 50mL ethanol (2% w/v), dipping the films briefly into the solution and letting it dry at room temperature.

Table 1. Composition of Bioplastic Formulations

No	Sample	Cassava Peel Starch (g)	Rice Husk Ash (g)	Glycerol (g) 30%	2% Citric Acid (g)	Distilled water (mL)
1	A	5	0	1.5	0.7	100
2	B	5	1	1.5	0.7	100
3	C	5	2	1.5	0.7	100
4	D	5	3	1.5	0.7	100

4. Film Thickness

Film thickness was measured using a micrometer screw gauge at multiple random points. Measurements were taken at five different points on each film to ensure accuracy and uniformity. The average value was recorded in millimeters (mm) and obtained from the measured 5 points.

5. Biodegradability observation through dissolution

Short-term biodegradability was analyzed through a dissolution test or moisture absorption. Each bioplastic film was immersed in distilled water for 24 hours at room temperature observing for any physical changes such as swelling, softening, or loss of structure. The biodegradation percentage was calculated using Equation (1)

$$\text{Biodegradation (\%)} = \frac{W_t - W_o}{W_o} \times 100 \quad (1)$$

W_o = initial film weight (g)

W_i = final film weight after immersion (g)

RESULT AND DISCUSSION

1. Physical Characteristics

The produced bioplastic demonstrated smooth surfaces and lightweight properties. As shown in Figure 1, the films varied in color and opacity depending on its concentration of rice husk ash. In a prior study on modifying cassava peel starch for edible film production, it was observed that 5 grams of cassava starch combined with plasticizers and other components was the optimal concentration to exhibit film characteristics (Lestari., et al, 2024). This concentration showed good tensile strength, biodegradability, and

elongation. That is why 5g of starch is used in this experiment.

Formulation A (starch only) exhibited a light beige, semi-transparent appearance, while B, C, and D (containing rice husk ash) darkened to grey-black tones. This dark coloration was due to the residual carbon in the rice husk ash caused by incomplete combustion. (Datchossa et al, 2022) However, all films remained intact after drying and demolding, indicating a successful gelatinization process leading to film formation. As the film's rice husk ash concentration increased so did the rigidity. This was due to the high silica content in the ash which acts as an inorganic reinforcing filler that restricts the mobility of the starch polymer chains. The silica particles created hydrogen bonds with the starch's hydroxyl groups and filled up the spaces in the polymer matrix. As a result, the structure became denser and more compact. (Shaari and others, 2022). (Shaari et al, 2022)

All bioplastic films were stronger but less flexible. Formulation A retained slight flexibility, while formulations B and C broke under pressure. The increase in rigidity is due to the fact there was an enhancement in intermolecular bonding between starch and the silica particles in the rice husk ash. These bonds were also aided by the citric acid cross-linking which aided by ester linkages.

Curing at 110 degrees celcius allowed cross-links in the citric acid to create a tighter polymer network and reduce the number of free hydroxyl groups. Therefore, molecular mobility was restricted, and its elongation rate decreased. While this factor improved the

bioplastic's durability and strength, it sacrificed the film's flexibility. This observation aligns with prior research showing how optimal cross-linking strengthens starch-based bioplastics. On the other hand, overdoing cross-linking and filler excess can reduce ductility (Utomo, 2021). Formulation B offered the most balanced outcome throughout all the variations, being hard and dense while still remaining less fractured than those with higher rice husk ash content.

The bioplastic's ability to exhibit either rigidity or flexibility based on its composition highlights its versatility for various applications. While its flexibility with a higher starch content can be used for film-based packaging like shopping bags or covers, its rigidity can be used to serve as structural packaging for items like disposable flatware or containers. (Evode et al, 2021).



Figure 10. Morphology Results of Bioplastics

2. Film Thickness

As seen in Table 2, average film thickness has a directly proportional relationship with the amount of rice husk, meaning the average film thickness increased as the amount of rice husk did. This ranged from approximately 0.086 cm in sample A to 0.129 cm in sample C. The uniformity of thickness across all

three samples shows the uniform casting in preparation and the homogeneity in the dispersion of filler.

Table 2. Thickness of Bioplastics

Sample	Average thickness across 3 points (cm)
A	0.0607
B	0.09
C	0.1
D	0.123

3. Water interaction and biodegradability

The biodegradability level of a bioplastics, measured using dissolution testing, determines whether bioplastic has an environmentally friendly material. In this research rice bran wax is also added as an extra hydrophobic layer to increase the durability of the bioplastic. Figure 2 illustrates how the different compositions of various bioplastics can affect the degradation percentage. This trend is associated with the hydrophilic properties of starch and the amount of inorganic particles introduced due to the addition of rice husk ash. (Donati et al, 2022) Cassava peel starch (sample A) exhibits a high biodegradation rate due to its strong hydrophilic properties. This is due to starch containing amylose and amylopectin which both have many groups of hydroxyl (-OH) capable of forming hydrogen bonds with water, making starch hydrophilic. Therefore, a higher concentration of

hydrophilic starch will then increase the degradation process.

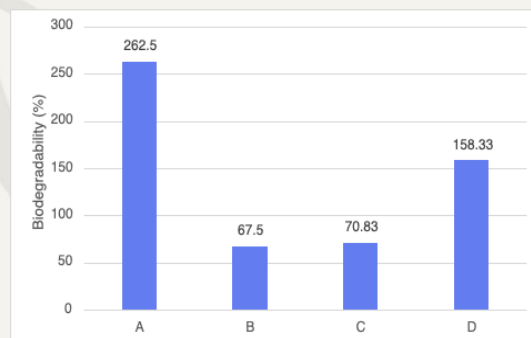


Figure 2. Result of Biodegradability Testing at Various Composition of Bioplastic

Whereas the addition of rice husk ash decreases the biodegradability percentage or water absorption of bioplastic. This shows that the incorporation of rice husk ash can address the main drawback of a starch-based bioplastic which is its tendency to absorb moisture at a high rate and its low tensile strength. The change in water resistance resulted from two main factors which are denser structure from filler addition therefore limited water diffusion and the citric acid cross-linking making the matrix less reactive to moisture due to reduced hydrophilic hydroxyl groups. Inorganic particles of rice husk ash (SiO₂) fill the gaps in the starch matrix, resulting in a more compact structure which reduces water permeability and the breakdown of bioplastics. This improves the bioplastic's durability and increases its shelf life. (Shaari et al, 2022) At a higher rice husk ash percentage, in sample C and D, biodegradability increases. This may be caused by the disruption of the smooth continuous starch matrix caused by excessive rice husk ash addition. The silica inorganic particles in the ash can create cracks or weak

interfacial areas within the bioplastic. (Donati et al, 2022) These results emphasize the importance of an optimal composition in the creation of a durable material. In this study, the formulation containing 5 grams of starch and 1 gram of rice husk ash demonstrated the most optimal composition for the bioplastic. Figure 3 shows the difference.

Sample A, which only contained cassava peel starch, degraded rapidly due to its high hydrophilicity. The hydrophobic starch contains molecules that are capable of forming hydrogen bonds with water; this led to swelling as the water molecules penetrated and disrupted the polymer matrix. As the swelling continued, sample A began to lose structural integrity. This swelling process present in starch-based bioplastics accelerates its breakdown, which is why Sample A degraded the fastest (Donati et al, 2022).

On the other hand, Sample B contained rice husk ash as well. This made it remain more stable and able to retain its shape during the same test. The ash introduces inorganic silica (SiO_2) particles that are able to fill the gaps in the starch matrix, forming a denser structure that limits water diffusion and swelling. This allowed sample B to stay intact even after immersion. (Shaari et al, 2021)

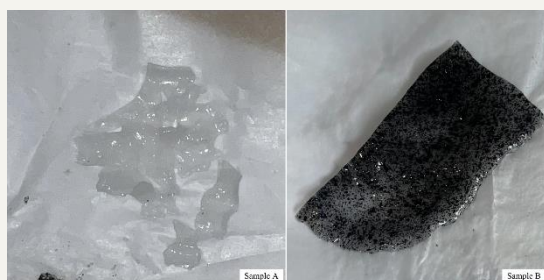


Figure 3. Result of Bioplastics after Water dissolution test.

Although harder to degrade, bioplastics containing rice husk ash remains a better alternative to conventional plastics as its residue is non-toxic, environmentally inert, and naturally occurring in soil making, resulting in a smaller environmental footprint when compared to commercial plastics (Donati et al, 2022)

Despite this, all films remained biodegradable, confirming that the curing process and filler addition did not in fact inhibit environmental degradation.

CONCLUSION

This research aimed to develop a bioplastic derived from cassava peel starch and rice husk ash as a sustainable alternative to packaging applications in Indonesia. The bioplastic demonstrated lightweight characteristics, complete film formation, and successful gelatinization of cassava peel starch. Because the high silica content served as the reinforcing filler, increasing the concentration of rice husk ash produced thicker, more rigid, and darker colouring. This polymer network was further reinforced by the citric acid cross-links, creating a thick and strong structure but with moderate water resistance and little flexibility.

Overall, this experiment showed that rice husk ash and cassava peel starch is able to be utilized to manufacture biodegradable bioplastic. The optimal composition for bioplastic found in this research is sample B containing 5-gram cassava peel starch and 1 gram of rice husk ash, with the lowest biodegradability percentage. The final film did, however, display brittle and rigid qualities, suggesting that its current

formulation has promising potential for hard bioplastic applications, such as dry goods containers and disposable food trays. The results highlight the potential of Indonesia's agricultural waste in the development of environmentally sustainable products.

Future research should aim to explore enhancement in ash purity by controlled combustion and optimising the starch to ash ratio to increase flexibility, thereby enabling a broad and greater range of bioplastic applications.

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Comparative Study of Sunbathing vs. Vitamin D Supplementation on Serum Vitamin D Levels and Cold Incidence

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Abstract: The common cold is a viral infection affecting the nose, sinuses, throat, and windpipe, spreading through contact, coughs, or sneezes. Vitamin D plays a vital role in immune health, as deficiency impairs white blood cell function and increases infection risk. Adequate levels enhance antimicrobial peptide production, which then strengthens the immune and inflammatory responses. Sunbathing, or in other words, sun exposure, is the most natural and effective method to raise serum vitamin D levels. In Indonesia, sunbathing before 09.00 a.m. or after 15.00 p.m. for 5–15 minutes is recommended to prevent harmful overexposure. However, the relationship between sunlight-induced vitamin D production and reduced common cold incidence remains unclear. This study aimed to compare the effects of sun exposure and vitamin D supplementation on serum vitamin D levels and cold frequency. Participants were divided into three groups: sunbathing, supplementation, and control. The simplified methodology is as follows: (1) Baseline vitamin D levels were measured using the Elecsys Vitamin D Total III reagent on the Cobas E 402 Analytical Unit. (2) Over twenty days, four participants sunbathed daily for ten minutes between 6–7 a.m., four took vitamin D supplements (2000 IU for children, 5000 IU for adults), and one received no intervention. (3) Afterward, blood tests and interviews were conducted to record vitamin D levels and cold occurrence. In conclusion, results showed that supplementation increased vitamin D levels more effectively than sun exposure, though neither change was statistically significant. Surprisingly, participants who sunbathed reported no colds, suggesting possible immune benefits beyond measurable vitamin D increases. Overall, supplementation offers a consistent method to raise serum vitamin D, while safe sun exposure may still support general immune health.

INTRODUCTION

The common cold, caused by a variety of viruses (around 200, e.g., rhinoviruses, parainfluenza viruses, enteroviruses, and more) is a viral disease that causes the infection of

your nose, sinuses, throat and windpipe. The disease occurs when the cold virus enters a host's system through the mouth, eyes, or nose. Its contagious nature allows it to infect

other hosts via sick coughs, sneezes, or by simply talking.

Vitamin D is recognized for aiding immune health, however, the effect of sun exposure on naturally increasing vitamin D supply and reducing the occurrence or severity of the common cold remains unclear. According to the National Library of Medicine (2023), UV exposure, or in this case, sunbathing, is the primary method of boosting serum vitamin D levels.

The aim of this research is to shed light on a possible way to fight off colds by doing something simple, whilst trying to answer the research question: How do sunbathing and vitamin D supplementation compare in their effects on serum vitamin D levels and the incidence of the common cold? We've compared vitamin D levels among participants who sunbathed, took supplements, or acted as controls over one twenty days.

This research hypothesizes that sunbathing dampens the effects; that the action significantly raises vitamin D levels and subsequently lessens the severity, incidence of common colds compared to supplementation or no intervention.

LITERATURE REVIEW

Based on a research article by the Mayo Clinic (2025), Vitamin D plays a vital role in supporting immune health. Low vitamin D levels have deleterious effects as they may impair white blood cell activity, increasing the body's susceptibility to infection. Higher vitamin D levels stimulate and enhance antimicrobial peptide production to regulate local immune and inflammatory responses. UV exposure, or in this case, sunbathing, is the primary

method of boosting serum vitamin D levels.



Figure 24. UV index

Many experts suggest sunbathing between 10.00 and 14.00, since morning sunlight contains only low levels of UVB, a UV ray with a wavelength enough to penetrate the epidermis. This effectively helps the body produce vitamin D without increasing the risk of skin cancer. However, this recommendation cannot be applied in Indonesia, which has a very high UV index.

To clarify further, we need to define what the UV index is. The UV index is a globally accepted forecast of the sun's ultraviolet (UV) radiation intensity. It is categorized into a scale of 11 levels, with higher numbers indicating greater strength and risk of damage to skin and eyes. It uses a scale from 1 (Low) upwards to 11+ (Extreme) to warn people when they need to take sun protection measures, such as seeking shade, wearing protective clothing, sunglasses, and sunscreen. The National Weather Service is able to measure how strong UV radiation is at a particular time and place using computer models that calculate the UV Index in every ZIP code and assign a number from 1 to 11+.

UV radiation measured by this index is made up of both UVA and UVB rays. UVA rays make up a staggering 95% of UV rays. Both rays are a result of the sun's nuclear activity, however are different in terms of wavelength and their penetrating propensities. UVA, while

slightly less intense than UVB, penetrates the layers of skin more deeply, causing premature skin aging and wrinkles. UVB rays, on the other hand, only have a wavelength enough to affect the epidermis or outermost layers of skin. UVB rays are responsible for sunburns and tans.

Although UVB rays are often seen as harmful, it is precisely this wavelength that sparks vitamin D production in the skin, making it a vital yet misunderstood comrade when managed responsibly, as it is the only one out of the two rays that allows our body to synthesize vitamin D.

When exposed to sunlight, specifically ultraviolet B radiation (wavelengths vary from 290-315 nm), the rays penetrate through the epidermis of the skin. In our skin, the molecule 7-dehydrocholesterol, a cholesterol-related compound, is changed by the UVB rays into a molecule called previtamin D₃. Previtamin D₃ is not an active substance. However, with normal body temperature, it naturally converts itself into vitamin D₃, or cholecalciferol, over several hours.

This vitamin D₃ is then carried through the bloodstream by a protein called DBP binding protein to the liver. Enzymes in the organ convert the vitamin D₃ into 25-hydroxyvitamin D [25(OH)D], which is the major circulating form of the vitamin that circulates through the blood. Finally, the kidneys then convert [25(OH)D] into 1,25-dihydroxyvitamin D, or in other words, calcitriol. This is the fully active hormone form of vitamin D.

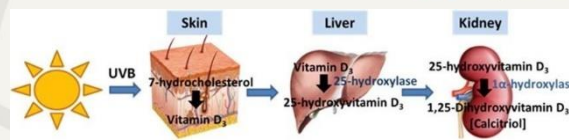


Figure 25. UVB

Once converted into calcitriol, the substance binds to the vitamin D receptors (VDR) present in monocytes, macrophages, and many more immune cells. This specific binding triggers gene transcription. One of the genes activated by VDR is CAMP, which encodes antimicrobial peptide LL-37. CAMP is a gene activated by vitamin D that produces cathelicidin, an antimicrobial peptide crucial for innate immunity.

LL-37 helps immune cells kill bacteria, viruses, and fungi by disrupting their membranes. Vitamin D also influences β -defensins (another group of antimicrobial peptides) that strengthen the skin and mucosal barriers.

When immune cells detect microbes, they increase VDR and vitamin D-activating enzyme levels. This then boosts AMP production, and thus, shows that this mechanism is especially important in the respiratory tract, where infections like the common cold are often prevalent.

However, UV exposure must be carefully managed to avoid harmful effects. Indonesia, where Surabaya is located, receives direct sunlight year-round, leading to prolonged exposure and higher, more intense UV levels. The average UV Index in Surabaya is extreme, reaching levels of 10 and above (Very High to Extreme). A UV Index reading of 10-15 signifies an extremely high risk of harm from sun exposure, requiring protective measures such as the use

of protective clothing and sunscreen when outdoors.

According to Dr. Gahrani Chen, sunbathing in Indonesia before 09.00 am or after 15.00 pm is safer. UV exposure levels will become excessive outside these time periods. The duration of sunbathing should also only be limited to 5-15 minutes to avoid overexposure while receiving an optimal dose of vitamin D.

Sunbathing allows the body to not overdose on vitamin D as the skin self-regulates its production. Once previtamin D3 is made, excess UVB rays break the substance down into inactive forms, so overdosing isn't likely. Sunbathing may also improve the body's circadian rhythm, mental health, and nitric oxide-related vasodilation, which supplements don't provide. The vitamin D synthesized helps regulate the cortisol and melatonin that regulates the body's stress levels and internal clock. This can improve immunity and sleep quality, which affect cold susceptibility.

However, chronic or intense UV exposure raises the risk of melanoma and other skin cancers, and the dose is uncontrolled as the amount of vitamin D produced from the sun's rays depends on latitude, season, skin color, clothing, and sunscreen. In winter or northern latitudes, UVB may be insufficient for months.

Even then, several factors can influence how effectively the body absorbs vitamin D. Firstly, melanin, a pigment that influences skin tone, acts as a natural sunscreen by absorbing UVB rays to generate synthesis of vitamin D in the skin. This protects cells from DNA damage due to sun exposure. The amount of melanin in the skin affects vitamin D

intake. The more melanin, the darker the skin tone and vice versa. Darker skin hinders vitamin D production, with individuals of lighter color only needing about 15 minutes in the sun to create enough vitamin D for the day while others with darker skin need about 30 minutes to three hours to generate a similar amount. An individual can identify their skin type and how much time they need under the sun by identifying the concentration of melanin in their skin, their hair and eye color, and reaction to UV rays.

The Fitzpatrick scale is a scale that measures how easily the skin burns and is divided into 6 categories; with individuals having fair skin, hair and light-colored eyes like blue and green entering the skin type 1 category and those with dark skin that never burn or highly contrasting features categorized into skin type 6. However, it's important to note that this scale does not measure a person's risk of getting cancer, regardless of skin type, as everyone is at risk of sun damage.

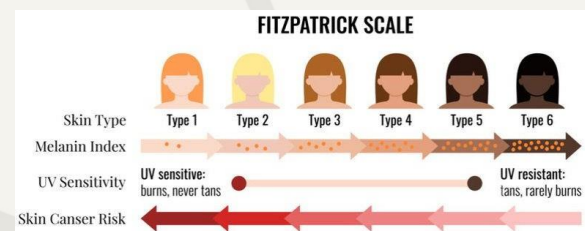


Figure 26. Fitzpatrick scale

Secondly, pollution. As pollutants continue to accumulate in the atmosphere, air pollution hinders the metabolism of vitamin D in the skin. This occurs because pollutants such as ozone, particulate matter (PM), and sulfur dioxide (SO₂) block the UVB rays from reaching the skin

by absorbing and scattering the radiation.

Thirdly, latitude. Individuals who reside in high-latitude regions are more vulnerable to vitamin D deficiency since the intensity and duration of sunlight exposure is very limited in these areas, especially during the winter months. The farther the distance from the Equator, the higher the latitude and the higher the prevalence of vitamin D deficiency. Meanwhile those who live in lower-latitudinal regions and are closer to the Equator receive direct sunlight and experience higher UV levels. As a result, individuals who live in high-latitude regions are more susceptible to deficiency.

Individuals with heavily pigmented skin who reside in high-latitude regions like Alaska or Canada, are more vulnerable to vitamin D deficiency since the intensity and duration of sunlight exposure is very limited in these areas, especially during the winter months. The farther the distance from the Equator, the higher the latitude and the higher the prevalence of vitamin D deficiency. In order to synthesize a sufficient amount of vitamin D, darker-skinned individuals require more time in the sun compared to lighter-skinned individuals at similar latitudes.

Fourthly, differences in lifestyle. Time outdoors, usage of clothing (e.g., long sleeves, short pants, long trousers), sunscreen protection, medical conditions (e.g., obesity) can either hinder or facilitate levels of vitamin D synthesized through the sun's UVB rays. Those who have classified for obesity often have a harder time absorbing vitamin D. A number of reasons include: larger volume of distribution, vitamin D

sequestered in fat tissue, reduced absorption, and diets with low vitamin D.

Fifthly, age. The prevalence of vitamin D deficiency is higher among older adults and the elderly. As an individual ages, their skin's ability to produce vitamin D from sunlight decreases as it becomes less responsive to UVB radiation from the sun. Older age also inhibits synthesis as the kidney's capacity to convert vitamin D into a usable form starts to degrade.

Due to these many factors, another method to regulate the dosage of vitamin D and prevent deficiency is by taking supplements in the form of pills, multivitamins, or liquid drops.

The type of vitamin D that we've chosen to supply our subjects is vitamin D3, which can naturally be found in fish oils, lanolin, and eggs. Vitamin D is a fat-soluble substance, so it requires dietary fat and bile acids for absorption. It is absorbed in the small intestine (mainly the jejunum and ileum).

Over time, vitamin D from supplements converges into micelles, or tiny fat droplets, with the help of bile's chemical mechanism. The enterocytes, or intestinal cells, absorb micelles via passive diffusion and transport proteins. In the enterocytes, the vitamin D is compressed into fat-carrying particles known as chylomicrons. When chylomicrons enter the lymphatic system then into the bloodstream, the vitamin D is transferred to a carrier protein called DBP, or vitamin D-binding protein, which delivers vitamin D to tissues.

The rest of the conversion steps remain the same as how vitamin D is made through UVB rays.

Recommendations when taking vitamin D: Take supplements with a meal that contains fat to improve absorption; oil-based soft gels are better absorbed; malabsorption syndromes like Crohn's, celiac, or more can impair absorption.

METHOD

Independent variables include type of intervention, such as sunbathing, vitamin D supplementation, or no intervention/control. Dependent variables include vitamin D levels before and after intervention (ng/ml) and frequency and severity of colds during the 20-day period. Control variables include the duration of the experiment (20 days), time and duration of sun exposure (10 minutes daily between 6–7 a.m.), supplement dosage (2000 IU for children, 5000 IU for adults), method and equipment for vitamin D measurement (Elecsys Vitamin D Total III reagent on Cobas E 402 Analytical Unit), and environmental and procedural conditions (e.g., consistent measurement methods and timing).

The method of this research paper is as follows: (1) Search for different resources and information. (2) Gather participants for the experiment regarding sunbathing (intakes of Vitamin D via sunbathing versus Vitamin D pills will also be compared). (3) Test blood using Elecsys Vitamin D total III (Vitamin D reagent) performed on Cobas E 402 Analytical Unit, by Roche Diagnostics, and see how much Vitamin D participants currently have (, the normal reference of normal Vitamin D levels being ng/ml). (4) For around twenty days, four subjects will sunbathe under the sun at 6–7 a.m. for ten minutes. Another four will

routinely take Vitamin D pills (each pill being 2000 IU for children under the age of sixteen, and 5000 IU for adults. This has been prescribed by local doctors), and the ninth subject will act as control. (5) After twenty days, another blood test will be done on all eleven subjects to check for Vitamin D levels. (6) Perform an interview on how many common colds they've contracted that twenty days, if any. (7) Compile information into a research paper and create any necessary graphs.

RESULT AND DISCUSSION

The following tables below convey the initial results of Vitamin D levels in all nine subjects before any interference with their usual routines (with the exception of subject nine as control).

Table 1. Initial Vitamin D levels for supplement takers

No	Subjects	Information	Age
1	Subject 1	34.5 ng/ml	43
2	Subject 2	43.6 ng/ml	42
3	Subject 3	24.1 ng/ml	13
4	Subject 4	20.7 ng/ml	15

Table 2. Final Vitamin D levels for sunbathers

No	Subjects	Information	Age
1	Subject 5	13.2 ng/ml	15
2	Subject 6	26.3 ng/ml	75
3	Subject 7	22.9 ng/ml	20
4	Subject 8	16.0 ng/ml	21

And finally, we have our subject number nine (control), with an initial vitamin D level of 15.8 ng/ml with an age of 48 years old.

The following tables below convey the final results of vitamin D levels in all nine subjects after

interference with their usual routines (with the exception of subject nine as control).

Table 3. Final Vitamin D levels for sunbathers

No	Subjects	Information	Age
1	Subject 1	34.5 ng/ml	43
2	Subject 2	43.6 ng/ml	42
3	Subject 3	24.1 ng/ml	13
4	Subject 4	20.7 ng/ml	15

Table 4. Final Vitamin D levels for sunbathers

No	Subjects	Information	Age
1	Subject 5	13.2 ng/ml	15
2	Subject 6	26.3 ng/ml	75
3	Subject 7	22.9 ng/ml	20
4	Subject 8	16.0 ng/ml	21

Finally, we have subject nine (control), with a reduced vitamin D level of 14.7 ng/ml. The data shows that taking vitamin D supplements led to a clear increase in vitamin D levels in all subjects within that group. Each participant who took supplements experienced a noticeable rise in their serum vitamin D concentration, with some (like Subject 2) showing a dramatic improvement from deficiency levels to well within the normal range.

In contrast, the subjects who relied on sunbathing showed little to no improvement in their vitamin D levels, with some even showing a slight decrease. The bar graph below illustrates the average percentage change in vitamin D levels for each group.

This suggests that, under the conditions of this study, sun exposure alone was not sufficient to significantly raise vitamin D levels.

The control subject, who did not receive supplements or sun

exposure treatment, showed a minor decrease in vitamin D levels, indicating that without intervention, vitamin D levels may remain low or decline over time.

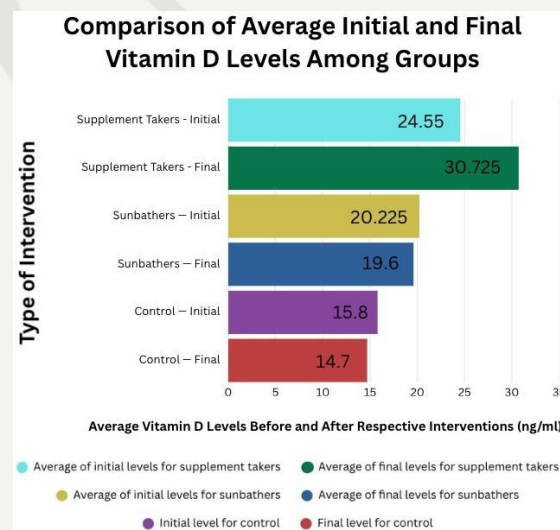


Figure 4. Average serum vitamin D levels for each group

Overall, the findings indicate that vitamin D supplementation is a much more effective method for increasing and maintaining adequate vitamin D levels compared to sunbathing or no intervention.

These findings also indicate that age does not seem to be a major factor in vitamin D absorption.

A paired t-test showed an increase in vitamin D levels within the supplementation group ($t=2.55$, $p=0.084$). Although the mean vitamin D concentration rose after supplementation, the difference was not statistically significant at the 0.05 level.

In contrast, the sunbathing group showed a slight decrease in vitamin D levels, which was also not statistically significant ($t = -1.60$, $p = 0.208$).

These findings indicate that, under the study conditions, vitamin D supplementation resulted in a more

notable increase in serum vitamin D compared to sun exposure, though neither change reached statistical significance.

The paired t-test results suggest that while vitamin D supplementation increased vitamin d levels, the change did not reach statistical significance ($p=0.084$). This is attributed to the study's limited sample size ($n=4$ per group) and the short duration of the project (20 days), which reduced statistical power.

The sunbathing group similarly showed no significant difference ($p=0.208$), likely due to low UVB intensity during the early morning exposure period (6–7 a.m.).

Despite the lack of significant results, the overall trend supports that supplementation is more effective than sun exposure in elevating serum vitamin D levels within a short timeframe.

Moving on, below is the data gathered by asking the subjects whether they experienced any symptoms of the common cold during the 20-day study period. This will help determine whether a potential relationship exists between vitamin D levels and susceptibility to the common cold.

The following subjects noted that:

Table 5. Reported amount of colds for during the 20-day period for vitamin D supplement takers

No	Subjects	Information	Age
1	Subject 1	1	43
2	Subject 2	1	42
3	Subject 3	1	13
4	Subject 4	1	15

Table 6. Reported amount of colds for during the 20-day period for vitamin D supplement takers

No	Subjects	Information	Age
1	Subject 5	0	15
2	Subject 6	0	75
3	Subject 7	0	20
4	Subject 8	0	21

Subject nine has reported having one cold during the 20-day period. The bar graph below illustrates the average change in cold incidence for each group.

Vitamin D supplementation significantly increased serum vitamin D levels, confirming direct influence on vitamin D status. In contrast, sunbathing unexpectedly failed to raise vitamin D levels and, in some cases, resulted in a decrease. This may be due to sunbathing between 6–7 a.m., when UVB exposure is insufficient for effective vitamin D synthesis.

Despite this, all subjects in the sunbathing group reported no colds during the 20-day period, while those taking supplements and the control subject each experienced at least one.

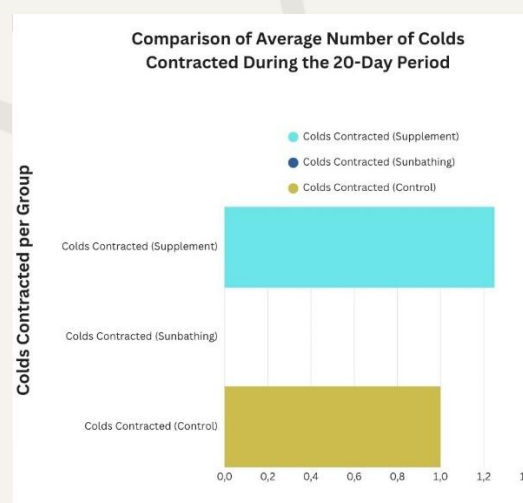


Figure 5. Average number of colds contracted during 20-day period

This suggests that while supplementation effectively elevates vitamin D concentrations, sun exposure may offer other health benefits not reflected in serum levels. A key limitation of this study was the short duration; a longer experimental period would be necessary to more accurately assess long-term effects and variations.

Ultimately, the question is how to most effectively increase vitamin D levels. Fixed doses from supplements of vitamin D allows consistency regardless of season, latitude, or weather. There aren't any cancer risks either, as supplements bypass the UV-induced DNA damage. However, there's a risk in overdosing on vitamin D supplements when not careful. High doses over time can cause hypercalcemia, though rare. Supplements don't provide the extra benefits that sunbathing carries either, and absorption also relies on gut health and whether the supplements are taken with fat-containing meals. The vitamin D obtained also absorbs calcium for bone health to prevent rickets and combat osteoporosis in children and adults.

For immune health alone, both ways of gaining vitamin D are sufficient. Supplements are safer and more reliable for maintaining stable blood vitamin D levels; however, sunbathing provides additional immune and systemic benefits beyond vitamin D, but comes with risks if overdone.

CONCLUSION

Vitamin D supplementation proved to be the most effective method for increasing serum vitamin D levels, while sunbathing,

conducted during low-UVB hours to avoid unwanted risks of overexposure, did not yield the expected rise. Nevertheless, the absence of colds among the sunbathing group suggests additional immune benefits unrelated to vitamin D concentration. Overall, supplementation offers a consistent, safe, and controllable means of maintaining adequate vitamin D levels without UV-related risks, though excessive intake may lead to rare cases of hypercalcemia. Sun exposure, while less reliable for vitamin D synthesis, may support broader systemic health when practiced safely.

Limitations of this research project include its short duration, small sample size, and difficulty in ensuring participants shared similar lifestyles, which may have introduced external variables affecting the results. Future research should involve a larger, more diverse population over an extended period to obtain more reliable and generalizable findings.

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Development of an IoT-Based Waste Bin with Real-Time Ultrasonic Fill-Level Monitoring to Support Improved Hygiene Management

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Abstract: The mixing of organic and inorganic waste at Edu Global Senior High School Bandung has become a major obstacle to effective waste management, risking waste overflow and creating unhygienic conditions. To address this problem, research was conducted on developing a waste management system by integrating an Internet of Things (IoT)-based waste monitoring system integrated with a website to enable real-time tracking and management. Employing a Research and Development (R&D) approach, we developed a system that uses the HC-SR04 ultrasonic distance sensor for fill-level detection and the ESP32 microcontroller for processing and data transmission over Wi-Fi. Sensor data is delivered to a central server and presented on a web interface that provides fill-level monitoring and overflow alert notifications. Sensor readings are compared to manual ground-truth measurements to quantify fill-level accuracy. Alert notification performance is evaluated by delivery success rate and end-to-end latency. Through this approach, waste management within the school building is made more effective, promotes eco-friendly practices, and supports the application of digital technology in routine activities.

INTRODUCTION

The rapid increase in population has created significant pressure on the environment. The growing number of human activities has accelerated environmental pollution. According to Fadzoli et al. (2023), one of the major and ongoing forms of environmental pollution is waste.

Waste is defined as an accumulated waste can cause various diseases. As stated by Axmalia et al. (2020), waste accumulation can lead to respiratory problems, chest pain, eye irritation, headaches, coughing, worm

infections, and shortness of breath. Furthermore, Ritonga et al. (2023) also mentioned that waste accumulation can cause pollution and disturbances to the environment. Such conditions often occur at final waste disposal sites (TPA). However, similar situations can also be studied in smaller environments, such as schools.

Waste accumulation frequently occurs at SMA Edu Global Bandung, where waste bins often exceed their proper capacity. The problem is worsened by the mixing of organic and inorganic waste, causing

unpleasant odors and dizziness. One of the main reasons is the delay of operational staff in collecting the waste on time.

Therefore, developing a waste monitoring system based on the Internet of Things (IoT) at SMA Edu Global Bandung has become highly relevant. An IoT-Integrated trash bin offers a potential solution to this problem. The system utilizes an ultrasonic sensor HC-SR04 combined with a website interface, allowing it to send notifications when the bin is full.

This system aims to improve waste management efficiency by helping schedule waste collection more effectively, reducing waste accumulation, and minimizing the risk of disease caused by piled-up garbage.

LITERATURE REVIEW

Internet of Things (IoT)

The Internet of Things (IoT) can be understood as an ecosystem of interconnected physical objects (things), embedded with sensors, actuators, and communication capabilities, that are accessible via the Internet and can exchange data among themselves and with other systems in order to provide value, automate processes, and respond to changes (Gubbi et al., 2012). A report by Afkarien et al. (2025) shows that IoT-Enabled waste management systems can improve operational efficiency by enabling faster response to full bins.

Ultrasonic Distance Sensor

Wei (2024) described ultrasonic distance sensors as non-contact devices that measure the distance to an object by emitting high-frequency sound waves and detecting their reflection (echo),

calculating distance via the time-of-flight of the wave under known propagation speed. Compared to other distance measurement methods (e.g., IR sensors, optical ToF sensors, LIDAR), ultrasonic sensors offer several advantages: they are relatively inexpensive, not sensitive to ambient light, color, or transparency of the target, and can reliably sense many types of materials. However, they are less precise over long distances, have limited angular resolution, and require compensation for environmental factors, as demonstrated by Rahman (2025).

Waste

Sutanto et al. (2024) states that waste can be categorized based on its physical and chemical characteristics as follows: 1) Organic waste, such as vegetable matter, meat, leaves, and similar items, which decompose rapidly; 2) Inorganic waste, such as plastic, paper, rubber, metal, and leftover construction materials, which do not decompose quickly; 3) Dust or ash; and 4) Hazardous waste, such as industrial and hospital waste containing harmful chemicals and pathogens.

METHOD

The research method used in this study is Research and Development (R&D) with a 3D approach. According to Thiagarajan et al. (1974), 3D stands for Define, Design and Develop. This model started gaining popularity in the early 1970s. It is an improvement of the development steps that were commonly used at the time, which included Analysis, Design, and Development

Analysis

In this study, we developed a product designed to address the problem of waste bins that become full and exceed their capacity. The bin is integrated with an HC-SR04 ultrasonic distance sensor, which functions to detect the waste fill-level inside. When the waste reaches its maximum limit, a micro servo automatically locks the bin as an indicator that it is full and needs to be emptied. In addition, the system sends a notification to the waste management personnel, prompting immediate collection. This mechanism allows waste to be managed more quickly and efficiently, reducing waste accumulation. Consequently, the reduction of accumulated waste can help minimize the risk of disease outbreaks.

Design

In the system design stage, a detailed design process is carried out to illustrate the overall functionality of the device. This design includes both the hardware and software architecture, as well as other components used in the project.

Table 1. Components

No	Hardware	Software	Others
1	Computer	Node.js environment	Waste bin
2	ESP 32	Python Interpreter	Jumper cables
3	HC-SR04 Ultrasonic distance sensor	Visual Studio Code	Rubber hose
4	1.3" I ² C OLED Display	PlatformIO	Solder
5	Mercury Tilt Switch	-	Acrylic glass

6	Micro Servo motor	-	Electrical tape
7	Wi-Fi Network	-	Hot glue gun

Development

We developed a smart trash bin that can automatically lock and send notifications when it becomes full. The HC-SR04 ultrasonic distance sensor is used to detect the waste level inside the bin, while the micro servo functions as a locking mechanism once the bin reaches its maximum capacity. When the bin is full, the website sends a notification to the waste management personnel that can be received on a computer or smartphone. This system helps prevent waste accumulation, thereby reducing the potential spread of diseases caused by piled-up waste.

RESULT AND DISCUSSION

System Flow

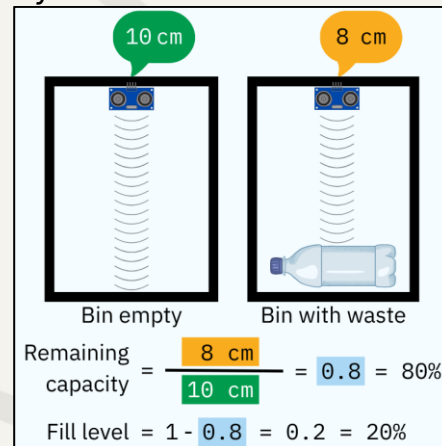


Figure 1. Example fill-level calculation

Here is an explanation of the system flow:

1. Waste is placed into the bin.
2. The ESP32 microcontroller triggers the HC-SR04 ultrasonic sensor to measure the distance between the sensor and the surface below (either waste or the bottom of the bin).

3. The measured distance is compared to the baseline distance recorded when the bin is empty. From this comparison, the ESP32 calculates the current fill level of the bin.

4. The state of the tilt switch is measured and used to determine whether the waste bin lid's state is open or closed

5. The fill level and lid state data are transmitted via Wi-Fi to a Node.js server connected to the Internet.

6. The Node.js web server stores and displays the fill-level on a web interface and triggers notifications when the bin reaches capacity. To prevent false positives, notifications will not be triggered if the lid is open.

7. When the bin reaches capacity, the micro servo automatically locks the bin. To prevent the bin from being locked open, a tilt sensor is used to detect the lid's status. The servo will only lock if the lid is closed.

Hardware Design

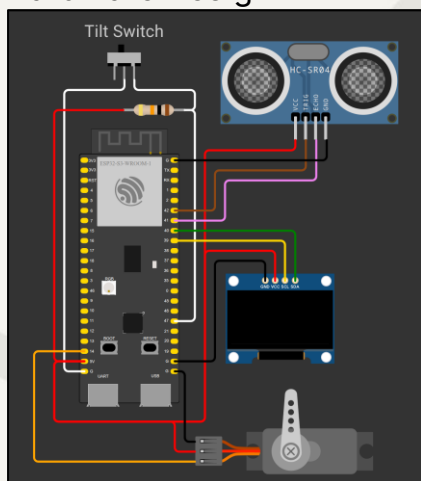


Figure 2. Hardware Design

Figure 2 illustrates the wiring diagram of the hardware configuration. The ESP32 microcontroller serves as the central processing unit, managing communication and control across all components. The HC-SR04

ultrasonic sensor is utilized to measure distance, for estimating the bin's fill-level. A tilt switch is used to detect the lid's open or closed state, while an OLED display provides a visualization of the current fill-level. A micro servo motor is employed to lock the bin mechanism, preventing it from being opened.

Software Design

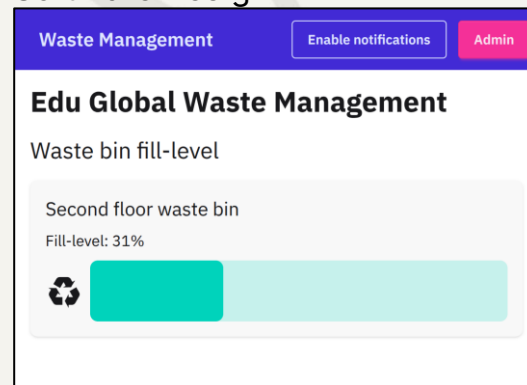


Figure 3. Website main page

Figure 3 shows the main interface of the waste management website. This page displays the status and fill-level of all registered waste bins, allowing users to monitor their conditions. It also provides access to configuration options for notifications.

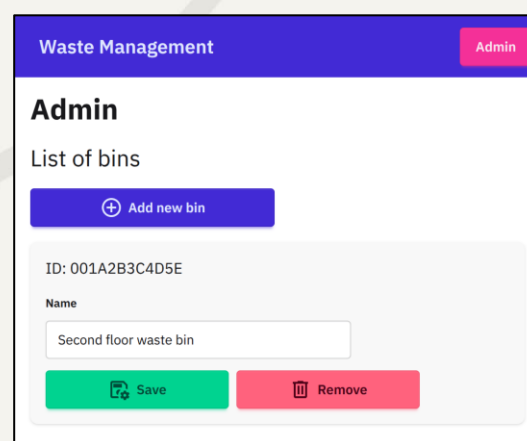


Figure 4. Website administrator page

Figure 4 presents the administrative interface of the waste management website, which is secured by a user authentication

system. This page allows authorized users to add, rename, and remove registered waste bins within the system.

CONCLUSION

Based on the research conducted on waste accumulation, which can lead to various diseases such as respiratory problems, eye irritation, headaches, coughing, and parasitic infections, we proposed a solution that aims to reduce the transmission of disease. Waste accumulation in school environments is often overlooked, even though it can cause serious impacts such as air pollution and the spread of diseases. This condition highlights the need for a more modern, effective, and responsive waste management system that can adapt to real conditions in the field.

To address this issue, we developed an Internet of Things (IoT)-based smart trash bin integrated with an HC-SR04 ultrasonic distance sensor to detect the waste level and a micro servo that functions as a locking mechanism when the bin is full. The HC-SR04 sensor detects the fullness of the bin and sends a notification to waste management personnel via smartphones or computers, enabling timely waste collection. Based on the testing results, the system successfully detected waste levels accurately and transmitted notifications quickly, demonstrating that the integration between hardware and software components worked as intended.

With this system, waste accumulation can be minimized, thereby reducing the risk of disease outbreaks caused by unmanaged waste. In the future, this system can

be further improved by adding features such as gas sensors for odor detection, visual indicators, or mobile applications to allow real-time monitoring and enhance sustainable waste management efficiency.

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The Production of Bioplastics from Royal Palm Leaves, Red Bean Starch, and Snake Fruit Skin

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Abstract: This study aims to develop bioplastics made from royal palm leaves (*Roystonea regia*), red bean starch, and snake fruit skin as an environmentally friendly alternative to conventional plastics that are difficult to decompose. Royal palm leaves are rich in cellulose, while red bean starch has a high amylose content, and snake fruit skin contains antimicrobial compounds that contribute to the mechanical properties of bioplastics. The manufacturing process involves extracting cellulose from royal palm leaves, mixing the main ingredients, and adding glycerin plasticizer. This study evaluated the properties of bioplastics through organoleptic tests, weight tests, water absorption, and biodegradability. The results showed that the bioplastic had a smooth texture, brown color, and elasticity that varied depending on the composition of the material. The weight test revealed that the bioplastic was able to withstand loads of up to 30 grams, indicating adequate mechanical strength. The water absorption capacity of bioplastics with higher snake fruit skin content increased, which facilitated the biodegradation process. In the biodegradation test, bioplastics with higher snake fruit skin content experienced faster degradation within 7 days. Statistical analysis using t-test showed significant differences between sample formulations, confirming the importance of ingredient composition in determining the characteristics of the final product. This study concluded that bioplastics made from king palm leaves, red bean starch, and snake fruit skin are potential solutions to reduce plastic waste and support environmental sustainability. The use of these natural and renewable materials is not only environmentally friendly but also provides economic opportunities in utilizing organic waste. Further research is needed for formulation optimization and large-scale production.

INTRODUCTION

Single-use plastics, which are widely used in daily life, contribute significantly to the increase of global plastic waste, reaching up to 1 trillion pieces per year. Conventional plastics, made from petroleum,

require an extremely long time to decompose — even up to 1,000 years — making them one of the major sources of waste and a serious environmental threat (Melanie et al., 2017).

In Yogyakarta, plastic waste increases every year. Data from Bappeda DIY in 2023 recorded waste reaching 1,231.55 tons, with 23.94% consisting of plastic waste. This issue has been worsened by the closure of the Piyungan Final Disposal Site (TPA), which has placed Yogyakarta into a state of emergency regarding waste management (Governor's Decree, 2023).

Bioplastics are an environmentally friendly alternative that can be decomposed by microorganisms into water and carbon dioxide without leaving harmful substances. In Indonesia, bioplastics have been developed for the past 20 years, with abundant raw materials available such as sugarcane starch, glucose, and starch from various plants.

Red bean starch, which contains about 39.45% starch, has great potential for bioplastic production due to its high amylose content that produces flexible and strong edible films (Dalimunthe et al., 2023). Meanwhile, snake fruit skin, rich in proteins, carbohydrates, and antimicrobial compounds such as tannins, flavonoids, and alkaloids, can improve the mechanical properties of bioplastics (Shabir et al., 2018).

This study aims to determine whether there are differences in degradability between two groups of bioplastics made from royal palm leaves, red bean starch, and snake fruit skin. In addition, this study also aims to describe the durability, water absorption capacity, and elasticity of the bioplastics. Finally, the research will compare the strength of bioplastics made from these natural materials with conventional plastics.

LITERATURE REVIEW

Bioplastics are biodegradable plastics that can be used similarly to commercial plastics, but after use, they are broken down by microbial activity and decompose into water and carbon dioxide, which are safe for the environment (IBAW Publication, 2005). Bioplastics are polymers that can be converted into biomass through depolymerization and mineralization processes. Depolymerization occurs through enzymatic activity, and the end products of biodegradable polymers vary depending on the type of polymer, the organisms involved, and the surrounding environment (IBAW, 2005).

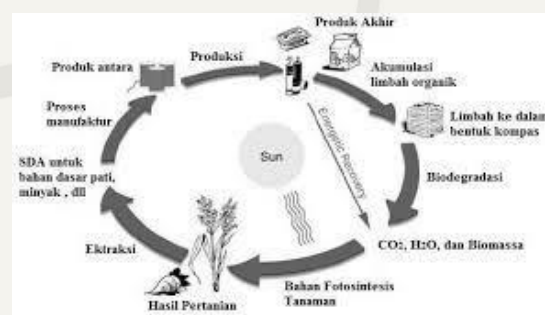


Figure 1. illustrates the bioplastic cycle, showing how they decompose easily due to agricultural plant components such as starch, oils, and fats used in their production.

Snake fruit (*Salacca zalacca*) is an indigenous Indonesian fruit with high agricultural potential, producing thousands of tons annually (Ministry of Agriculture, 2017). Snake fruit skin, which contains around 3.8% carbohydrates (Rahmadini, 2016), is often left as unused waste. However, it has significant potential as a sustainable bioplastic raw material. Because snake fruit skin is relatively tough, it is important to isolate its carbohydrate content to optimize its

use in eco-friendly bioplastic production.

Red beans, with a starch content of 39.45% (Central Bureau of Statistics, 2023), also show potential for bioplastic production. Their high amylose starch produces flexible and strong edible films, as demonstrated in research by Asmara (2018). Using red bean starch as a bioplastic material creates an environmentally friendly and easily degradable product, supporting the reduction of non-biodegradable plastic waste in the environment.

The royal palm tree (*Roystonea regia*) also has great potential as a bioplastic raw material due to the lignocellulose content in its leaves, which consists of cellulose, hemicellulose, and lignin (Surati, 2018). The process of extracting and processing royal palm leaves into bioplastics involves depolymerization and thermal treatment to improve the physical and mechanical properties of the final product. Bioplastics derived from royal palm leaves have good tensile strength, flexibility, and higher degradability compared to conventional plastics, making them a sustainable solution for reducing plastic waste.

The plasticizer process involves the dispersion of plasticizer molecules into the polymer. When plasticizers interact with the polymer, they form a polymer-plasticizer solution at the molecular level. The physical and mechanical properties of the polymer depend on the distribution and compatibility of the plasticizer within the system. If the plasticizer and polymer do not mix well, poor physical properties will result (Krochta & Mulder, 1997). This study uses glycerin as the plasticizer.

METHOD

This research was conducted to develop bioplastics made from royal palm leaves, red bean starch, and snake fruit skin through an experimental method. The study aimed to determine the effect of variations in raw materials on the physical and mechanical properties of the resulting bioplastics.

The subject of this scientific study is biodegradable bioplastic made using snake fruit skin starch, red bean starch, and cellulose from royal palm leaves as the main ingredients. The object of the research is the effect of varying concentrations of snake fruit skin starch and red bean starch on the characteristics of the bioplastics produced, including durability, water absorption, and biodegradability.

The scope of this research involves several aspects, including the use of snake fruit peel starch and red bean starch as the main raw materials for bioplastic production, the utilization of cellulose from royal palm leaves as a reinforcing agent, the use of glycerin as a plasticizer to improve the flexibility of the bioplastic, and the testing of the physical and mechanical properties of the bioplastic.

This type of research is a laboratory experiment, conducted through a series of trials to obtain results in accordance with the research objectives. The research was carried out through the following stages:

1. Cellulose Extraction

Royal palm leaves were boiled in water for 1 hour, followed by a delignification process using NaOH. The leaves were then washed and

dried until cellulose powder was obtained.

2. Bioplastic Production

The main materials were mixed with glycerin and water, then heated until homogeneous. The mixture was poured into molds and dried.

Table 1. Formulation Sample

Sample	Snake fruit peel starch (gr)	Red bean starch (gr)	Palm leaf Cellulose (gr)
A1	3,5	0,5	3,0
A2	0,5	3,5	3,0

The main ingredients—red beans, salak peel, cellulose from royal palm leaves, 3 g of tapioca flour, and 3 mL of glycerin—were mixed together. Then, 20 mL of distilled water was added. After mixing, the materials were heated and stirred until sticky. Once the mixture became sticky, it was poured into a 12 cm × 12 cm bioplastic mold. During molding, the bioplastic was pressed from both the top and bottom sides. The bioplastic was then left to dry.

3. Testing

Organoleptic tests, water absorption tests, biodegradability tests, and weight resistance tests were conducted.

Data were collected through several analytical tests as follows:

- **Organoleptic Test:** Conducted to observe the texture, color, and aroma of the bioplastic visually.
- **Water Absorption Test:** Measured the bioplastic's ability to absorb water by immersing it for a certain period of time. % water absorption:

$$\frac{W_f - W_i}{W_f} \times 100\%$$

Note:

W_f = Mass of Bioplastic After Immersion (g)

W_i = Initial Mass of Bioplastic (g)

- **Biodegradability Test:** Measured degradation of bioplastics buried in soil over a certain period of time. The data obtained will be processed using the following formula:

$$\frac{M_o - M_i}{M_i} \times 100\%$$

Note:

M_o = Initial Dry Weight (g)

M_i = Final Dry Weight (g)

- **Weight Resistance Test:** Determined the strength of bioplastics in holding loads of 10 g, 20 g, and 30 g.

Data obtained were analyzed quantitatively using statistical methods, including an Independent Sample t-Test to determine whether there were significant differences between the sample groups.

RESULT AND DISCUSSION

This section presents the results and analysis of bioplastics made from royal palm leaves, red bean starch, and snake fruit skin.

1. Organoleptic Test

The organoleptic test was conducted using human senses to observe texture, color, and aroma.

Table 2. Organoleptic Test Results

Sample	Texture	Color	Aroma	Picture

A1	Smooth	Dark brown	Odorless	
A2	Smooth	Light brown	Odorless	

The bioplastics produced had a smooth texture, brownish color, and no aroma. The darker brown color resulted from cellulose extract, red bean starch, and snake fruit skin extract. The results showed that the higher the snake fruit skin content, the stiffer and darker (brownish-black) the plastic became. This is because cellulose from royal palm leaves increased texture but reduced elasticity

2. Weight Resistance Test

The weight resistance test used two samples (A1 and A2) with loads of 10 g, 20 g, and 30 g of sugar.

Table 3. Weight Resistance Results

No	10 gr	20 gr	30 gr
A1	Withstood	Withstood	Withstood
A2	Withstood	Withstood	Withstood

The table shows that both samples could withstand weights up to 30 g. This was due to the cellulose content in the bioplastic, which reinforced the structure. This finding supports Panjaitan et al. (2017), who stated that cellulose strengthens bioplastics

3. Water Absorption Test

The water absorption test was conducted on samples A1 and A2 by immersion for 5, 15, and 30 minutes.

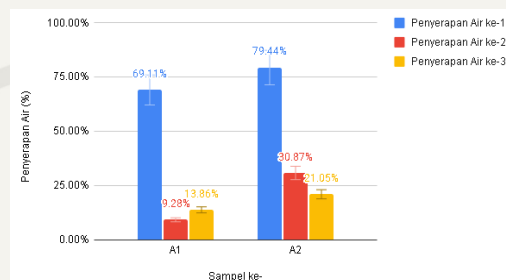


Figure 2. Water Absorption Graph

The graph shows an increasing trend of water absorption over time. Sample A1 had higher water absorption than A2 because it contained more snake fruit skin starch, which dissolves more easily in water. Since starch and cellulose are polysaccharides, they degrade more easily in nature (Panjaitan et al., 2017). The increase in mass after immersion indicates water absorption, which facilitates biodegradation.

4. Biodegradability Test

The biodegradability test was conducted by burying the bioplastics in soil for 7 days.

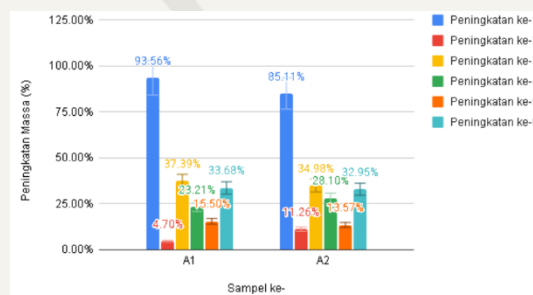


Figure 3. Biodegradability Graph

The graph showed that A1 degraded more quickly than A2. This is because A1 contained more snake fruit skin starch, a material that decomposes easily. Thus, the higher the starch content, the faster the biodegradability of the bioplastic.

5. Independent Sample t-Test Analysis

The Independent Sample t-Test was used to determine significant differences between A1 and A2.

- H0: No significant difference between A1 and A2.

- H1: There is a significant difference between A1 and A2.

The test results using SPSS showed a significance value of 0.01 (< 0.05). Therefore, H0 was rejected and H1 was accepted, meaning there was a significant difference between A1 and A2.

6. Practical and Theoretical Implications

Research on biodegradable plastics has been conducted since 2015 alongside the rise of plastic waste worldwide. Studies such as those by Parveen et al. (2024) on Bioplastic Packaging in Circular Economy and Kwong et al. (2023) on Reinforced Bioplastics in Various Industries confirmed that starch is a primary material for bioplastic development.

This study compared red bean starch with snake fruit skin starch, aiming to utilize organic waste (snake fruit skin) alongside agricultural products (red beans). Therefore, this research contributes to solving the problem of non-biodegradable plastic waste by promoting the use of biodegradable organic materials.

CONCLUSION

Based on the research conducted, it can be concluded that there are differences in degradability between the two groups of bioplastics made from royal palm leaves, red bean starch, and snake fruit skin. This was shown by the Independent Sample t-Test with a significance value of 0.01.

Bioplastics from these materials demonstrated good water absorption (especially in Sample A1) and showed stiffness due to the addition of cellulose. Moreover, the bioplastics produced were able to withstand loads of up to 30 grams. Thus, bioplastics made from royal palm leaves, red bean starch, and snake fruit skin can serve as an environmentally friendly alternative to conventional plastics.

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Youth and the Javanese Language: Proficiency, Usage, and Attitudes toward Preservation Challenges in Modernity, Cultural Identity, and Sustainability

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Abstract: The sustainability of minority languages in globalization is pressing, with Javanese, the largest local language in Indonesia, illustrating tensions between identity and modernity. Despite its history and symbolic value, Javanese is steadily declining in everyday use among younger generations who prioritize Indonesian and English. This study examines Javanese vitality among youth through a survey assessing proficiency, usage, attitudes, identity, preservation, modernity, registers, script literacy, and digital engagement. Five indices measured self-reported abilities and practices, combining quantitative and interpretive analysis. Findings reveal a paradox. Proficiency clustered around moderate (22.4%) and high (23.9%), yet 14.9% reported very low ability, especially in formal registers. Usage was similarly limited: 26.9% moderate, while 25.4% almost never used Javanese. In contrast, attitudes and identity were strong, with 40.3% very high, showing pride in Javanese as a cultural heritage. Preservation-modernity indices indicated moderate (40.3%) to high (28.4%) suggesting awareness but limited action. Refined registers polarized respondents, with very low (20%) and very high (19.4%) groups. Literacy was weak, with 22.4% very low and only 26.8% moderate, reflecting its marginal role in education. Most critical was digital-global engagement: 34.3% very low and only 3% very high, underscoring Javanese's absence in youth online culture. Overall, the study highlights a contradiction: strong cultural identification but weak functional use. Javanese as a symbol of identity, starts to lose its role in daily and digital life. For cultural sustainability, Javanese must be embedded into contemporary contexts, digital media, creative industries, and education to convert positive attitudes into active practice and ensure intergenerational continuity.

INTRODUCTION

The sustainability of minority languages has become a pressing concern in the era of globalization. Across the world, many indigenous

languages face decline as younger generations increasingly adopt dominant national and international languages. This global trend is highly relevant in Indonesia, where

Javanese despite being the largest local language with over 80 million speakers shows signs of erosion in its functional use. While Javanese carries immense historical and cultural significance, its role in daily communication is weakening, particularly among youth who prioritize Indonesian and English for education, career, and digital interaction. This tension between identity and modernity creates a paradox that requires deeper scholarly attention.

Language preservation is closely tied to cultural identity and intergenerational continuity. In Java, the younger generation grows up in a bilingual or even trilingual environment where Javanese is often viewed as informal or outdated compared to Indonesian and English. Urbanization and modernization have further accelerated this linguistic shift, as urban youth increasingly use Indonesian as their main communication medium. Meanwhile, rural youth who still speak Javanese tend to simplify or mix it with Indonesian, signaling a gradual loss of linguistic depth. These shifts reflect not only language preference but also changing social aspirations, where global competence often outweighs local linguistic pride.

Scholars have begun to highlight the complex status of Javanese within contemporary society. A 2023 report by Universitas Gadjah Mada challenges modern perceptions of *primbon* a traditional Javanese manuscript arguing that while younger generations often dismiss it as irrelevant, it reflects broader shifts in how Javanese heritage is perceived (UGM, 2023). This study illustrates that cultural

practices linked to the Javanese language risk marginalization when framed as outdated, underlining the importance of recontextualizing traditions for modern audiences. Similarly, research published in *Paradigma: Jurnal Kajian Budaya* (UI, 2021) emphasized that Javanese continues to function as a marker of identity, yet its practical use in formal and urban contexts has significantly declined. This supports the argument that symbolic attachment alone is insufficient to ensure intergenerational continuity.

Recent studies have explored strategies to address this decline. A 2024 article in *Edupij* highlighted the potential of digital media in preserving local languages, integrating Javanese learning into online platforms for high school students (Edupij, 2024). Such approaches show promise in connecting tradition with digital-native youth. Similarly, the 2023 International Conference on Social Sciences (Atlantis Press, 2023) reported that revitalizing Javanese literacy and script in schools can strengthen cultural preservation from an early age. Beyond Indonesia, the *Asia Pacific Journal of Education* (Tandfonline, 2024) found that minority languages across Asia face similar challenges, reinforcing that revitalization requires embedding local languages within modern education and media systems.

Despite these efforts, research gaps remain. Previous studies often focus on specific aspects such as symbolic identity, tradition, or education but rarely provide a comprehensive view of Javanese vitality among youth. Few have examined how proficiency, usage, attitude, identity, literacy, and digital

participation intersect to shape linguistic sustainability. This study addresses that gap through a survey-based approach measuring five key indices of Javanese vitality. By analyzing youth perspectives, it aims to identify not only patterns of decline but also potential pathways for revitalization. Therefore, this study aims to examine the vitality of the Javanese language among youth through a survey-based approach using five key indices: proficiency, usage, attitudes, identity, literacy, and digital participation. The research seeks to provide empirical insights that contribute to understanding how these dimensions interact and influence the sustainability of Javanese in modern society.

METHOD

This study used a survey method (Holmes, 2013) with an online questionnaire designed to assess Javanese language vitality. The survey was distributed via social media (e.g., WhatsApp, Instagram) and completed by respondents from various cities/regencies in Indonesia. It had seven sections: demographics, proficiency, daily use, attitudes and identity, preservation and modernity, refined registers, and open-ended questions. Most items used a 5-point Likert scale. Data were analyzed descriptively using percentages and interpretation to identify patterns.

RESULT AND DISCUSSION

The study reveals a paradox: youth show strong pride in Javanese identity, yet their proficiency, literacy, and daily use are weak, especially in formal and digital settings. Javanese is valued more as

a cultural symbol than as a functional language. This highlights the need to embed it into schools, creative industries, and digital media so that pride can translate into active use and long-term sustainability.

Proficiency

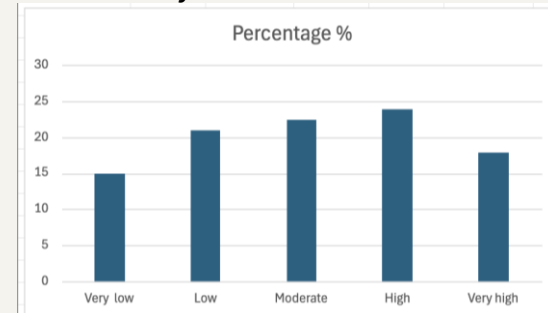


Figure 1. Proficiency Index

As shown in Figure 1, the majority of respondents fall within the *moderate* (22.4%) and *high* (23.9%) proficiency categories, while *very high* proficiency accounts for 17.9%. Meanwhile, 35.8% of participants demonstrate *low* (20.9%) or *very low* (14.9%) proficiency. This distribution indicates that while many youths still maintain a workable command of Javanese, a considerable portion shows declining fluency.

The findings indicate a gradual erosion of Javanese language proficiency among younger generations, particularly in active communication skills. The substantial proportion of respondents in the *low* and *very low* categories implies that many youths understand Javanese but struggle to use it effectively in daily contexts. This trend corresponds with recent studies noting the reduced intergenerational transmission of Javanese in urban and semi-urban areas (Rahmawati & Wijayanti, 2022; Sari et al., 2023).

The persistence of moderate to high proficiency levels, however,

reflects linguistic resilience in regions where Javanese remains embedded in family communication and local traditions. Similar patterns have been observed in Central and East Java, where youths continue to acquire receptive competence, understanding the language but using it less frequently (Wibowo, 2021). This aligns with Fishman's (1991) notion of "receptive bilingualism," where passive fluency outlasts active use due to reduced communicative need.

Overall, the data illustrate a transitional linguistic phase in which Javanese retains cultural value but faces decreasing functional relevance. Without targeted revitalization strategies—such as community-based language programs or integration of local languages into school activities—further decline in active proficiency may be inevitable.

Usage

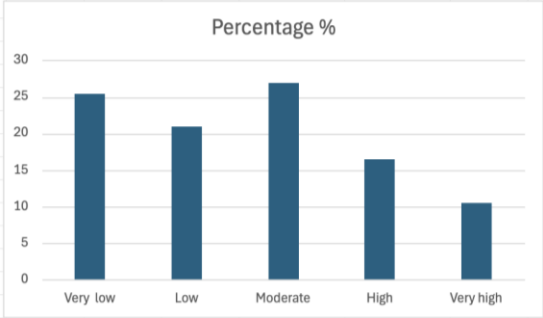


Figure 2. Usage Index

Daily usage of Javanese is limited. 26.9% use it moderately, while 25.4% almost never use it. This reflects a trend where many youths move away from using the language actively in daily life.

The results suggest a decline in the functional use of Javanese among youth despite their moderate levels of comprehension and proficiency. The relatively high

proportion of respondents in the *very low* and *low* usage categories (46.26% combined) indicates that Javanese is increasingly confined to passive or context-specific functions, such as communication with older family members or during cultural events.

This shift mirrors a broader language domain restriction trend observed across Indonesia, where local languages are gradually replaced by Bahasa Indonesia in educational, digital, and professional contexts (Andayani & Fitriani, 2022; Hidayat & Sudirman, 2023). The reduced use of Javanese in informal peer communication further underscores how social identity and practicality now favor Indonesian or even English as prestige languages (Rizki & Nuraeni, 2021).

Moreover, the data reflect the impact of urbanization and education on language behavior. Studies have shown that urban youth often associate the use of local languages with rural or traditional identity markers, leading to decreased usage in formal and social domains (Sutopo & Widodo, 2022). This symbolic distancing from Javanese correlates with the perceived modernity associated with national and global languages.

Despite this, the moderate usage category, representing around one-fourth of respondents, demonstrates that Javanese still retains sociocultural significance in certain interactions, particularly within households or regional communities. However, unless reinforced through family language policies or creative youth initiatives (e.g., Javanese in digital media, music, or education), continued

intergenerational decline remains probable.

Attitudes & Identity

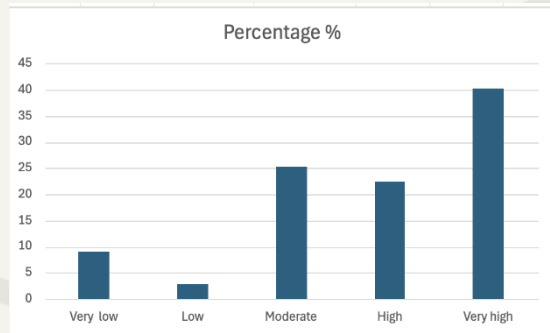


Figure 3. Attitudes & Identity

As presented in Figure 3, the largest proportion of respondents 40.30% fall under the *very high* category, showing deeply embedded cultural identity and strong commitment to the Javanese language. This is followed by *moderate* (25.37%) and *high* (22.38%) categories. Only a small minority reported *very low* (8.96%) or *low* (2.99%) attitudes. This distribution suggests that most participants maintain positive affective ties and cultural pride associated with the Javanese language, despite varied proficiency and usage levels.

The results show that students still have positive feelings and respect for the Javanese language, even though many do not use it often in daily life. This means that while their fluency and usage may be lower, they still believe the language is valuable and should be preserved. Similar results were found in other studies in Central Java, where young people see Javanese as a symbol of their heritage and family connection (Astuti & Prasetyo, 2021).

Many students in this study also said that Javanese represents who they are and where they come from, which shows that cultural pride is still

strong. However, having a good attitude alone is not enough to keep a language alive. Other research shows that positive attitude needs to be supported by regular use in schools, families, and media to prevent language loss (Holmes & Wilson, 2022; Nurhadi & Wulandari, 2023).

Overall, the results suggest that students still care about the Javanese language, but they need more chances to use it in daily activities. If families, schools, and local communities give more space for Javanese to be used, this positive attitude can help support the language's survival for future generations.

Preservation–Modernity

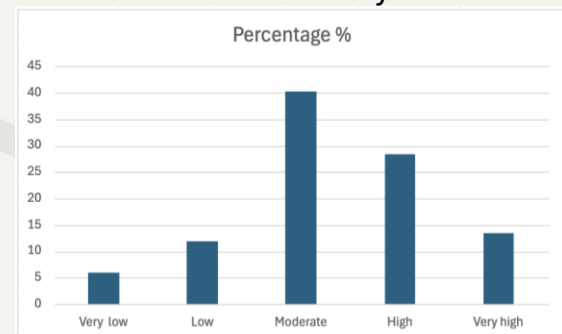


Figure 4. Preservation and Modernity

According to Figure 4, most respondents show a *moderate* level of awareness toward language preservation, with 40.29% in the *moderate* category. This is followed by 28.36% in the *high* category and 13.43% in the *very high* category. Meanwhile, 11.94% of students show *low* awareness, and 5.97% fall in the *very low* category. These results suggest that while many students understand the importance of preserving the Javanese language, only a smaller portion actively participate in preservation efforts or connect them to modern life.

The results show that most students agree with the idea of preserving the Javanese language, but not all are actively involved in doing so. Many respondents understand that the language is part of their cultural identity, but only some take action to use it in daily communication or share it through modern media. This pattern is also seen in other studies, which found that young people often support cultural preservation in theory but struggle to apply it in a modern lifestyle (Rahmawati & Wijayanti, 2022).

The moderate level of engagement may come from a lack of practical opportunities to use Javanese outside of school or family settings. In many cases, Bahasa Indonesia and English are more dominant in education and technology, so students use Javanese only in limited situations (Sari et al., 2023). However, the presence of students in the *high* and *very high* categories shows that there is still motivation to protect the language, especially when it can be connected to digital content, such as social media, videos, or online learning platforms.

In short, students are aware that the Javanese language needs to be preserved, but they need more creative and modern ways to do it. Schools, cultural organizations, and youth communities can help by introducing projects that link Javanese language use with digital literacy, music, or storytelling. This would allow students to preserve their heritage while keeping it relevant in today's world.

Refined Registers

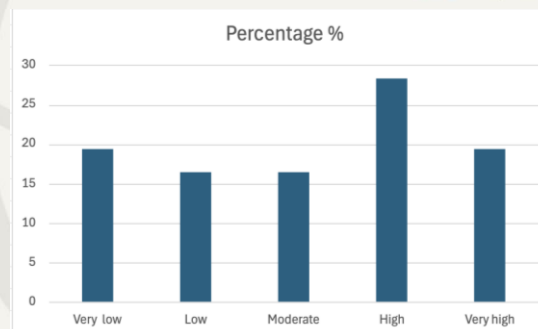


Figure 5. Politeness Register Subscale

As shown in Figure 5, the distribution of politeness registers proficiency shows that 28.36% of respondents are in the *high* category, while *very high* and *very low* categories each account for 19.40%. Respondents in the *moderate* and *low* categories make up 16.41% each. This pattern suggests that while many students still understand and can use Javanese politeness levels (*krama* and *madya*), others show declining consistency in applying them during communication.

The findings reveal that a fair number of students still maintain awareness of Javanese speech levels and use them appropriately, particularly when speaking to elders or in formal situations. The relatively strong proportion of students in the *high* and *very high* categories indicates that traditional politeness norms have not disappeared entirely. This is likely influenced by family and school environments, where respect for elders remains emphasized in daily interaction (Pradana & Lestari, 2022).

However, the equal percentage of respondents in the *very low* category points to a growing inconsistency in the use of polite registers. Many youths now rely more on informal or mixed-language speech, combining Javanese with

Indonesian or English (Rahardjo, 2023). This *code-mixing* behavior often occurs in peer communication or online spaces where social hierarchy is less visible, making polite speech forms seem unnecessary or old-fashioned.

This shift reflects broader sociolinguistic adaptation; students understand the concept of politeness but express it differently in modern communication contexts. Instead of relying solely on speech levels, they may use tone, emojis, or respectful phrases in Indonesian or English. While this adaptation shows creativity and flexibility, it also signals that the traditional *krama* and *madya* levels are at risk of being replaced by more neutral forms of politeness.

To strengthen cultural continuity, contextual education, such as integrating polite register practice into school interactions or digital storytelling, can help students experience Javanese politeness as part of modern identity rather than a formal requirement.

Literacy

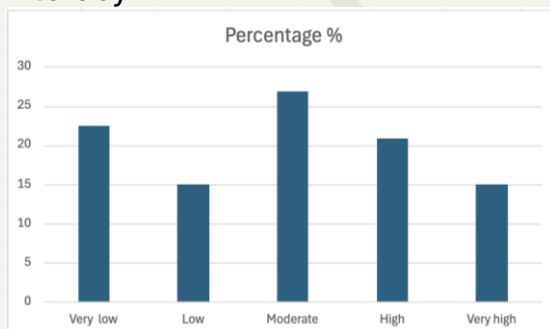


Figure 6. Javanese Script Literacy Subscale

Based on Figure 6, the majority of respondents fall under the *moderate* literacy category (26.87%), followed by *very low* (22.39%) and *high* (20.90%) levels. Meanwhile, *low* and *very high*

categories each account for 14.93% of respondents. These results show that most students have a basic understanding of the Javanese script (*hanacaraka*), but their ability to read and write fluently, especially using complete characters and *sandhangan* (diacritics), is still limited.

The data suggest that Javanese script literacy among young people remains at a moderate level, showing awareness of the writing system but not full mastery. This pattern is consistent with findings from previous studies indicating that many students can recognize Javanese letters but struggle to apply them in writing or digital communication (Nugroho & Sari, 2022).

The relatively high number of respondents in the *very low* category (22.39%) points to a lack of exposure and practice, especially since Javanese script is often taught only briefly in school and rarely used outside of academic settings. The limited availability of digital tools or fonts for typing Javanese may also contribute to this gap (Setyawan et al., 2023).

However, the presence of students in the *high* and *very high* categories indicates that interest in script learning still exists, particularly among those who view it as part of cultural identity. Some schools and cultural communities have begun to use technology, such as Javanese script apps or IME keyboards, to make script learning more engaging (Rahmawati & Dewi, 2022).

To strengthen Javanese literacy, schools could integrate the script into creative projects, such as designing posters, digital art, or social media posts using *hanacaraka*. This approach not only

builds literacy but also connects the traditional script with modern digital expression, making preservation efforts more appealing to youth.

Digital-Global Engagement

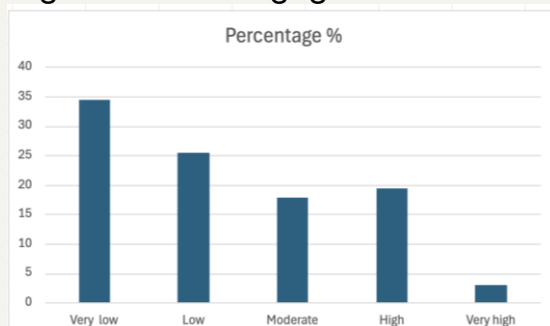


Figure 7. Digital and Global Usage Index

The biggest gap lies in digital use. 34.3% show very low engagement, while only 3% report very high use of Javanese online. This underscores its absence in the digital culture of youth.

The data suggest that while many students still value the Javanese language in personal and cultural contexts, its presence in the digital world is very limited. Most respondents do not regularly use Javanese in social media posts, comments, or digital creative works. This pattern aligns with recent studies showing that younger generations tend to switch to Indonesian or English when communicating online because those languages are considered more practical and widely understood (Hidayati & Rukmini, 2022).

The low proportion of students in the *high* and *very high* categories indicates that digital participation using Javanese remains niche and often confined to specific cultural or regional pages. This reflects a growing gap between traditional identity and digital identity, where students express cultural pride

offline but prefer global languages online to connect with a wider audience (Santosa & Puspita, 2023).

Nevertheless, some students in the *moderate to high* categories demonstrate that Javanese can coexist with global communication through creative digital means, such as memes, YouTube content, or online storytelling. These examples show that digital platforms can be a powerful tool for preservation, especially when the language is used creatively and informally rather than only in formal writing.

To strengthen this digital engagement, schools and communities can encourage digital literacy projects that use Javanese as part of content creation, like making short videos, podcasts, or online campaigns. This approach not only preserves the language but also redefines it as part of students' modern identity and self-expression.

The findings of this study reveal that modernization and globalization have shaped how young people perceive, use, and value the Javanese language. Across all indices, proficiency, usage, attitude and identity, literacy, and digital engagement, the results indicate that while students still view the Javanese language as an important part of their cultural identity, its daily use continues to decline, particularly in formal communication and digital spaces. This reflects an ongoing shift where local languages are appreciated as symbols of heritage but are less practiced as tools of everyday expression.

This condition directly relates to the study's main purpose: to understand how modern social and technological changes affect youth connection to their local language.



The moderate proficiency and positive attitudes shown by participants demonstrate that knowledge of the Javanese language still exists, but the motivation and contexts for active use are weakening. Indonesian and English increasingly dominate education, entertainment, and online communication, leaving little space for Javanese to function as a language of relevance. Similar observations were made by Rahardjo (2023) and Kusuma (2022), who noted that modernization narrows the use of regional languages by shifting their function from daily communication to cultural identity.

However, the results also show that globalization does not entirely erase cultural attachment, it can become a bridge for renewal. The strong sense of pride found among respondents suggests that revitalization remains possible if modern contexts are utilized creatively. Rather than viewing digitalization as a threat, it can serve as a medium for reimagining Javanese culture. Through digital storytelling, local music, memes, and social media engagement, youth can express their identity in ways that align tradition with innovation. Fishman (1991) emphasized that successful language preservation depends not only on knowledge transmission but also on the creation of new, meaningful spaces for use, an idea that becomes increasingly relevant in today's digital era.

The relatively low results in Javanese literacy and digital usage show that revitalization cannot depend solely on formal education. Instead, it must involve broader cultural participation that connects language with creativity and

technology. Schools, communities, and local governments could collaborate to integrate Javanese into art, media, and education programs that promote bilingual and bicultural competence. These actions would make the language more visible and functional in modern life, encouraging youth to use it naturally in both personal and social settings.

From a sustainability perspective, this connection between cultural preservation and modernization aligns closely with the principles of the United Nations Sustainable Development Goals (SDGs). By promoting education that values linguistic and cultural diversity, the findings support SDG 4 (Quality Education), which emphasizes inclusive learning that strengthens cultural identity. Encouraging the use of local languages in modern society also contributes to SDG 11 (Sustainable Cities and Communities), which seeks to protect cultural heritage as part of community resilience. Furthermore, when young people engage in local-language innovation and responsible cultural production, they embody the values of SDG 12 (Responsible Consumption and Production), ensuring that cultural resources, such as language, are sustained and adapted responsibly for future generations.

In conclusion, this study highlights that the influence of modernization and globalization on the Javanese language among youth is complex: it challenges traditional use but simultaneously creates opportunities for renewal. Revitalization requires not merely preservation but transformation, linking education, culture, and

technology to help young people rediscover Javanese as a living, expressive, and relevant language. Through collaboration between schools, cultural institutions, and digital platforms, the Javanese language can continue to evolve as both a foundation of identity and a means of sustainable cultural growth in an increasingly globalized world.

Table 1. Summary of Finding and Implications

No	Description	Information
1	Proficiency and Usage	Moderate-high, weak in formal use
2	Attitudes & Identity	Strong pride, low practice
3	Literacy	Low, limited in schools
4	Digital-Global Engagement	Very low online presence
5	Implication	Implication

CONCLUSION

This study highlights a paradox in the vitality of Javanese among youth. Pride and cultural identity remain strong, but proficiency, literacy, daily use, and digital engagement are weak. Proficiency is uneven, formal registers are rarely mastered, and literacy is marginal in education, while preservation awareness is high but not consistently acted upon.

These results show that Javanese risks becoming more symbolic than functional. To address this, the language needs stronger integration into schools, greater support in creative industries, and a stronger presence in digital platforms. Turning positive attitudes into active practice is essential to ensure Javanese remains sustainable across generations.

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Innovation in the Digital Complaint System to Address Bandung's Stunting and Increase Social Assistance Transparency

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Abstract: Malnutrition and stunting remain pressing issues in Indonesia. In Bandung City, the toddler stunting rate is 19.4%, lower than the national (21.6%) and West Java (20.2%) averages, according to SSGI 2022. As of March 2025, there were 85,963 toddlers, with Kiaracondong District recording the highest number (4,972). Of the 3,667 examined, 690 were stunted—147 severely and 543 moderately—highlighting the need for targeted intervention in this area. The problem is worsened by unequal distribution of social assistance, often due to inaccurate data, duplicate recipients, and delivery delays, reflecting weak data validation, transparency, and inter-agency coordination. This study aims to develop and evaluate a web-based system that functions as a community complaint forum while supporting social assistance delivery. The system enables health centers, sub-districts, and villages to communicate, report issues, access official information, and track aid in real time. By expanding access to health services and assistance, it contributes to Goal 3 (Good Health and Well-Being) and Goal 9 (Industry, Innovation, and Infrastructure) through innovative and sustainable web-based solutions. This study addresses the urgent need for digital solutions that enhance the efficacy, accountability, and transparency of social assistance distribution. Community health centers play a key role in improving health monitoring, particularly for stunting and malnutrition, enabling more holistic interventions. Using a qualitative case study in Bandung City, West Java, data were collected through field observations and literature review to analyze challenges in aid distribution and malnutrition. Based on this approach, a more responsive web-based complaint system was developed. According to the study's findings, using a public complaint website can boost citizen participation, speed up communication, and boost public confidence in the government. More precise monitoring of public health situations is another benefit of integration with community health centers. It is therefore hoped that this will contribute to lowering the chronic rate of malnutrition.

INTRODUCTION

Stunting and malnutrition remain pressing public health issues

in Indonesia. According to the 2022 Indonesian Nutritional Status Survey (SSGI), the national stunting prevalence among toddlers reached 21.6%, with West Java at 20.2% and Bandung City slightly lower at 19.4%. Despite this, Bandung still recorded 85,963 toddlers in March 2025, with Kiaracondong District showing the highest prevalence, including severe cases, indicating the urgency of targeted interventions.

The persistence of stunting is not only related to nutrition but also to socio-economic conditions, particularly the distribution of social assistance. In West Java, challenges such as duplicate beneficiaries, inaccurate data, and delayed disbursements often result in aid missing its intended targets. These inefficiencies highlight the lack of data validation, coordination, and transparency among agencies, which limits the effectiveness of public health and welfare programs.

To address these issues, this study proposes a digital complaint system that integrates community participation with transparent social assistance management. By enabling real-time reporting and monitoring, and linking with local health centers, the system seeks to improve accountability, enhance citizen trust, and strengthen stunting prevention efforts in Bandung City. This initiative also contributes to the Sustainable Development Goals, particularly SDG 3 (Good Health and Well-being) and SDG 9 (Industry, Innovation, and Infrastructure).

RESULT AND DISCUSSION

Field observations in Bandung City, especially in Kiaracondong District, showed that stunting remains a major concern, with 690

cases identified out of 3,667 toddlers examined. This condition reflects the broader provincial and national trends reported by SSGI 2022 and emphasizes the need for integrated interventions. At the same time, social assistance programs continue to face issues such as duplicate beneficiaries, inaccurate data, and delayed disbursements, which limit their effectiveness in addressing malnutrition.

To overcome these challenges, a prototype web-based complaint system was developed. The system allows citizens to report problems, access official information, and monitor social assistance in real time, while integration with health centers enables better tracking of stunting cases. This innovation enhances transparency, strengthens citizen participation, and builds public trust, contributing to Bandung's stunting reduction efforts as well as national goals aligned with SDG 3 (Good Health and Well-being) and SDG 9 (Industry, Innovation, and Infrastructure).

CONCLUSION

This study highlights the role of digital innovations in addressing stunting and improving transparency in social assistance distribution. The web-based complaint system enhances community participation, strengthens coordination among health partners, and increases accountability in aid delivery. By contributing to SDG 3 and SDG 9, this approach demonstrates how local solutions in Bandung can serve as a model for broader applications in public health and social welfare. For future development, the system should be expanded to other districts and cities to test its scalability and



effectiveness. Strong collaboration with local governments, health centers, and communities is needed to ensure sustainability. Integrating the system with national health and social assistance databases is also recommended to further improve accuracy, transparency, and overall impact.

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