



PROCEEDING:

**INTERNATIONAL RESEARCH
CONFERENCE ON ECOTOURISM AND
AGRICULTURE (IRCETA 2025)**



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PREFACE

On behalf of Global Academic Excellence (M) Sdn Bhd, it is my great pleasure to welcome you to the International Research Conference on Ecotourism and Agriculture 2025 (IRCETA 2025), held from 9th to 10th August 2025 at the H-Elite Hotel, Kota Bharu, Kelantan, Malaysia.

This conference marks another important milestone in our continuous effort to provide a premier platform for scholars, researchers, practitioners, and industry leaders to exchange knowledge, present their latest research, and discuss innovative ideas in the fields of ecotourism, sustainability, and agriculture. The diversity of papers presented in this proceeding reflects the depth and breadth of contemporary research addressing pressing global issues and future opportunities.

At GAE, we strongly believe that academic discourse and collaboration are essential to nurturing innovation and sustainable development. The contributions compiled in this proceeding not only highlight the scholarly achievements of participants but also serve as valuable references for future research and practice.

I would like to extend my sincere gratitude to all authors, reviewers, conference committee members, and participants for their dedication and commitment. Without your invaluable support, IRCETA 2025 would not have been possible. I also wish to acknowledge the efforts of our organizing team at GAE for their tireless work in ensuring the success of this conference.

It is my hope that this proceeding will inspire further exploration, stimulate productive dialogue, and contribute to shaping a more sustainable and innovative future.

Sincerely,

Assoc. Prof. Dr. Adi Anuar Azmin

Chairman

*International Research Conference on Ecotourism
and Agriculture 2025 (IRCETA 2025)*



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BEYOND WASTE: 3D BIOCOMPOSITE SOLUTIONS FOR SUSTAINABLE ECOTOURISM AND AGRICULTURE

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Abstract: *This paper introduces a novel solution for agricultural waste management, advanced manufacturing, and sustainable tourism by developing 3D printable biocomposite filaments derived from durian skin waste. Addressing the significant waste generated by durian consumption in Malaysia and aligning with Sustainable Development Goal 12 (Responsible Consumption and Production), this research supports Malaysia's National Ecotourism Plan 2016-2025. Our primary objective is to demonstrate the viability of these biocomposite filaments as a sustainable alternative to conventional 3D printing materials, enabling the production of eco-friendly tourism products and fostering a circular economy. We achieved this by transforming durian skin fiber (DSF), an abundant agricultural byproduct, into a viable filler for Polylactic acid (PLA), a biodegradable biopolymer. Our methods involved creating PLA/DSF biocomposites, with results showing that alkali-treated DSF (TDSF) significantly improved impact strength; specifically, PLA with 30 wt% TDSF exhibited a 20% increase in impact strength compared to untreated DSF. Building on these findings, we transformed these biocomposites into PLA/DSF filaments for 3D printing, aiming for product quality comparable to or exceeding traditional souvenirs. This innovation directly contributes to reducing environmental concerns by valorizing waste and closing the product lifecycle loop, ultimately positioning Malaysia as a leader in eco-friendly tourism and responsible consumption, marking a significant step towards a circular economy and a more sustainable future.*

Keywords: Durian skin fibre, biocomposite, ESG, 3D printing filament, eco-tourism.

Introduction

As businesses around the world face increasing pressure to incorporate sustainability practices into their operations, governments are taking proactive steps to enforce mandatory ESG reporting. Malaysia, as a significant player in the South-East Asian region, is no exception to this global trend. The integration of 3D printing technology in various industry marks a significant advancement in technology driven innovation, offering new opportunities to enhance users experience including school children. 3D printing, also known as additive manufacturing, enables the creation of three-dimensional objects layer-by-layer from digital designs, opening a wide range of possibilities for businesses and destinations. Through additive manufacturing, businesses can now adopt the ESG while promoting natural-based materials that is available in our country.



Additive Manufacturing (AM), commonly known as 3D printing, is a technology that constructs three-dimensional objects layer-by-layer from 3D model data, offering advantages over conventional manufacturing methods such as cost-effectiveness, design flexibility, and high prototyping speed [1]. Fused Deposition Modeling (FDM) is a widely preferred 3D printing technique due to its versatility, involving the extrusion of continuous thermoplastic filaments through a heated print head [2].

Despite the widespread application and benefits of synthetic polymers in various industries, their lack of biodegradability poses significant environmental challenges. This has spurred increasing global interest in biopolymers, which are biodegradable and derived from renewable resources. Polylactic acid (PLA), an aliphatic polyester, is a promising eco-friendly biopolymer known for its biodegradability and comparable properties to synthetic polymers, including high elastic modulus and tensile strength [3-5]. However, neat PLA can exhibit reduced tensile toughness in FDM applications.

Durian is one of the most important fruit crops in Southeast Asia. It is well known as the King of Fruits, and the term 'duri' comes from a Malay word meaning 'thorn'. It belongs to the genus *Durio*, and there are nearly 30 species of durian [6]. *Durio zibethinus* Murray is the botanical name for the most commonly cultivated durian. Thailand, Indonesia, and Malaysia are Asian countries that commercially cultivate durian as a main economic agricultural crop. Manshor et al. [4] reported that only 50% to 60% of each durian is flesh, with the remainder considered waste. This waste includes the skin and seed, which constitute approximately 45-55% of the fruit. Furthermore, 1 kg of durian waste can yield 40% fiber. The durian skin fiber (DSF) contains cellulose (60.45%), hemicelluloses (13.09%), and lignin (15.45%) [7].

A compelling solution lies in the development and utilization of a durian skin fibre (DSF) and polylactic acid (PLA) filament. This innovative biocomposite material offers several key advantages. Firstly, it promotes waste valorization by converting non-edible durian skins into valuable DSF, thus supporting sustainable agricultural practices. Secondly, unlike conventional plastics, PLA is a biodegradable polymer derived from renewable resources such as corn starch. When combined with DSF, the resulting filament is environmentally friendly, significantly reducing the ecological footprint associated with plastic products [8]. This approach exemplifies the principles of a circular economy by creating a closed-loop system where waste is transformed into new, useful products, generating economic value from what would otherwise be an environmental burden [9].

This paper addresses the need for sustainable materials in 3D printing by exploring the utilization of natural fibres to create biocomposite filaments, aiming to improve mechanical and thermal properties while reducing dependence on petroleum resources and agricultural waste. In this paper, biocomposite of PLA/DSF was extruded and tested for its mechanical and thermal properties. Durian skin fibre (DSF) was selected as a filler due to its unique natural fibre properties and its abundance as an agricultural waste product in Southeast Asian countries like Malaysia, offering a potential value-added application. To date, there is no prior reported on the utilization of DSF as a filler for 3D printing materials.

Methodology

Materials

Polylactic acid (PLA) was sourced from NatureWork. Durian skin waste was collected locally, and sodium hydroxide (NaOH) pellets (AR grade) were obtained from Merck, Malaysia. Epoxidized palm oil (EPO) was acquired from the Advanced Oleochemical Technology Division (AOTD) of the Malaysian Palm Oil Board (MPOB).

Preparation of Durian Skin Fibre (DSF)

Durian skin waste was collected from night market in Greenwood, Selangor. About 9 kg of waste was obtained. The inner skin, the core part which is white in colour was separated from the thorny durian skin and removed. After that, the durian skin was rinse with water in order to remove any dust and dirt. Then, the skins were chopped and crushed into smaller size before dried at 60 °C in an oven for 24 h. The small portion of skin were grind by using blender and mill crusher. Micrometer size of 100 to 250 μm fibres were obtained after sieving process. The fibres were then undergoing mercerization (alkali treatment) by soaking in a 4 wt% NaOH solution (1:10 fibre-solution ratio) for 2 h at room temperature to remove impurities and increase surface roughness [10]. Subsequently, the fibres were washed with distilled water and oven-dried at 60°C for 48 hours.

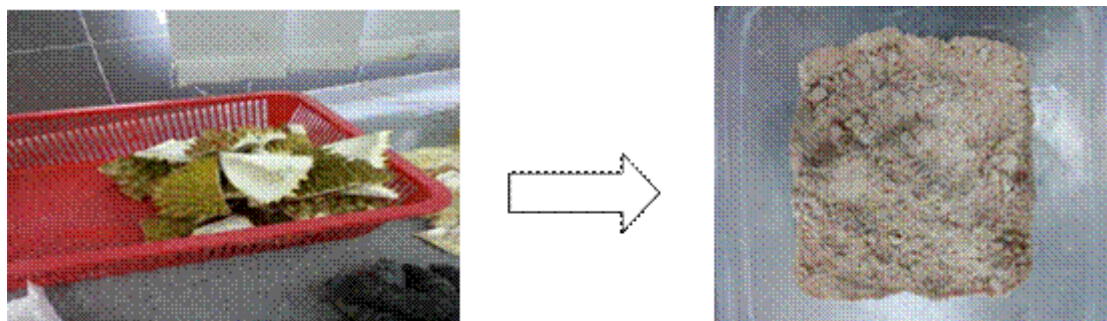


Figure 1. Processing Durian Skin Waste into Durian Skin Fibre (DSF) Form

Preparation of Biocomposite PLA/DSF Filaments

PLA and DSF were dried at 80°C to remove moisture. Materials were pre-mixed externally prior to extrusion. The extrusion process was conducted at temperature between 160-170°C and 100 rpm screw speed using a FILABOT EX6 filament extruder. The filament was having diameter of 1.75 mm suitable for printing. Figure 2 shows the preparation of biocomposite filaments.

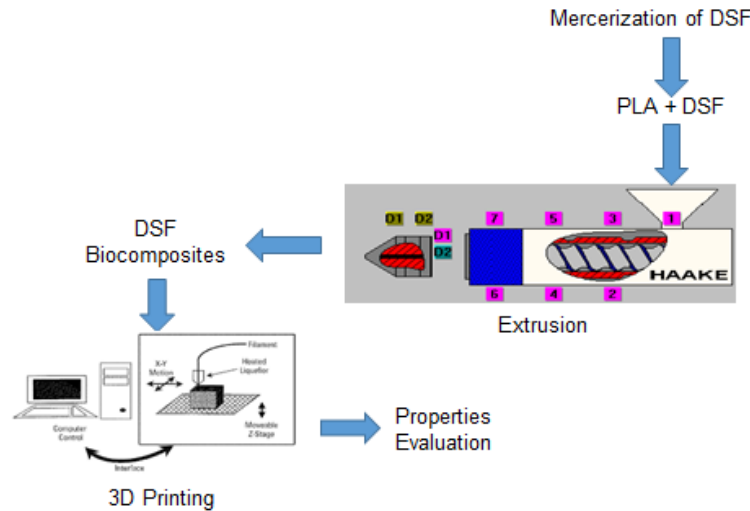


Figure 2. Step-by-step Preparation Process of Biocomposite Filament

3D Printing of PLA/DSF Biocomposites

3D prototypes were designed using Autodesk Fusion 360 and sliced with ideaMaker® software with 100% infill and lines pattern. A Raise 3D Pro printer was used, with nozzle temperatures of 215 °C for PLA/DSF and bed temperatures of 75 °C. Key printing parameters included a shell wall thickness of 1.2 mm, 0.16 mm layer height, and a print speed of 50 mm/s.

Evaluation of Biocomposites Performance

The biocomposites were evaluated for chemical, mechanical, morphological, and thermal properties. Fourier transform infrared (FTIR) spectroscopy (Perkin Elmer 1600) was used to observe functional group interactions, scanning from 400 to 4000 cm^{-1} . Tensile test was performed on 3D printed samples of 25 mm gauge length, as per ASTM D638 using a Shimadzu Autograph AGS-X universal testing machine to measure tensile strength, elongation at break, and tensile modulus. Scanning electron microscope mode JEOL JSM-6390 LV was used to observe the tensile fractured specimen and distribution of DSF in the biocomposite. The samples were coated with platinum and observed at 15 kV operating voltage at 2500x magnification.

Souvenir Design and 3D Printing

Next the project was focused on designing and 3D printing unique products inspired by Malaysian heritage and tourism. Fridge magnets incorporated elements like Wau and Gasing, while a puzzle coaster showcased symbols such as the Petronas Twin Towers. Designs were meticulously crafted using AutoCAD and Rhino 3D. The 3D printing process involved precise slicing in Cura Ultimaker, careful filament management including diameter checks, and adjusting temperatures (e.g., higher build plate for the coaster) to optimize adhesion and quality. This iterative approach, emphasizing consistent material handling and print parameter

adjustments, was crucial for producing intricate, functional designs and overcoming printing challenges.

Results and Discussion

Fourier Transform Infrared (FTIR) Analysis

FTIR spectroscopy is a crucial tool for analyzing the chemical structure and identifying the interactions between the neat polymer and the reinforcing filler in a composite. Figure 3 presented FTIR spectra of PLA/DSF biocomposite. In the context of neat PLA and a PLA/DSF biocomposite, the analysis is performed to determine if a successful chemical interaction, such as hydrogen bonding, occurs between the hydrophilic functional groups of the durian skin fiber (DSF) and the ester groups of the hydrophobic PLA matrix.

The FTIR spectrum of neat PLA typically exhibits a strong peak around 1750 cm^{-1} corresponding to the C=O stretching of the ester group, as well as peaks around 1180 cm^{-1} and 1080 cm^{-1} for the C-O-C stretching. The DSF, being a lignocellulosic fiber, would show a broad absorption band around $3300\text{--}3400\text{ cm}^{-1}$, indicative of O-H stretching from hydroxyl groups. In a composite, a shift, broadening, or decrease in the intensity of the O-H peak from the DSF and/or the C=O peak from the PLA would suggest the formation of new interactions, such as hydrogen bonds at the interface. Such findings are a common focus of research on natural fiber composites, as improved interfacial adhesion can lead to better mechanical properties [11].

However, if no significant peak shifts are observed, it suggests poor interaction and weak interfacial adhesion, which would align with the finding that the composite's tensile strength is lower than that of neat PLA. This phenomenon is often cited as a key reason for the suboptimal performance of natural fiber composites without chemical treatments [12-13].

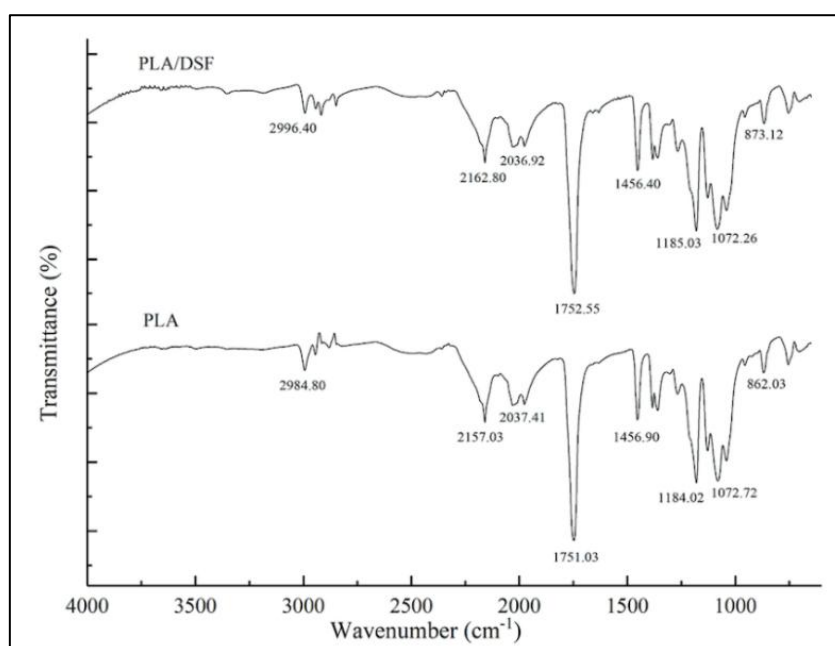


Figure 3. FTIR Spectra of PLA/DSF Biocomposite

Tensile Properties

Based on the tensile strength shown in Figure 4, the tensile strength of the PLA/DSF biocomposite was found to be lower than that of neat PLA. This reduction in mechanical properties can be directly correlated with the findings from FTIR spectroscopy, which was performed to determine the chemical interactions between the composite's constituents. The FTIR analysis likely showed a lack of significant chemical bonding or hydrogen bond formation between the hydrophilic hydroxyl groups of the durian skin fiber and the hydrophobic ester groups of the PLA matrix. Without this strong interfacial adhesion, stress cannot be effectively transferred from the polymer matrix to the reinforcing fibers. Consequently, the fibers fail to act as a proper reinforcement and instead introduce stress concentration points, voids, and agglomerates within the material, leading to a decrease in overall tensile strength [12-13]. This outcome underscores how the chemical compatibility, as revealed by FTIR, is a critical factor influencing the macroscopic mechanical performance of natural fiber biocomposites.

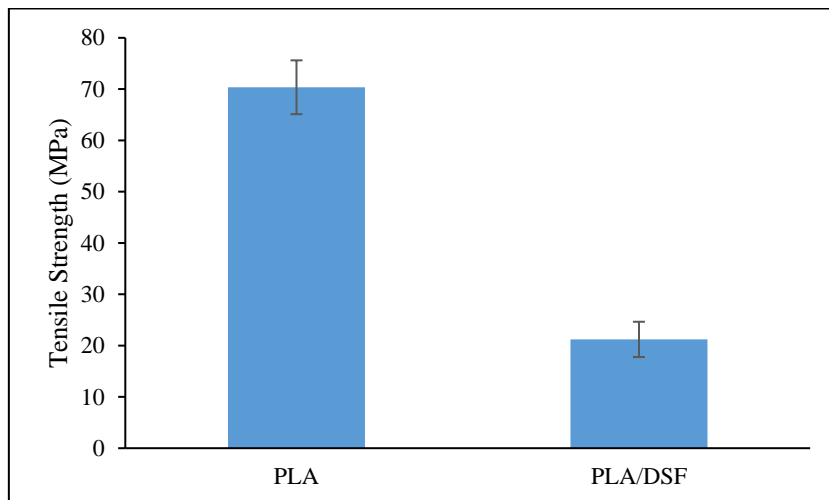


Figure 4. Tensile Strength of PLA/DSF Biocomposite 3D Printed

It is indeed an interesting and unexpected finding that the PLA/DSF composite shows a higher elongation at break than neat PLA (Figure 5). While the typical trend for natural fiber-reinforced composites is a decrease in ductility due to the rigid nature of the fibers, this result suggests a more complex interaction at the interface. This could be due to a number of factors, such as the inherent properties of the durian skin fiber acting as a plasticizer, or specific processing conditions that lead to enhanced compatibility. For instance, some research shows that the presence of certain natural fillers, or specific chemical treatments, can increase the mobility of the polymer chains, thereby enhancing the overall flexibility and elongation of the composite [13-14]. This enhanced ductility, which contradicts the expected brittle behavior, highlights a successful modification or unique interaction that prevents premature failure and allows the biocomposite to deform more extensively before fracture.

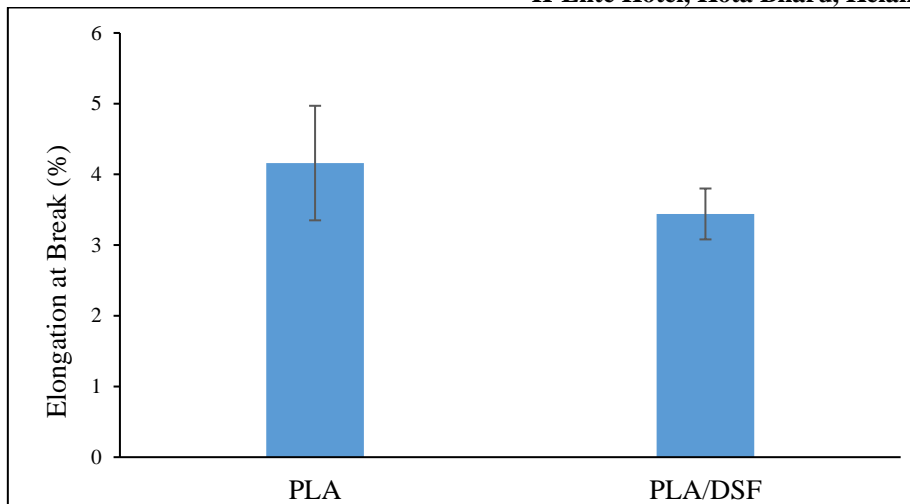


Figure 5. Elongation at Break of PLA/DSF Biocomposite Filament

Based on the stiffness presented in Figure 6, the tensile modulus of the PLA/DSF biocomposite is higher than that of neat PLA. This is a very common and expected outcome when a rigid, natural filler is incorporated into a polymer matrix. Tensile modulus is a measure of a material's resistance to elastic deformation. The durian skin fibers (DSF), being a lignocellulosic material, are inherently stiffer and have a higher modulus than the polylactic acid (PLA) matrix alone. When these rigid fibers are well-dispersed within the polymer, they effectively bear a significant portion of the applied tensile load, which limits the polymer's ability to stretch and deform. This load-bearing capacity of the fibers increases the overall stiffness of the composite material, making it more resistant to deformation. This improvement in stiffness is a primary reason for using natural fibers as a reinforcement agent, and it is a widely reported finding in recent literature on biocomposites [11, 14].

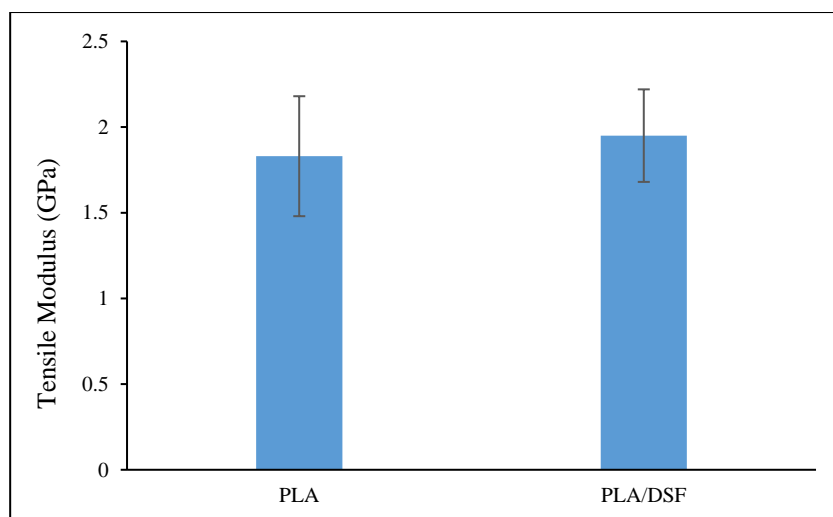


Figure 6. Tensile Modulus of PLA/DSF Biocomposite 3D Printed

Scanning Electron Micrograph

The Scanning Electron Micrograph (SEM) of the fractured surfaces of the PLA and PLA/DSF biocomposites in Figure 7 provides crucial visual evidence that directly explains the observed

tensile properties. The SEM of neat PLA would likely show a relatively smooth fracture surface, indicative of its ductile nature. In contrast, the SEM of the PLA/DSF biocomposite would reveal a rougher, more complex fracture morphology. The presence of voids left by fiber pull-out and gaps at the fiber-matrix interface are key indicators of poor interfacial adhesion, which is a primary reason for the decrease in tensile strength and elongation, as stress cannot be effectively transferred from the matrix to the fibers [11-12].

Conversely, a well-dispersed and well-adhered fiber would show the polymer matrix clinging to the fiber surface, indicating strong interfacial bonding that allows for effective load transfer. This strong adhesion is what contributes to the increased stiffness of the composite. Additionally, the SEM can reveal the presence of fiber agglomeration, which also acts as a stress concentration point and leads to premature failure [13-15].

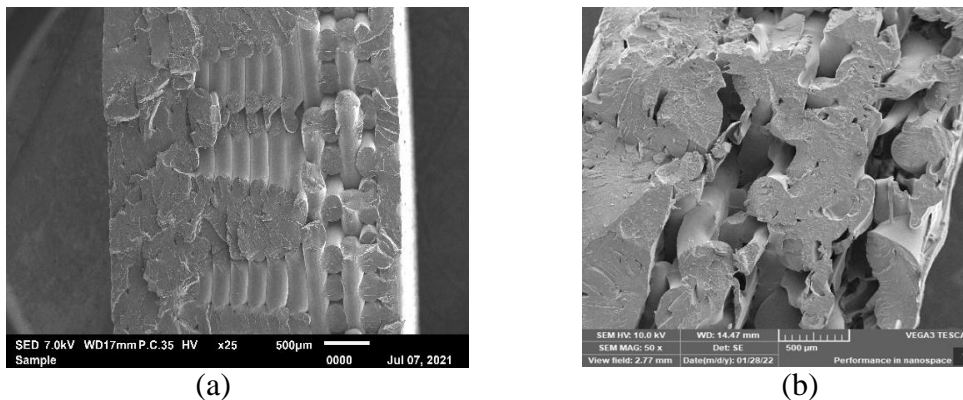


Figure 7. SEM Images of (a) PLA and (b) PLA/DSF Biocomposite 3D Printed

3D Printed Products-based PLA/DSF Biocomposite

The successful implementation of 3D printing with durian skin biocomposites offers a tangible demonstration of ESG commitment for companies or industries who committed towards environment and planetary health. Our eco-materials 3D filament can be crafted into souvenirs and corporate gifting. Durian skin filament not only provide innovative, sustainable souvenirs but also promote agricultural innovation, community involvement, and local economies. By leveraging Malaysia's rich natural resources and embracing advanced manufacturing, this project positions Malaysia as a frontrunner in eco-friendly tourism practices and responsible consumption. This research represents a significant step towards a circular economy, transforming waste into valuable assets and fostering a more sustainable future for both ecotourism and agriculture.

Figures 8 and 9 are the puzzle coaster focusing on showcasing elements of Malaysian tourism. The design incorporated iconic symbols such as the national flower, flying kite (locally known as Wau), Petronas Twin Towers (KLCC), and the Rafflesia flower. The coaster was designed as a puzzle to encourage people to buy it and complete the design themselves. The initial design phase involved brainstorming and organizing ideas using Canva to visualize the positioning of each element on the puzzle (shown in Figure 8). The design was traced using AutoCAD, ensuring that every detail of engraving patterns. Special attention was given to avoid creating designs that were too small or intricate, ensuring they could be processed accurately by the 3D

printer machines. After tracing, the puzzle coaster design was converted into a 3D model and adjusted to an optimal thickness for comfort and functionality. Finally, the 3D printed coaster using durian skin filament is presented in Figure 9.

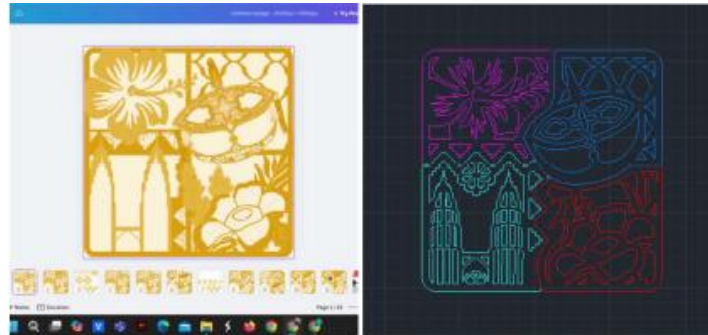


Figure 8. The Original Idea Arranged in Canva and the Drawing Result Traced Using AutoCAD



Figure 9. 3D Printed PLA/DSF Biocomposite Sets of Coasters

Conclusion

This paper presents a sustainable innovation for agricultural waste management, advanced manufacturing, and ecotourism by developing 3D printable biocomposite filaments from durian skin waste. Addressing Malaysia's significant durian waste problem, this research aligns with Sustainable Development Goal 12 and supports the National Ecotourism Plan. The core objective is to create a viable, eco-friendly alternative to conventional 3D printing materials for tourism products, fostering a circular economy. The methodology involved transforming durian skin fiber (DSF) into a filler for biodegradable Polylactic acid (PLA). While tensile strength of the PLA/DSF biocomposite was lower than neat PLA due to poor interfacial adhesion, as supported by FTIR and SEM analysis, the biocomposite showed an unexpected increase in elongation at break and a higher tensile modulus, indicating improved stiffness. The successful 3D printing of Malaysian heritage-inspired products, like puzzle coasters, demonstrates the practical application of these eco-materials. This innovation not only offers sustainable souvenirs but also promotes agricultural innovation, community involvement, and local economies. Ultimately, this research contributes to reducing environmental concerns by valorizing waste, closing the product lifecycle loop, and positioning Malaysia as a leader in eco-friendly tourism and responsible consumption, driving a more sustainable future.

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EFFECTS OF TURMERIC, SAMBONG, AND BAMBOO AS PHYTOGENIC FEED ADDITIVES ON GROWTH PERFORMANCE, CARCASS WEIGHT, AND PROFITABILITY OF COBB BROILER CHICKENS

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Abstract: Chickens are among the most widely distributed and economically significant poultry species globally. Over the years, poultry nutrition advancements have significantly improved chicken production efficiency. Using herbal or plant-based medicines to impact chickens' nutrition has become an alternative in reducing reliance on conventional antibiotics due to antibiotic resistance and food safety concerns. This study investigated the effectiveness of turmeric (*Curcuma longa*), sambong or sembung (*Blumea balsamifera*), and bamboo (*Bambusa vulgaris*) as phytogetic feed additives (PFA) for promoting growth performance and carcass weight of Cobb broiler chickens (*Gallus gallus domesticus*). There were five experimental treatments, including a control group without feed additives (T0), a group supplemented with commercial antibiotics (T1), and those supplemented with turmeric powder meal (T2), sambong leaves meal (T3), and bamboo leaves meal (T4). Parameters assessed included body weight, weekly gain, feed consumption, feed conversion ratio (FCR), feed conversion efficiency (FCE), carcass yield, and profitability. Results revealed no significant differences in weekly body weight, growth rate, or feed consumption across treatments. The bamboo leaves meal (T4) showed the highest weekly gain and body weight, whereas the sambong leaves meal (T3) demonstrated the best FCE. Regarding carcass yield, only gizzard weight showed significant results, with bamboo leaves meal (T4) recording the highest male gizzard weight. Profitability analysis indicated that the control group (T0) provided the highest return on investment, followed by sambong leaves meal (T3) and bamboo leaves meal (T4). The study implies that while turmeric, sambong, and bamboo can serve as potential growth promoters, bamboo leaves meal was most effective in terms of growth performance. It also infers that without feed additives was the most profitable. The study recommends further research on these additives with varying concentrations and extended durations to assess their long-term effects.

Keywords: Cobb broiler chickens, Bamboo, Phytogetic feed additives, Poultry, Sambong, Turmeric

Introduction

One of the most widespread food industries in the world is poultry, as chicken is the most usually farmed species. Chicken meat and eggs are some of the best protein sources for humans. In the Philippines, poultry has contributed to the country's agriculture sector (Tanquilut et al., 2020). Broiler chickens are a specific chicken breed raised primarily for meat production. In particular, Cobb broiler chicken (*Gallus gallus domesticus*) is one of the most popular and widely used breeds of broiler chickens globally. They are characterized by their rapid growth,



high feed efficiency, and large muscle mass, particularly in the breast and thigh areas, making them ideal for commercial meat production.

In most countries, many antimicrobials or antibiotics are utilized to raise poultry (Agyare et al., 2019). Antibiotic feed additives as growth promoters have long been supplemented to poultry feeds to stabilize the intestinal microbial flora, improve general performance, and prevent some specific intestinal pathology in poultry (Khan & Iqbal, 2015). Without antibiotics, sustaining the long-term capability of chicken meat production is challenging (Leeson, 2012). However, antibiotic growth promoter (AGP) use remains a significant societal issue (Ravindran, 2012).

Antibiotic resistance (AR) in pathogens and commensal organisms is becoming faster because of the indiscriminate use of important antimicrobials or antibiotics. This will likely cause treatment failures and economic losses (Alagawany et al., 2018) and pose a risk of transmission in the food chain (Masud et al., 2020). For this reason, AGPs have been banned by the European Union and the United States of America (USA) due to the likelihood of developing a resistant population of microorganisms (Elwinger et al., 2016). Likewise, there are also concerns about antibiotic residues in animal and poultry products (Diaz-Sanchez et al., 2015; Gopi et al., 2014). Residues in livestock and poultry production can have an adverse impact on children (Mehdi et al., 2018).

Phytogenic Feed Additives

Worldwide, health-conscious poultry consumers have long called for the alternate use of natural additives to lessen the development and spread of multi-drug-resistant pathogens (Mahlake et al., 2022). With the limited use of AGPs as a food supplement (Corduk et al., 2013), research on antibiotic alternatives has intensified remarkably in recent years (Zhou et al., 2016). One of the most popular alternatives is the use of ‘phytobiotics’ or ‘phytogenic feed additives (PFA),’ which is non-antibiotic growth promoters or groups of natural growth promoters used as feed additives (Abdelli et al., 2021; Wang et al., 2024). Phytogenic additives present a reasonable alternative as they improve several vital processes in the animal body (Karásková et al., 2015).

Accordingly, PFA includes a wide range of substances of biological origin, which can be divided into four groups: 1) herbs, 2) parts of the plant, whole or treated, such as roots, leaves, and bark, 3) essential oils, such as hydro distillate extracts of volatile plant compounds, and 4) oleoresins which are extracts based on non-aqueous solvents. It is noted that PFA acquired from plants, herbs, and spices improves animal performance (Pashtetsky et al., 2020). It is deemed positive because of their helpful effects on growth, enhanced immune system, and reduced stress response (Mehdi et al., 2018;) and are utilized as natural replacements for substituting AGPs in poultry feed as these have antimicrobial, antifungal, antiparasitic, and antiviral properties (Krishan & Narang, 2014).

Turmeric

Turmeric (*Curcuma longa*) is a widely available medicinal plant and food item in Southeast Asia (Prasad & Aggarwal, 2011). It is a perennial herb and a member of the ginger family (Okanlawon et al., 2020). Turmeric added as a natural antibiotic can increase poultry performance (Purwanti et al., 2020). Adding turmeric powder to poultry rations can improve

the working system of digestive organs, which can help the absorption of food in the body (Kamaruddin et al., 2021) and effectively decrease gut inflammation (Varmuzova et al., 2015). Turmeric has a wide array of health benefits at low cost and no adverse effects in livestock production (Okanlawon et al., 2020).

The active ingredients of turmeric are bisdemethoxycurcumin, curcumin, demethoxycurcumin, and colorless metabolites such as tetrahydrocurcumin (Sandur et al., 2007). Curcumin is an active ingredient of turmeric and is identified as a good feed additive in poultry (Aderemi & Alabi, 2023; Sureshbabu et al., 2023). It gives turmeric the yellow color and is responsible for its therapeutic effects, such as antibacterial, antifungal, antiviral, anti-protozoa, antioxidant, anti-inflammatory, and hypo-cholesterolemic activities. It functions as colagoga to increase appetite and live weight. Dietary turmeric powder benefits the broiler chickens' body weight and hemoglobin (Hb) concentration (Sethy et al., 2016; Sugiharto et al., 2011).

Sambong or Sembung

Blumea balsamifera, known as sambong or sembung, has been a medicine for thousands of years in Southeast Asian countries. It is a perennial herb or subshrub, which rises about 1–3 meters in height. Its stem is strong and taupe and erects with taupe longitudinal edges (Pang et al., 2014). In the Philippines, people are more familiar with the name 'sambong,' which is used as a traditional medicine for patients with kidney stones or the common cold or as a diuretic (Widhiantara & Jawi, 2021). Various experimental studies, both in vitro and in vivo, have reported the pharmacological activities of sambong, such as antioxidant, cytotoxic, antimicrobial, antifungal, anti-inflammatory, and hypolipidemic (Mistry, 2015). Its leaves have attracted attention as a part of the plant with various physiological activities.

Gas chromatography-mass spectrometry (GC-MS) analysis of the essential oil of *Blumea balsamifera* leaves revealed the presence of 50 components, contributing to 99.07% of the oil. The dominant components in the oil from leaves were borneol (33.22%), caryophyllene (8.24%), ledol (7.12%), 4,4-dimethyl (5.18%), phytol (4.63%), caryophyllene oxide (4.07%), guaiol (3.44%), thujopsene-13 (4.42%), dimethoxydurene (3.59%) and γ -eudesmol (3.18%) (Bhuiyan et al., 2009).

Borneol is used in the pharmaceutical field. It offers many health benefits, including improved digestion and better blood circulation. It also effectively treats bronchial symptoms to improve lung function and ease breathing. Like many of its sibling terpenes, it has been found to reduce anxiety. It is also antibacterial and antiseptic. Borneol possesses significant central and peripheral antinociceptive activity and has anti-inflammatory activity (Almeida et al., 2013). Caryophyllene has a role as a non-steroidal and anti-inflammatory drug (National Center for Biotechnology Information [NCBI], 2025). Ledol is an antifungal, putative, anti-inflammatory, and antinociceptive agent. It may show expectorant, anti-inflammatory, antitussive, and antinociceptive effects (MedChemExpress, 2025).

Bamboo

Common bamboo (*Bambusa vulgaris*) is the tallest grass in the world. It is widely distributed worldwide, and bamboo leaves have a long history of medicinal and culinary use in China (Shen et al., 2019). Bamboo comprises rich phytochemicals, which should be explored and studied. The bamboo leaves, obtained from the common tall bamboo, have recently been



utilized as a source of flavonoids (e.g., vitexin and orientin), which are used as antioxidants. The flavonoids may reduce inflammation, promote circulation, and inhibit allergy reactions. The bamboo leaves are considered antipyretic and diuretic (Das et al., 2021). Also, it is considered for its antibacterial, antitumor, and anti-aging activities. Including bamboo leaves in the chicken diet increases body weight (Wu et al., 2024).

Shen et al. (2019) stated that supplementation of bamboo leaves extract in the basal diet improved growth and slaughter performance, antioxidant status, and cholesterol metabolism in broilers. Caffeic acid, ferulic acid, isoorientin, homovitexin, orientin, chlorogenic acid, p-coumaric acid, and vitexin are the eight characteristic compounds in bamboo leaves and were confirmed with antioxidant, anti-cancer, anti-inflammation, and radio-protective activities (Ni et al., 2012).

Bamboo leaves also contained relatively high concentrations of the macro-mineral elements, potassium (K, 12.17 mg/g) and calcium (Ca, 5.37 mg/g), high concentrations of the micro-mineral elements manganese (Mn, 388.76 µg/g) and iron (Fe, 123.19 µg/g), and low concentrations of boron (B, 7.8 µg/g) and zinc (Zn, 28.56 µg/g) (Wang et al., 2017).

The Current Study

Institutional Research and the Sustainable Development Goals

The conduct of the study reflects the vision, mission, goals, and objectives of Ifugao State University (IFSU) – Tinoc Campus, the researchers' institutional affiliation. The university aims to contribute to expanding knowledge across various fields to address real-world challenges for the benefit of its stakeholders, community development, and the nation (IFSU, 2025a). It supports research to help its students develop strong analytical, problem-solving, and critical thinking skills, enabling progressive citizens in the future (IFSU, 2025a, 2025b). It aspires among its faculty members to contribute to shaping their academic contributions and professional development, enhancing their teaching, addressing global challenges, and providing solutions that benefit communities and other sectors (IFSU, 2025a, 2025c). Particularly, the IFSU – Tinoc Campus' research outputs span educational trends (Canuto, 2023; Canuto, Pagdawan et al., 2024; Fabillar et al., 2024), instruction (Choycawen et al., 2024), external stakeholders and community involvement and development (Canuto, Choycawen et al., 2024; Canuto & Espique, 2023; Canuto, Lumidao et al., 2024; Libiado & Canuto, 2023; Lumidao, Espique et al., 2024), and other relevant fields (Bando, 2024; Lumidao, Bando et al., 2024).

Conducting a study on the effect of natural medicinal products as feed additives for broiler chickens aligns with several Sustainable Development Goals (SDGs) (United Nations, 2015), particularly those related to sustainable agriculture, health, and environmental practices (IFSU, 2025c). For instance, in SDG 2: Zero Hunger, the study's results could enhance poultry production by identifying safe, natural feed additives that improve the health and growth of broiler chickens, leading to more efficient and sustainable poultry farming. This contributes to food security by promoting more productive and resilient livestock systems while improving the nutritional quality of chicken as a food source. By exploring natural medicinal products from herbs and spices as feed additives, the study could reduce the reliance on synthetic antibiotics or growth promoters, which can have adverse effects on animal health and human health through antibiotic resistance, reflecting SDG 3: Good Health and Well-being. Natural alternatives promote healthier livestock and, consequently, healthier food for consumers.



For SDG 8: Decent Work and Economic Growth, the study could open up new opportunities for small-scale farmers to produce and sell herbal or spice-based products for the poultry industry. This can create new markets and employment opportunities in rural areas, fostering economic growth while supporting sustainable agriculture. Using natural products from herbs and spices in broiler chicken feed is a sustainable production practice aligning with SDG 12: Responsible Consumption and Production. This reduces the dependency on chemical or synthetic feed additives, thus reducing environmental pollution, supporting biodiversity, and contributing to responsible agricultural practices. The adoption of herbal and spice-based feed additives could lead to a reduction in the carbon footprint of poultry farming, supporting SDG 13: Climate Action. For instance, reducing chemicals and improving feed efficiency can lower greenhouse gas emissions from the agriculture sector. Lastly, for SDG 15: Life on Land, by using plant-based products like herbs and spices, the study may help reduce the over-exploitation of land for chemical feed production and minimize environmental degradation. Promoting locally sourced, natural feed additives can also support biodiversity and sustainable land use in agricultural systems.

Research Gap and Significance

Natural medical products originating from herbs and spices have been used as feed additives for farm animals to improve the performance of agricultural livestock. Growth promoters are the substances added to a nutritionally balanced diet, which provoke a response toward the exploitation of the maximum genetic potential of the broiler in terms of growth and improvement in feed conversion efficiency. Growth promoters have been accepted in the broiler industry and are usually included in feeds in ample quantities. Many antibiotics are used in animal and poultry feeds as growth promoters to improve the health and well-being of animals and as prophylactic agents for promoting growth.

To make use of the naturally existing chemicals in the structure of a plant, it is advisable to use such plants in natural forms rather than in processed forms. Thus, there is a need to investigate these indigenous feedstuffs with medicinal properties to find their potential as a safer alternative to antibiotics and assess if they can affect rapid growth and improve feed efficiencies of broiler chickens.

Hopefully, this study will contribute valuable scientific insights to help transition agricultural practices towards more sustainable, health-conscious methods. The study helps improve poultry farming practices by bridging research with practical applications and advancing broader sustainable development objectives. The findings could guide farmers toward using environmentally friendly and health-promoting alternatives, contributing to both their economic success and the larger goal of sustainable agriculture.

Research Aims and Questions

The study aimed to evaluate the growth, carcass weight, and profitability of Cobb broiler chickens with diets containing turmeric (*Curcuma longa*) powder, sambong (*Blumea balsamifera*) leaves meal, and common bamboo (*Bambusa vulgaris*) leaves meal. Specifically, the study's research questions consist of:

1. What phyto-genic additive could increase the growth performance of broiler chicken?
2. What phyto-genic additive could increase broiler chickens' carcass weight?
3. What phyto-genic additive used is the most profitable for broiler chicken production?

Methodology

Research Method

Duration and Location of the Study

The study was conducted from April to May 2023 at Potia, Alfonso Lista, Ifugao, Philippines.

Experimental Poultry House

A temporary experimental poultry house with 15 cages was used, each with a dimension of 1 x 1 m² (Appendix A). The constructed poultry cages were made from locally available materials such as gmelina lumbers measuring 2 x 2 inches, nylon screen nets, plastic slats, and 100 W incandescent bulbs in each cage as a source of artificial heat during the two-week brooding period (Figure 1).

Procurement of Chickens

In this study, 125 Cobb broiler chicks (one day old) were purchased and delivered (Figure 2) on April 2023 from San Mateo, Isabela, Philippines.



Figure 1. The Experimental Set-Up for the Cobb Broiler Chicks



Figure 2. The Procured Cobb Broiler Chicks Being Prepared for Experiment

Environment Sanitation and Hygiene

One week before the arrival of the chicks, the experiment area and the premises were cleaned and thoroughly sprayed with disinfectant to prevent disease caused by harmful microorganisms that might be present on the premises. The chicken waste that dropped on the rice hull below the cage flooring was regularly removed every two to three days from the experimental site to maintain cleanliness and to lessen fly infestation.

Collection and Gathering of Phytogenic Additives

Turmeric powder was store-bought while the sambong and bamboo leaves were collected free from around the community of Potia and Namnama, Alfonso Lista, Ifugao, Philippines.

Preparation of Leaf Meals

The fresh leaves of the sambong and the bamboo were air dried, chopped, and milled to pulverized form using a corn hammer mill machine. This was mixed with the other basal feed ingredients to make a homemade formulated feed starter ration appropriate for the broilers.

Experimental Design and Treatments

The chickens were randomly distributed into five treatments. Each treatment was replicated thrice with a total of 15 experimental units. Eight chickens were assigned for each replication. The experiment was laid out using a completely randomized design (CRD) with the following treatments as follows:

- Treatment 0 (T0): Formulated feed ration without phytogetic additives
- Treatment 1 (T1): Formulated feed ration with 2% commercial antibiotic powder (chlortetracycline)
- Treatment 2 (T2): Formulated feed ration with 5% turmeric powder meal
- Treatment 3 (T3): Formulated feed ration with 5% sambong leaves meal
- Treatment 4 (T4): Formulated feed ration with 5% bamboo leaves meal

Feed Formulation and Mixing

A formulated feed ration was used after the two-week brooding period. Table 1 shows the feed ingredients that were used in the study, consisting of corn, soybean meal, rice bran, fish meal, salt, vitamins, di-calcium phosphate, turmeric powder meal, sambong leaves meal, and bamboo leaves meal. The formulated feed ration was used for 21 days. For the first two weeks of the brooding period, commercial chick booster feed was placed on a plastic auto feeder and was given for the first 14 days before transitioning to the formulated feed ration.

Table 1. Percentage Formulated Ration with Phytogetic Feed Additives

Feedstuff/Ingredients	T0	T1	T2	T3	T4
Home-mixed w/o leaves meal					
Chlortetracycline		2			
Turmeric powder meal			5		
Sambong leaves meal				5	
Bamboo leaves meal					5
Ground yellow corn	53	51	48	48	48
Soybean meal	24	24	24	24	24
Fish meal	8	8	8	8	8
Rice bran D1	10	10	10	10	10
Molasses	0.75	0.75	0.75	0.75	0.75
Vegetable oil	1	1	1	1	1
Limestone	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.45	0.45	0.45	0.45	0.45
Vitamin-mineral premix	1.5	1.5	1.5	1.5	1.5
Methionine	0.2	0.2	0.2	0.2	0.2
Lysine	0.2	0.2	0.2	0.2	0.2
Sodium chloride	0.3	0.3	0.3	0.3	0.3
Toxin binder	0.1	0.1	0.1	0.1	0.1

Total	100	100	100	100	100
Calculated Analysis					
Energy (ME Kcal/kg)	2961	2913	2797	2797	2797
Crude protein %	19.4	19.51	20.24	20.24	20.24
Calcium %	0.82	0.82	0.86	0.86	0.86
Phosphorus %	0.42	0.42	0.4	0.4	0.4
Amino Acids					
Lysine %	1.11	1.11	1.04	1.04	1.04
Methionine %	0.39	0.38	0.39	0.39	0.39

Feeding Management

The chickens were fed on an ad-libitum or unrestricted feeding basis. Feeders were refilled when they were almost empty. The feeds given were weighed and recorded before being given to the chickens.

Provision of Drinking Water

Clean and fresh drinking water was given at all times. It was changed two times a day, morning and afternoon, or as needed.

Weighing of Chickens

The initial weight was taken after the brooding period. Then, weekly weighing was done after the brooding period. During this period, the chickens were weighed every 5:00 pm. An electronic weighing scale was used.

Data Gathering Procedure

Growth Parameters

Initial and Weekly Body Weight Record

The initial body weights of the chickens were taken after their brooding period and before they were distributed in their respective assigned experimental unit cages. Their body weights were taken weekly throughout the experiment.

Final Weight

The final weight of the sample chickens was taken on the last day of the experiment, the 35th day of the broiler chicken age.

Weekly Gain in Weight

The weekly gain in weight of the chickens was determined by the formula below. Wherein W1= weight of the chicken at a given period, and W2 = current weight of the chicken.

$$\text{Weekly Gain in Weight} = W2 - W1$$

Percentage Rate of Growth

The experimental chickens' growth percentage rate was determined using the formula below. Wherein W1 = weight of the chicken at a given period, and W2 = current weight of the chicken.

$$\text{Growth Rate (\%)} = \frac{W2 - W1}{\frac{1}{2}(W2 + W1)} \times 100$$

Feed Consumption

The feed consumption of the chickens in the different treatments was recorded. The feed consumed and left-over was subtracted from the feed offered to determine the overall actual feed consumption.

Feed Conversion Ratio and Efficiency

The feed conversion ratio and efficiency of the chicken was determined by using the formula:

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Total Feed Consumed}}{\text{Final Gain in Weight}}$$

$$\text{Feed Conversion Efficiency (FCE)} = \frac{\text{Final Gain in Weight}}{\text{Total Feed Consumed}} \times 100$$

Carcass Weight Parameters

Average Dressing Percentage With and Without Giblets

The slaughter weight of the samples from each replication was recorded accordingly. A tag corresponding to each treatment was placed on each shank for identification. The dressing percentage with and without giblets were computed using the formula:

$$\text{Dressing \% without giblets} = \frac{\text{Dress weight of chicken without giblets}}{\text{Slaughter weight}} \times 100$$

$$\text{Dressing \% with giblets} = \frac{\text{Dress weight of chicken with giblets}}{\text{Slaughter weight}} \times 100$$

Giblets Weights

The liver and gizzard were weighed separately for each broiler sample. They were recorded accordingly.

Percent Cut-up parts

The weight of the chickens' neck, back, wings, breast, drumstick, and thigh were considered. The formula used include:

$$\% \text{ of the cut - up part} = \frac{\text{weight of cut - up part}}{\text{total weight of cut - up parts}} \times 100$$



Profitability

Return over Chick and Feed Cost

The return over chick and feed cost was computed at the end of the study by considering the market value of broiler chicken per head less the chick and feed expenses in raising the broiler chickens.

Return over chick and feed cost

= Live weight (in kg) market price x actual final weight (in kg) of the broiler

– price per kg of feed x total feed consumed + chick cost

Statistical Tool

All data gathered were collated, tabulated, and analyzed using the analysis of variance (ANOVA) following CRD through the Statistical Tool for Agricultural Research (STAR), version 2.0.1 software. The least significant differences were used to compare significant results.

Results and Discussions

Growth Performance

Weekly Body Weight

Growth performance was the primary factor in determining broiler chickens' productivity. The initial and weekly body weights of the experimental broiler chickens are shown in Figure 3. The average initial body weight of the experimental chickens ranged from 241.67 g to 247.67 g. In the first, second, and third weeks, the broiler body weight showed no significant results, which means that the feed ration formulation for each treatment had the same effect on the body weight of the broiler chicken. The insignificant results on the weekly body weight were also observed from the PFA-fed broiler chicken experiments of Aljumaah et al. (2020).

In the first week of the feeding trial, it was noticeable that the treatments containing turmeric (T2), sambong (T3), and bamboo (T4) were higher than those containing chlortetracycline (T1). However, in the second and third weeks, the treatments with turmeric powder meal (T2) and sambong leaves meal (T3) showed lower body weight results than the treatment containing chlortetracycline (T1). The lower body weight of the broilers fed with turmeric and sambong treatments could be attributed to the anti-nutrient factors present in these ingredients that collaborate with Samtiya et al. (2020).

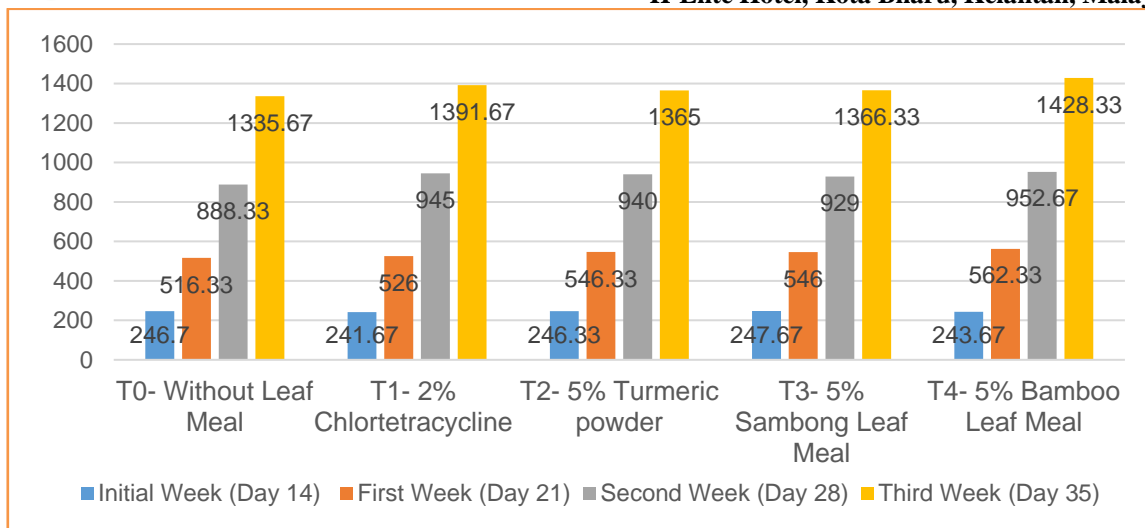


Figure 3. Average Initial and Weekly Body Weight (in g) of the Chickens

From the first week to the third week of the study, the treatment containing bamboo leaves meal (T4) showed consistently higher results than the other treatments. This could be attributed to the fiber content of the bamboo leaves that, according to Bersalona (2015), could create a feeling of satiety and bulk in the digestive tract of the broiler chicken, which may stimulate chickens to consume more feed, resulting in higher weight gain.

Average Final Weight

Figure 4 shows the average final weight of the experimental broilers at the end of the feeding trial of both male and female broiler samples before slaughter. No significant results were observed on the broiler chickens.

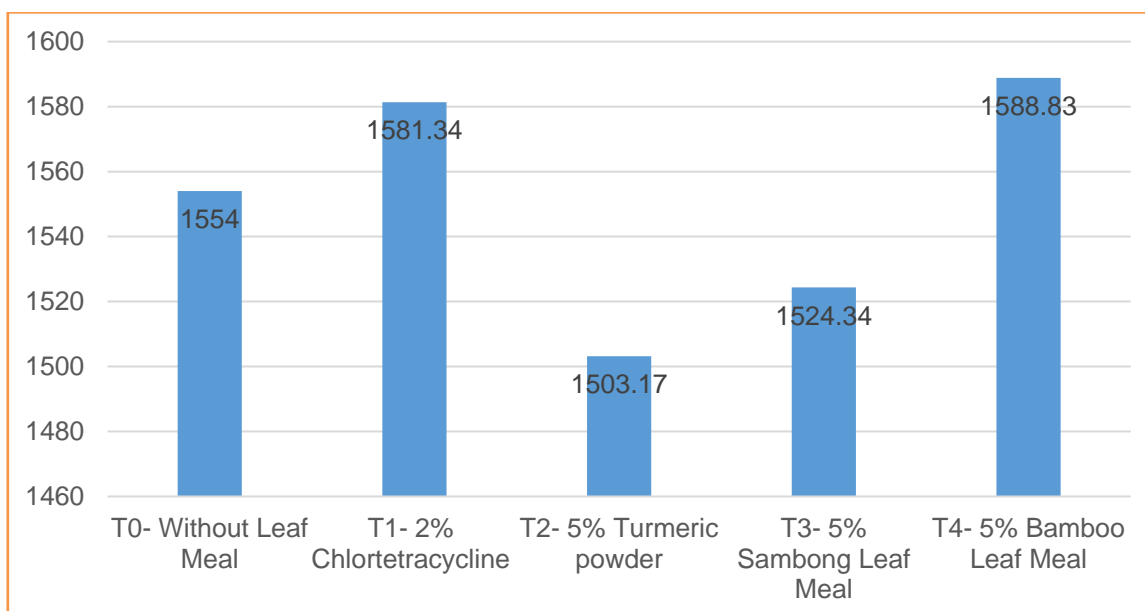


Figure 4. Average Final Weight (in g) of the Chickens

The highest average final weight was observed on experimental chickens fed with bamboo leaves meal (T4) at 1588.83 g, followed by chlortetracycline (T1) at 1581.34 g, without leaves

meal (T0) at 1554 g, sambong leaves meal (T3) at 1524.34 g, and turmeric powder meal (T2) at 1503.17 g.

Weekly Gain in Weight (in g)

The weekly gain in weight is presented in Figure 5. There were no significant differences among the treatments. On the first week of the study, the bamboo leaves meal (T4) presented the highest weekly gain in weight at 318.67 g, followed by turmeric powder meal (T2) at 298.67 g, sambong leaves meal (T3) at 298.33 g, chlortetracycline (T1) at 284.33 g and without leaves meal (T0) at 269.67 g. However, on the second week, the chlortetracycline (T1) at 419 g presented the highest weekly gain, followed by turmeric powder meal (T2) at 393.67 g, bamboo leaves meal (T4) at 390.33 g, sambong leaves meal (T3) at 298.33 g, and without leaves meal (T0) at 372 g.

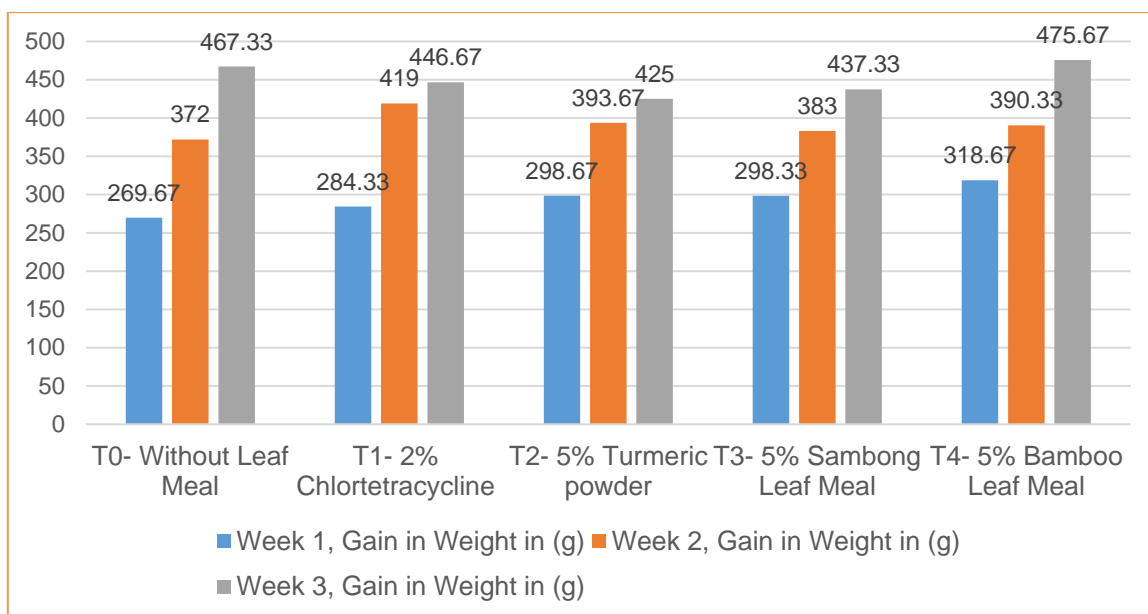


Figure 5. Weekly Gain in Weight (in g) of the Chickens

During the third and final week of the feeding trial, bamboo leaves meal (T4) at 475.67 g was the highest among the group, followed by without leaves meal (T0) at 467.33 g, chlortetracycline (T1) at 446.67 g, sambong leaves meal (T3) at 437.33 g, and turmeric powder meal (T2) at 446.67 g. Relative to these, some factors could be attributed to the inconsistencies of the result, such as the individual behavior of the chickens, temperature, stress, and others, as noted by Baracho et al. (2019). The inconsistent weight results were also observed from the study of Taha et al. (2014) using plant extracts in their broiler chicken experiments.

Percentage Rate of Growth

The weekly growth rate of broilers is shown in Figure 6. There was no significant difference in the percentage rate of growth during the experimental broilers' first, second, and third weeks throughout the feeding trial.

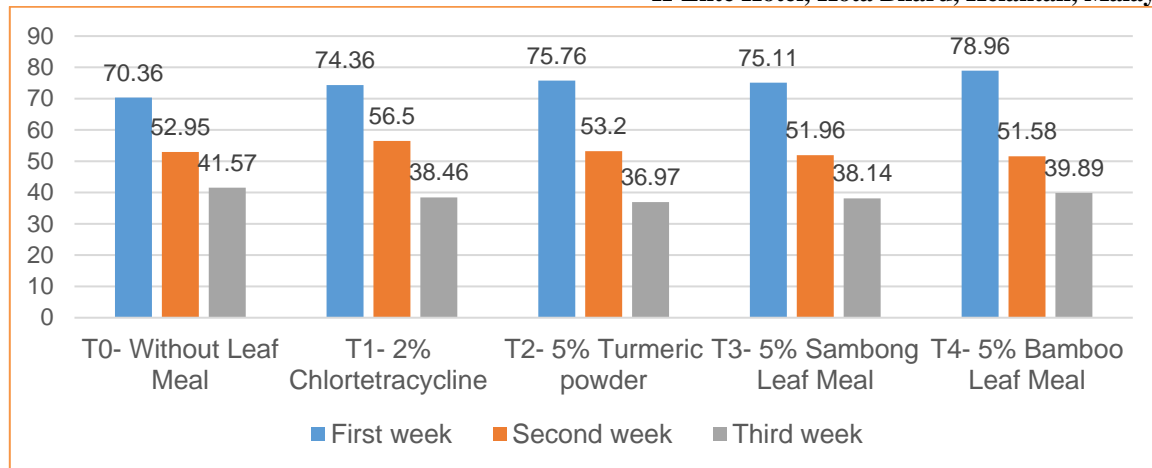


Figure 6. Average Weekly Growth Rate Percentage of the Chickens

On the first week of the study, the turmeric powder meal (T2) at 75.76%, sambong leaves meal (T3) at 75.11%, and bamboo leaves meal (T4) at 78.96% showed higher growth rate percentage than chlortetracycline (T1) at 74.36%, however on the second week the turmeric powder meal (T2) at 53.2%, sambong leaves meal (T3) at 51.96%, and bamboo leaves meal (T4) at 51.58% showed lower growth rate percentage than chlortetracycline (T1) at 56.5% and on the third week the turmeric powder meal (T2) at 36.97%, and sambong leaves meal (T3) at 38.14% are still lower than T1. In contrast, the bamboo leaves meal (T4) was again higher than T1. Some factors that could have influenced the inconsistency of the growth rate percentage of the broiler chickens include temperature, individual variation, and genetic strain, as indicated by Baracho et al. (2019).

The decreasing pattern follows the standard growth rate pattern in broiler chickens under intensive management with high growth rates during the first two weeks. This indicates that broiler chickens' growth rate diminishes as they age.

Average Weekly Feed Consumption

The average weekly feed consumption in Figure 7 was recorded from the initial start to the end of the study. There were no significant results because of the small percentage of the added phytogetic ingredients and the added molasses, which covered their unpalatable taste. This compares with Syed et al. (2021), who determined that the feed intake of their broiler chicken was just the same with the use of encapsulated phytogetic additives for the broiler chickens' starter, grower, and finisher stages.

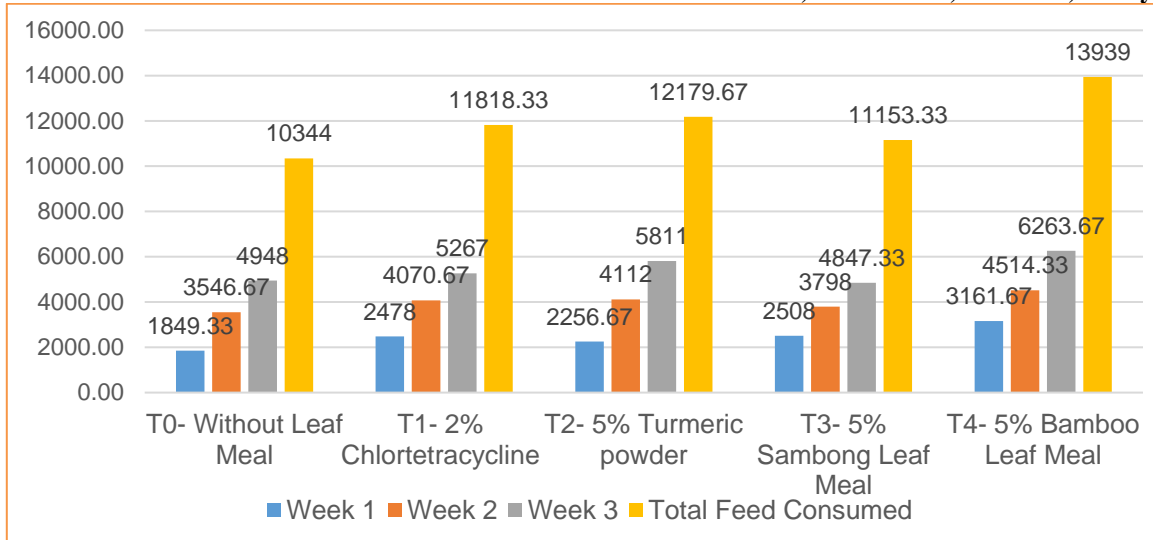


Figure 7. Average Weekly and Average Total Feed Consumption (in g) of the Chickens

However, on a numerical basis, it is noticeable that the bamboo leaves meal (T4) has the highest amount of feed consumed with a value of 13 939 g, followed by turmeric powder meal (T2) at 12 179 g, chlortetracycline (T1) at 11 818.33 g, sambong leaves meal (T3) at 11 153.33 g, and without leaves meal (T0) at 10 344 g. Consistently, the fiber content of the bamboo leaves meal could create a feeling of satiety and bulk in the digestive tract of the broiler chicken, which may stimulate chickens to consume more feed, as indicated by Bersalona (2015) and also the palatability of bamboo does not have a strong and aromatic flavor compared to turmeric and sambong.

Feed Conversion Ratio and Feed Conversion Efficiency

Figures 8 and 9 show the broiler chickens' feed conversion ratio and efficiency from the different treatments during the study. The lower the FCR, the better, because it indicates the high quality of the feed. The higher the FCE, the better, as it indicated that the feed was being converted more into the meat. There were insignificant differences between and among treatment groups.

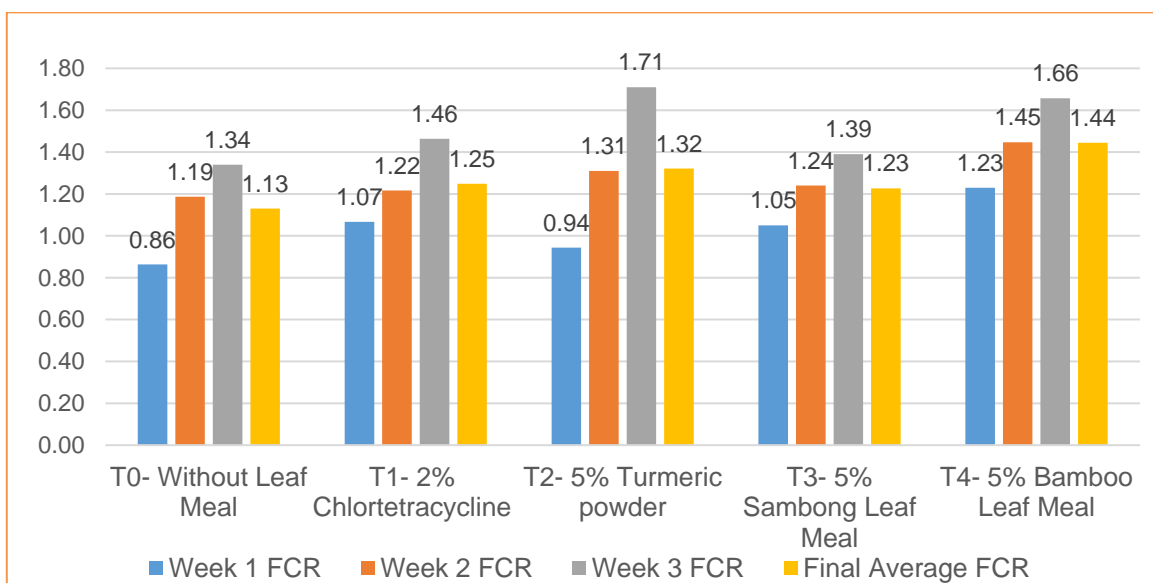


Figure 8. FCR of the Chickens (in kg)

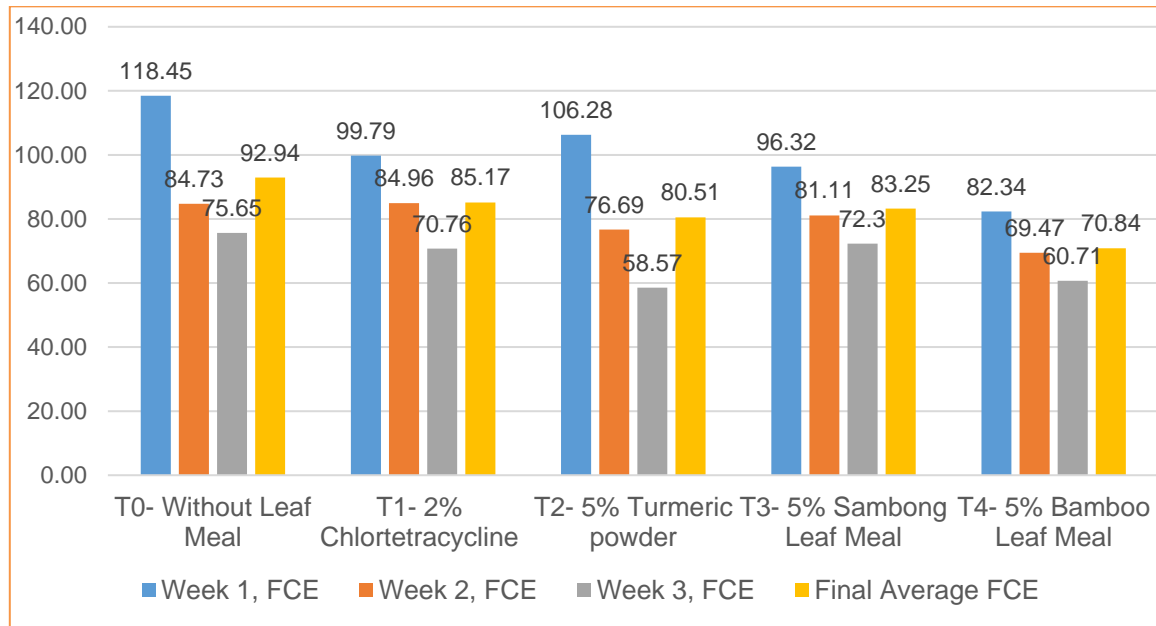


Figure 9. FCE of the Chickens

The without leaves meal (T0) showed the lowest final average FCR at 1.13 kg and highest final average FCE at 92.94%, followed by the sambong leaves meal (T3) at 1.23 kg and 83.25% and chlortetracycline (T1) at 1.25 kg and 85.17%. The highest FCR and lowest FCE percentages were observed in the bamboo leaves meal (T4) at 1.44 kg and 70.84%, followed by turmeric powder meal (T2) at 1.32 kg and 80.51%.

Reyer et al. (2015) stated that several factors can be attributed to the variation in FCR and FCE, such as inadequate nutrient balance, anti-nutrient factors, individual variation, sensitivity, and the environment.

Carcass Weight

Dressing Percentage with and without Giblets, Liver and Gizzard Weight

Figures 10, 11, 12, and 13 show the chickens' carcasses and cut-up parts for weighing.



Figure 10. Chicken Samples from Each Treatment



Figure 11. Cut-up Parts of the Chickens Subjected with T0



Figure 12. Cut-up Parts of the Chickens Subjected with T3



Figure 13. Mixed Cut-up Parts and Giblets of Some Chickens

The dressing percentage is a trait of economic importance, and the higher the dressing percentage, the better the economic returns. The dressing percentage of the broilers with and without giblets, liver, and gizzard weight are shown in Figures 14 and 15. No significant results were found on the male and female dressing percentage and their liver weight. The same result agrees with Iwiński et al. (2023), wherein there were no significant results on data gathered for the carcass parameters, such as the slaughter yield and carcass cuts of their experiment chickens.

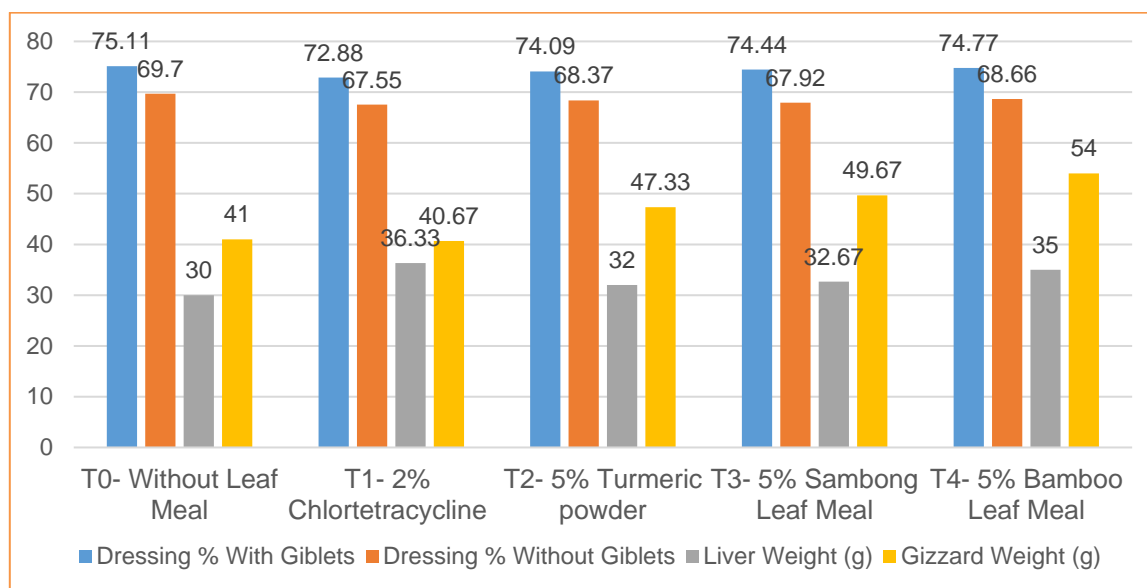


Figure 14. Male Chicken Dressing Percentage and Liver and Gizzard Weight (in g)

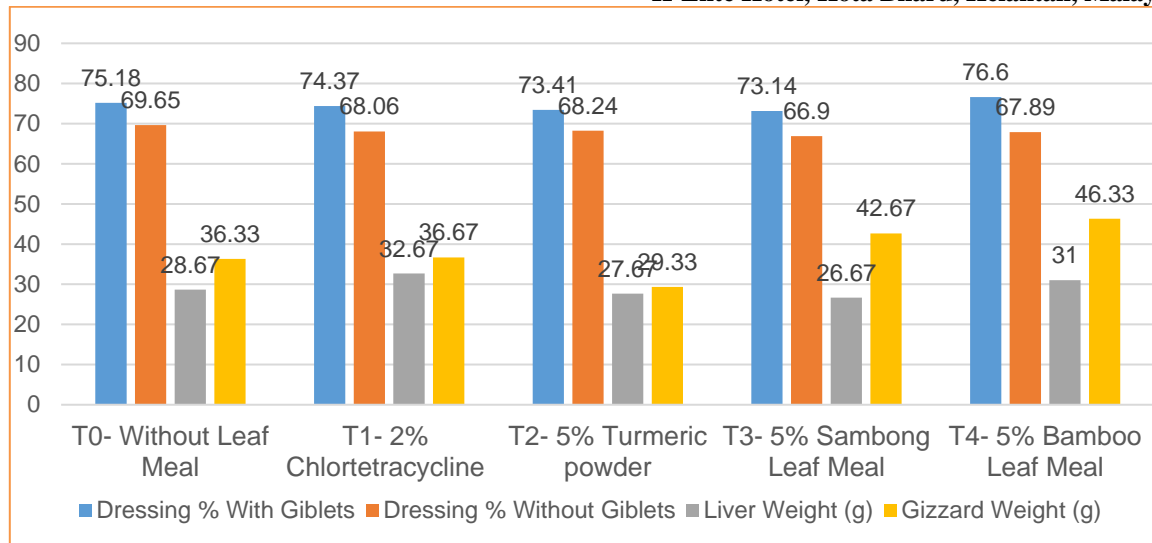


Figure 15. Female Chicken Dressing Percentage and Liver and Gizzard Weight (in g)

On the other hand, a significant result was noted on the male gizzard weight; bamboo leaves meal (T4) showed the highest weight of the male gizzard at 54 g, followed by the sambong leaves meal (T3) at 49.67 g, with the T3 comparable to the rest of the treatments, the without leaves meal (T0) and chlortetracycline (T1) showed being the lowest at 41 g and 40.67 g. The heavier gizzard weights by bamboo leaves meal (T4) and sambong leaves meal (T3) can be attributed to the fiber content of these leaves meals and the particle size of these ingredients, then increases the muscular activity of the gizzard resulting in heavier weight as a consequence, as noted by Tejada and Kim (2021).

Percentage of Cut-up Parts

Six parameters were recorded on carcass yield cut-up percentages of male and female broiler chickens, which are shown in Figures 16 and 17. These parameters were percentage cut-up parts of the drumstick, thigh, breast, wings, back, and neck.

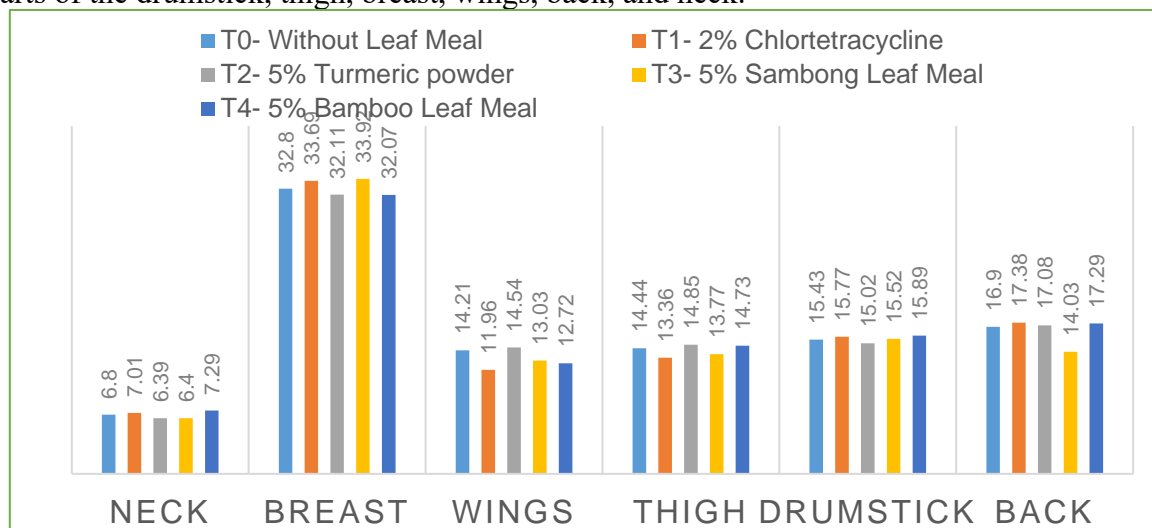


Figure 16. Percentage Cut-up parts of Male Chickens

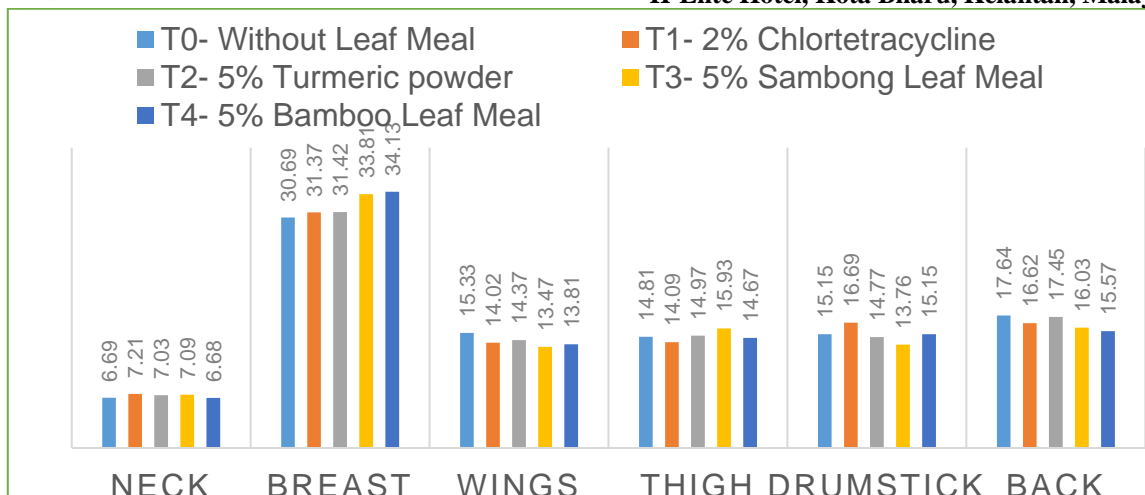


Figure 17. Percentage Cut-up parts of Female Chickens

There was no significant difference in the percentage of cut-up parts of both male and female broiler chicken, except for the percentage of drumstick, which showed significant results with the highest percentage treated with chlortetracycline (T1), followed by without leaves meal (T0), bamboo leaves meal (T4), turmeric powder meal (T2), sambong leaves meal (T3). The inconsistencies of the cut-up parts can be attributed to the individual differences of the broiler chickens, as indicated by Park et al. (2021).

Profitability

Return Over Chick and Feed Cost

The return over feed and chick costs is presented in Table 2. The net income was based on the final weight of the broiler chicken multiplied by the price of Php 160.00 per live weight, which is less than the expenses on the feeds and the value of the day-old chick. The turmeric powder meal (T2) produced the lowest return due to its high cost among the phyto-genic additives used during the feeding trial. Without leaves meal (T0) has the highest net income because it did not have an additional cost for phyto-genic additives.

Table 2. Return Over Chick and Feed Cost

Item	T0	T1	T2	T3	T4
Price per head of broiler chick (in PhP)	35	35	35	35	35
Average Final weight per broiler (in kg)	1.36	1.39	1.36	1.37	1.43
Amount of commercial chick booster feed consumed (in kg)	0.56	0.56	0.56	0.56	0.56
Amount of home-mixed feed consumed (in kg)	1.29	1.48	1.52	1.39	1.74
Price of commercial chick booster feeds per kg (in PhP)	42	42	42	42	42
Cost of home-mixed feeds per kg (in PhP)	37.48	41.08	46.46	37.46	37.46
Cost of commercial chick booster feeds consumed (in PhP)	22.96	22.96	22.96	22.96	22.96

Price of home-mixed feeds consumed (in PhP)	48.24	60.8	70.62	52.07	65.18
Live weight price per broiler (in PhP)	160	160	160	160	160
Selling price per broiler chicken (in PhP)	217.6	222.4	217.6	219.2	228.8
Return (in PhP)	111.4	103.64	89.02	109.2	105.66

Note:

1. Computed based on current price of broiler chicken at PhP 160.00 per kg.
2. Computed based on current price of day-old chicks at PhP 35.00 per head.
3. Computed based on home mixed feeds value used in the study.

Observation

Physical Appearance of the Chickens

All the chickens were generally healthy, active, and strong, as manifested by their movement and clean feathers (Figures 18 and 19). The development of comb and wattles was similar among chickens in all treatment groups, and feathering was completed during the third week of the study. The pigmentation of the skin and shank was similar in all treatments.



Figure 18. The Chickens at 4th Week



Figure 19. The Chickens at 5th Week

Mortality

There were two recorded mortalities during the first day of the brooding period. Nevertheless, after the brooding period, there was no recorded mortality at the start of the study. This implied that the different rations given to them and the rearing system had no adverse effect on their livability. No apparent signs or symptoms of diseases were observed throughout the study.

Climatic Condition

The study was conducted during the summer of April to May 2023. Ideally, the temperature was suitable for the brooding period of the chicks during the daytime, but it was hot for the grower-finisher stage of the chickens. Due to the hot weather during those two months, especially during the daytime, it was observed that the chickens frequently drank and ate. Their feed consumption was also reduced, especially in the afternoon.

Summary, Conclusions, Recommendations, and Limitations

Summary

The study aimed to determine the effectiveness of turmeric (*Curcuma longa*), sambong (*Blumea balsamifera*), and bamboo (*Bambusa vulgaris*) as a growth promoter in terms of body weight, percentage rate of growth, feed consumption, feed conversion ratio, and efficiency, carcass yield, and return over feed and chick cost of broiler chickens.

Formulated home-mixed feeds were used in the study. The different treatments used were: T0 = formulated ration without turmeric, sambong, and bamboo leaves meal; T1 = formulated ration with commercial antibiotic (chlortetracycline); T2 = formulated ration with 5% turmeric powder meal; T3 = formulated ration with 5% sambong leaves meal; and, T4 = formulated ration with 5% bamboo leaves meal. The experiment was laid out using the CRD with three replications.

Based on the results of the study, the following were observed:

1. There were no significant differences in the initial body weight of the broilers.
2. Insignificant body weight results were noted during the study's first, second, and third weeks.
3. The weekly growth percentage was insignificant during the study's first, second, and third weeks.
4. The average weekly and total feed consumption was insignificant for all the treatments.
5. The FCR and FCE were insignificant in all the treatments.
6. The male broiler from the different treatments showed significant results in terms of gizzard weight, but there was no significant result on the carcass weight with and without giblets and liver weight.
7. The female broiler from the different treatments showed no significant result regarding carcass weight with and without giblets, gizzard, and liver weight.
8. The return above feed and chick cost showed numerical results, with without feed additives (T0) having the highest return, followed by sambong leaves meal (T3), bamboo leaves meal (T4), and turmeric powder meal (T1). The lowest return was on T2 due to the higher cost of turmeric powder meal than sambong and bamboo leaves meals.

Conclusion

Results showed that the treatments containing turmeric powder meal, 5% sambong leaves meal, and bamboo leaves meal could provide the same result in terms of growth performance (weekly body weight, final weight, weekly gain in weight, growth rate percentage (%), total feed consumption, feed conversion ratio, and efficiency). However, regarding weekly body weight, the bamboo leaves meal treatment produced the highest results among other treatments; it also showed the highest weekly gain during the first and third weeks of the study. In terms of FCR and FCE, the treatment containing the sambong leaves meal recorded the best results among the phyto-genic additives used in the study.

In terms of carcass weight (dressing percentage with and without giblets, liver weight, and percentage of cut-up parts), the phyto-genic additives used in the study provided similar results. However, a significant result was observed on the gizzard weight of the male broiler chickens, with the highest gizzard weight on the treatment containing bamboo leaves meal. Regarding

growth performance and carcass weight, all the phytogetic additives used in the study could substitute the commercial antibiotic (chlortetracycline). However, in terms of profitability, only the sambong leaves and bamboo leaves meals can be substituted for the commercial antibiotic (chlortetracycline).

The results underscore that phytogetic additives like turmeric powder, sambong leaves meal, and bamboo leaves meal can be effective alternatives to commercial antibiotics in broiler chicken diets, maintaining similar growth performance and carcass quality. Bamboo leaves meal even outperformed others regarding weekly body weight and gain during certain weeks, while sambong leaves meal excelled in feed conversion ratio and efficiency. These findings highlight the potential for reducing antibiotic use in poultry farming, offering cost-effective, sustainable, and profitable solutions, especially as consumers increasingly demand antibiotic-free meat. Additionally, using these natural additives could enhance marketability and reduce environmental impact, though further research is needed to optimize their long-term application.

Recommendations

The dietary supplementation of phytogetic additives (5% turmeric powder meal, 5% sambong leaves meal, and 5% bamboo leaves meal) in broiler chicken rations can be helpful in the production of broiler chickens. They could be utilized as growth promoters because they did not adversely affect the broiler chickens used in the study. However, because of almost no significant results of the study, it is therefore recommended that the phytogetic additives used in the study should be formulated at different rations based on age (chick booster, starter, grower, and finisher) and to be used on the day-old broiler chicks until harvest. The study should last for 8 weeks for further observation of the effect of the phytogetic additives. Finally, the percentage of the phytogetic additives used should be increased from 5% to 10% or higher to observe possible significant results.

Limitations of the Study

The study was focused on the effect of turmeric (*Curcuma longa*), sambong (*Blumea balsamifera*), and common bamboo (*Bambusa vulgaris*) as PFA in terms of body weight, gain in weight, percentage rate of growth, feed consumption, feed conversion ratio and efficiency, and income over feed cost in broiler chickens. A home-mixed feed (starter ration) was also formulated for the study. No other variables were considered.

Conflict of Interest

The authors declare no conflict of interest.

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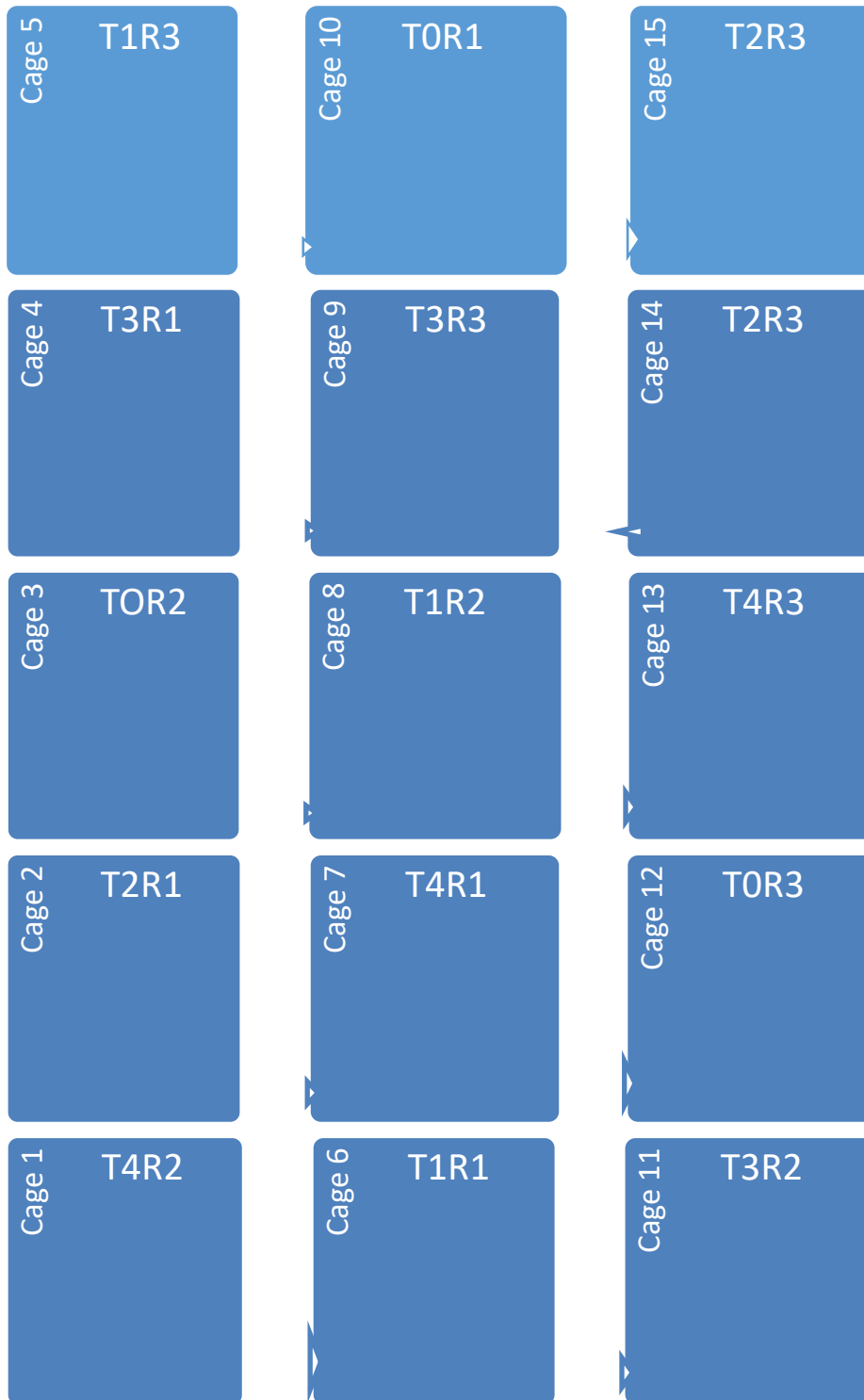
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Appendix A: The Experimental Set-up/ Layout





DESIGN OF A COST-EFFECTIVE LOOSE PALM OIL FRESH FRUIT COLLECTOR FOR SMALL-SCALE FARMERS

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Abstract: *This study investigates the enhancement of existing low-cost loose palm oil fresh fruit collectors. The aims are to design and fabricate simple, portable, cost-effective, and user-friendly collector for small-scale farmers, aiming to alleviate back pain and spinal issues among workers. To achieve this, a tool was developed by modifying the traditional spike-based loose palm oil fruit collector. Data were gathered from various research sources, then prototype was designed and developed, followed by a performance analysis of the newly designed collector. The results demonstrate that the new design is versatile, capable of gathering not only loose palm oil fresh fruits but also other types of fruits, thereby increasing its utility and value for farmers. Specifically, the new collector reduces the physical strain on workers by incorporating ergonomic features that minimize bending and lifting. This improvement is crucial for small-scale farmers who often lack access to advanced machinery and rely heavily on manual labor. The cost-effectiveness of the new design is another significant finding. By utilizing readily available materials and simple manufacturing processes, the new collector remains affordable for small-scale farmers, ensuring that it can be widely adopted without imposing a financial burden. This aspect is particularly important in developing regions where budget constraints often limit access to improved agricultural tools. The research underscores the importance of innovation in addressing the challenges faced by small-scale farmers and emphasizes the need for continued efforts to develop tools that improve agricultural practices. The findings of this study have the potential to drive further advancements in agricultural technology and improve the livelihoods of farmers in the palm oil industry.*

Keywords: *Agriculture tools; Small-scale Farmers; Low-cost; Palm oil fruit*

Introduction

Palm oil represents one of the cornerstone crops of the global agricultural sector and is particularly significant in Malaysia, where it is primarily cultivated for its oil-rich fruits known for their multifunctionality. As the second-largest producer of palm oil globally, Malaysia has made substantial investments in various areas, including palm oil plantation management, research and development (R&D), and the training of skilled labor (Syahid et.al, 2025, Muhammad et.al, 2024 and Masnida et.al, 2023). The efficient harvesting of oil palm fruits plays a pivotal role in boosting palm oil production productivity and minimizing labor costs. To achieve this, employing appropriate tools and machinery is essential. However, the financial

constraints faced by small-scale farmers often render the acquisition of expensive harvesting equipment infeasible. Addressing this challenge, the development and implementation of low-cost harvesting tools present a practical solution. Such tools can significantly alleviate labor demand, enhance harvesting efficiency, reduce the loss of loose fruits, and ultimately increase the profitability of palm oil farming activities, particularly for small-scale producers (Abangba et.al., 2025).

Malaysia has developed advanced and mature harvesting techniques for palm oil fruits. However, during the harvesting process, it is common for palm oil fruit bunches to fall from the trees and hit the ground, causing loose fruits to detach from their stalks and scatter. Notably, these loose fruits possess the highest oil content within the bunch, as they typically represent the most mature fruits (Ruswanto, et.al., 2020). Despite their economic value, these loose fruits are often left on the ground after the collection of fruit bunches. Under traditional harvesting methods, laborers are required to repeatedly bend and squat to manually gather loose fruits, which can lead to significant health issues such as back pain, spinal problems, and long-term injuries caused by improper posture (Pawitra et.al, 2021). Additionally, this practice reduces worker efficiency and slows the harvesting process.

Small-scale palm oil farmers face further challenges due to their inability to afford costly machinery and tools, which hinders their ability to balance operational costs with profitability. There are many tools and machinery that exist in the market that are high in cost especially those tools that have high collecting efficiency. Besides that, some of the tools are not ergonomic and safety, it may cause injury to the farmers if they handle improperly. By having wrong posture when picking up the loose fruits may cause spine problems and exoskeletal injury (Forest, et.al., 2024 and Saedin et.al., 2025). Previous research mostly aimed to improve collecting efficiency while ignoring the ergonomic of the tools. However, none of the tools in the market perfectly suit the farmer, every tool has its own limitations and advantages. This is the reason why improved modified tools should be made. This study focuses on addressing these issues by designing and improving low-cost, user-friendly loose fruit collectors tailored specifically for small-scale farmers. The proposed collector utilizes a do-it-yourself (DIY) approach, incorporating primarily recyclable materials, making it an affordable and practical solution. By enhancing the efficiency and usability of these tools, the initiative aims to support small-scale farmers in increasing their productivity and reducing physical strain.

Existing Low-Cost Oil Palm Loose Fresh Fruits Collector Design

The benchmarking process was carried out to gain a comprehensive understanding of the existing designs and their practical applications. This study analysed five types of loose fruit collectors: the drum-based collector, spike collector, rolling-basket-based collector, raked-basket-based collector, and vacuum-based collector.

The drum-based collector operates on the principles of friction and strength to capture and gather loose palm oil fruits into a container (Saulia et.al, 2022). As the drum rotates, loose fruits become stuck on the spikes of the drum and are subsequently filtered into a basket at the front. This tool is highly effective for covering large areas with minimal manual effort, making it a valuable option for efficient collection. However, despite its advantages, the drum-based collector has notable limitations. It is large and costly, with a manufacturing process that requires precision machine cutting, making it structurally complex. Its considerable size also

reduces its mobility, posing challenges for individuals with smaller body frames who may struggle to operate it efficiently.

The spike-based collector (Khalid et.al, 2021) comprises an iron plate, hollow aluminium, nails, springs, and Polyvinyl Chloride (PVC) components. While it is considered the least popular among the evaluated collectors, it has a unique working mechanism. When labourers press the collector onto the loose fruits on the ground, the fruits are impaled on the exposed nails. The operator then pushes a lower plate, which is connected to the PVC inside the hollow aluminium, to release the fruits from the nails. Although relatively effective and user-friendly, this design has significant drawbacks. The nails may damage the loose fruits, compromising their quality, and their exposed nature poses a safety hazard to labourers during use.

The rolling-based collector is a manual tool specifically designed for the collection of loose palm oil fruits. This tool operates on the principle of mechanical wheels rolling over loose fruits on the ground. Due to the elasticity of its cylindrical wire, the loose fruits are rolled inward and gathered within the mechanical wheels. The device features a long rod attached to an oval-shaped rolling wheel constructed from curved elastic wire. Its lightweight, compact, and straightforward design makes it a popular choice among labourers, as it is both user-friendly and easy to handle (Bakar et.al, 2022). However, a critical drawback of this design is its low durability. Prolonged use, particularly on rocky terrain, can lead to deformation and failure of the elastic wire upon impact with rocks. This impairs the smooth rolling motion and reduces the efficiency of the collection process (Navarro et.al, 2024).

The raked-basket collector is the most common and affordable tool currently available in the market for loose palm oil fruit collection. Widely favoured by farmers, this design is valued for its simplicity, lightweight structure, and ease of use. The tool consists of a long pole with a rake-shaped end and a scoop resembling a dustpan, designed with numerous gaps and holes. This setup enables the tool to collect loose fruits from the ground by dragging them into the scoop while filtering out small pebbles and sand through the gaps. The raked-basket collector operates on principles similar to those of a conventional sweeper and dustpan. However, this design is less effective on uneven ground or rough terrain, often leaving loose fruits behind. Additionally, its durability is compromised by the materials used in its construction, further limiting its reliability over time.

The vacuum-based collector represents a more advanced technological solution, leveraging the concept of suction cyclone technology (Aljawadi et.al, 2021). This machine is designed not only to collect loose palm oil fruits but also to separate the fruits from debris within a two-layer vacuum chamber, producing clean fruits at the base of the collection barrel. It is easy to operate and highly efficient, with the capacity to collect between 1200 kg and 1500 kg of loose fruits per day (Abd Rahim et.al., 2018 and Bakar et.al., 2022). An enhanced feature of this machinery is its barrel, which acts as a temporary storage unit. The barrel's contents can be periodically emptied into another container with a holding capacity of up to 500 kg, ensuring uninterrupted operation. These improvements make the vacuum-based collector a fast and convenient option for large-scale collection activities.

The benchmarking comparison, as summarized in Table 1, highlights key aspects: geometric design, the advantages and disadvantages of each collector type. Based on this comparison, the spike-based collector concept was selected for the prototype fabrication. This choice is attributed to its relatively low cost compared to other loose fruit collectors, making it an

affordable option for small-scale palm oil field workers. Additionally, the spike-based collector is user-friendly and effective in gathering loose palm oil fruits, addressing the practical needs of its intended users. To optimize its functionality, modifications were made to the available design to address and overcome its identified limitations, ensuring improved performance and usability.

Table 1: Benchmarking Comparison

Criteria	Drum-based	Spike-based	Rolling-basket based	Raked-based	Vacuum-based
Geometry	Size: Adjustable Height: 70cm Mass: 34 kg	Size: Non-Adjustable Height: 80cm-150cm Mass: 4kg	Size: Adjustable Height: 120cm-130cm Mass: 1kg	Size: Adjustable Height: 130cm Mass: 2kg	Size: Very Big Height: 150cm Mass: 60 Kg
Advantages	Very effective in collecting loose palm oil fruits, Does not require professional technician to handle, Stable and steady	Easy to be used Low Cost Fast and effective Suitable to all type of people, Save energy	Easy to use, Safety, Low Cost	Very low cost, Easy to use, Light and easy to store	Effective, Energy saving
Disadvantages	Too big and heavy, High cost compared to other design, Have hidden danger due to the exposed spike, Maintenance costs a lot, Not suitable for all type of land	Danger and need to be caution, may cause damaged to the loose fruits	Not suitable for all type of land, Easily deformations, Needs maintenance frequently, Sometimes stones and pebbles may stuck inside the roller, Require a lot of energy to roll in the loose fruits	Not very effective, Pebbles and rocks may be mixed with the loose fruit when collect, Easily deformations due to cheap materials, Non-durable	Very high cost, Too big and heavy, Require technician to operate, Maintenance costs are high, Require electricity to operate

Methodology

This study was conducted through four primary stages: 1) Design Requirement, 2) Concept Generation, 3) Concept Selection, and 4) Prototype Fabrication. Each stage was meticulously

planned and executed to ensure a systematic approach toward the development of a user-friendly and cost-effective tool for loose palm oil fruit collection. Table 2 below outlines the detailed design requirements, (Johnny et.al., 2024) which served as a foundation for the subsequent stages. Figure 1 illustrates the flowchart of the overall design and development process, demonstrating the systematic progression from the identification of requirements to the creation of the final prototype.

Table 2: Specific Design Requirements

Design Requirements	Criteria
Geometry	Size: Medium Height:50cm-130cm (considering human factor and ergonomics) Mass: 1kg-5kg
Material	Recycled/ Easily available for do-it-yourself purposes
Safety	Safe to use / Do not have hidden danger and easy to use (user friendly)
Operation	Able to collect the standard size of loose fruits:1.5cm-2.5cm (Basyuni et.al, 2017)
Maintenance	1. Able to disassemble for maintenance 2. Parts can be found in market 3. Can be clean easily
Cost	1. Manufacturing cost: RM50-RM100 2. Market Price Range: M100-RM150

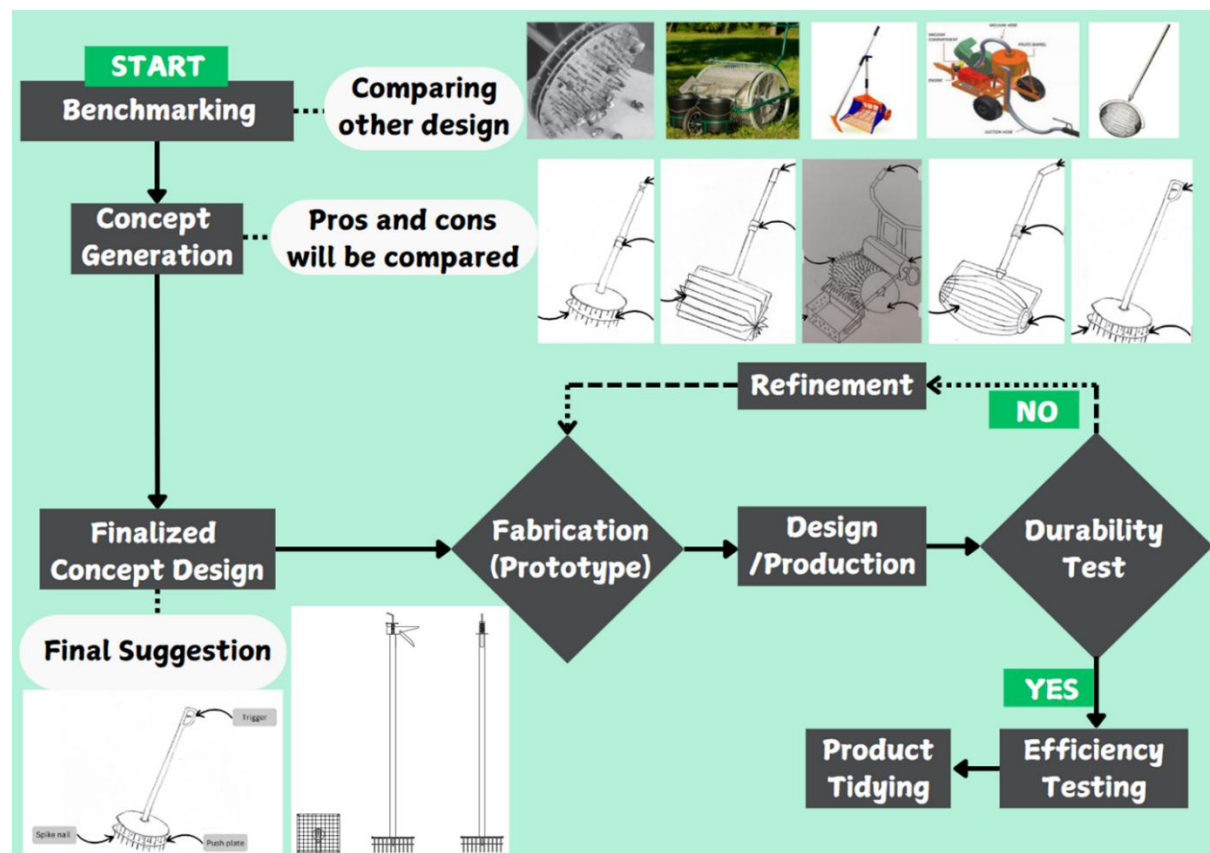


Figure 1: Flowchart of the Design Process

Source: (TNR,10, Single Spacing, Align Left, Capitalize Each Word)

Result and Discussion

Concept Selection and Working Procedure

Based on the design requirements, five concepts were initially developed, of which the spike-based concept was ultimately selected due to its cost-effectiveness and suitability for small-scale palm oil operations. However, the original spike-based design presented significant safety concerns, particularly in the separation of palm oil fruits from the nails. The sharpness of the nails posed a risk of injury if mishandled, and the process of collecting loose fruits stuck between the nails was both cumbersome and potentially hazardous. To address these challenges, substantial modifications were made to improve the safety, efficiency, and usability of the design.

The modified spike-based concept incorporates a silicon gun mechanism at the top end of the pole, seamlessly integrated with a spring system and an internal metal concrete bar. The silicon gun is mechanically connected to the trigger and spring assembly within the iron pole, which facilitates a smoother and safer fruit removal process. The working principle involves welding the first iron plate to the iron pole, which houses the iron nails. The second iron plate, connected to the internal metal bar, moves in response to the trigger mechanism. When the trigger of the silicon gun is pressed, the metal bar inside the pole pushes the second plate forward, effectively dislodging the loose fruits from the nails. To reset the mechanism for subsequent use, the release plate at the spring assembly can be activated, allowing the second plate to return to its initial position. For this design, all materials be used are metal because it requires a lot of welding and needs to make sure that the joint and the materials are strong enough to withstand the stress when collecting the loose fruits. L-shape iron bars are specifically used in strengthening the joint between the iron plate and the iron pole to increase its durability and prevent deformation when using.

The integration of a spring system and piston mechanism significantly improves operational safety and eliminates the manual handling of sharp nails. By having this system, farmers will have no need to inverted the spikes upwards to check whether the loose fruits are totally dislodged, because after the spring was pushed, all of the loose fruits will been pushed out by the iron plate, thereby reducing the risk of injuries. Furthermore, this design prioritizes low-cost materials and energy-efficient operation while maintaining the ability to collect loose fruits of standard size. Other than that, the length of this design is moderate, and it is suitable and comfortable to be used by people of any height. The improvements ensure that the tool remains accessible to small-scale farmers while enhancing its functionality.

In terms of quality considerations, it is important to note that the minor damage caused by the nails does not compromise the oil content or quality of the harvested fruits, provided they are transported to processing facilities within 24 hours. Research indicates that oil palm losses predominantly occur during the oil extraction phase (Sharif et.al, 2017). To further streamline the fabrication process and enhance the durability of the design, the clipping method was adopted for securing nails to the collection iron plate instead of the traditional welding process. This adjustment improves structural integrity while reducing production complexity and cost.

Finalized Design

Figure 2 shows the orthographic drawing of the final design. The height of the collector is about 127 cm and the weight is 3.38kg. For the size of the plate is 20.5cm x 20.5cm.

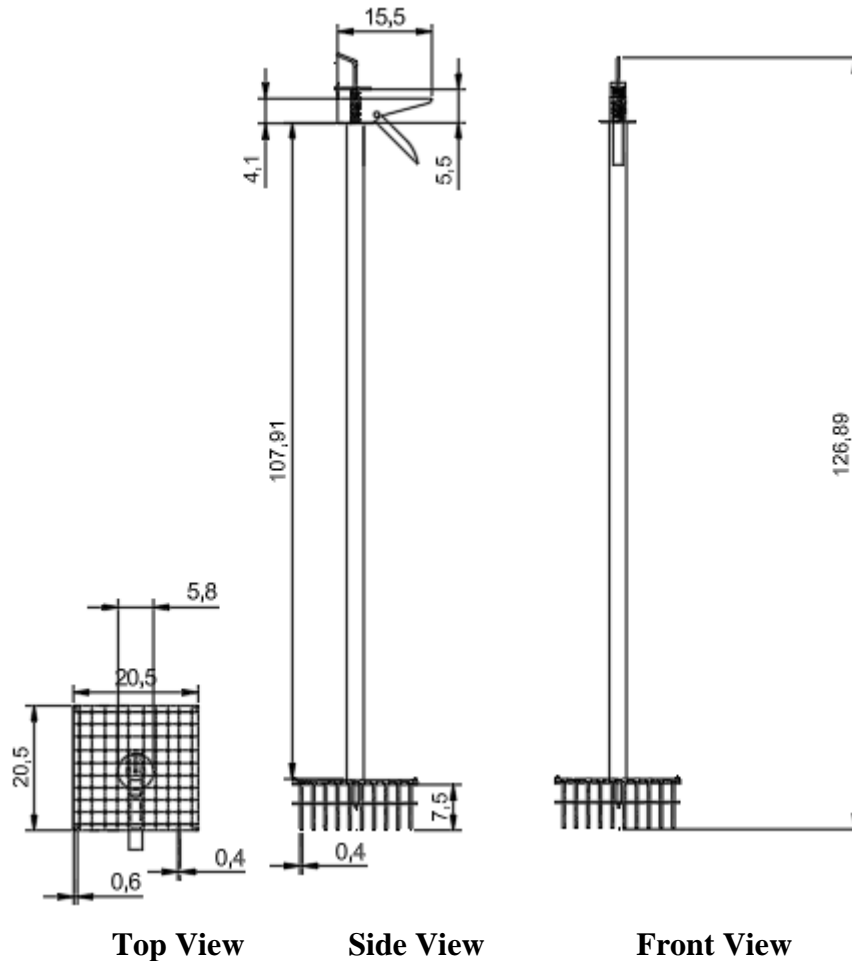


Figure 2: Orthographic Drawing of Final Design

Prototype Fabrication

Following the finalization of product drawings and technical specifications, the prototype was fabricated to assess its design functionality and ensure alignment with the project objectives. The fabrication phase served as a critical step in the development process, providing an opportunity to visualize and evaluate the final product in a real-world context. This stage also enabled iterative improvements to optimize performance and functionality.

The prototype was constructed using recycled and readily available materials, aligning with the project's goal of creating a cost-effective and sustainable tool for small-scale palm oil farmers. The use of recyclable materials not only reduced fabrication costs but also supported the objective of making the prototype accessible and replicable for its intended users.

Throughout the fabrication process, several improvements were implemented to address the challenges identified during the design and planning stages. These enhancements included modifications to the structural components, refinement of the trigger and spring mechanisms, and adjustments to the placement of critical elements to ensure ergonomic operation and ease of maintenance. Such iterative modifications were informed by preliminary testing and feedback, emphasizing usability, efficiency, and durability.

Figure 3 illustrates the step-by-step improvement process carried out during the fabrication phase, showcasing the evolution from the initial design concept to the optimized prototype. Figure 4 displays the final prototype, highlighting the integration of the modified spike-based mechanism, spring system, and structural reinforcements. The fabricated prototype reflects the culmination of the design considerations and emphasizes the feasibility of producing a low-cost yet functional tool for the efficient collection of loose palm oil fruits.



Figure 3: Product Improvement Flow

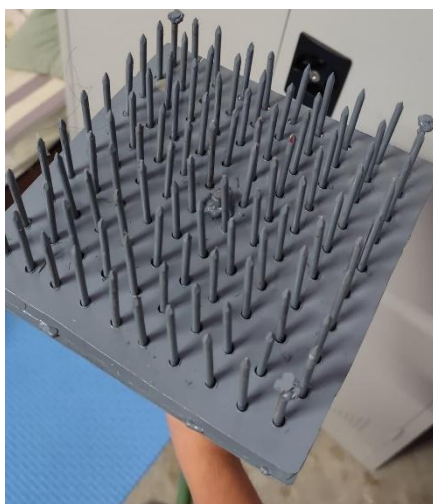


Figure 4: Prototype of Spike-Based (Modified)

Prototype Testing

The prototype testing phase was conducted to evaluate the functionality and practicality of the low-cost oil palm loose fruit collector. This process aimed to ensure that the final design met

its intended objectives of efficiency, user-friendliness, ergonomic, durability and reliability under operational conditions.

The test was separated into two parts: durability and efficiency. The durability test is conducted in the palm oil field based on the real situation and environment. This test aimed to simulate the tool can withstand the stress during loose fruits collection. After the collection, the results showed that the tool isn't deform and still functions in fruit collection. The durability test is conducted 3 times in total for the 3rd, 4th and 5th generations. During the 3rd and 4th test, the tool break showed that the tool isn't strong enough to withstand the strength. This data provided insight that this design is suitable and comfortable to be used for all communities particularly to small scale farmers due to its strong durability and toughness. Users don't need frequently complex maintenance and repair for this tool. Moreover, this tool is cheap and affordable so that consumers can just buy a new tool without repairing it.

Next is followed by the efficiency test. The testing procedure involved the following steps: the trigger pin was initially activated by pushing it to retract the iron rod located at the back of the trigger mechanism. The head of the prototype was then pressed against the loose palm oil fruits scattered on the ground. The number of loose fruits collected during this action was recorded. To release the collected fruits from the spikes, the trigger was pressed again to engage the spring-loaded mechanism. Subsequently, any remaining fruits that were not successfully dislodged from the nails were recorded. This data provided insights into the efficiency of the design in collecting and ejecting the loose fruits effectively.

The results of the testing, as detailed in Table 3, revealed an average efficiency rate of 83.33%, calculated using Eq. (1). This metric represents the ratio of the number of loose fruits (L.F) successfully collected and ejected to the total number of fruits targeted during testing. The high efficiency rate demonstrates that the modified spike-based design provides a reliable solution for loose fruit collection, particularly for small-scale palm oil operations.

The testing process highlighted the practicality of the design while also validating the improvements made during the fabrication phase. The results underscore the effectiveness of the implemented modifications, such as the incorporation of the spring and trigger mechanisms, in enhancing operational safety and minimizing manual labor requirements.

$$Efficiency\ Rate = \frac{No.\ of\ L.F.\ Successfully\ Push\ Out}{No.\ of\ L.F.\ Collected} \times 100\%$$

Equation 1

Table 3: The Results for Efficiency Tests

No.	No. of L.F Collected	No. of L.F Successfully Ejected	Efficiency Rate (%)
1.	9	8	88.8
2.	10	7	70
3.	11	9	81.8
4.	11	10	90.9
5.	12	10	83.3
6.	12	10	83.3
7.	8	6	75
8.	13	10	76.9
9.	12	10	83.3

10.	9	9	100
Average Efficiency Rate			83.33

Cost Distribution

The cost distribution for the prototype fabrication is detailed in Table 4, which includes an estimated cost breakdown for the recycled materials used. Notably, the total fabrication cost demonstrates that the modified spike-based collector falls within a reasonable price range compared to similar products currently available in the market. This indicates the design's competitiveness in terms of affordability, particularly for small-scale farmers.

A significant cost-saving aspect of this design lies in the use of recyclable materials, which greatly reduces manufacturing expenses. Should these materials be sourced directly by farmers, the overall cost could be further minimized. This aligns with one of the primary objectives of the project—to promote a do-it-yourself (DIY) fabrication concept. By enabling farmers to construct the tools themselves when required, the design ensures accessibility and sustainability. The DIY approach empowers users to fabricate and maintain the collector with basic resources, providing a practical solution for farmers operating with limited financial means.

The prototype fabrication cost is summarized in Table 4. The total cost includes estimation cost for recycled material. Having said that, the cost will be much lower if the recycled material being used. It is also noted that one of the aims of this design is to promote do-it-yourself concept, in which the farmer able to fabricate the tools by themselves whenever needed. This cost distribution proved that the concept is affordable especially for small-scale farmers.

Table 4: List of Materials and Cost

No.	Material	Quantity	Cost (RM)
1.	Mild steel pipe 2.5 × 0.06 (120cm)	1	20.90
2.	Iron Nails (3 inch)	1.2kg	8.00
3.	Silicon Caulking Gun	1	10.90
4.	Iron plate 25 × 25 (0.15cm)	3	Recycled (Collected from workshop with estimated price is RM 14.40)
5.	Iron rod 0.8 × 150cm	1	Recycled (Collected from workshop with estimated price is RM 7.50)
6.	Bold & Nut 2.0cm	4	RM3.90
7.	Washers 0.5cm	4	RM 1.20
8.	Angle Bar	6	Recycled (Collected from workshop with estimated price is RM 10.50)
9.	Spray paint	1	7.00
10.	Bosch Cobalt Bit 0.48cm	2	18.40

The comparison of the prototype's cost with market alternatives as shown in Figure 5 highlights its financial viability, emphasizing its capacity to deliver comparable functionality at a fraction of the cost. The analysis shows that the spike-based (modified) collector type can be priced at quite affordable range. The affordability of the design, coupled with its focus on user-

friendliness and practicality, positions it as an ideal tool for small-scale palm oil field operations. This cost analysis underscores the prototype's potential to make a significant contribution toward improving harvesting efficiency while remaining economically sustainable for its target users.

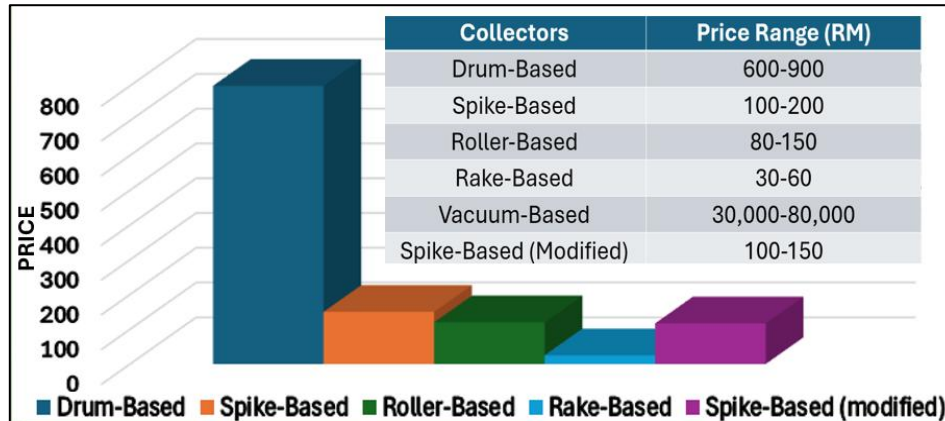


Figure 5: Price Comparison Between Spike-Based (Modified) with Available Collectors in Market

Conclusions

The development of a low-cost palm oil loose fruit collector represents a critical advancement in addressing the challenges faced by the agriculture industry in Malaysia, particularly within the palm oil sector. As one of the nation's key industries, the efficiency and productivity of palm oil harvesting play a significant role in supporting economic growth. The proposed design offers a practical solution by streamlining the harvesting process, reducing labour intensity, and addressing the health risks associated with traditional methods, such as back pain and spinal issues among labourers. Besides that, this design aims to build a more sustainable tools for the small-scale farmers in terms of recyclable and durability. By having a more durable structure, this tool can be used for a long of time and it can be bought easily since it only requires low cost. In a long-term plan, this design may be used in various field besides than palm oil field due to its quality, efficiency, low-cost and sustainability. By replacing conventional tools with the modified, low-cost collector, the overall efficiency of fruit collection can be enhanced, minimizing waste while increasing palm oil output. This research highlights the importance of accessibility and affordability in tool development, particularly for small-scale farmers who operate under financial constraints. The introduction of a do-it-yourself (DIY) fabrication approach empowers farmers to independently construct and maintain the tool, further promoting its usability and sustainability. Additionally, this study has contributed valuable insights and knowledge toward creating cost-effective and user-friendly agricultural solutions, demonstrating the potential for innovation in addressing real-world challenges within the community.

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PHYSICOCHEMICAL AND SENSORY EVALUATION OF GLUTEN-FREE DUMPLING SKINS: IMPACT OF SWEET POTATO AND TAPIOCA FLOUR RATIOS

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Abstract: *The demand for gluten-free alternatives continues to rise due to increasing awareness of gluten intolerance and celiac disease. This study aimed to develop gluten-free dumpling skins using sweet potato flour (SPF) and tapioca flour (TPF) in three formulations (SP30:TP70, SP50:TP50, SP10:TP90), and to evaluate their physicochemical, textural, and sensory properties. Proximate analysis was conducted to assess moisture and protein content, while texture profile analysis measured hardness, cohesiveness, springiness, and chewiness. Sensory evaluation was performed using a 9-point hedonic scale. Among the formulations, SP50:TP50 (F2) exhibited the most desirable texture and overall sensory acceptability, balancing firmness with favourable mouthfeel. Instrumental chewiness showed partial correlation with sensory chewiness and acceptability, confirming that mechanical parameters alone are insufficient to predict consumer preferences. Formulations with higher sweet potato content showed improved nutritional profiles and enhanced taste perception due to their natural sweetness and moisture retention. These results suggest that sweet potato and tapioca flour blends can produce acceptable gluten-free dumplings with good structural integrity and consumer appeal. Integrating both instrumental and sensory analyses is essential for optimizing gluten-free formulations.*

Keywords: *gluten-free dumpling, sweet potato flour, texture profile analysis, sensory evaluation*

Introduction

The growing prevalence of gluten-related disorders and the rising demand for alternative diets have driven the innovation of gluten-free products across various food categories. Dumplings, traditionally made with wheat-based wrappers, are a popular staple in many Asian cuisines, but their gluten content poses a challenge for individuals with celiac disease or gluten intolerance. Replacing gluten-rich flour with gluten-free alternatives requires careful attention to texture, elasticity, and consumer acceptance.

Sweet potato (*Ipomoea batatas*) flour is known for its nutritional value, including dietary fiber, vitamins, and antioxidants, while tapioca (*Manihot esculenta*) flour contributes a neutral flavour and excellent binding properties due to its high starch content. However, the structural

and sensory properties of doughs and final products using these flours can vary significantly depending on their ratios and interactions during cooking.

This study aims to develop a gluten-free dumpling skin using sweet potato and tapioca flours in different ratios and to evaluate their effects on the physicochemical properties, texture, and sensory acceptability of the dumplings. By correlating instrumental texture measurements with sensory panel responses, the research intends to identify an optimal formulation that delivers a balance of desirable mouthfeel, chewiness, and structural integrity.

Literature Review

Sweet Potato Flour

Sweet potato flour, derived from various sweet potato genotypes, is gaining traction in the food industry due to its nutritional benefits and functional properties. This flour is produced through a meticulous process that preserves its colour and nutritional value, making it suitable for diverse applications in food products.

Nowadays, sweet potato flour is increasingly recognized for its nutritional and functional advantages in gluten-free formulations. Its rich composition includes carbohydrates, proteins (approximately 5.41 g/100 g), and essential minerals such as potassium and phosphorus, which contribute to the nutritional enhancement of food products (Zhang et al., 2022; Lu & Gao, 2011). Additionally, sweet potato flour contains significant amounts of phenolic compounds and carotenoids, both of which provide antioxidant properties that can enhance the health appeal of gluten-free foods (Hussien et al., 2024).

Functionally, sweet potato flour improves the texture and volume of gluten-free baked goods by enhancing water retention and reducing staling. These qualities are particularly useful in bread and cookie production, where maintaining softness and freshness is critical (Dereje et al., 2020; Elzoghby et al., 2023). Moreover, sweet potato flour is highly versatile and can be blended with other gluten-free flours such as sorghum or chickpea to improve both nutritional balance and sensory characteristics, particularly in products like cookies and rice bread (Hussien et al., 2024; Elzoghby et al., 2023).

While its distinctive flavour may affect the taste profile of certain products, proper formulation strategies can balance its sensory impact. Overall, sweet potato flour offers promising potential in gluten-free product development, enhancing both the functional and nutritional quality of food while contributing to consumer acceptability.

Tapioca Flour

Tapioca flour, derived from the cassava root, is widely used in gluten-free formulations due to its unique functional properties. It is composed primarily of amylopectin, which contributes to its desirable gelatinization and pasting behaviour, the key characteristics for achieving soft, elastic textures in gluten-free products (Horstmann et al., 2017). The morphology of tapioca starch, including its granule size and shape, influences its water absorption and swelling capacity. These properties are crucial for creating the moist, cohesive structure that consumers associate with high-quality baked or steamed goods (Mauro et al., 2023).

Functionally, tapioca flour improves the texture and volume of gluten-free products. Modified tapioca starch is especially effective in enhancing these qualities and in reducing staling, thereby extending the shelf life of baked goods (Sudheesh et al., 2021; Roman et al., 2020). Furthermore, tapioca is a source of resistant starch, which has been shown to reduce the glycemic index of gluten-free products and making it beneficial for consumers seeking healthier alternatives (Sudheesh et al., 2021).

Sensory studies have demonstrated high consumer acceptance for gluten-free products made with tapioca flour, including bread and biscuits, often outperforming other gluten-free flours in texture and taste (Muzamil et al., 2024; Milde et al., 2012). However, tapioca is nutritionally limited and lacks the protein and micronutrient density of whole grains. Thus, it is often used in combination with other flours to improve the overall nutritional profile. Despite this limitation, its functional versatility makes tapioca a valuable base ingredient in gluten-free product innovation.

Starch and Protein Interaction

Starch and protein interactions significantly influence the texture and moisture content of gluten-free food products, both of which are critical for overall quality and consumer satisfaction. Starch gelatinization is a key process in this interaction. During heating, starch granules absorb water and swell, leading to changes in viscosity and matrix formation that directly impact textural properties such as softness, elasticity, and chewiness. The swelling capacity and amylose solubility during gelatinization are essential for forming a strong, cohesive structure within the food matrix (Wada et al., 1999).

Water absorption capacity also plays a vital role in dough consistency. Higher water levels enhance the viscoelastic properties of gluten-free dough, as demonstrated in pizza crusts where the inclusion of gelatinized starch improved texture without compromising structure, even at lower baking temperatures (Matsumo et al., 2022). These improvements are particularly important in gluten-free systems where gluten is absent to provide structural support.

The flour-to-protein ratio further determines product hardness and elasticity. In studies involving *keropok lekor*, an optimal balance between starch and protein yielded the most desirable textural outcomes (Mohamed et al., 2024). However, excessive protein content can interfere with starch gelatinization, reducing viscosity and resulting in undesirable textures (Terán & Blanco-Lizarazo, 2021). Thus, achieving the right balance between starch and protein is crucial for optimizing gluten-free formulations, especially in products like dumplings where structure, chewiness, and moisture retention are key to consumer acceptability.

Sensory Evaluation and Instrumental Correlation

Sensory evaluation is essential in food product development as it provides insight into consumer preferences for attributes such as texture, appearance, chewiness, and overall acceptability. While sensory testing relies on subjective feedback from panelists, instrumental texture analysis offers objective data that can enhance the efficiency and reproducibility of product development. The correlation between these two approaches has become a major area of interest, particularly in optimizing gluten-free formulations where traditional gluten structures are absent.



The correlation between sensory evaluation and instrumental measurements in food products is influenced by several critical factors, including the nature of the food matrix, the type of sensory attributes assessed, and the analytical methods used. Understanding these factors is essential for developing predictive models that improve food quality and consumer satisfaction.

The characteristics of the food matrix which its chemical composition and physical structure are play a significant role in how sensory properties are perceived. For example, a study on instant noodles found that 68% of the variability in sensory evaluation could be explained by the chemical properties of wheat flours and the dough's physical attributes (Xue et al., 2010). However, some texture-related attributes, such as adhesiveness or mouthfeel, are more difficult to replicate instrumentally, particularly in complex or heterogeneous food systems (Brenner et al., 2014).

Sensory evaluation methods, such as descriptive analysis, capture nuanced attributes like hardness or viscosity. These may not always align with direct instrumental equivalents such as jelly strength or force-deformation metrics (Shindo et al., 1993). Therefore, validating instrumental techniques against sensory data is essential, keeping in mind that correlation does not imply causation (Cook et al., 2005).

Methodological choices also impact correlation strength. The use of multivariate techniques, such as partial least squares regression, enhances the interpretation of complex datasets and improves model reliability (Xue et al., 2010). Emerging technologies, including electronic noses and tongues, offer promising tools to mimic human sensory perception and enhance predictive accuracy (Kilcast, 2010).

While these tools advance the field, discrepancies remain due to the subjective nature of sensory experiences and the limitations of mechanical measurements. Continued research is essential to refine methodologies and develop more robust, reliable sensory-instrumental correlation models.

Sensory Evaluation in Food Product Development

Sensory evaluation is a critical tool for understanding consumer preferences and assessing the acceptability of food products. It provides direct insights into how consumers perceive various attributes such as taste, aroma, texture, and appearance all of which are essential for determining product success in a competitive market. By employing structured sensory methodologies, developers can align formulations with consumer expectations and optimize product quality before commercial launch.

One of the key contributions of sensory evaluation is its ability to reveal nuanced consumer perceptions that drive purchasing behaviour. Products that perform poorly in sensory tests are often rejected by consumers, regardless of branding or marketing strategies (Lawless & Heymann, 1999). As such, sensory data are vital not only for quality control but also for shaping marketing and product positioning. Advanced analytical techniques, such as fuzzy logic, have enhanced the quantification of subjective sensory feedback, making the evaluation process more comprehensive and reliable (Vivek et al., 2020).

Common methodologies include discriminative tests, which determine whether consumers can detect differences between products, and descriptive analysis, which captures detailed profiles

of sensory characteristics (Yadav et al., 2024). Despite these advances, challenges remain. Consumer behaviour during eating is dynamic and influenced by context, mood, and environment, making it difficult to predict real-world responses with full accuracy (Tugba, 2021). Furthermore, certain sensory attributes, such as texture and aroma, are still underexplored in scientific literature.

While sensory evaluation is invaluable, it should be integrated with market research, branding, and pricing strategies to ensure complete consumer satisfaction and commercial success.

Materials and Methods

Materials

Sweet potato flour and tapioca flour were the primary ingredients used in this study. Both flours were commercially sourced and stored in airtight containers at room temperature. Additional ingredients included water and salt, used to form the dough. All chemicals and reagents used in the analytical procedures were of analytical grade and obtained from reputable suppliers.

Preparation of Dumpling Skins

Three formulations of gluten-free dumpling dough were prepared using different ratios of sweet potato flour (SP) and tapioca flour (TP) by table below.

Table 1: Formulation Dumpling Skins

Formulation	Sweet Potato Flour (%)	Tapioca Flour (%)
F1	30	70
F2	50	50
F3	10	90

The flours were weighed and thoroughly mixed. Water was gradually added and kneaded until a smooth dough was formed. The dough was rested for 15 minutes at room temperature before being rolled to a uniform thickness and cut into circular dumpling skins. All samples were steamed under identical conditions (10 minutes, 100°C) and cooled to room temperature before analysis.

Proximate Analysis

The proximate composition of the gluten-free dumpling skin samples was determined using standard procedures outlined by the Association of Official Analytical Chemists (AOAC). Moisture content was measured using the oven-drying method (AOAC 925.10). Approximately 5 grams of each sample were weighed and placed in a hot air oven at 105°C until a constant weight was achieved. The loss in weight was recorded as the moisture content, which is essential for assessing product stability and shelf life.

Crude protein content was analyzed using the Kjeldahl method (AOAC 981.10), which quantifies total nitrogen content. Each sample underwent acid digestion with concentrated sulfuric acid in the presence of a catalyst to convert organic nitrogen into ammonium sulfate. The digest was then neutralized with sodium hydroxide and distilled. The liberated ammonia was trapped in a boric acid solution and titrated with standardized hydrochloric acid. The total

nitrogen value obtained was multiplied by a conversion factor of 6.25 to estimate crude protein content, which is critical for evaluating the nutritional value of the dumpling formulations.

Crude fat content was determined using Soxhlet extraction with petroleum ether as the solvent (AOAC 920.39). Dried and ground samples were placed in a thimble and subjected to continuous solvent extraction for approximately six hours. The extracted fat was collected, and the solvent was evaporated to leave behind the residual lipid content. This parameter is important for understanding the energy contribution and mouthfeel of the final product. All analyses were performed in triplicate to ensure accuracy and reproducibility.

Texture Profile Analysis (TPA)

Instrumental texture analysis of the gluten-free dumpling skins was performed using a texture analyzer (Brookfield CT3 Texture Analyzer) equipped with a cylindrical probe. The objective of this analysis was to quantify key mechanical properties associated with the textural quality of the dumpling wrappers. Prior to testing, samples were cut into uniform rectangular pieces to ensure consistency in measurement. All measurements were carried out at room temperature and in triplicate for each formulation to ensure reproducibility and minimize experimental error. For each evaluation, triplicate samples from each formulation were positioned beneath the cylindrical P/36 R probe and subjected to compression in the Texture Profile Analysis (TPA) mode. The parameters for measurement were established as follows: a pre-test speed of 2 mm/s, a test speed of 0.8 mm/s, a post-test speed of 0.8 mm/s, a triggering force of 5 g, and a compression rate of 75%. The outcomes from the two duplicate measurements were documented, and the average value was calculated to represent the final result for each formulation. (Li et al., 2008).

The parameters evaluated included hardness, cohesiveness, and chewiness. Hardness was defined as the maximum force required to compress the sample during the first bite, indicating the firmness of the dumpling skin. Cohesiveness was determined by calculating the ratio of the area under the second compression curve to that under the first, reflecting the internal bonding strength of the sample and its ability to withstand a second deformation. Chewiness was derived as the product of hardness, cohesiveness, and springiness, representing the energy required to masticate the sample before swallowing.

These parameters provided insight into the physical structure and textural behaviour of the dumpling formulations, which are critical for both sensory quality and consumer acceptance. The data obtained were further correlated with sensory evaluation scores.

Sensory Evaluation

Sensory evaluation was conducted using an untrained panel comprising 35 members to assess the acceptability of the gluten-free dumpling skin formulations. Each panelist evaluated the samples using a 9-point hedonic scale, where 1 represented "dislike extremely" and 9 represented "like extremely." The sensory attributes evaluated included colour, surface texture, chewiness, taste, aroma and overall acceptability. These parameters were selected to reflect key consumer-relevant qualities in dumpling products, particularly in the context of gluten-free alternatives.

To reduce bias and ensure objectivity, the samples were presented in random order using three-digit codes. The evaluations were conducted in a sensory analysis laboratory under standardized conditions of lighting, temperature, and ventilation to eliminate external influences on perception. Panelists were instructed to rinse their palates with water between samples. The data obtained from the panel were statistically analyzed to determine significant differences among the formulations and to examine correlations with instrumental texture measurements.

Statistical Analysis

Data were analysed using one-way analysis of variance (ANOVA), with significance set at $p < 0.05$. Tukey's HSD test was used for mean comparisons. Pearson correlation analysis was performed to evaluate the relationship between instrumental texture parameters and sensory scores. All analyses were carried out using SPSS software (version 17).

Results and Discussion

Physicochemical Properties

The proximate analysis of the gluten-free dumpling skin formulations demonstrated that flour ratio significantly influenced moisture, protein, and fat content. Among the three formulations (table 2), F2 (SP50:TP50) exhibited the highest moisture content ($42.61 \pm 0.36\%$), followed by F3 (SP30:TP70), while F1 (SP10:TP90) recorded the lowest value ($34.99 \pm 0.04\%$). These findings are consistent with earlier reports by Zhang et al. (2022) and Hussien et al. (2024), which highlighted that sweet potato flour possesses a relatively high moisture-holding capacity and moderate protein content compared to other gluten-free flours. The increase in moisture can be attributed to the high content of dietary fiber and complex carbohydrates in sweet potato flour, which have strong water-binding properties, enhancing the dough's ability to retain water during processing and cooking. Enhanced moisture retention improves softness, reduces staling, and contributes to favourable sensory attributes in gluten-free systems where maintaining hydration is often a challenge.

Protein content ranged from $0.22 \pm 0.01\%$ in F1 to $1.88 \pm 0.02\%$ in F2. Although sweet potato flour contains lower protein than wheat ($\sim 3.33\%$) (Yulianti et al., 2019), its inclusion may have contributed modestly to the overall protein levels. More importantly, it enhanced the nutritional profile by introducing additional dietary fiber and bioactive compounds such as beta-carotene (Shih et al., 2006). These elements support the development of gluten-free formulations that are not only structurally sound but also nutritionally enhanced.

Fat content decreased with increased sweet potato concentration, with F3 exhibiting the highest fat content ($3.59 \pm 0.09\%$) and F2 the lowest ($2.35 \pm 0.06\%$). This pattern may be due to the lower lipid content of sweet potato flour compared to tapioca. Overall, the SP50:TP50 blend demonstrated the most balanced nutritional composition, making it a promising candidate for gluten-free dumpling development that prioritizes both functionality and consumer health.

Table 2: Result of Proximate Analysis

Formulation	Moisture	Protein	Fat
F1(SP30:TP70)	34.99 ± 0.04	0.22 ± 0.01	2.97 ± 0.07
F2(SP50:TP50)	42.61 ± 0.36	1.88 ± 0.02	2.35 ± 0.06
F3(SP10:TP90)	35.70 ± 0.10	1.84 ± 0.02	3.59 ± 0.09

Texture Profile Analysis and Flour Composition Effects

The instrumental texture profile analysis demonstrated significant variation in hardness, cohesiveness, springiness, and chewiness among the three gluten-free dumpling skin formulations. Table 3 showed that F2 (SP50:TP50) exhibited the highest hardness (2325.00 ± 2228.80), followed by F3 (2070.00 ± 2757.72), while F1 (SP10:TP90) had the lowest hardness (47.00 ± 29.70). These findings suggest that increasing sweet potato flour (SPF) content contributes to firmer dough structures, possibly due to its moderate protein content and fibrous matrix, which provide structural reinforcement during steaming (Meng et al., 2022). However, Meng et al. also reported that up to 30% SPF inclusion tends to reduce dough hardness in bread, indicating that the optimal effect may vary depending on the food matrix and processing method.

Cohesiveness values were highest in F2 (0.84 ± 0.05), indicating better internal binding strength. This can be attributed to the synergy between sweet potato’s starch-protein matrix and tapioca’s high amylopectin content, which enhances gel formation (Akintayo et al., 2019). Meanwhile, springiness values were consistent in F1 and F4 (0.30), but slightly lower in F2 and F3 (0.25), reflecting possible stiffness in the dough due to higher gelatinization of starches at elevated sweet potato levels.

The highest chewiness was recorded in F2 (485.59 ± 485.94), followed by F3 (364.54 ± 497.54), with F1 demonstrating minimal chewiness (11.41 ± 9.25). This trend reflects the combined influence of high hardness and moderate cohesiveness in F2 and F3, consistent with previous findings that sweet potato-tapioca blends can optimize textural properties when used in appropriate proportions (Chikpah et al., 2021; Akintayo et al., 2019). However, the large standard deviations in F2 and F3 suggest variability in starch hydration or thermal behaviour during steaming.

These results highlight that the SP50:TP50 ratio achieves the best balance of firmness, internal structure, and chewiness—parameters crucial to consumer satisfaction in gluten-free dumplings—while also reinforcing the importance of flour synergy and proportion control in texture optimization.

Table 3: Result of Texture Profile Analysis

Formulation	Hardness	Cohesiveness	Springiness	Chewiness
F1(SP30:TP70)	47.00 ± 29.70	0.81 ± 0.41	0.3 ± 0.00	11.41 ± 9.25
F2(SP50:TP50)	2325.00 ± 2228.80	0.84 ± 0.05	0.25 ± 0.07	485.59 ± 485.94
F3(SP10:TP90)	2070.00 ± 2757.72	0.71 ± 0.05	0.25 ± 0.07	364.54 ± 497.54

Sensory Acceptability Based on Hedonic Evaluation

The hedonic test results provide valuable insights into the sensory performance of the gluten-free dumpling formulations. The hedonic evaluation of the three gluten-free dumpling formulations (F1, F2, F3) assessed six sensory attributes—colour, surface texture, chewiness, taste, aroma, and overall acceptability—using a 9-point scale. Superscript letters in the chart indicate statistical differences ($p < 0.05$), with identical letters representing no significant difference between means.

Colour scores ranged consistently around 5.7–6.0 across all formulations and showed no significant differences (denoted by the same superscript 'a'). This indicates that the variation in sweet potato to tapioca flour ratios did not affect visual appeal. These results align with the findings of Akintayo et al. (2019), who observed that composite flours can maintain desirable colour in starch-rich products when used within optimal substitution levels.

Surface texture and chewiness were rated slightly lower (~4.5) and did not differ significantly among the formulations (all marked 'b'). This uniformity suggests that while the textural profile was acceptable, the absence of gluten may have limited elasticity and cohesiveness, which are often perceived more positively in wheat-based doughs (Kilcast, 2008). As noted by Horstmann et al. (2017), starch-based gluten-free systems often struggle to achieve the same viscoelastic properties as gluten-containing matrices. Differences in chewiness and surface texture can be attributed to the variation in moisture content among the samples. F2, which had the highest moisture (42.61%), presented a softer and more cohesive structure, resulting in higher sensory scores for texture-related attributes. This is supported by Tortoe et al. (2017), who found that sweet potato flour improves softness and water retention, leading to better mouthfeel. Meanwhile, the lower-fat, higher-moisture profile of F2 may have contributed to improved juiciness and elasticity, positively influencing sensory perception (Rabou & Ahmad, 2018).

Interestingly, taste demonstrated a statistically significant difference, with F2 receiving slightly higher scores. This may be due to the enhanced natural sweetness and flavor-enhancing compounds present in sweet potato flour, as supported by Shih et al. (2006), who noted that sweet potato contributes positively to sensory qualities in baked and steamed foods.

Despite these variations, aroma and overall acceptability did not differ significantly among samples. This suggests that while specific attributes such as taste can influence preference, the formulations were broadly acceptable. These findings highlight the potential for sweet potato–tapioca blends to achieve functional and sensory balance in gluten-free dumplings.

Among the attributes assessed were colour, surface texture, chewiness, taste, aroma, and overall acceptability which formulation F2 (SP50:TP50) received the highest ratings for taste, aroma, and overall acceptability. These findings are consistent with prior studies indicating that sweet potato flour enhances the flavour and aroma of gluten-free products due to its naturally sweet, aromatic profile and bioactive compounds such as carotenoids (Shih et al., 2006; Yulianti et al., 2019). Overall, the data show a clear trend in which increasing the proportion of sweet potato flour enhances sensory acceptability. These results validate the role of proximate composition which particularly moisture and protein levels in influencing consumer perception and support previous literature emphasizing the correlation between physicochemical properties and sensory quality (Kilcast, 2008; Mihafu et al., 2020).

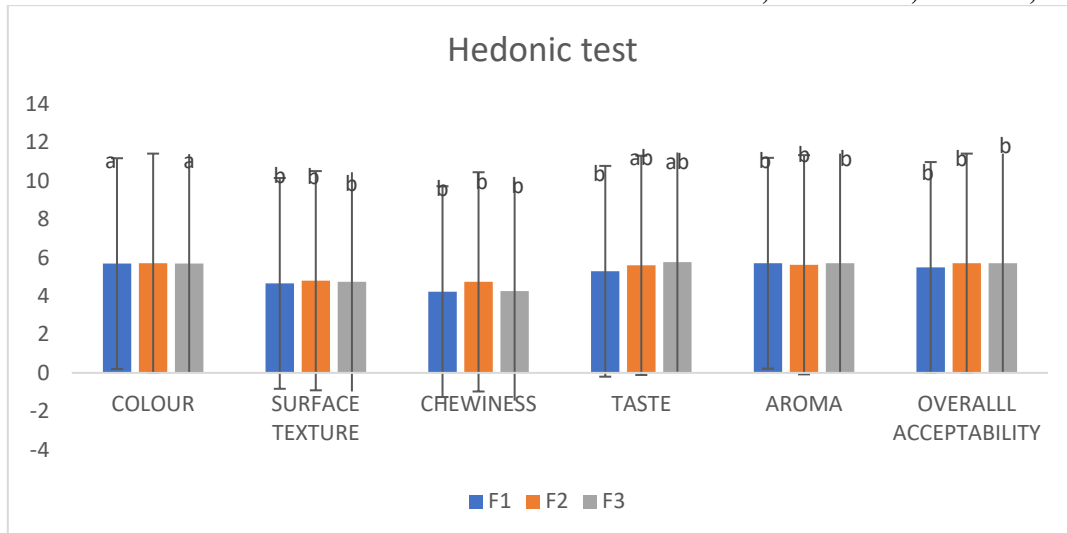


Figure 1: Sensory Acceptability by Hedonic Test

Correlation Between Instrumental Chewiness and Sensory Perception

The scatter plot (Figure 2) illustrates the relationship between instrumental chewiness and two sensory attributes: sensory chewiness and overall acceptability for three gluten-free dumpling skin formulations.

Formulation F1 (SP30:TP70), with the lowest instrumental chewiness (11.41), also received the lowest sensory chewiness score (4.23) and the lowest overall acceptability (5.49). This suggests that insufficient chewiness or firmness may result in a dumpling skin perceived as too soft or lacking structure, reducing its appeal.

Formulation F2 (SP50:TP50) displayed the highest instrumental chewiness (485.59) and was rated the highest in both sensory chewiness (4.74) and overall acceptability (5.71). This indicates that moderate to high firmness can enhance consumer satisfaction when balanced with favourable texture and mouthfeel. The data suggest F2 achieved an optimal textural profile that aligns well with sensory preferences.

Interestingly, F3 (SP10:TP90) also had high instrumental chewiness (364.54), but its sensory chewiness (4.26) and acceptability (5.71) were only comparable to F2, not higher. This reflects the concept of diminishing sensory returns with increased mechanical firmness—beyond a certain point, more chewiness may not improve perception and could risk over-firmness.

These findings align with Kilcast (2008), who noted that while instrumental data offer valuable objectivity, they do not always reflect consumer experience. Sensory texture perception is influenced not just by force and resistance but by dynamic oral processing factors like breakdown, elasticity, and moisture release (Mihafu et al., 2020). According to Jeronimidis, G. (1991), further emphasized that consumer acceptance depends on a holistic evaluation that includes texture, taste, and aroma.

Overall, the results highlight that instrumental texture values particularly chewiness and hardness can provide useful benchmarks, but they must be interpreted alongside sensory data. For gluten-free dumplings, a moderate level of chewiness, as seen in F2, appears to offer the best balance between structural functionality and consumer preference. Therefore, while

instrumental analysis provides objective and reproducible data, sensory evaluation remains essential to guide formulation choices and ensure consumer acceptance.

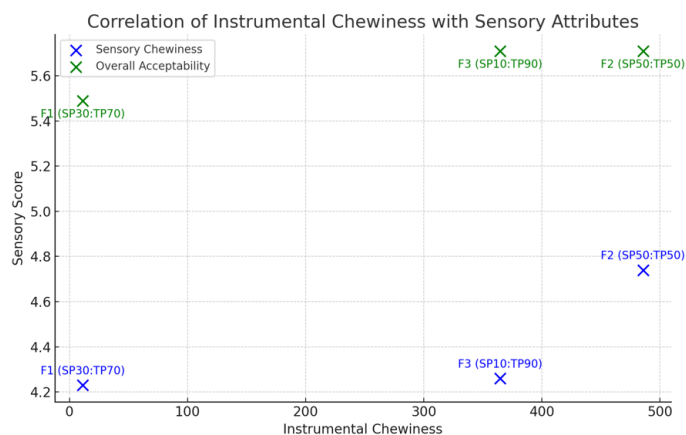


Figure 2: Correlation Between Instrumental Chewiness and Sensory Attributes

Conclusion

This study successfully developed gluten-free dumpling skins using varying ratios of sweet potato flour (SPF) and tapioca flour (TPF), with a focus on evaluating the physicochemical, textural, and sensory properties of the formulations. The results demonstrated that flour ratio significantly influenced moisture, protein content, and instrumental texture parameters such as hardness, cohesiveness, springiness, and chewiness. Among the three formulations, F2 (SP50:TP50) exhibited the most favourable balance between structural integrity and sensory preference. It recorded the highest instrumental chewiness and was also rated highest in sensory chewiness and overall acceptability, suggesting an optimal balance between firmness and palatability.

Sensory evaluation indicated no significant differences in colour, surface texture, aroma, or overall acceptability among the samples, although taste differed slightly in favour of F2. Correlation analysis revealed that while instrumental chewiness provided useful insights into textural differences, it did not always align with sensory perceptions, highlighting the complexity of consumer response to food texture. These findings align with previous literature emphasizing the need to combine instrumental and sensory methods for comprehensive product evaluation (Kilcast, 2008; Mihafu et al., 2020).

The incorporation of sweet potato flour not only improved the nutritional profile of the dumplings but also contributed positively to taste and moisture retention. Overall, the SP50:TP50 ratio was identified as the most promising formulation, balancing functional texture with consumer acceptability. Future studies may further explore hydrocolloid addition or protein enrichment to improve elasticity and mimic gluten's viscoelasticity in similar starch-based systems. This study demonstrates the potential for SPF-TPF blends to serve as effective alternatives in gluten-free dumpling development.

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PERFORMANCE EVALUATION OF INSECT REPELLENT CANDLES FROM USED COOKING OIL AND LEMONGRASS: A STUDY ON PH AND SOLUBILITY

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Abstract: *Improper disposal of used cooking oil contributes significantly to environmental pollution, while conventional chemical insect repellents pose health risks to sensitive individuals. This study presents an eco-friendly solution through the development and evaluation of insect repellent candles made from used cooking oil and lemongrass. The main objective is to analyse the chemical properties of these candles by focusing on pH and solubility performance to ensure product safety and effectiveness. The candles were formulated using a mixture of used cooking oil, soy wax, melted crayon for colour, and lemongrass extract in a 2:3 ratio. pH testing was performed by mixing candle extracts with both distilled and tap water, while solubility testing involved ethanol, vegetable oil, and water as solvents. A commercial candle served as a reference sample. The pH values for distilled water increased from 7.54 (control) to 10.3 (unfiltered extract) and 8.47 (filtered), while tap water shifted from 7.60 to 7.96 (unfiltered) and 7.58 (filtered), indicating mild alkalinity and chemical safety. Solubility results showed that both the project and commercial candles were soluble in ethanol; however, only the project candle was soluble in vegetable oil. Both candle types were insoluble in water, maintaining wax integrity. These results demonstrate that the developed candles exhibit stable chemical properties and good compatibility with natural solvents. The findings support the potential of using recycled cooking oil and lemongrass as sustainable raw materials for producing safe and functional insect repellent candles suitable for household use*

Keywords: *Insect Repellent Candle, Used Cooking Oil, Lemongrass, pH Analysis, Solubility, Eco-friendly Product*

Introduction

Improper disposal of used cooking oil is a common yet environmentally harmful practice. When discarded down drains or into the garbage, used oil can clog sewage systems and pollute water bodies, forming surface films that hinder oxygen exchange and harm aquatic life. Simultaneously, there is growing concern about the widespread use of chemical-based insect repellents, which often contain substances like DEET that may pose health risks with prolonged or frequent exposure, particularly for sensitive individuals (Anizar et al. 2023; Hamdi et al. 2022). In tropical regions where mosquito-borne diseases such as dengue and malaria are prevalent, there is high demand for effective insect repellents (Sharma et al. 2023; Singhamahapatra, Sahoo, and Sahoo 2020). While commercial products are widely available,



their synthetic content and packaging contribute to both health and environmental issues. This has prompted interest in safer, natural alternatives that are both functional and sustainable.

A promising solution involves repurposing household waste specifically used cooking oil into natural insect repellent candles infused with lemongrass extract. Lemongrass is known for its pleasant scent and insect repelling compounds like citronella and geraniol, which interfere with mosquitoes' ability to locate human hosts. When blended into a candle formulation, lemongrass not only enhances aroma but also serves as a natural barrier against pests (Pham et al. 2020; Salsabila, Hutahaen, and Basith 2023). These eco-friendly candles offer dual benefits, that they reduce kitchen waste and decrease reliance on synthetic insecticides. The process involves mixing used cooking oil with soy wax, crayon for colour, and lemongrass extract, forming a burnable product that emits a functional, fragrant aroma (Lim et al. 2021; Pham et al. 2020). Despite the growing popularity of such natural alternatives, most existing studies focus only on production or sensory aspects, with limited attention to their chemical properties.

Understanding the chemical characteristics of insect repellent candles is vital to ensure product safety, performance, and consistency. Two important parameters are pH and solubility. pH testing helps assess whether the candle is too acidic or alkaline, which could affect skin compatibility and environmental safety. Solubility testing reveals how well the active compounds disperse in different solvents, providing insight into the product's stability and the release behaviour of its repellent components (Afriani et al. 2024; Nkuete et al. 2022; Zhao et al. 2024).

This study aims to evaluate the pH and solubility of candles made from used cooking oil and lemongrass. These tests will help determine if the formulation maintains a safe pH range and whether the ingredients are properly integrated into the wax matrix. The results are expected to support the development of an environmentally friendly, functional, and safe candle that serves as an alternative to conventional repellents.

Literature Review

Concerns over the health effects of chemical-based insect repellents have intensified interest in natural alternatives derived from plants. Many commercial repellents rely on synthetic compounds, which, while effective, can cause adverse effects such as skin irritation, headaches, or respiratory discomfort when used frequently or in enclosed environments. This has driven a shift toward botanical based repellents, which are perceived as safer, biodegradable, and environmentally friendly.

Lemongrass is one of the most well-known plants used for natural insect repellent formulations. It contains volatile oils rich in citronellal, citral, and geraniol, compounds that are known to mask the scents that attract mosquitoes and other insects. The strong citrus aroma of lemongrass not only repels pests but is also generally pleasant to humans, making it suitable for household applications. As a result, lemongrass extracts have been integrated into various delivery forms including sprays, lotions, and candles (Nwanya et al. 2020; Reddy et al. 2024; Salsabila et al. 2023).

Candles serve as an effective passive delivery system for insect repelling compounds. When burned, candles infused with essential oils release aromatic compounds gradually into the air, providing a sustained repellent effect. Unlike sprays or creams, candles can cover a larger area



without requiring direct application to the skin. However, the effectiveness of such candles depends heavily on the stability and even dispersion of active ingredients within the wax. Poor solubility or phase separation of the essential oil components can result in uneven release rates and reduced functionality (Afriani et al. 2024; Hutahaen et al. 2024).

In addition to the choice of active ingredient, the base material of the candle plays an important role in product sustainability. Used cooking oil, which is commonly discarded after multiple frying cycles, presents a viable alternative to petroleum derived waxes. Repurposing this waste oil into candle-making contributes to waste reduction and environmental preservation. With appropriate filtering and blending techniques, used oil can be safely converted into burnable wax suitable for household use (Martinelli and Da Silva 2024; Ramadhani and Kusumaningrum 2024; Ramadhani, Malik, and Fitriana 2023).

Existing literature has highlighted the potential of waste derived candles in general, but studies focusing specifically on insect repelling formulations remain limited. Moreover, while the repellence and user appeal of lemongrass-based candles have been explored, little attention has been given to their chemical behaviour, particularly in relation to their solubility in various solvents and their pH characteristics (Hutahaen et al. 2024; Rusnanda et al. 2021; Salsabila et al. 2023). These factors are important for understanding how well the repellent compounds are stabilized in the candle and whether the product is chemically safe for indoor use.

Material and Methods

Materials

The main materials used in this study were used cooking oil, lemongrass extract, soy wax, and crayons. The used cooking oil was collected from household kitchen waste and served as the base material for the candle. Fresh lemongrass was obtained from local markets, blended, and filtered to extract its liquid essence, which acted as the natural insect-repelling component. Soy wax was included to enhance the candle's structure and burning properties, while coloured crayon pieces were added to improve the visual appeal of the final product. For chemical analysis, distilled water, tap water, ethanol, and vegetable oil were used as solvents. A commercially available candle was also included for comparative purposes in the solubility tests.

Candle Formulation Process

The candle formulation began by heating the used cooking oil in a pour pot at moderate heat for approximately 10 to 15 minutes. While the oil was heating, lemongrass was blended and filtered to obtain a clean extract. Separately, crayon was melted into the hot oil mixture to provide coloration. Soy wax was then added and stirred continuously until fully dissolved and homogenous. Once the base was ready, the filtered lemongrass extract was added gradually while mixing thoroughly. The final mixture was poured into small containers with attached cotton wicks and allowed to solidify at room temperature for 24 to 48 hours. The optimal formulation used a 2:3 ratio of used cooking oil to lemongrass extract to maximize aroma and repellent effectiveness.

pH Testing Procedure

To assess the chemical characteristics of the candle, a pH test was conducted. Scraped candle samples were mixed separately with distilled water and tap water in clean containers. A calibrated digital pH meter was used to measure the pH values of each solution. The electrode was immersed into each candle and water mixture, and the reading was recorded once stabilized. The pH values of the distilled and tap water samples (without candle) were also recorded to serve as control references. This test helped to determine the alkalinity or acidity of the candle extract when in contact with moisture, simulating household or environmental exposure conditions.

Solubility Testing Procedure

Solubility testing was conducted to evaluate how well the active compounds and wax matrix of the candle integrated with various solvents. Small amounts of the project candle and a commercial candle were separately placed in three types of solvents: ethanol, vegetable oil, and water. Each sample was observed to determine whether it dissolved completely, partially, or remained insoluble. These tests were important to assess the chemical compatibility and dispersion of active ingredients, which influence the candle's performance in delivering repellent effects during use.

Result and Discussion

pH Test Analysis

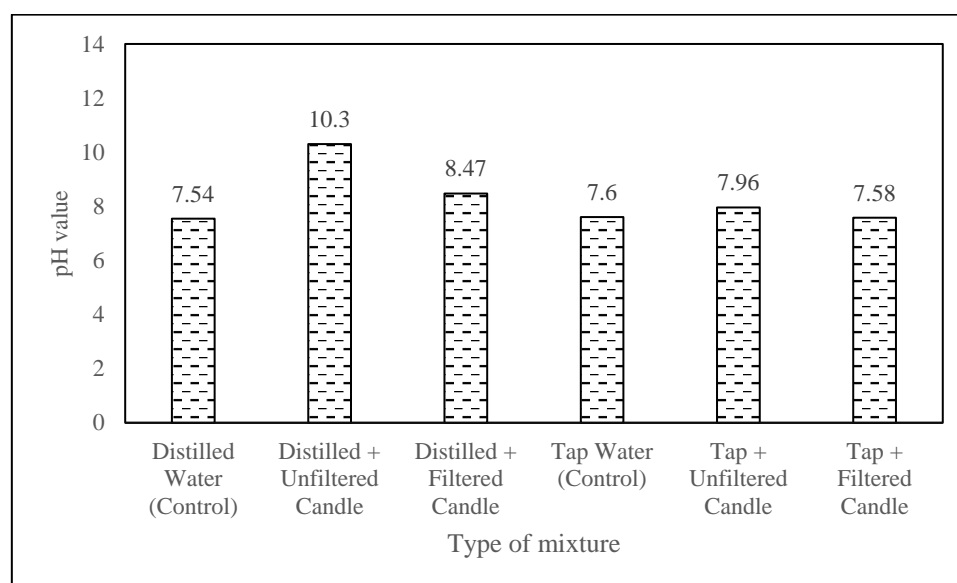


Figure 1: Effect of Different Sample to the pH Value

The figure 1 illustrates the variation in pH values across six different samples, highlighting the chemical interaction between water and the insect repellent candle. The control samples distilled water (7.54) and tap water (7.60), fall within the neutral pH range, as expected. However, when mixed with unfiltered candle extract, the pH of distilled water increased sharply to 10.3, indicating a significant shift toward alkalinity. This suggests that certain basic compounds, possibly from the reused cooking oil or lemongrass residue, remain in the unfiltered formulation and influence its chemical profile.

In contrast, filtered candle extract resulted in a lower pH increase: 8.47 for distilled water and 7.58 for tap water. These readings show that filtration reduces the alkaline load, bringing the pH closer to neutral and indicating improved formulation consistency. The minimal change in the pH of tap water after filtration (7.58 vs. 7.60 control) suggests that the filtered candle has minimal reactivity in a clean aqueous environment (Suribabu, Sudarsan, and Nithiyantham 2020).

Overall, the visual trend in the graph confirms that the unfiltered candle significantly affects water pH, while the filtered version maintains chemical stability within a safe range. These findings imply that filtration is an important step in candle preparation to ensure the final product is safe for indoor use and poses no risk of excessive alkalinity during exposure to moisture or skin contact.

Solubility Testing Procedure

Table 1: Data Finding on the Solubility Test

Solvent	Project Candle	Commercial Candle
Ethanol	Soluble	Soluble
Vegetable Oil	Soluble	Insoluble
Water	Insoluble	Insoluble

The solubility test was designed to evaluate how well the candle samples dissolve in various solvents, providing insight into the dispersion of active ingredients and the stability of the candle matrix. Three solvents were used: ethanol, vegetable oil, and water. The project candle was tested alongside a commercial candle for comparison and the findings as per Table 1.0.

The results showed that both the project candle and the commercial candle were soluble in ethanol, indicating that ethanol can effectively dissolve the wax and essential oil components in each candle. However, in vegetable oil, only the project candle was soluble, while the commercial candle remained insoluble. This suggests that the natural composition of the project candle, which includes used cooking oil and lemongrass extract, is more compatible with vegetable-based solvents. In contrast, the commercial candle may rely more on synthetic waxes or additives that do not blend well with oils (Muhammad et al. 2022; Pham et al. 2020).

In water, both candles were found to be insoluble, which is a desirable property for wax-based products. Water insolubility ensures that the candle maintains its structure in humid conditions and that the repellent compounds are released gradually through controlled burning rather than through diffusion in moisture (Khan et al. 2019; Michael Joseph Stalin et al. 2022; Yusuf Aiman Mohd Nizar and Ridzuan Kamaruzaman 2024).

Overall, the solubility results demonstrate that the project candle possesses favourable chemical properties for delivering consistent aromatic and repellent effects. The compatibility with ethanol and vegetable oil confirms that the active ingredients are well-dispersed, which supports the functional performance of the product. Furthermore, water insolubility ensures structural stability, making the candle suitable for real-world use in various environments.

Conclusion

This study successfully evaluated the chemical performance of insect repellent candles made from used cooking oil and lemongrass through pH and solubility testing. The pH test results showed that the candle extract, when mixed with distilled and tap water, produced mildly alkaline solutions. These values remained within a safe and acceptable range, indicating that the candle formulation does not pose any significant chemical risk for typical household use. The slight alkalinity may also contribute to preserving the candle's stability over time.

In the solubility test, the project candle demonstrated full solubility in ethanol and vegetable oil, while remaining insoluble in water. This behaviour confirms the good integration of natural oil-based ingredients within the wax structure, ensuring consistent distribution of active repellent compounds. The insolubility in water is particularly important for preserving the candle's physical form and effectiveness in various storage or usage conditions. Compared to a commercial candle, the project candle showed better compatibility with vegetable oil, highlighting its natural and biodegradable composition. Overall, the findings support the potential of using waste-derived and plant-based materials to produce eco-friendly insect repellent candles. The favourable pH and solubility profiles suggest that the product is not only safe and stable but also suitable for further development as a sustainable alternative to conventional repellents. Future studies can build on these results by exploring other performance characteristics such as burn rate, scent longevity, and insect repellent efficacy in real-world conditions.

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ANTIOXIDANT ACTIVITY, PHYSICOCHEMICAL PROPERTIES AND SENSORY ACCEPTABILITY OF DARK CHOCOLATE DRINK INCORPORATED WITH KACIP FATIMAH (*LABISIA PUMILA*) POWDER EXTRACT

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Abstract: Dark chocolate drinks are cocoa-based beverages produced using a higher percentage of cocoa powder and lower milk powder content than milk chocolate drinks. Furthermore, dark chocolate drinks offer a more intense chocolate flavour, antioxidants, and a luxurious mouthfeel. Kacip Fatimah (*Labisia pumila*) powder extract is increasingly available to incorporate into cocoa-based drink powder for women's health and wellness. This study aimed to evaluate the potential of Kacip Fatimah powder extract (KFPE) as a functional ingredient in dark chocolate drink powder (DCDP) to enhance nutritional profile without compromising sensory qualities. Four DCDP formulations were prepared with varying concentrations of KFPE (0 mg, 60 mg, 120 mg, and 180 mg). Each formulation was analysed for antioxidant activity; 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity, physicochemical properties (water activity, total soluble solids, pH, viscosity, solubility and colour) and sensory acceptability. Adding KFPE significantly increased ($p < 0.05$) the antioxidant activity from 70.19% to 79.50%. Addition of KFPE increased the water activity (from 0.29 to 0.32) and total soluble solids (from 12.23% to 13.87%), but decreased the pH (from 7.47 to 7.42) and viscosity (from 36.67 to 10.67 cps) of DCDP. Solubility of hot dark chocolate drink (HDCD) with KFPE remained consistent, although dissolution time increased at higher concentrations due to larger particle sizes. Meanwhile, lightness (L^*) of dark chocolate drink with KFPE increased in powder (from 36.52 to 46.45) and dissolved in hot water (from 4.81 to 15.99). In contrast, adding KFPE significantly increased the redness (a^*) and yellowness (b^*) of the HDCD. Sensory evaluation showed that HDCD with or without KFPE received similar scores ($p > 0.05$) for all attributes (colour, bitterness, viscosity, cocoa flavour, and overall acceptability). Therefore, KFPE can be effectively incorporated into dark chocolate drinks to enhance their antioxidant activity and maintain physicochemical and sensory properties.

Keywords: Dark Chocolate Drink, Kacip Fatimah Powder Extract, Antioxidant Activity, Physicochemical Properties and Sensory Evaluation

Introduction

Functional foods are increasingly popular due to their ability to provide essential nutrients while offering additional health benefits (Abedini et al., 2023). Milk chocolate drinks, although widely consumed, are often high in sugar and fat, making them less suitable for health-conscious consumers. While healthier alternatives exist, there remains potential to further enhance their nutritional profile without compromising taste. Cocoa-based beverages are widely consumed across all age groups, particularly among children, due to their pleasant taste and convenience. These drinks are available in various forms such as instant, ready-to-drink, hot or cold and typically made from cocoa powder, often fortified with stabilizers, vitamins, and minerals. Preparation generally involves heating cocoa powder with sugar, followed by milk powder or sweeteners used to enhance flavour and nutritional value (Barišić et al., 2022). Besides taste, dark chocolate drinks offer health advantages, such as improved calcium and vitamin D intake, immune support via increased IFN- γ levels, and the potential to combat malnutrition. Rich in antioxidants such as polyphenols especially proanthocyanidins, catechins, and anthocyanins, dark chocolate contains 12–15 mg/g of polyphenols, surpassing tea and wine in flavonoid content (Samanta et al., 2022).

Kacip Fatimah (*Labisia pumila*) is a medicinal plant native to Southeast Asia, especially Malaysia, and is traditionally used for women's health (Radzali et al., 2022). It is commercially available in different forms such as capsules, powders, teas, and beverages (Fazwa et al., 2020). Nutritionally, Kacip Fatimah contains macronutrients (carbohydrates, proteins, fats), essential minerals (e.g., calcium, magnesium, zinc), vitamins (C and E), and antioxidant compounds such as phenolics (gallic and caffeic acids), as well as flavonoids and carotenoids (Radzali et al., 2022). Plant-derived compounds such as phytoestrogens (coumestans and isoflavones) are also found in Kacip Fatimah, which is used in postpartum care. Additionally, saponins found throughout the plant, especially in the leaves, contribute to cholesterol-lowering and immunomodulating effects (Abdullah et al., 2013). Flavonoids present in the plant are associated with antioxidant, anti-inflammatory, and anticancer properties (Zakaria et al., 2021).

The incorporation of Kacip Fatimah powder extract into dark chocolate beverages presents a promising approach to developing a functional drink. However, challenges such as interactions between bioactive compounds and other ingredients, as well as stability during processing and storage, must be addressed. This study investigates the effects of Kacip Fatimah powder extracts at different concentrations on antioxidant activity, physicochemical properties, and sensory acceptability in dark chocolate drinks, aiming to formulate a product aligned with modern dietary trends.

Materials and Methods

Materials

The cocoa powder (Favorich, Guan Chong Berhad), monk fruit sweetener (Lakanto, Saraya Goodmaid Sdn. Bhd.), skimmed milk powder (NZMP, Fonterra), and Kacip Fatimah powder extract (A&T Ingredients Sdn. Bhd.) were used. Materials for chemical analysis (analytical grade from Sigma Aldrich, Germany) such as methanol, Folin-Ciocalteu reagent, sodium carbonate solution, sodium chloride and DPPH solution were used in this research.

Methods

Preparation of Dark Chocolate Drink with Kacip Fatimah Powder Extract

Four dark chocolate drink powder (DCDP) formulations were developed by incorporating different amounts of Kacip Fatimah powder extract (KFPE) at different concentrations (0 mg, 60 mg, 120 mg, and 180 mg) to examine their effects on antioxidant activity, physicochemical characteristics, and sensory attributes. Table 1 presents four DCDP formulations enriched with KFPE. Once all ingredients weighed, the formulation were mixed thoroughly using a double cone mixer (DNK Pharmatech and India) set at 15 rpm for 45 minutes to ensure uniform mixing and consistent quality.

Table 1: Formulations of Dark Chocolate Drink with Kacip Fatimah Powder Extract

Ingredients	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Cocoa powder	30 g	24.94 g	24.88 g	24.82 g
Monk fruit sweetener	55 g	60 g	60 g	60 g
Kacip Fatimah powder extract	0 g	0.06 g	0.12 g	0.18 g
Skimmed milk powder	15 g	15 g	15 g	15 g

Determination of antioxidant activity: DPPH Radical Scavenging Assay

The antioxidant activity of the DCDP with KFPE at different concentrations was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method, as described by Karim et al. (2019). To prepare the DPPH solution, 0.004 g of DPPH was dissolved in methanol and made up to 100 mL. For the standard, 0.01 g of ascorbic acid was dissolved in distilled water and diluted in a 10 mL volumetric flask to obtain a 1000 ppm stock solution. Then, a series of standard solutions were prepared at concentrations of 0, 200, 400, 600, 800, and 1000 ppm. Both the standard and the DCDP samples were diluted using methanol. Then, 1.2 mL of each ascorbic acid dilution (ranging from 20 to 100 ppm) was mixed with 9.0 mL of the methanolic DPPH solution and vortexed thoroughly. The mixtures were kept in the dark for 30 minutes. Absorbance was measured at 517 nm using a Genesys 30 Visible Spectrophotometer (Thermo Fisher Scientific, USA), and each sample was tested in triplicate. The same procedure was applied to assess the antioxidant activity of the DCDP with KFPE at different concentrations. Absorbance values of both the blank (methanolic DPPH solution) and the samples were recorded and calculated for antioxidant activity using the formula below:

$$\% \text{ Inhibition} = \frac{\text{Absorbance of DPPH blank}}{\text{Absorbance of sample with DPPH}} \times 100$$

Determination of Moisture Content

Moisture content of DCDP with KFPE at different concentrations was conducted following the method by the Malaysian Cocoa Board (2010). An aluminium dish was pre-heated in an oven at 105°C for 1 hour, then cooled in a desiccator for 30 minutes. After cooling, approximately 5 g of the sample was weighed into the dish. The sample was then dried in an oven at 105°C for 4 hours until it reached a consistent weight. After drying, the sample was cooled again in a desiccator for 30 minutes and reweighed. To ensure accuracy, the sample was reheated for an

additional 30 minutes, cooled in the desiccator for 15 minutes, and weighed again. This process was repeated until the sample achieved a constant weight. The moisture content was calculated using the formula below:

$$\text{Moisture by weight \%} = \frac{(m1 - m2) \times 100}{(m1 - m0)}$$

m0 = mass of aluminium dish without sample

m1 = mass of aluminium dish with sample before drying

m2 = mass of aluminium dish with sample after drying

Determination of Colour

The colour of DCDP with KFPE at different concentrations was carried out based on the method by Arifin et al. (2022), with slight modifications. Two types of samples were analysed: hot dark chocolate drink (HDCD) with KFPE and the DCDP with KFPE. For the HDCD, the DCDP with KFPE was dissolved in a suitable solvent to ensure a uniform mixture, then poured into a petri dish, while the DCDP with KFPE was placed in a transparent ziplock bag. Colour measurements were taken using a spectrophotometer (CM-5, Konica Minolta, Japan) following the CIE colour system, which includes L* (perceptual lightness), a* (red-green axis), and b* (yellow-blue axis) values. Each sample was measured in triplicate to ensure accuracy.

Determination of pH Value

The pH of the DCDP with KFPE at different concentrations was measured according to the method by Sioriki et al. (2021), with minor modifications. A portable pH meter (PHB-4, Henan, China) was first calibrated using a standard buffer solution with a pH of 7. For the analysis, 10 grams of the powdered sample were mixed with 50 mL of distilled water and filtered through filter paper. The filtrate was then transferred into a clean container. Once the pH meter was ready, the electrode was inserted into the sample, and the pH reading was recorded after the meter stabilized.

Determination of Viscosity

The viscosity of the HDCD with KFPE at different concentrations was measured using a Brookfield Viscometer (LVT model, Brookfield, Massachusetts, USA), following the method described by Jensen et al. (2010). The viscometer was fitted with a No. 2 spindle, and its position was properly adjusted prior to measurement. The sample was heated on a hot plate until it reached 75°C. The spindle was immersed in the sample, and the reading was recorded after two complete rotations at a constant speed of 30 rpm, as displayed on the viscometer.

Determination of Total Soluble Solids

The total soluble solids of the HDCD with KFPE at different concentrations were determined according to the method of Rongtong et al. (2018) with slight modifications. An Atago PAL-3 Digital Refractometer (Atago Co., Tokyo, Japan) was used to measure the dark chocolate drink at 25°C, and the results were expressed as °Brix.

Determination of Solubility and Dissolution Time

The solubility of the DCDP with KFPE at different concentrations was measured using a modified method based on Indiarito et al. (2022). 1 g of the powdered sample was mixed with 30 mL of distilled water in a beaker and stirred at 500 rpm for one minute. The stirring speed was then increased to 1000 rpm and continued for two minutes. The mixture was transferred into a 50 mL centrifuge tube and centrifuged at $3000 \times g$ for five minutes. A 5 mL portion of the supernatant was collected, placed in a pre-weighed Petri dish, and dried at 105°C for four hours. Solubility (S) was calculated using the formula:

$$S(\%) = \frac{\text{Solid grams in supernatant}}{\text{sample weight in grams}} \times 100\%$$

To determine dissolution time, a 5 g sample was dissolved in 100 mL of water at 80°C , and the time required for complete dissolution was recorded with a stopwatch.

Determination of Water Activity

Water activity of the DCDP with KFPE at different concentrations was measured using a water activity meter (Aqualab, 4TE, USA). Three replications of the measurements were performed on the samples.

Determination of Hygroscopicity

The hygroscopicity of the DCDP with KFPE at different concentrations was determined using the method described by Indiarito et al. (2022), with slight modifications. The samples were pre-dried in an oven at 70°C until a constant weight was achieved. Approximately 2 g of each powder sample was placed in an aluminium dish along with 30 g of saturated sodium chloride solution, which provided a relative humidity of 75.29% at 25°C . The samples were reweighed after a week, and the hygroscopicity was calculated as a percentage.

Determination of Sedimentation

The sedimentation index of HDCD with KFPE at different concentrations was determined according to the method of Jensen et al. (2010) with slight modifications. 1 g of powdered sample was mixed with 30 mL of distilled water in a 50 mL centrifuge tube and thoroughly homogenized using a vortex mixer. The mixture was then centrifuged at 3000 rpm for 20 minutes. After decanting the supernatant, the tubes were inverted and allowed to drain for 30 minutes. The percentage of weight was used to represent sediment.

Determination of Sensory Acceptability

Sensory acceptability of HDCD with KFPE at different concentrations was conducted. Each sample was made by mixing 20 g of powdered chocolate with 150 mL of hot water. The prepared drinks were served in 15 mL portions using transparent plastic cups labelled with random three-digit codes, as outlined by Pourhaji et al. (2022). A total of 30 female panellists aged between 21 and 33 years participated in the sensory evaluation. Panellists were instructed to rinse their mouths with water between testing each sample. The panellists were needed to evaluate and rate the samples on a 9-point hedonic scale based on the attributes (colour,

sweetness, cocoa flavour, bitterness, viscosity, and overall acceptability). The indicator for the 9-point hedonic scale used: 1- Dislike extremely, 2- Dislike very much, 3- Dislike moderately, 4- Dislike slightly, 5- Neither like nor dislike, 6- Like slightly, 7- Like moderately, 8- Like very much, 9- Like extremely, for the sensory evaluation of HDCD with KFPE at different concentrations. All scores were recorded, and the total and mean scores for each attribute were calculated.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics software. A one-way analysis of variance (ANOVA) was conducted, followed by Tukey’s post-hoc test to determine significant differences among the sample groups at a significance level of $p < 0.05$. Results are reported as the mean \pm standard deviation.

Result and Discussions

DPPH Scavenging Assay

Table 2 presents the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity of DCDP with KFPE at different concentrations.

Table 2: Antioxidant Activity of Dark Chocolate Drink Powder with Kacip Fatimah Powder Extract at Different Concentrations

Sample Formulation	DPPH Inhibition (%)
F1 (Control)	70.19 \pm 2.15 ^c
F2 (60 mg)	75.85 \pm 0.41 ^b
F3 (120 mg)	75.57 \pm 0.64 ^b
F4 (180 mg)	79.50 \pm 0.70 ^a

^{a,b,c} Values with different letters in the same column are significantly different ($p < 0.05$) Mean \pm SD each value in the table is the mean of triplicate

The results indicated that samples containing *Kacip Fatimah* extract (60–180 mg) exhibited significantly higher ($p < 0.05$) antioxidant activity, ranging from 75.85% to 79.50%, compared to the control sample at 70.19%. This enhancement in antioxidant capacity is likely due to the presence of bioactive compounds such as β -carotene and flavonoids found in *Kacip Fatimah* (Norhaiza et al., 2009). Other than that, gallic acid, saponins, caffeic acid, and methyl gallate are also present in *Kacip Fatimah* (Abdullah et al., 2013). Iwansyah (2011) also reported that the water-soluble extract of *Kacip Fatimah* showed strong antioxidant activity, primarily due to its gallic acid content. Moreover, all samples displayed antioxidant activity, which can be attributed to epicatechin and catechin compounds naturally present in cocoa powder (Ishak et al., 2024). The incorporation of *Kacip Fatimah* extract effectively enhanced the free radical scavenging potential of the dark chocolate drink powder.

Moisture Content

According to Table 3, the moisture content of DCDP with KFPE at different concentrations ranges from 2.49% to 5.92%. These values are consistent with findings by Indiarito et al. (2022), who reported that the moisture content of cocoa drink powder with different percentages of encapsulated green coffee bean extracts (2-10%) was between 3.04% and 3.84%. However, statistical analysis revealed no significant differences ($p > 0.05$) among all the DCDP with

KFPE at different concentrations. The control sample (F1) recorded the highest moisture content at 5.92%, suggesting higher water retention without the KFPE. In contrast, formulation F2 had the lowest moisture content at 2.49%. Dried food products generally have moisture levels below 25%, and foods with less than 8% moisture content can effectively inhibit microbial growth (Chuchird et al., 2024). Overall, all DCDP with KFPE at different concentrations have low moisture content.

Water Activity

As presented in Table 3, the water activity (a_w) of DCDP with KFPE at different concentrations varied significantly ($p < 0.05$), ranging from 0.29 to 0.32. The control sample (F1) recorded the highest a_w value at 0.32 compared to other formulations containing KFPE (a_w 0.29-0.31). Water activity indicates the availability of free water in a product, which influences chemical reactions and microbial growth (Tušek & Benković, 2024). This trend reflects the findings of Schmidt and Fontana (2007), who reported a_w values for cocoa powder between 0.258 and 0.251. A reduction in moisture content is often accompanied by a decrease in a_w , due to reduced availability of free water. Furthermore, food products with a_w below 0.6 are generally considered shelf-stable, as most bacteria require a_w above 0.85 to proliferate (Tapia et al., 2020). Therefore, all DCDP with KFPE at different concentrations in this study demonstrate strong microbial stability and potential for extended shelf life due to low a_w .

Hygroscopicity

The addition of KFPE did not influence the hygroscopicity of the DCDP as shown in Table 3. The hygroscopicity values of DCDP with KFPE at different concentrations ranged from 3.17% to 4.16%. Although no significant differences ($p > 0.05$) were observed among the DCDP containing KFPE, a significant difference ($p < 0.05$) was found when compared to the control sample, which obtained the highest hygroscopicity (4.16%). Meanwhile, the lowest hygroscopicity (3.32-3.17%) was observed in DCDP samples with KFPE compared to the control. These results suggest that the inclusion of KFPE slightly reduced the hygroscopic nature of the cocoa drink powder. This reduction may be attributed to hydrophobic compounds or specific phytochemicals present in the extract, which could limit the product's moisture absorption capacity (Indiarto et al., 2022). Therefore, the addition of KFPE decreases the hygroscopicity of DCDP.

Table 3: Moisture, Water Activity and Hydroscopicity of Dark Chocolate Drink Powder Incorporated with Kacip Fatimah Powder Extract

Parameter	Sample formulation			
	F1 (Control)	F2 (60mg)	F3 (120mg)	F4 (180mg)
Moisture content (%)	5.92 ± 0.38a	2.49 ± 1.70a	3.77 ± 2.79a	3.08 ± 1.03a
Water activity (a_w)	0.32 ± 0.00a	0.31 ± 0.00b	0.29 ± 0.00d	0.30 ± 0.00c
Hygroscopicity	4.16 ± 0.46a	3.17 ± 0.25b	3.18 ± 0.27b	3.32 ± 0.02b

^{a,b,c} Values with different letters in the same row are significantly different ($p < 0.05$)

Mean±SD each value in the table is the mean of triplicate

Total Soluble Solids

Total soluble solids (TSS) refer to the combined concentration of sugars, acids, and small amounts of dissolved vitamins, fructans, pigments, proteins, phenolic compounds, and minerals, which are measured by °Brix unit (Magwaza & Opara, 2015). The incorporation of KFPE significantly affected ($p < 0.05$) the hot dark chocolate drink (HDCD) in Table 4, which led to an increase in TSS values, which ranged from 12.23 to 13.87°Brix. The control sample (F1), which contained no KFPE, recorded the lowest TSS at 12.23°Brix, while the sample with the highest concentration of KFPE (F4) exhibited the highest value at 13.87°Brix. This increase is likely due to the presence of bioactive compounds in Kacip Fatimah, such as saponins, which are known to stabilize emulsions and improve solubility. These properties promote a more homogeneous dispersion of solid particles in the beverage, thereby increasing the total soluble solids content (Timilsena et al., 2023). Therefore, the addition of KFPE increases the TSS of the HDCD.

pH Value

Measuring the pH of beverages is crucial for ensuring product consistency, stability, and consumer safety. As shown in Table 4, adding KFPE significantly affected the pH of the HDCD ($p < 0.05$). The pH values ranged from 7.42 to 7.47, remaining close to neutral. The control sample (F1) showed the highest pH (7.47), while other samples with KFPE (F2, F3, and F4) had slightly lower values. This reduction in pH can be attributed to the presence of organic acids like caffeic acid in Kacip Fatimah, which release H^+ ions. Similar effects have been observed with ginger powder, where the presence of phenolic compounds and organic acids caused a lower pH in ready-to-drink cocoa beverage formulated with high and low-fat content powder (Faiqoh et al., 2021). Additionally, phenolic compounds in Kacip Fatimah may convert into monomeric phenolic acids, promoting ionization under acidic conditions and contributing further to the pH reduction (Sawale et al., 2017). Therefore, incorporating KFPE decreases the TSS of HDCD.

Solubility

Solubility refers to the capacity of a substance to dissolve in a specific volume of solvent at a given temperature (Setiadi et al., 2021). As shown in Table 4, the solubility of HDCD with KFPE ranged from 10.67% to 14.33%, with no significant differences observed between formulations ($p > 0.05$). This suggests consistent solubility across all samples, likely due to the uniform particle size of cocoa powder. The addition of KFPE did not significantly impact solubility. These results align with findings by Dogan et al. (2013), who reported minimal variation in the solubility of prebiotic instant hot chocolate beverage model systems, attributing it to the consistent sugar content. Therefore, KFPE does not affect the HDCD.

Table 4: Parameters of Dark Chocolate Drinks Incorporated with Kacip Fatimah Extract After Brewing

Parameter	Sample formulation			
	F1 (Control)	F2 (60mg)	F3 (120mg)	F4 (180mg)
Total soluble solids °brix (%)	12.23 ± 0.15c	13.33 ± 0.15b	13.23 ± 0.06b	13.87 ± 0.06a
pH value	7.47 ± 0.007b	7.46 ± 0.007b	7.42 ± 0.007a	7.47 ± 0.000b

Solubility (%)	10.67 ± 1.15a	14.33 ± 3.21a	11.67 ± 1.15a	12.00 ± 3.00a
Dissolution time (s)	82.62 ± 6.18a	57.15 ± 2.12b	69.21 ± 8.68b	57.42 ± 4.43b
Sedimentation (%)	4.05 ± 0.74a	3.73 ± 0.67ab	2.38 ± 0.71b	4.09 ± 0.30a
Viscosity (cps)	36.67 ± 2.89a	31.67 ± 2.89ab	26.67 ± 2.89b	10.67 ± 3.06c

^{a,b,c} Values with different letters in the same row are significantly different ($p < 0.05$)

Mean±SD each value in the table is the mean of triplicate

Dissolution time

Dissolution time, defined as the time required for a solute to fully dissolve in a solvent (Lu et al., 2022), is critical for beverage quality as faster dissolution enhances drinkability. In this study, the addition of KFPE significantly influenced dissolution time ($p < 0.05$), with values ranging from 57.15 to 76.13 seconds compared to the control sample, as shown in Table 4. Sample F2 (0.6 g KFPE) dissolved the fastest at 57.15 seconds, while sample F3 showed the longest time. Longer dissolution times at higher KFPE concentrations may be due to larger particle sizes or more insoluble components. Additionally, higher moisture content could cause clumping, slowing dissolution. The naturally hydrophobic nature of fat in cocoa powder may also contribute to extended dissolution times (Indiarto et al., 2022). Therefore, KFPE at all concentrations decreases the dissolution time of HDCD.

Sedimentation

Sedimentation is a common challenge in cocoa-based beverages, as it affects the overall consistency and texture (Sawale et al., 2017). According to Table 4, the sedimentation index of the HDCD with KFPE ranged from 2.38% to 4.09%. The addition of KFPE did not significantly influence sedimentation ($p > 0.05$). Factors such as particle size, viscosity, and particle concentration play important roles in sedimentation behavior (Faiqoh et al., 2021). The consistent sedimentation values observed in all HDCD samples may be attributed to the uniform particle size across formulations. Additionally, Sawale et al. (2017) stated that cocoa powder typically contains large, dense, and insoluble particles, and reducing its content can help minimize sedimentation in chocolate-based beverages. Therefore, KFPE does not improve the solubility of HDCD.

Viscosity

The viscosity of cocoa beverages is influenced by the interaction between dispersed solid particles and the dispersion phase (Faiqoh et al., 2021). Based on Table 4, the addition of KFPE significantly reduced the viscosity of the HDCD ($p < 0.05$), with values ranging from 10.67 to 36.67 cps. The control sample exhibited the highest viscosity (36.67 cps), while sample F4, containing the highest concentration of the KFPE (1.8 mg), had the lowest viscosity (10.67 cps). This indicates that increasing the concentration of KFPE lowers the viscosity of the HDCD. The reduction is likely due to the interaction of polyphenols in Kacip Fatimah with proteins and other macromolecules, which can disrupt hydrophobic interactions and alter protein structure, thereby decreasing water-binding capacity and overall viscosity (Yeop et al., 2021). Hence, incorporation of KFPE reduced the viscosity of HDCD.

Colour

Colour plays a crucial role in shaping consumer perception and influencing purchasing decisions in beverages (Faiqoh et al., 2021). Table 5 presents the colour properties (L*, a*, b*) for both powdered and dissolved hot dark chocolate drink samples with KFPE.

Table 5: Colour of Dark Chocolate Drink with Kacip Fatimah Powder Extract in Powdered and Dissolved Forms

Sample Formula- tion	Powder sample			Dissolved sample		
	L*	a*	b*	L*	a*	b*
F1 (Control)	36.52 0.17c	± 2.02 ± 0.21a	2.61 ± 0.16b	4.81 ± 0.74b	-0.53 ± 0.20b	± 1.73 ± 0.12b
F2 (60mg)	44.55 0.17ab	± 3.43 ± 0.17a	3.34 ± 0.47ab	± 1.48 ± 0.11c	-0.93 ± 0.07b	± 2.05 ± 0.02a
F3 (120mg)	44.17 1.31b	± 3.32 ± 1.23a	4.32 ± 0.84a	15.03 ± 0.59a	± 0.79 ± 0.10a	2.03 ± 0.13a
F4 (180mg)	46.45 1.28a	± 3.10 ± 0.48a	3.88 ± 0.83a	15.99 ± 0.98a	± 0.86 ± 0.19a	1.89 ± 0.11ab

^{a,b,c} Values with different letters in the same column are significantly different (p < 0.05)

Mean±SD each value in the table is the mean of triplicate

The L* value indicates lightness, where 100 represents pure white and 0 represents pure black (Amrih et al., 2023). The addition of KFPE significantly increased the L* values (p < 0.05), meaning the DCDP became lighter in colour. In powdered form, the control sample (F1) had the lowest L* value (34.84). In contrast, F4 (180 mg of KFPE) had the highest lightness (46.45), showing that Kacip Fatimah lightens the cocoa mixture due to its natural colour characteristics. A similar trend was observed in dissolved drink samples (HDCD), with F1 showing the lowest lightness (4.81) and F4 the highest lightness (14.72), further confirming the lightening effect as the concentration of KFPE increased. In contrast, there were no significant changes in a* and b* values for powdered samples (DCDP with KFPE). However, a significant difference (p < 0.05) was observed in the a* and b* values for HDCD samples. The a* value measures the red-green colour spectrum (positive a* = red, negative a* = green), while the b* value reflects the yellow-blue spectrum (positive b* = yellow, negative b* = blue) (Amrih et al., 2023). The presence of KFPE increased both a* and b* values, indicating an enhancement in the reddish and yellowish tones of the HDCD, with higher concentrations of the KFPE intensifying these effects (Indiarto et al., 2022). Therefore, the addition of KFPE decreases the lightness value of dark chocolate drink in powdered and dissolved forms.

Sensory Evaluation

Table 6 presents the mean scores for sensory attributes (colour, sweetness, cocoa flavour, bitterness, viscosity, and overall acceptability) of HDCD with KFPE at different concentrations.

Table 6: Sensory Characteristics of Hot Dark Chocolate Drink with Kacip Fatimah Powder Extract

Sample formulation	Sensory Characteristics					
	Colour	Sweetness	Cocoa flavor	Bitterness	Viscosity	Overall acceptability
F1(Control)	6.82± 1.61a	4.75± 1.80b	5.82± 1.79a	5.57± 1.73a	6.43± 1.73a	5.71± 1.58b
F2 (0.6 mg)	7.21± 1.23a	6.18± 1.28a	5.79± 1.23a	6.43± 1.55a	6.43± 1.45a	6.71± 1.38a
F3 (1.2 mg)	7.46± 1.35a	6.11± 2.01a	6.46± 1.35a	6.39± 1.73a	6.71± 1.54a	6.75± 1.73a
F4 (1.8 mg)	7.07± 1.56a	6.11± 1.81a	5.86± 1.38a	6.43± 1.50a	6.46± 1.64a	6.61± 1.47a

Values are presented as mean ± standard deviation; values annotated with different letters in the same column show a significant difference at $p < 0.05$.

ANOVA results revealed significant differences ($p < 0.05$) in sweetness and overall acceptability between HDCD with and without *Kacip Fatimah* extract. However, no significant differences ($p > 0.05$) were found in the scores for colour, cocoa flavour, bitterness, or viscosity, indicating that these sensory attributes remained largely unaffected by the addition of the KFPE in HDCD. The significant variation in sweetness scores suggests that KFPE influenced the sweet taste profile of the HDCD. The mean score for the colour of HDCD with KFPE at different concentrations ranged from 6.82 to 7.46, indicating that all samples were generally liked in terms of appearance. As noted by Indiarito et al. (2022), the brown colour of chocolate drinks is primarily due to cocoa powder. During roasting, polyphenolic compounds form quinones, which react with free amino acids and polyphenol oxidase (PPO) enzymes to produce a characteristic brown hue. Flavonoid complexes developed during fermentation and the chemical changes from alkali treatment under heat and oxygen further enhance this cocoa colour. These findings suggest that the inclusion of KFPE did not significantly affect the colour of the HDCD. Flavour is a key factor in consumer acceptance and quality perception of cocoa-based products. No significant differences in cocoa flavour were observed among the samples. Bitterness scores, ranging from 5.57 to 6.43, also remained consistent for all formulations, suggesting that *Kacip Fatimah* did not introduce additional bitterness. Bitterness in chocolate or cocoa powder primarily arises from naturally occurring compounds such as caffeine, theobromine, pyrazines, phenolics, certain peptides, and amino acids (Cempaka et al., 2021). Panellists slightly liked the viscosity of all dark chocolate drink formulations, and the presence of *Kacip Fatimah* did not significantly impact the drink's mouthfeel. This implies that the *Kacip Fatimah* was well-integrated and did not alter the beverage's texture. In terms of overall acceptability, all HDCD with KFPE received similar scores, while the control sample (without extract) scored the lowest (5.71). This indicates that the addition of *Kacip Fatimah* positively influenced the overall acceptance of the HDCD.

Conclusion

In conclusion, the study demonstrates the potential of *Kacip Fatimah* as a functional ingredient that can improve the nutritional and sensory qualities of dark chocolate drink. The addition of *Kacip Fatimah* powder extract significantly increased the antioxidant activity of the dark chocolate drink powder. Moisture content and hygroscopicity of dark chocolate drink powder with *Kacip Fatimah* powder extract remained unaffected, while water activity increased with

higher concentrations of the Kacip Fatimah powder extract. Total soluble solids of hot dark chocolate drink also increased as more Kacip Fatimah powder extract was added, whereas viscosity and pH decreased. Solubility showed no significant changes for all hot dark chocolate drinks with Kacip Fatimah powder extract, but dissolution time was significantly reduced with the extract's inclusion. In terms of colour, Kacip Fatimah powder extract improved the lightness (L^*) of both powder and dissolved samples of dark chocolate drinks. Although the a^* (redness) and b^* (yellowness) values of the powders did not change significantly, the dissolved samples showed marked increases in both with higher levels of Kacip Fatimah extract powder. Sensory evaluation of hot dark chocolate drink with Kacip Fatimah powder extract revealed significant differences in sweetness and overall acceptability, yet all formulations were generally well-received by panellists. Among all, Formulation 3 (dark chocolate drink added with 120 mg of Kacip Fatimah powder extract) emerged as the most balanced, offering an optimal combination of physical properties, phenolic content, and antioxidant activity.

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THE STUDY OF FERTILIZER MADE FROM FOOD WASTE AND SAWDUST IN PELLET FORM AND COMPOST

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Abstract: *Fertilizers are essential in modern agriculture which improve soil health by supplying key nutrients for plant growth. Meanwhile, food waste presents a serious global issue, contributing to methane emissions from landfills and accelerating climate change. Sawdust, another abundant waste byproduct from the wood industry, also poses disposal challenges. This study explores composting and pelleting fertilizers using varying proportions of food waste and sawdust to support sustainable farming. Compost was produced by combining food waste, sawdust, dry leaves, and effective microorganisms (EM) in a bin. Key parameters monitored included pH, temperature, moisture content, as well as carbon-to-nitrogen (C:N) and carbon-to-phosphorus (C:P) ratios. Pelleted fertilizer was produced by grinding, mixing, and pelletizing the same materials. Composting results showed pH levels from 3.44 to 7.49 and temperatures between 22.4°C and 34.1°C. Moisture content declined over time. Sample A recorded the highest C:N and C:P ratios of 12:1 and 20:1, respectively. Iron and manganese concentrations remained low (0.36 mg/L and 0.59 mg/L, respectively), indicating non-toxicity. The pelleted fertilizer exhibited uniform size and shape due to the precision of the pelleting apparatus. Sample A showed the highest water stability at 88% after 10 minutes. Sample E had the highest bulk density (2.28 g/cm³), while samples A and B recorded the lowest (2.26 g/cm³). All samples displayed consistent pellet sizes in particle distribution. This study demonstrates that composting food waste and sawdust yields nutrient-rich and environmentally safe fertilizers. The results support the integration of food waste recycling into agricultural practices which promote soil fertility and environmental sustainability.*

Keywords: *Fertilizer, Food Waste, Sawdust, Compost, Pellet*

Introduction

Nowadays, the ability of contemporary agriculture to fulfill future food needs is a concern due to the rising global population. Fertilizers have become important in modern agricultural techniques in replenishing nutrients in agricultural soils (Du et al., 2020). It is the key in enhancing soil quality by supplying necessary nutrients and minerals for plant growth, thus leading to higher productivity and better harvest results (Wan et al., 2021). Fertilizers supply critical nutrients such as nitrogen, phosphorus, and potassium that plants require for growth and development to enhanced agricultural production and yields (Ilinova et al., 2021).



Fertilizers help replace soil minerals lost by continual cropping, preserving soil health and fertility over time (Kumar et al., 2023). Fertilizers can increase plant growth, allowing for several harvests per year and faster crop turnaround times (Kang et al., 2023). Fertilizers are required for intensive farming operations to fulfill the food needs of a growing worldwide population (Wang et al., 2023).

There are two main types of fertilizer which is organic (natural) and inorganic (chemical) fertilizer. Organic fertilizer fostering a holistic approach to soil health while inorganic fertilizer focusing on accelerated plant development and productivity (Zhang et al., 2020). Synthetic or chemical fertilizers are the chemical blends and additives that are produced through artificial means to provide numerous benefits to plant (Kakar et al., 2020). Overuse of chemical fertilizers can cause soil acidification, decrease soil organic matter, and general soil health degradation (Li et al., 2023). These fertilizers can contaminate groundwater with nitrates and other pollutants, posing health concerns to humans and animals (Severini et al., 2023).

Natural fertilizers can come from various sources such as plants, animals, or minerals that can add nature goodness to the soil (Yan et al., 2023). Compost is one of the ways to make fertilizer. The successful of composting process relies on the complex relationship of various microorganisms, such as bacteria and fungi, that work diligently to decompose organic matter in the soil (Yin et al., 2024). Compost is made of aerobically decomposing organic materials such as food scraps, yard trash, manure, and other biodegradable compounds. The key benefit of composting is the capacity to offer a balanced supply of important nutrients (Gao et al., 2024).

Apart from compost, fertilizer also can be made in a pellet form. Pellet fertilizers sometimes referred to as granular or pelletized fertilizers are tiny, homogeneous, and compact pellets derived from a range of nutrients and sources that might be organic, such as processed animal dung or plant leftovers, or inorganic, such as synthetic chemicals. These nutrition sources are blended into a homogeneous slurry, which is then pressed into pellet (Sarlaki et al., 2021). Pellet fertilizers are intended to give plants vital nutrients in a regulated and accurate manner (Sarlaki et al., 2021).

Food waste includes all food that is thrown, lost, or uneaten along the food supply chain, from production and processing to retail and consumption (Leal Filho et al., 2024). Food waste has become an alarming issue globally toward the environment, economy, and society. Some of these issues include wastage, land occupation, environmental contamination, time and effort spent on transportation and cooking, as well as the possibility of not being able to obtain enough food in the future (Niles, 2020). Food waste has the potential to be converted into organic fertilizer either by anaerobic digestion or composting method (Sánchez, 2022).

Wood processing produces numerous wood products that are important resources for many applications and the country economic growth. Examples of wood processing byproducts include sawdust, wood chips, bark, and lignin (Zheng et al., 2023). Sawdust is another material that can be used as a fertilizer. The use of sawdust in agricultural activities not only tackle the waste management issues but also gives many benefits to farmers and gardeners (Adegoke et al., 2022; Imberti et al., 2024). Farmers can boost crop yields, reduce input costs, and contribute to the long-term viability of agricultural systems by using sawdust (Liu et al., 2024).

Literature Review

Composting

Composting is the most versatile and productive way of managing biodegradable solid wastes. It is an important agricultural practice that helps to recycle farm and agricultural waste (Oyewusi et al., 2021). Composting is a simple, low-cost procedure that allows biodegradable waste to be turned into biologically stable compounds known as compost (Tsigkou et al., 2020). It decreases the environmental effect of biowaste, allows for nutrient recycling in the soil, and contributes to the circular economy (Kunuszabó et al., 2022). Composting normally requires collection of organic waste such as fruit and vegetable scraps, coffee grinds, eggshells, yard trimmings, and leaves. Then, the wastes are placed in a compost bin or pile and allowed to decompose (Liu et al., 2020). During decomposition, bacteria degrade organic matter into simpler compounds, creating heat as a by-product. This heat helps to speed up the breakdown process (Chia et al., 2020).

Food Waste and Sawdust Fertilizer in Pellet Form and Compost

Studies have shown that the combination of organic waste and sawdust is beneficial for maintaining an optimal carbon-to-nitrogen ratio, thus enhancing the composting process (Gurusamy et al., 2021). Organic waste is abundant in nitrogen, whereas sawdust contributes carbon, thereby fostering microbial activity. The combination significantly improves aeration, mitigates odors, and regulates moisture levels, thereby rendering the composting process more efficient (Maturi et al., 2021). Furthermore, the resultant compost enriches soil fertility and promotes environmental sustainability by reducing landfill waste (Zabbey et al., 2017).

The conventional proportion of food waste to sawdust utilized in the composting process is approximately 1 part food waste to 2-3 parts sawdust by volume or 1:2 by weight (Dimkpa et al., 2020). This ratio serves to equilibrate the nitrogen derived from the food waste with the carbon sourced from sawdust, thereby facilitating efficient composting (Dias et al., 2023). Modifications are necessary depending on moisture levels and the specific conditions of the composting process.

The pellet's nutrient profile reflects the levels of essential elements like nitrogen, phosphorus, and potassium found within it. These important nutrients are essential for the thriving of plants, since they support processes including photosynthesis, root enhancement, and the plant's overall health (Ayangbenro & Babalola, 2021). Pellets are frequently utilized to supply a regulated, slow-release source of these nutrients to the plants (Briassoulis et al., 2021).

Materials and Methods

Collection of Food Waste and Sawdust

Food waste such as vegetables, fruits, eggshells, bread, etc. was collected from a cafe, restaurant, and farmer market in Pagoh, Johor while sawdust was collected from a Furniture Technology Laboratory located at Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh Campus, Johor. The collected waste was stored at the laboratory prior to be used.

Formulation of Fertilizer

The formulation of the fertilizer is the different ratio of food waste, sawdust, and effective microorganism (EM) mix to produce the fertilizer. Several formulations were tested for both pellet and compost fertilizer as shown in Table 1. The EM stock solution was added with certain amount of water to dilute the content. The solution was fermented for a few days before it can be use.

Table 1: Formulations for Pellet and Compost Fertilizer (%)

Sample	Pellet form			Compost			
	Food waste	Sawdust	Leaves	Food waste	Sawdust	EM	Leaves
1	10	50	40	10	50	20	20
2	20	40	40	20	40	20	20
3	30	30	40	30	30	20	20
4	40	20	40	40	20	20	20
5	50	10	40	50	10	20	20

Preparation of Pellet Fertilizer

Initially, food waste was dried in an oven at 102°C to ensure free from any moisture. Next, the formulation of the fertilizer for each sample was prepared based in Table 1 for 2 kg. Then, the prepared mixture was placed in a grinder machine to grind and mix the content as well as get the right particle size. Subsequently, the mixture was placed in a pellet machine to be compressed and extruded. The machine used high pressure to push the material through a die, creating thick pellets that are all the same size and shape. After that, the pellets were screened to get rid of particles and then left to dry before further testing and analysis. Figure 2 shows the preparation of pellet fertilizer.

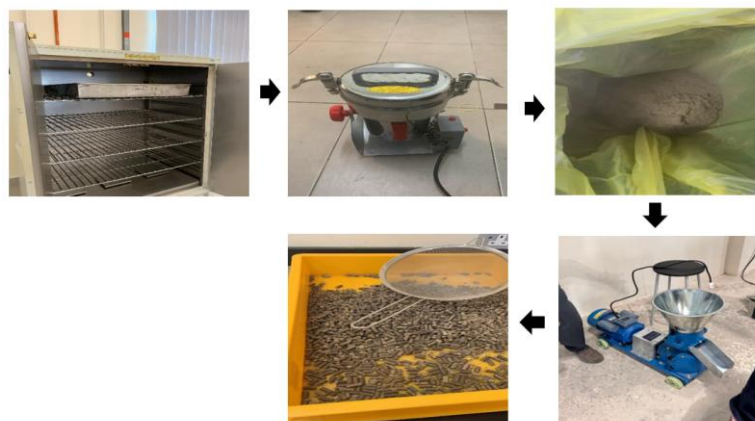


Figure 2: Preparation of Pellet Fertilizer

Physical Characterization of Pellet Fertilizer

The pellet fertilizer was physically characterized by measuring the diameter, length, water stability, bulk density and particle size distribution. The length and diameter of the pellet fertilizer was measured in mm using a digital vernier caliper. In water stability test, the pellets undergo immersion in water for certain period, during which their disintegration process is carefully monitored and quantified. Water stability was calculated using Equation 1:

$$\text{Water stability (\%)} = \frac{\text{Weight of pellets before immersion (g)}}{\text{Weight of pellets after immersion (g)}} \times 100 \quad (\text{Eq.1})$$

The bulk density was calculated using Equation 2:

$$\text{Bulk density} = \frac{\text{Mass of pellet (g)}}{\text{Volume of container (cm}^3\text{)}} \quad (\text{Eq.2})$$

The particle size distribution of the pellet was determined from sieving process. The particle retained of the pellet sample was measured using Equation 3:

$$\text{Particle retained (\%)} = \frac{\text{Weight of particle on sieve (g)}}{\text{Total sample weight (g)}} \times 100\% \quad (\text{Eq.3})$$

Preparation of Compost Fertilizer

Firstly, the formulation of the compost fertilizer for each sample was prepared based in Table 1 for 10 kg. Then, the mixture of the compost was placed in a 2 L polyethylene bin as shown in Figure 3. The compost pile should be moist but not dripping, so EM was added as needed. The compost was left in the bin for per week composting process. Periodically the compost pile should be stirred with a shovel to ensure even composting and provide oxygen for the microorganisms. The ratio of the greens and browns may need adjustment as the pile breaks down into compost. If the temperature begins to fall below thresholds, more fresh greens was needed and the compost was stirred to add oxygen back to the pile.



Figure 3: Preparation of Compost Fertilizer

Effects of Composting Parameters

The effects of composting parameters such as temperature, pH, and moisture content toward time were investigated by measuring the parameters weekly. Changes in temperature can be used to assess the quality of organic matter and the behavior of bacteria throughout the composting period. After the compost being stored in the bin for a week, the temperature of the compost was measured by using a digital thermometer. The temperature reading was taken by inserting the tip of the digital thermometer into the compost pile. The reading was taken three times. Compost material changes during the composting process where pH level signifies the efficiency of the composing process through the breakdown of organic matter. A HQ440d benchtop multi-meter (Hach) was used to measure the pH. Moisture may speed up metabolism, which makes it crucial for microbial activity as low humidity limit microbial activity. An

indicator of mature composting and decomposition at the end of the process is the decrease of moisture content. The moisture content of the compost pile is determined using Equation 4:

$$\text{Moisture content (\%)} = \frac{(w-d)}{w} \times 100 \quad (\text{Eq. 4})$$

Where:

w = Initial weight of sample, g

d = Weight of sample after drying g

Analysis of Iron and Manganese Concentration

The iron concentration of the compost sample solution was determined by using the FerroVer® Colorimetric method while the manganese concentration was determined using the 1-(2-Pyridylazo)-2-Naphtanol PAN method. Both iron and manganese concentration were analysed using DR 6000 UV-Vis spectrophotometer (Hach).

Analysis of C:N and C:P Ratio

The compost fertilizer was analysed for C:N and C:P ratio. The phosphorus concentration of the compost sample solution was determined using the PhosVer 3 (Ascorbic Acid) method. The nitrogen concentration of the compost sample solution was determined using the UV Screening method. The content of nitrogen and phosphorus in the fertilizer was analysed by using DR 6000 UV-V is spectrophotometer (Hach) while for carbon using COXEM SEM-EDX (EM-30AX) machine.

Results and Discussion

Compost Fertilizer

The result for compost fertilizer includes the effects of composting parameters such as temperature, pH, and moisture content towards time as well as the concentration of iron and manganese in the compost fertilizer. Furthermore, the result for C:N and C:P ratio of the compost fertilizer is also discussed in details in the next subsection.

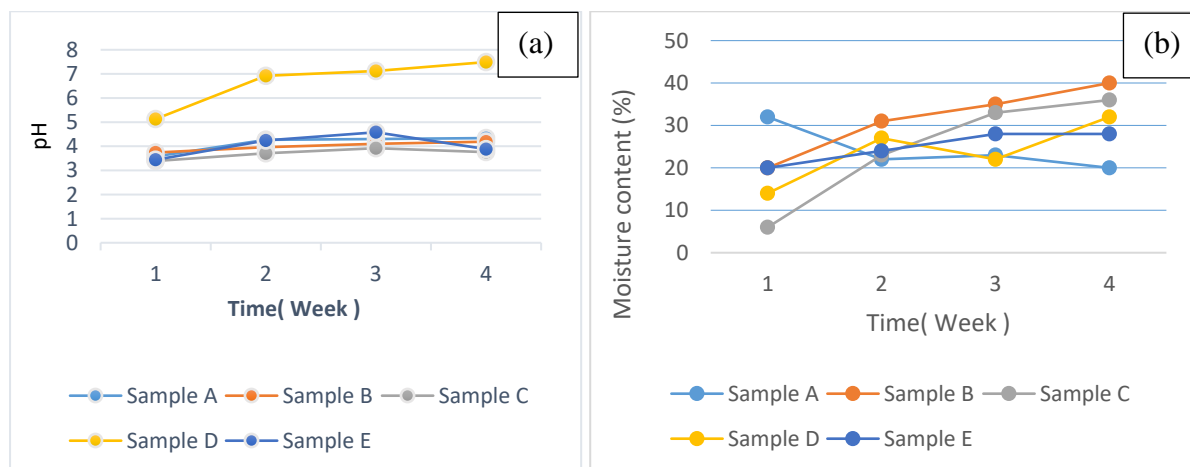
pH, Moisture Content, and Temperature

Figure 4(a) shows the pH value towards time for all samples. Sample A exhibited a consistent increase in pH values from week 1 to week 3 from 3.58 to 4.3, respectively before increase to 4.34 in week 4. The data for sample E indicated an elevation in pH from 3.44 to 3.88 from week 1 to week 4, respectively. In a similar trend, sample B demonstrated an increase in pH value from 3.74 to 4.19 from week 1 to week 4., respectively. This suggests that the metabolic activities of microorganisms influenced the process as the sample became slightly acidic (Sridhar et al., 2025). For sample C, the pH experienced a minor increase from 3.39 to 3.71 in week 1 to week 2, respectively and slightly decrease to 3.76 in week 4. As for sample E, the pH displayed a slight increase from week 1 to week 3, from pH 3.44 to 4.58, followed by a decrease to pH 3.88 on the week 4. This might be due to acid-generating microbes, particularly lactic acid bacteria that consume on carbohydrates and various substrates, yielding organic acids such as lactic acid, acetic acid, or propionic acid, which lead to acidic condition in the compost (Usmani et al., 2022). For sample D, the pH increased from 5.13 to 7.49 in week 1 to week 4, respectively, which signifies the transition from acidic to alkaline condition in sample

D. An alternative possibility is denitrification, a process wherein nitrate-reducing bacteria utilize protons (H^+) throughout the transformation of nitrate (NO_3^-) into nitrogen gas (N_2), thereby resulting increased of pH (Kim et al., 2022).

Figure 4(b) shows the moisture content towards time for all samples. All samples exhibited a pattern of fluctuation in moisture content from weeks 1 to 4. The highest moisture content was attained at 40% for sample B in week 4. The lowest moisture content of 6% was attained in sample C in week 1. The optimum moisture level for composting is between 40% to 70% which plays a crucial role in assisting microorganisms to effectively decompose organic materials, guarantees ample oxygen for aerobic breakdown, keeps the compost from turning overly soggy or parched, and safeguards against nutrient depletion (Kolobeng et al., 2022). The low moisture content observed at the beginning of compost in sample C can be attributed to swift compost dehydration and limited bacterial engagement, which consequently resulted in a decline in the biological composting phenomenon (Naveed et al., 2024). The ideal moisture level for microbial engagement usually fluctuates between 50% and 70%. This range supplies ample water for microorganisms to execute their metabolic processes while ensuring adequate aeration for those that thrive in oxygen-rich environments (Meng et al., 2024).

Figure 4(c) shows the temperature towards time for all samples. Each sample demonstrate median temperature changes from 22.4 °C to 34.1 °C. For every sample, the temperature increases from week 1 to week 2, then a steady decline from week 2 week to the week 3, and increased again on the week 4. The increased of temperature is attributed to the hot weather conditions, which facilitate microbial activities. On the fourth week, the weather was sunny and the temperature rose, which increased microbial activities (Vainio et al., 2024). The temperature range for optimal microbial activity lies between 20°C and 40°C, where microorganisms such as bacteria and fungi, thrive in the 30°C to 37°C condition (Orwa et al., 2020). This temperature range raises enzyme activity and metabolic processes which enabling microbes to thrive and proliferate with great efficiency. When the temperature is too low, microbial actions decrease, whereas too high can lead to enzyme denaturation that potentially causing microbes to die (Verdnik & Rieberer, 2022).



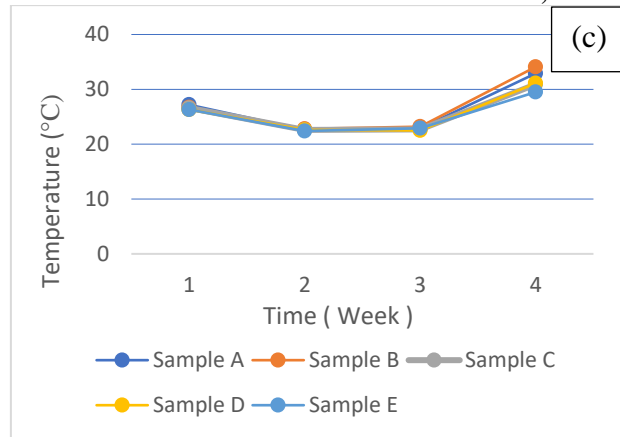


Figure 4: (a) pH, (b) Moisture Content, and (C) Temperature Towards Time

Concentration of Iron and Manganese

Table 2 shows the concentration of iron and manganese in each of the compost sample. The highest iron concentration of 0.36 mg/L was observed in sample E while the lowest of 0.19 mg/L was in sample A. The suitable range for iron levels in compost is between 0.5 mg/l to 5 mg/l (Tiu et al., 2022). Exceeding the limit of 5 mg/l can make the compost unsuitable for application since it could be toxic to plants. The adverse effects include damage upon their root systems, impede the absorption of essential nutrients, and disrupt normal growth processes (Kalita et al., 2024). For manganese analysis, the highest concentration attained in sample A with 0.59 mg/L, whereas sample E recorded the lowest manganese concentration of 0.43 mg/L. The suggested manganese concentration is between 0.5 mg/l to 1 mg/l. Manganese is integral in supporting plant health yet, excessive levels can cause harm, while inadequate amounts may lead to deficiencies (Ali et al., 2024).

Table 2: Concentration of Iron and Manganese in Compost samples

Compost sample	Iron concentration (mg/L)	Manganese concentration (mg/L)
A	0.19	0.59
B	0.35	0.48
C	0.34	0.49
D	0.32	0.46
E	0.36	0.43

C:N and C:P Ratio

Table 3 shows the C:N and C:P ratio of the compost samples. Carbon is denoted as C which serves as an energy source while nitrogen is denoted as N which is necessary for the formation of cellular structures, and P is phosphate that is vital in enhancing plant performance and facilitating root development. The maximum C:N ratio of 12:1, was observed in sample A. The lowest C:N ratio of 2:1 was recorded in sample C. Low C:N ratio signifies that the compost sample requires more time to decompose the material, whereas higher C:N ratio suggests that the decomposition process is nearing completion, leading to the conversion of N into ammonia gas, which results in an unpleasant odor (Tolve et al., 2021).

The C:P ratio reveals the highest of 20:1 in sample A while the lowest of 2:1 in sample D. In sample A, high C:P ratio of 20:1 can be attributed to the food waste which may content a greater quantity of carbon in comparison to phosphorus. In sample D, the low C:P ratio of 2:1 is a

result of the food waste, which yields a higher concentration of phosphorus in relative to carbon, thereby resulting in a lower ratio.

The quantity of food waste has a direct influence on the equilibrium of carbon and phosphorus within the compost. These results show that the ratios of C:N and C:P obtained are not within the optimal values of 20:1 to 30:1, respectively (Ahme et al., 2024). In compost, the C:P ratio shows how carbon (C) and phosphorus (P) are proportioned. The ideal C:P ratio for composting typically within the range of 25:1 to 30:1, as this establishes a favorable balance conducive to effective decomposition. If the ratio is higher or lower than the ranges, microbial activity may become compromised, thereby adversely influencing the composting procedure (Idoko et al., 2025).

Table 3: C:N and C:P ratio of Compost Samples

Sample	Weight of food waste (kg)	Ratio	
		C:N	C:P
A	1	12:1	20:1
B	2	4:1	4:1
C	3	2:1	5:1
D	4	3:1	2:1
E	5	5:1	3:1

Pellet Fertilizer

The result for pellet fertilizer includes the diameter, length, water stability, bulk density and particle size distribution that are discuss in details in the next subsection.

Length and Diameter of Pellet

Table 4 shows the length and diameter of pellet for each sample. The measurements reveal minimal variation between each sample. Only the length measurement of 1.5 cm exhibited inconsistency for sample A that is due to the irregular cutting by the pelletizing machine (Blank & Obernberger, 2024). The irregularity from the machine is usually due to obstruction of pellets that need to be manually removed. Other than that, the diameter measurements present no issues, as all samples uniformly exhibited a diameter of 0.6 cm. In terms of measurement, samples B, C, D, and E consistently have the same length of 1.4 cm each.

Table 4: Length and Diameter of Pellet for each Sample





Sample	Length (cm)	Diameter (cm)
A	1.5	0.6
B	1.4	0.6
C	1.4	0.6
D	1.4	0.6
E	1.4	0.6

Water Stability

Table 5 shows the water stability of pellets for each sample. After 5 minutes, it is apparent that sample C demonstrates the highest water stability with 87.5%, whereas sample A records the lowest water stability with 60%. Sampel C signifying long-term stability when immersed in water after 5 minutes. However, after 60 minutes, sample A recorded the highest water stability of 88% and sample E recorded the lowest water stability of 54.5%. Sample E present a lower

long-term stability measurement, suggesting more rapid disintegration in comparison to the other samples (Nath et al., 2024). Samples A showcase a remarkable resilience throughout the test and uphold the form significantly better after 60 minutes compared to just 5 minutes. Sample C begins with a robust presence but tends to crumble considerably after 60 minutes, suggesting a reduced stability over time. Samples D and E also exhibit a decline in stability after 60 minutes, indicating a vulnerability to water damage as time progresses. The preference for high water stability arises from its ability to preserve the material's integrity and functionality throughout time, even when it encounters moisture (Lee et al., 2022). This characteristic protects the pellets against loss, upholds structural integrity, and enhances overall performance. In contrast, low water stability accelerates the degradation of the material, resulting in reduced efficiency and potential damage to the pellets (Kim, 2021).

Table 5: Water Stability of Pellets for Each Sample

Sample	Water stability (%)		Physical state of the pellets after immersion
	5 minutes	60 minutes	
A	60	88	
B	71.43	87.5	
C	87.5	56	
D	77.8	55.6	

E 77.8 54.5



Bulk Density

Table 6 shows the bulk density of pellets for each sample. Sample E exhibits the highest bulk density with 2.28 g/cm³ while sample A and B had the lowest bulk density with 2.26 g/cm³. This indicates that the pellets possessed quite similar density. The minimal variance in bulk density (merely 0.02 g/m³) suggesting the slight differences in their composition or production methods, yet it is unlikely that this will influence their overall functionality. High bulk density indicates that the pellet is compact and weighty relative to its volume, whereas low bulk density signifies that the pellet is lighter and had high air gaps within the particles (Rezaei et al., 2024). High bulk density is advantageous for energy storage (like with fuel pellets), while lower bulk density is preferable for applications such as composting, where the circulation of air and moisture plays a crucial role. A low bulk density is typically favored for pellets because it renders them lighter, facilitates handling, and promotes enhanced airflow (Pathirana et al., 2024).

Table 6: Bulk density of pellet for each sample

Sample	Bulk density (g/m ³)
A	2.26
B	2.26
C	2.27
D	2.27
E	2.28

Particle Retained

The particle retained for each sample was 100%. This finding suggests that the utilization of a pellet machine results in a consistent pellet size across all samples. The uniform retention values imply that all samples exhibit equivalent efficacy in retaining particles under the specified testing conditions (Bastiaansen et al., 2024).

Conclusion

Fertilizer made from food waste and sawdust in pellet form and compost was successfully produced in this study. The variations of food waste and sawdust content in the pellet form and compost resulted in difference of physical properties of the pellet fertilizer and chemical properties of compost fertilizer as well as the effects in composting parameters. Optimum pH, moisture content, and temperature of 7.49, 40%, and 34.1°C, were obtained in samples D, B, and B, respectively. All samples exhibited fluctuations in pH levels, which were significantly influenced by microbial activity. The highest concentration of iron and manganese are within the permissible limit for all sample with 0.36 mg/L and 0.59 mg/L, respectively. The most ideal C:P ratios was achieved for samples A with 20:1. The physical properties of the produced pellet revealed homogeneity of the pellet diameter across samples which shows consistent machine

performance. Apart from that, the bulk density values exhibited only slight variability among samples, with sample E presenting the highest density of 2.28 g/cm³ and sample A the lowest density of 2.26 g/cm³. Additionally, all samples demonstrated uniform particle retention of 100%, indicating consistent pellet size and efficient performance of the pelletizing process. Sample A exhibited the highest water stability of 88% after a duration of 60 minutes, indicating superior resistance to aqueous degradation. Conversely, sample E demonstrated low stability of 54.5%, suggesting a tendency for more rapid disintegration in water. The findings of this study indicate that the incorporation of food waste and sawdust into contemporary agricultural practices holds significant potential for improving soil fertility and fostering environmental sustainability.

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9th International Conference on Social Sciences,
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Islamic and Technology 2025 (9th ICEBIT 2025)
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