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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BIODEGRADABLE PACKAGING FROM CASSAVA STARCH AND CORN HUSK FIBRE: ENVIRONMENT PROPERTIES

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Faculty of Industrial and Manufacturing Technology and Engineering

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A thesis submitted
in fulfillment of the requirements for the degree of
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SESI PENGAJIAN: **2023-2024 Semester 1**

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Signature :

Name : NUR SYAZWANI BINTI AZHAR

Date : 10TH JANUARY 2024

APPROVAL

I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology with Honours.

Signature :
Supervisor Name : DR. RIDHWAN BIN JUMAIDIN
Date : 10TH JANUARY 2024

DEDICATION

Alhamdulillah

Praise to Allah for the strength, guidance and knowledge that was given by Allah for me to complete this proposal report

&

To my beloved parents for every support and encouragement that was given to me

&

To my supervisor, Dr. Ridhwan Bin Jumaidin for his guidance and advice in completing this proposal report

&

To all people who support me throughout this journey

&

To Al-Quran, the greatest source of knowledge.

ABSTRACT

Continuous use of non-biodegradable plastic packaging has led to environmental pollution. Increase awareness on the environmental issues linked to conventional plastics has led to extensive research of biodegradable material alternatives. In addition, thermoplastics are biodegradable, presenting a significant advantage over traditional non-biodegradable synthetic polymers. Thermoplastic starch polymers (TPS) have now been the subject of intensive research for use in packaging materials with several formulations including bio fillers or fibres to reinforce bio-based plastics, they are also developed from various natural sources that are biodegradable and compostable Besides, corn husk fibres, as a renewable and sustainable resource in thermoplastic composites, decrease dependence on non-renewable resources and advance the development of eco-friendly materials. Therefore, in this study, corn husk fibre (CHF) was incorporated into TPCS using compression moulding. Then the properties of CHF/TPCS biopolymer composites were investigated to evaluate their potential as a biodegradable reinforcement. The objective of this study is to investigate the possibilities of utilizing these materials for eco-friendly packaging solutions. This study was carried out by preparing thermoplastic cassava starch/palm wax blends incorporated with corn husk fibre (TCPS/PW/CHF) bio-composites at different CHF concentrations of 0 to 40 wt%. A composite material was formed by blending corn husk fibre, cassava starch, glycerol, and palm wax. The fabrication process involved hot compression moulding at 155 °C for 50 minutes. Several testing has been conducted to investigate the effects of corn husk fibre on environmental properties of the materials such as water affinity testing, environmental analysis, physical analysis and other testing. As the results, an increasing the addition of corn husk fibre from 0 to 40 wt. % resulted in a decrease in moisture content from 24% to 15%. Besides, result for density, its showed that decrease lowest value at 0.356 g/cm3. Next, for water solubility slightly decreased from 41% to 29% as an increasing the addition of corn husk fibre at 40 wt. %. In addition, an increase in water absorption for 30 minutes from 43% to 25% and for 2 hours from 73% to 56% as water is absorbed. Moreover, for thickness swelling as increase the addition of corn husk fibre, the value showed for 30 minutes 22% to 7% and for 2 hours from 41% to 23% as water is absorbed. Furthermore, increased weight losses during soil burial were observed, decreasing from 52% to 29.6% for 4 weeks and from 81.7% to 67.7% for 8 weeks, indicating accelerated biodegradation over an extended period. The SEM analysis confirmed heightened micro voids, fibre breakage, and positive adhesion, consistent with outcomes from water affinity testing, environmental analysis, and physical analysis. In conclusion, the thermoplastic cassava starch reinforced corn husk fibre composite showed great potential as good material for biodegradable products, particularly disposable packaging trays.

ABSTRAK

Penggunaan berterusan pembungkusan plastik tidak terbiodegradasi telah membawa kepada pencemaran alam sekitar. Meningkatkan kesedaran tentang isu alam sekitar yang dikaitkan dengan plastik konvensional telah membawa kepada penyelidikan meluas alternatif bahan terbiodegradasi. Selain itu, termoplastik boleh terbiodegradasi, memberikan kelebihan ketara berbanding polimer sintetik tradisional yang tidak boleh terbiodegradasi. Polimer kanji termoplastik (TPS) kini telah menjadi subjek penyelidikan intensif untuk digunakan dalam bahan pembungkusan dengan beberapa formulasi termasuk pengisi bio atau gentian untuk mengukuhkan plastik berasaskan bio, ia juga dibangunkan daripada pelbagai sumber semula jadi yang boleh terbiodegradasi dan kompos Selain itu, jagung. gentian sekam, sebagai sumber yang boleh diperbaharui dan mampan dalam komposit termoplastik, mengurangkan pergantungan kepada sumber yang tidak boleh diperbaharui dan memajukan pembangunan bahan mesra alam. Oleh itu, dalam kajian ini, serat sekam jagung (CHF) telah dimasukkan ke dalam TPCS menggunakan pengacuan mampatan. Kemudian sifat komposit biopolimer CHF/TPCS telah disiasat untuk menilai potensinya sebagai tetulang biodegradasi. Objektif kajian ini adalah untuk menyiasat kemungkinan menggunakan bahan ini untuk penyelesaian pembungkusan mesra alam. Kajian ini dijalankan dengan menyediakan adunan kanji ubi kayu termoplastik/lilin sawit yang digabungkan dengan biokomposit gentian sekam jagung (TCPS/PW/CHF) pada kepekatan CHF berbeza 0 hingga 40 wt%. Bahan komposit dibentuk dengan mengadun serat sekam jagung, kanji ubi kayu, gliserol, dan lilin kelapa sawit. Proses fabrikasi melibatkan pengacuan mampatan panas pada suhu 155 °C selama 50 minit. Beberapa ujian telah dijalankan untuk menyiasat kesan gentian sekam jagung terhadap sifat persekitaran bahan seperti ujian pertalian air, analisis alam sekitar, analisis fizikal dan ujian lain. Hasilnya, penambahan serat sekam jagung meningkat daripada 0 kepada 40 wt. % mengakibatkan penurunan kandungan lembapan daripada 24% kepada 15%. Selain itu, keputusan untuk ketumpatan menunjukkan penurunan nilai terendah pada 0.356 g/cm3. Seterusnya, untuk keterlarutan air sedikit menurun daripada 41% kepada 29% sebagai peningkatan penambahan serat sekam jagung pada 40 wt. %. Di samping itu, peningkatan dalam penyerapan air selama 30 minit daripada 43% kepada 25% dan selama 2 jam daripada 73% kepada 56% semasa air diserap. Selain itu, untuk pembengkakan ketebalan sebagai peningkatan penambahan serat sekam jagung, nilai menunjukkan selama 30 minit 22% hingga 7% dan selama 2 jam daripada 41% kepada 23% apabila air diserap. Tambahan pula, peningkatan kehilangan berat semasa pengebumian tanah diperhatikan, menurun daripada 52% kepada 29.6% selama 4 minggu dan daripada 81.7% kepada 67.7% selama 8 minggu, menunjukkan biodegradasi dipercepatkan dalam tempoh yang panjang. Analisis SEM mengesahkan lompang mikro yang meningkat, pecah gentian dan lekatan positif, selaras dengan hasil daripada ujian pertalian air, analisis alam sekitar dan analisis fizikal. Kesimpulannya, komposit gentian sekam jagung bertetulang kanji ubi kayu termoplastik menunjukkan potensi besar sebagai bahan yang baik untuk produk terbiodegradasi, terutamanya dulang pembungkusan pakai buang.

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In the Name of Allah, the Most Gracious, the Most Merciful

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LIST OF SYMBOLS AND ABBREVIATIONS

CHF - Corn Husk Fibre
TPS - Thermoplastic Starch
°C - Degree Celsius
(Wf) - Final Weight
(Wi) - Initial Weight
WSF - Walnut shell flour
TPS - Thermoplastic starch
CH - Corn Husk
PP - Polypropylene
PW - Palm Wax
CCF - Cymbopogan citratus fibre
TCPS - Thermoplastic cassava starch
BLF - Banana Leaf Fibre
NC - Nano Clay
PALF - Pineapple leaf Fibres

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CHAPTER 1

INTRODUCTION

1.1 Background

Solid waste or garbage encompasses unwanted materials that are discarded due to damage, wear, or expiration. Rahman (2017) defines solid waste as the waste generated from residential, commercial, and institutional activities, excluding clinical waste. In Malaysia, solid waste predominantly comprises organic matter (48-64%) and paper (12-30%). In comparison to clinical waste and scheduled waste, solid waste is generally easier to dispose of due to its non-toxic nature. The inefficiency of solid waste management systems, as indicated by directly affects public health, leads to the gradual deterioration of environmental quality, and results in both short-term and long-term aesthetic problems.

Bio-based and biodegradable materials hold the potential to replace conventional petroleum-based plastics in various product applications, thereby promoting a more circular economy. Biodegradable plastics find significant utility in packaging materials and garbage collection bags, with the ability to degrade within specific time frames and in various environments such as soil, water, anaerobic digestion facilities, or composting systems. However, the successful adoption of these materials hinges upon the conviction of consumers, manufacturers, and regulators regarding their effectiveness. Companies that actively embrace environmental protection can leverage environmental regulations as opportunities, leading to enhanced organizational performance and profitability. The electric utility industry enters an era of competitive market environment, uncertain world economics, and increasing fuel and equipment cost, there are rising concerns in the utility's affordability in operating and expanding the distribution network to meet the increasing energy demand. Furthermore, sustainability agenda are also driving the distribution network to accommodate sustainable, clean, and efficient energy supply and delivery system to reduce greenhouse gas (GHG) emission and reliance of fossil fuel energy sources (Rahman, 2017).

Starch, as an abundant and cost-effective biodegradable natural polymer, shows significant promise for bioplastic production. Extensive research has focused on optimizing properties such as mechanical strength, thermoforming abilities, permeability to gases and water vapor, transparency, and availability. Incorporating plasticizers into starch-based solutions increases water vapor permeability and elongation, though it decreases tensile strength. Studies by Abe et al, (2021) reveal that higher glycerol concentrations in rice flour bioplastics result in reduced modulus of elasticity and tensile strength, but increased water vapor permeability. This can be attributed to glycerol's hydrophilic nature, facilitating water molecule absorption and release. Starch-based bioplastics possess thermoplastic properties, making them potential substitutes for polystyrene in packaging applications. The ratio of amylose to amylopectin within the starch material directly impacts the properties, suggesting that manipulating their molecular structure and interactions can effectively enhance starch-based bioplastics.

Integrating natural fibres into bioplastics offers sustainable advantages, enhancing mechanical properties, reducing environmental impact, and improving biodegradability. Researchers aim to optimize compatibility between biopolymers and natural fibres through processing techniques and additives. This presents an opportunity to develop eco-friendly materials with diverse applications, including the focus on thermoplastic cassava starch with natural plant fibres. Therefore, the increase in the involvement of the new natural fibre that is Corn Husk in this study is one of the ways of producing a biodegradable product.

Corn husk serves as a valuable natural fibre in the development of bioplastic thermoplastics, offering several advantages in various applications. The use of corn husk as a natural fibre reinforcement enhances the mechanical properties of bioplastics, improving their strength and durability. Additionally, corn husk is readily available, renewable, and cost-effective, making it an attractive option for sustainable materials. The combination of corn husk with bioplastics contributes to the reduction of environmental impact, as bioplastics derived from renewable resources and natural fibres offer an eco-friendly alternative to conventional plastics. The utilization of corn husk in bioplastic thermoplastics showcases its potential to contribute to a more sustainable and circular economy (Abe et al., 2021).

In conclusion, bioplastics present a compelling alternative to traditional plastics, offering a sustainable and environmentally friendly option. With their biodegradability, sustainability, and renewable nature, bioplastics have become increasingly attractive. Among the various types of bioplastics, those derived from starch, particularly cassava-based bioplastics, show great promise due to the abundance of cassava as a raw material. Starch-based bioplastics offer significant advantages, including biodegradability and ease of processing. It is crucial to promote the reduction in the consumption of non-biodegradable plastics and advocate for the adoption of biodegradable alternatives. Embracing biodegradable options while minimizing the use of non-biodegradable plastics is a prudent and responsible approach to protect the environment.

1.2 Problem Statement

Plastic pollution has become a pressing environmental issue due to the extensive use of non-biodegradable plastics, resulting in widespread contamination of ecosystems such as oceans, rivers, and landfills. The long decomposition time of plastics, combined with improper disposal and inefficient recycling, further exacerbates the problem by endangering marine life and disrupting the food chain. Wildlife faces threats such as entanglement and ingestion, leading to injury and death, while the chemicals released by plastics harm human health and ecosystems. To address this issue, reducing single-use plastics, promoting biodegradable alternatives, improving waste management, and increasing recycling rates are vital. Education and awareness campaigns are necessary to foster responsible plastic use. By adopting sustainable practices, encouraging innovation in plastic alternatives, and transitioning to a circular economy, we can mitigate the adverse environmental impacts of plastic pollution and create a healthier planet for future generations (Gaurav et al., 2019).

The problem statement revolves around the weaknesses of thermoplastic starch, specifically its moisture sensitivity and inadequate physical and environmental properties. These limitations hinder its practical applications in various industries as it exhibits reduced mechanical strength, dimensional instability, and susceptibility to degradation when exposed to moisture. Moreover, thermoplastic starch possesses poor physical properties such as brittleness, low heat resistance, and limited flexibility, making it unsuitable for diverse applications. Its environmental properties, including biodegradability and compost ability, may not meet the desired sustainability standards. To unlock the full potential of thermoplastic starch as an alternative to conventional plastics, it is crucial to address these weaknesses by improving moisture resistance, enhancing physical properties, and ensuring favourable environmental characteristics. Overcoming these challenges will result in thermoplastic starch with improved performance, wider application possibilities, and a reduced environmental footprint (Ngo, 2020).

1.3 Research Objective

The primary objectives of this study are:

- To fabricate a composite material by reinforcing thermoplastic cassava starch with Corn Husk Fibre.
- To evaluate the water affinity properties, physical and environmental characteristics of the biodegradable composite material derived from thermoplastic cassava starch reinforced with Corn Husk Fibre.
- To develop biodegradable packaging utilizing Corn Husk Fibre as the primary material, contributing to the reduction of non-biodegradable packaging waste.

1.4 Significance of Study

The justification for this study can be summarized as follows:

- This study aims to provide new insights and information regarding the development of a biodegradable composite material using thermoplastic cassava starch reinforced with Corn Husk Fibre. The findings of this research have the potential to contribute to the existing knowledge in this field.
- By utilizing a fully bio-composite material derived from Corn Husk Fibre and thermoplastic cassava starch, this study seeks to address and mitigate environmental pollution issues. The adoption of such sustainable materials can help reduce the negative impact of conventional non-biodegradable materials on the environment.
- The introduction of the new material derived from cassava starch offers a potential solution to the problems associated with conventional thermoplastics. By exploring alternative materials, this study aims to

minimize the environmental impact caused by traditional thermoplastic materials.

- By incorporating palm wax and cassava starch into Corn Husk Fibre, this study aims to enhance the value and utilization of Corn Husk Fibre as a reinforcement material in the production of bio-composite products. This research strives to add value to agricultural by-products and promote their sustainable use in the industry.

1.5 Scope and Limitation of Study

The scope of this study involves investigating the environmental properties of a thermoplastic starch mixture comprising cassava starch, glycerol, and corn husk fibre. The inclusion of Palm Wax in the mixture aims to enhance the material's resistance to water absorption and moisture. Corn Husk Fibre is incorporated as a reinforcement material, following a predetermined percentage (0wt%, 10wt%, 20wt%, 30wt% and 40wt). Environmental testing is conducted to assess the performance of the thermoplastic starch composite under different conditions. The specific tests carried out include water solubility and soil burial, which evaluate the material's biodegradability and its behaviour when exposed to aqueous and soil environments. These tests provide insights into the potential environmental impact and degradation characteristics of the composite.

The study includes water affinity testing to assess the material's interaction with water and determine its ability to resist water penetration and maintain structural integrity. Morphological analysis using a Scanning Electron Microscope (SEM) examines the composite's microstructure, including fibre distribution and alignment. Density measurement helps evaluate the material's physical properties and suitability for various applications. Through these tests, the study aims to provide insights into the performance, sustainability, and potential uses of the thermoplastic starch composite made with cassava starch, glycerol, Palm Wax, and Corn Husk Fibre.

1.6 Structure of Thesis

This overview follows the prescribed format of University Technical Malaysia Melaka (UTeM) and aligns with the publication format of this study. The thesis is organized into six main sections, namely the introduction, literature review, methodology, results and discussion, and conclusion. The structure of each section is as follows:

Chapter 1

In this chapter, a comprehensive depiction of the study's objectives is presented, along with an emphasis on the underlying problem that prompted this research. The chapter delineates the significance and scope of the study, elucidating the broader context and relevance of the research. Furthermore, a detailed overview of the research work conducted is provided, offering a thorough understanding of the methods and approaches employed in this study.

Chapter 2

In this chapter, the overall literature review conducted in the relevant area of this thesis is justified. The chapter acknowledges and builds upon the existing body of knowledge established by previous studies. Additionally, the chapter highlights the research gap identified through the review of previous studies, emphasizing the need for further investigation and the contribution of this thesis to filling that gap.

Chapter 3

This chapter outlines the methodology employed in this research, encompassing the procedures used for material preparation, testing, and data collection. It provides a detailed explanation of the methods and techniques utilized throughout the research process, ensuring transparency and replicability. The chapter serves as a guide for readers to understand the systematic approach followed in conducting the study.

Chapter 4

This chapter focuses on the comprehensive discussion of the hypotheses underlying each testing category, namely physical testing, environmental testing, and water affinity testing. The hypotheses will be thoroughly examined and analysed in relation to the experimental data obtained. The preliminary results obtained from the experiments will be reported and subjected to data analysis, contributing to the understanding and interpretation of the research findings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The increasing environmental concerns have brought attention to the harmful consequences of non-biodegradable products, particularly plastic packaging. While significant strides have been made in researching biodegradable alternatives, there remains a notable lack of widespread knowledge and specific strategies to effectively tackle the pervasive issue of plastic waste. In response to this challenge, the integration of biodegradable thermoplastic starch has emerged as a promising solution to mitigate the environmental impact associated with plastic waste. This project aims to investigate the potential of utilizing thermoplastic starch, along with polypropylene and natural fibre, as a sustainable alternative. Extensive tests and research on natural fibre composites, including their applications, structural properties, and the effect on environmental characteristics, have been conducted. By delving into these aspects, this study seeks to contribute to the advancement of eco-friendly materials, fostering a more sustainable and greener future.

2.2 Composite

Composite materials are created by combining two or more separate materials, with one providing reinforcement and the other serving as the matrix. The reinforcement component adds strength and stiffness to support structural loads, while the matrix retains the position and orientation of the reinforcement. When these materials are combined, the resulting composite is lightweight, strong, stiff, and tough. The unique properties of composites arise from the interaction between their components. Composites can be natural or synthetic, and they are tailored to fulfil specific requirements such as increased strength, reduced weight, or improved electrical resistance. The utilization of composites allows for the enhancement of strength and stiffness in materials, leading to diverse applications in various industries (Arif et al, 2017).

Composite materials are favoured over traditional materials due ability to enhance the properties of the base material and their versatility in various applications. The combination of two or more materials in composites creates a synergistic effect, resulting in aggregate properties that are different from those of the individual constituents. Composites are formed by physically distinct phases, and this combination allows for the attainment of desirable properties such as low density, durability, design flexibility, and high strength. The utilization of composites offers a pathway to achieving improved material performance and expanded possibilities in engineering and design (Ngo, 2020). Figure 2.1 shows the process of composite below.

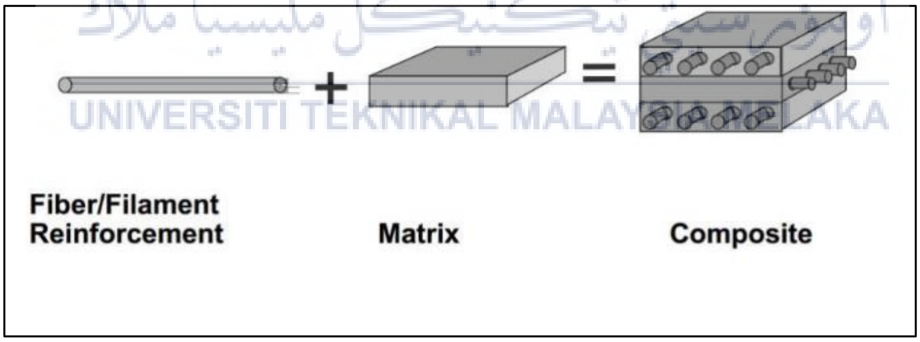


Figure 2.1: Process of Composite (Ngo, 2020)

2.2.1 Classification of Composite Materials

Composites are materials composed of two or more constituents that exhibit physical properties derived from their individual elements. These properties can either differ significantly from the constituents or closely resemble them. Composites are classified based on their form and the distribution of their ingredients, including fibre and particle reinforcement. Fibre reinforcement can be in the form of short fibres, either continuous or discontinuous, while long fibres are typically unidirectional or bidirectional. Particle reinforcement can take different shapes and orientations, with most homogenous composites having particles randomly dispersed. Continuous fibre composites require unidirectional laminations throughout for optimal performance. Understanding the classification and reinforcement methods of composites is essential for designing materials with desired properties and applications in various industries (Altenbach et al, 2004).

This course focuses on modeling and analyzing the behavior of fire-reinforced composite structural elements. The article emphasizes that the modeling and analysis presented in this study do not differentiate between different types of composite layers, such as unidirectional continuous fibres, oriented short-fibres, or woven fibre composites, as long as the material parameters characterizing their response are considered. Additionally, composite materials can be classified based on their constituent parts, including matrix composites made from biological, mineral, or metallic materials in figure 2.2. Understanding the behavior and classification of composite materials is essential for designing and optimizing their performance in various engineering applications, particularly in fire-resistant structures (Altenbach et al, 2004).

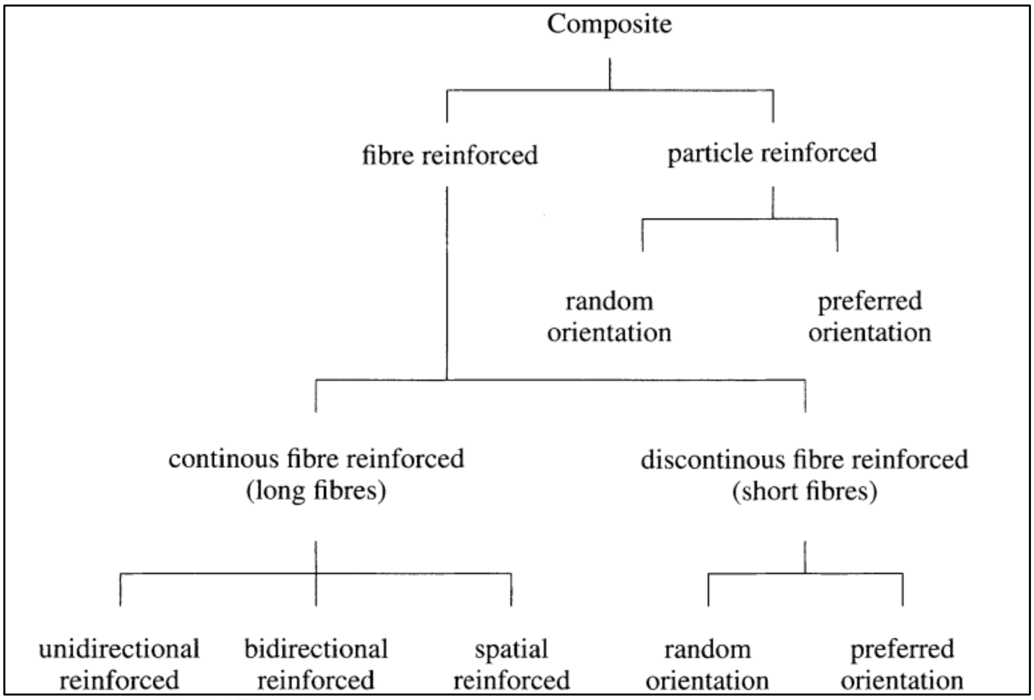


Figure 2.2: Classification of composite (Altenbach et al, 2004)

Composite materials consist of a matrix and fibre reinforcement. The matrix is typically made of polyester or epoxy resin and may contain fillers to improve its properties and reduce costs. While a resin-filler system is considered a homogeneous material, a composite material is a two-phase system comprising a matrix and a reinforcement. Understanding the distinction between these two material systems is crucial for mechanical modeling and the development of advanced composite materials with tailored properties and enhanced performance in various applications (Altenbach et al, 2004).

2.2.2 Polymer Composite

Polymer matrix composites are created by combining fibres with a polymer matrix, offering enhanced strength and stiffness. Synthetic fibres like carbon, nylon, rayon, and glass are commonly used as reinforcements in these composites. The polymers used can be classified into thermoplastic and thermosetting types. Thermoplastic polymers can be reshaped through the application of heat and pressure, and examples include nylons, polystyrene, polyamide, and polyethylene. Thermosetting polymers, on the other hand, do not melt but undergo decomposition when heated. Polyesters and epoxy are two significant categories of thermosetting resins used in composite materials. Understanding the properties and characteristics of different polymers and fibres is essential for the design and development of effective polymer matrix composites with tailored performance for various applications in industries such as aerospace, automotive, and construction (Gaurav et al, 2019).

Polymer composite materials are experiencing rapid growth in technological applications due to their low density, high specific strength, and stiffness. These materials offer the advantage of being customizable to meet specific technological challenges by altering and improving their properties. Furthermore, the use of polymeric materials with fillers and reinforcements is expanding in industrial applications where friction and wear are significant factors. The versatility and performance characteristics of polymer composites make them attractive for a wide range of industries, including aerospace, automotive, and construction, by providing lightweight and durable solutions to meet various engineering requirements. Understanding the capabilities and potential of polymer composites enables the development of innovative materials and designs to address the demands of modern technological challenges (Friedrich et al, 2011).

2.3 Fibre

Fibres are hair-like substances that can be spun into thread, filaments, ropes, and incorporated into composite materials. Fibre possesses flexibility, high aspect ratio, and delicacy. Fibre-reinforced composites consist of fibres providing reinforcement and a matrix that holds the fibres in position and transfers stresses. Fibres can be categorized as natural (plant, animal, or mineral-based) or synthetic (nylon, acrylic, polyester, etc.) as shown in figure 2.3. These diverse types of fibres offer a wide range of applications in various industries, including construction, textiles, and aerospace, by leveraging their unique properties and characteristics. Understanding the nature and classification of fibres is crucial for utilizing them effectively in different materials and product development processes (Ichalkaranji Kolhapur, 2020).

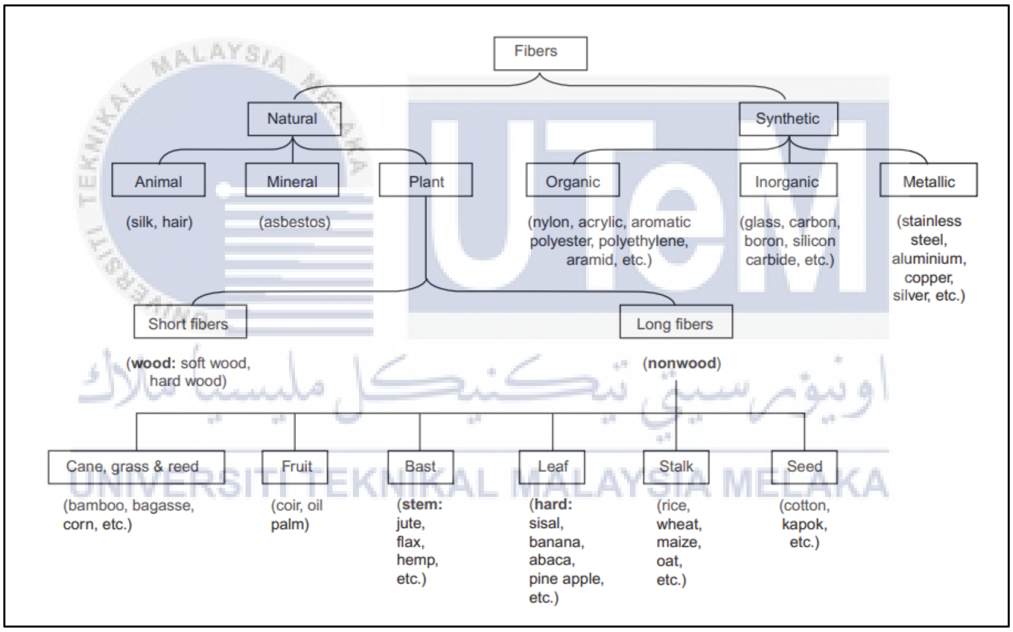


Figure 2.3: Classification of fibre (Ichalkaranji Kolhapur, 2020)

2.3.1 Natural Fibre

Natural fibres that are sourced from plants, possess technical cellulose, and exhibit a wide range of advantageous properties. These fibres present potential for various applications due to their natural origin and desirable characteristics. By exploring and harnessing the properties of natural plant fibres, industries can develop innovative and sustainable solutions in diverse fields. These fibres are environmentally friendly, lightweight, durable, renewable, cost-effective, and biodegradable. They have the potential to reinforce both thermosets and thermoplastic matrices, making them suitable for various composite applications. The utilization of natural fibres as reinforcements in composite materials presents an opportunity to develop sustainable and environmentally conscious solutions in industries such as automotive, construction, and packaging (Ichalkaranji Kolhapur, 2020).

Industry is increasingly interested in natural fibre composites because of their low density and ecological benefits compared to conventional composites. These composites are gaining popularity due to the non-carcinogenic and biodegradable nature of natural fibres. Natural fibre composites are cost-effective materials, especially in construction, packaging, automobile and railroad carriage interiors, and storage devices. However, the main drawback of natural fibre composites is their relatively high moisture absorption. To overcome this limitation, chemical treatments are employed to modify the surface properties of the fibres. These surface modifications aim to enhance the moisture resistance and overall performance of natural fibre composites in various applications (Ichalkaranji Kolhapur, 2020).

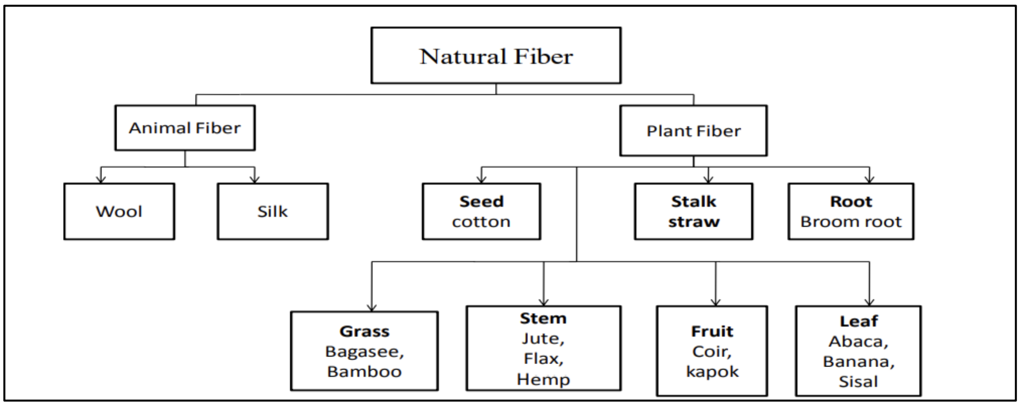


Figure 2.4: Classification of natural fibre (Ichalkaranji (Kolhapur), 2020)

Natural fibres encompass a wide range of materials derived from plants, animals, and minerals. Animal fibres, including wool, silk, and feathers, originate from sources such as sheep fleece, goat hair, horsehair, and various feathers. Mineral fibres are derived from minerals and can be categorized as asbestos, ceramic, or metal Fibres. Plant fibres, primarily composed of cellulose, can be further classified based on their source. Seed fibre, such as cotton and kapok, is obtained from the seeds and seed cases of plants. Leaf fibre, like sisal and agave, is extracted from foliage. Epidermis fibre is derived from the epidermis or bast surrounding the plant stem. Fruit fibre, such as coconut (coir) fibre, is obtained from plant fruits. Stalk fibre is derived from plant stems like wheat, rice, barley, bamboo, and grass. Additionally, wood is another type of natural fibre. The classification and diversity of natural fibres demonstrate their broad range of applications in various industries (Ichalkaranji Kolhapur, 2020).

2.3.2 Corn

Corn, which originated in Mexico's highlands approximately 7000-10,000 years ago, has a rich history in the development of New World agriculture. Archaeological evidence dating back to 2000-2500 BCE confirms the cultivation of maize during that time. The American Indians played a crucial role as the pioneers in maize breeding, transforming the small, two-rowed ear of teosinte into the first maize ear with four ranks of paired female spikelet’s. This significant transformation occurred over a span of 100-200 years. The evolutionary journey of corn highlights the ingenuity and agricultural advancements achieved by early civilizations in harnessing the potential of this crop. (García-Lara & Serna-Saldivar, 2018).

Corn has various names in different languages and regions, including "maiz" in Spanish, "mais" in French, "milho" in Portuguese, and "makka" in India. Wellhausen et al. (1951) identified several "indigenous or ancient" maize races such as Nal Tel, Chapalote, Palomero Toluquen, and Conico or Arrocillo amarillo. Presently, Latin America alone recognizes 220 corn races, with 64 races specifically associated with Mexico. The diverse range of corn races highlights the rich cultural and genetic diversity of this important crop, underscoring its significance in various regions around the world.(García-Lara & Serna-Saldivar, 2018).

Figure 2.5: Example of corn field (García-Lara & Serna-Saldivar, 2018)

2.3.3 Structure of Corn

The corn plant exhibits a fascinating reproductive process. Its ears, consisting of a corncob with rows of kernels, hold around 800 potential seeds. These ears are protected by husk leaves. The tassel, found at the top of the cornstalk, produces pollen that is carried by wind and gravity to the silks, connected to the female part of the plant. Each silk delivers pollen to a specific spot on the ear, resulting in the development of a kernel. With stalks reaching heights of seven to 12 feet, corn is harvested from August to September using a combine, which removes the husks and kernels. Understanding this reproductive process and employing efficient harvest methods are crucial for maximizing crop yield and agricultural productivity (Joaquin, 2011).

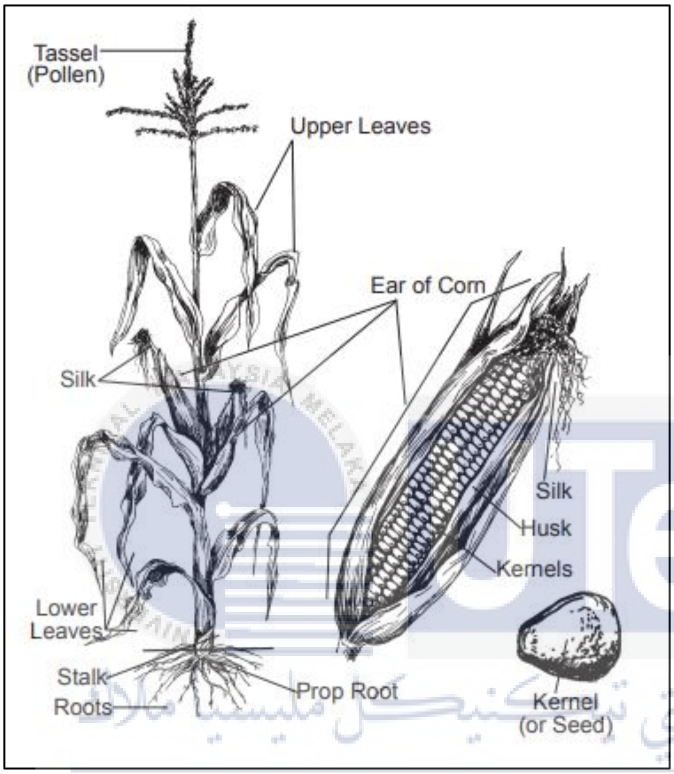


Figure 2.6: Parts of corn (Joaquin, 2011)

2.3.4 Application of Corn

The versatile applications of corn, including the utilization of cornstarch, corn oil, and its role as a source for industrial chemicals like lactic acid, demonstrate its significant contributions in promoting sustainability and addressing the needs of various industries. Cornstarch serves as a key ingredient in the production of bioplastics, adhesives, paper, and textiles, providing eco-friendly alternatives in these sectors. Similarly, corn oil finds application in the manufacturing of biodiesel, soaps, and personal care products, contributing to the production of renewable and sustainable materials. Furthermore, corn's potential as a source for industrial chemicals like lactic acid highlights its crucial role in the development of biodegradable plastics and other environmentally conscious materials. The multifaceted applications of corn emphasize its importance in fostering sustainability and meeting the demands of diverse industries. (Joaquin, 2011).

Corn plays a crucial role in animal nutrition as a significant component in feed formulations for livestock, poultry, and aquaculture. Its inclusion in feed pellets or as a supplementary ingredient ensures the provision of essential energy and nutrients to meet the dietary requirements of animals. The utilization of corn as a staple or supplemental feed ingredient highlights its significance in supporting sustainable and efficient animal production systems (García-Lara & Serna-Saldivar, 2018).

Cereals, including wheat, corn, and rice, are crucial food sources providing energy and nutrients to the global population. In addition to other commodities such as vegetables, roots, and tubers, the three cereal crops with the greatest production are wheat, corn, and maize (Figure 2.7). These cereal crops, along with other commodities, play a significant role in meeting dietary needs, particularly in developing nations, due to their accessibility and affordability. While wheat occupies the largest land area among these cereals, corn and rice surpass it in total production, primarily due to their higher average yield per unit of land area. Understanding the production and significance of these cereals is vital for addressing food security and nutrition challenges worldwide (Joaquin, 2011).

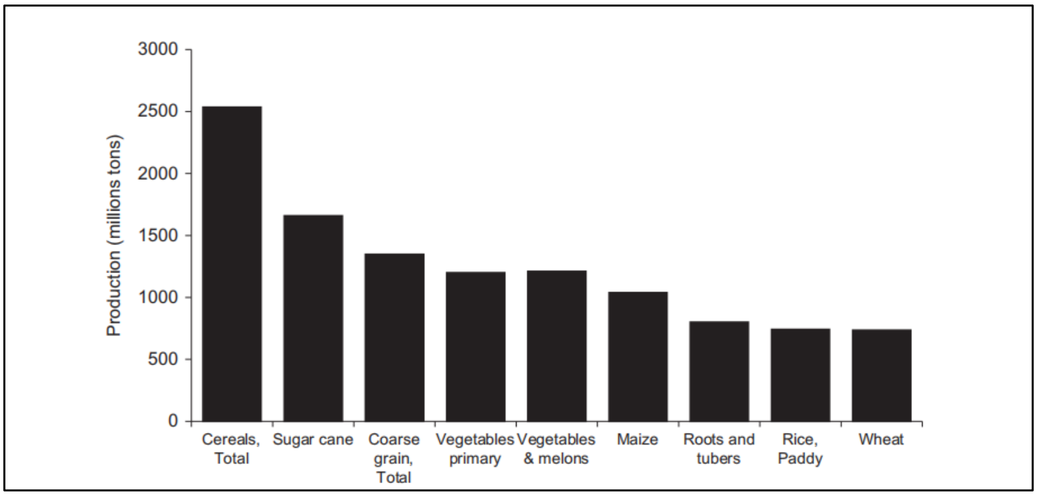


Figure 2.7: Most produced commodities in the world, 2016 (García-Lara & Serna-Saldivar, 2018)

2.4 Corn Husk Fibre

Corn husk Fibre is an organic material obtained from the protective coverings of corn ears, known as corn husks. It is an abundant and renewable resource that has garnered significant attention due to its wide range of applications in various industries. The utilization of corn husk fibre offers several notable benefits, such as its biodegradability, cost-effectiveness, and sustainable nature. This fibrous material possesses unique properties that render it suitable for diverse product and process applications. Its potential as an environmentally friendly substitute for traditional materials has been demonstrated in areas such as textiles and packaging. This comprehensive review paper aims to provide an in-depth exploration of the characteristics, processing techniques, and diverse applications of corn husk fibre. By shedding light on its potential, this review highlights the significant role that corn husk fibre can play in the development of sustainable and eco-friendly solutions across various fields (Ratna et al., 2022).

Corn husk is a prominent agricultural waste product, consisting of approximately 40% cellulose, 45% hemicelluloses, 7% lignin, 2% protein, and 3% ash by weight (Figure 2.8). The pre-treatment of lignocellulosic materials to produce films is an area of active research. The beneficial effects of pre-treatment on lignocellulosic materials have long been recognized. Recently, efforts have focused on converting corn husk, which is considered an environmentally hazardous waste, into industrially valuable materials. This approach not only addresses the problem of waste management but also utilizes the inherent properties of corn husk for the development of sustainable and practical applications. (Jaya Chitra & Vasantha Kumari, 2012).

Figure 2.8: Example of corn husk (Jaya Chitra & Vasantha Kumari, 2012)

2.4.1 Application of Corn Husk Fibre

Corn husk fibre, derived from the outer layer of corn husks, finds diverse applications, particularly in the production of environmentally friendly packaging materials. Through appropriate processing techniques, corn husk fibre can be converted into biodegradable and renewable packaging solutions like trays, containers, and boxes. Corn husk fibre, obtained from the outer layer of corn husks, exhibits a wide range of applications, with a notable focus on the development of environmentally friendly packaging materials (Ibrahim et al., 2019).

Corn husk fibre, derived from the husks and stalks of the corn plant, has been extensively utilized in the textile industry for the production of natural cellulosic fibres. These fibres, obtained from corn husk fibre, offer numerous advantages in textile applications. They can be processed to create fabrics and clothing items that are lightweight, breathable, and exhibit excellent moisture-wicking properties. This makes corn husk fibre-based textiles highly suitable for various apparel and accessory products, providing comfort and functionality to the end-users. The utilization of corn husk fibre in textile applications presents a sustainable and eco-friendly alternative to conventional synthetic fibres, contributing to the development of more environmentally conscious textile materials (Ratna et al., 2022).

Corn husks are a valuable source of dietary fibre for livestock, including cattle, chicken and sheep, and are commonly utilized in animal feed formulations or as a supplement to forage as shown in figure 2.9. However, it is essential to assess the nutritional composition of corn husks and their suitability for specific animal species and dietary needs. Adequate processing and supplementation may be required to ensure optimal nutrition. Therefore, it is imperative for farmers to possess a comprehensive understanding of the composition, digestibility, and practical feeding value of corn husks. Particularly during dry seasons characterized by limited forage growth, corn husks, alongside other lignocellulosic roughages like rice straw, often serve as substitutes for fresh forage, providing a vital feed source for livestock (Despal et al., 2022).

Figure 2.9: Feed the animals in the farm (Despal et al, 2022)

2.4.2 Application of Corn Husk Fibre

The utilization of corn husk fibres combined with a matrix material, such as a polymer resin, results in the creation of a composite material known as corn husk fibre composite. Corn husks, obtained from the outer covering of the corn cob, can be treated, and processed to extract the natural fibres contained within. These fibres are subsequently integrated into a matrix material that acts as a binding agent and offers supplementary structural reinforcement. By combining these components, the resulting composite material exhibits improved properties and characteristics (Sari & Suteja, 2020).

Chun et al, (2020) focuses on the utilization of corn husk fibres to fabricate a composite material through the vacuum-assisted resin infusion (VARI) technique. The corn husk fibres undergo pre-treatment involving alkali and bleaching processes before being transformed into a non-woven fibre mat. Subsequently, the fibre mat is impregnated with epoxy resin using the VARI technique to create the composite as shown in figure 2.10. The study investigates the impact of fibre treatments on the mechanical, morphological, and water absorption properties of the composite. Additionally, the treated fibres are also used to create a fibre mat through the wet-laying method. The findings indicate that the VARI technique with corn husk fibre mat achieves a favourable fibre/matrix mass ratio of 20/80 in the composite. The figure 2.11 shown the process of corn husk fibres through the vacuum-assisted resin infusion (VARI) technique.

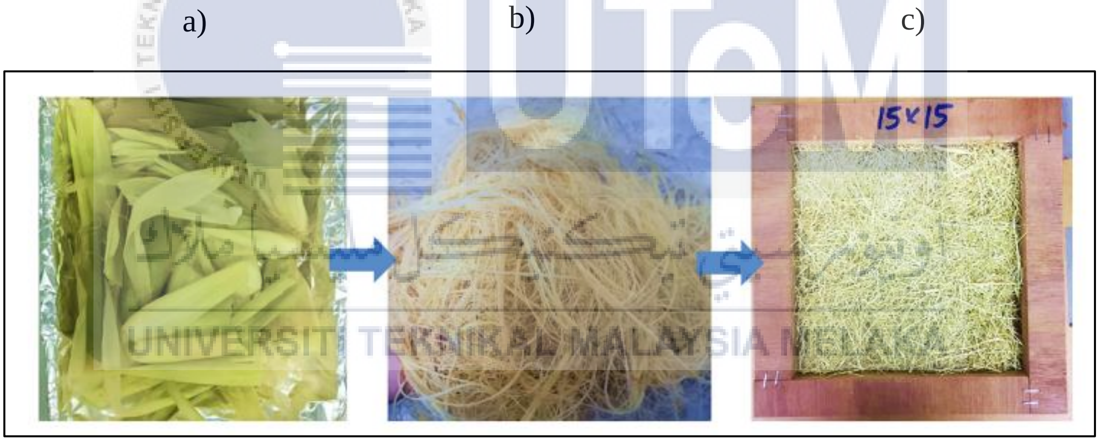


Figure 2.10: (a) Collected corn husk waste from wet market (b) Corn husk fibre extracted using water retting method (c) Corn husk fibre mat prepared by water laid method (Chun et al, 2020).

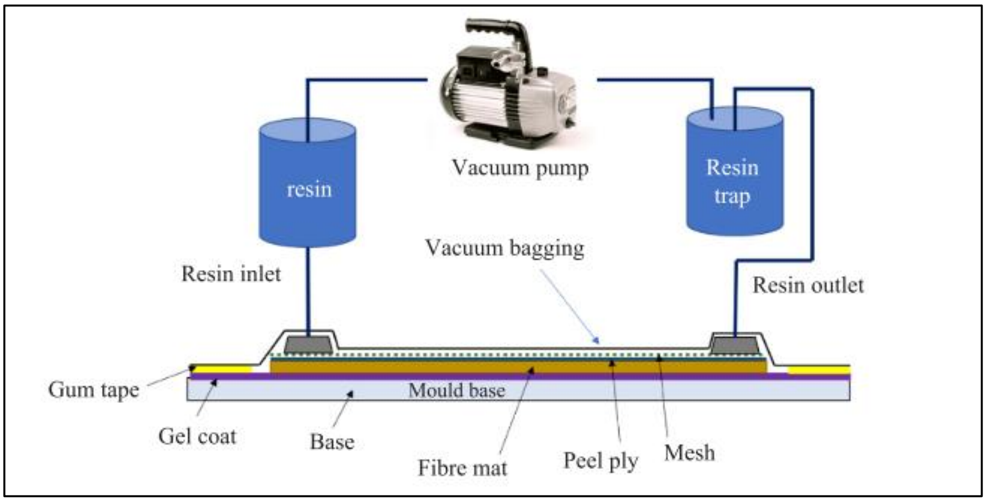


Figure 2.11: Setup of VARI technique for fabricating the composite (Chun et al, 2020).

2.5 Starch

Starch stands out as a highly promising natural polymer owing to its intrinsic biodegradability, abundant availability, and annual renewability. Its low-cost nature and compatibility with standard plastic processing equipment make starch an appealing alternative to traditional biodegradable polymers. The development and utilization of biodegradable starch-based materials have garnered significant attention in light of the well-known challenges posed by oil scarcity and the growing environmental concerns associated with the extensive use of petrochemically derived polymers. As depicted in Figure 2.12, starch-based products serve as an illustrative example. Numerous countries are increasingly implementing regulations on disposable plastics, with some even taking the decisive step of outright banning such products (Jiang et al, 2020).

Figure 2.12: Examples of starch-based product (Jiang et al, 2020).

Starch, along with cellulose, soy, and chitosan, is classified as a renewable natural polymer. It is present in various plant tissues and constitutes a significant portion of green plants due to the accumulation of starch during photosynthesis. While starch is strengthened in the presence of light through the production of sucrose, it undergoes degradation in the absence of light. Compared to other renewable natural polymers, starch offers advantages such as widespread availability, extensive processing capabilities, and cost-effectiveness. It is a soft, amorphous powder with a white color, possessing a pleasant and tasteless nature. Additionally, protein starch is non-reducing and insoluble in water, ether, and alcohol (Pokhrel, 2015).

2.5.1 Thermoplastic Starch

Thermoplastic starch (TPS) is an environmentally friendly polymer material with biodegradable and renewable properties. It exhibits thermoplastic behavior and is derived from starch, a natural polymer abundant in plant sources like wheat, corn, and potatoes. Through specific processing techniques, starch undergoes modifications to enhance its thermoplastic properties, enabling it to be easily processed and shaped when heated and solidified upon cooling (Xie et al, 2014).

TPS can be formed into various shapes using conventional plastic processing methods, including extrusion, injection molding, and film blowing. Furthermore, the remarkable feature of thermoplastic starch (TPS) lies in its ability to undergo multiple cycles of melting and hardening, qualifying it as a thermoplastic material. Thermoplastics, as a class of polymers, can be repeatedly reformed through the process of melting and solidification while maintaining their inherent properties. This recyclability aspect adds another favorable characteristic to TPS, alongside its renewable and biodegradable nature (Xie et al., 2014).

The utilization of TPS offers numerous advantages, such as the utilization of renewable plant-based resources, biodegradability, and renewability. These distinctive attributes position TPS as a promising substitute for conventional petroleum-based plastics, leading to the advancement of an environmentally friendly and sustainable future (Diyana et al, 2021).

2.5.2 Thermoplastic Starch Starch

Thermoplastic cassava starch, derived from the root vegetable cassava, exhibits thermoplastic properties that allow for processing and molding when heated and solidification upon cooling. Derived from the root vegetable cassava, which is also known as tapioca or manioc, cassava starch serves as a versatile raw material. By employing specific processing techniques, cassava starch can be transformed into a thermoplastic material, thereby gaining the ability to assume diverse forms through conventional plastics processing methods including extrusion, injection molding, and film blowing (Diyana et al, 2021).

This modification enables cassava starch to be utilized in a wide range of applications, leveraging its inherent thermoplastic properties to meet various industrial needs. The utilization of cassava starch as a thermoplastic material is showcased in Table 2.1, highlighting its applications in bio-composites. This renewable and biodegradable material offers several advantages, as it is derived from a sustainable and abundant source, providing an appealing alternative to petroleum-based plastics. Moreover, its biodegradability allows for natural decomposition over time, reducing its environmental impact (Diyana et al, 2021).

Table 2.1: Thermoplastic cassava starch composite (Diyana et al., 2021).

No.	Type of Starch	Type of Filler/Polymer	Potential Application	Reference
1.	Cassava	Kraft	Biodegradable Tray with Chitosan Coating	Campos et al, (2018)
2.	Cassava	Orange, Sugarcane, Malt Bagasse	Biodegradable Tray, Packaging Material	Ferreira et al, (2020)
3.	Cassava	Grape Stalks	Food Packaging Plastic	Engel et al, (2019)
4.	Cassava	Cassava Bagasse	Food Packaging Plastic	ravalini et al, (2019)

2.5.3 Thermoplastic Starch Composite

A thermoplastic starch composite is a material that combines starch, a natural plant-derived polymer, with a thermoplastic polymer through blending and processing. The starch serves as a reinforcement, while the thermoplastic polymer acts as the matrix. These composites offer advantages such as biodegradability, renewability, and reduced environmental impact compared to traditional plastics. They can be processed using conventional manufacturing techniques and find applications in packaging, disposable cutlery, agricultural films, and other single-use products. Utilizing thermoplastic starch composites contributes to reducing reliance on fossil-fuel-based plastics and promoting sustainable alternatives (Surendren et al, 2022).

In one review paper for example, Chen et al, (2020) focus on the development of a thermoplastic starch composite known as microcrystalline cellulose (MCC) thermoplastic starch (TPS). MCC, a natural polysaccharide derived from cellulose, is utilized as a filler in this composite, which is incorporated into a starch matrix through extrusion mixing with glycerol as a plasticizer. The starch, derived from renewable sources like food-grade corn starch, acts as a reinforcing component, while MCC serves as the matrix material.

The blending process involves high-temperature extrusion and subsequent hot pressing, resulting in the formation of solid MCC TPS granules as shown in figure 2.13. This composite material offers the advantage of reduced environmental impact compared to conventional petroleum-based plastics, as both starch and MCC are derived from renewable plant sources. Additionally, it provides functional and cost-effective alternatives in various applications (Chen et al, 2020).

By exploring the incorporation of MCC into the TPS matrix, this review paper highlights the potential of thermoplastic starch composites as sustainable and versatile materials for different industries (Chen et al, 2020).

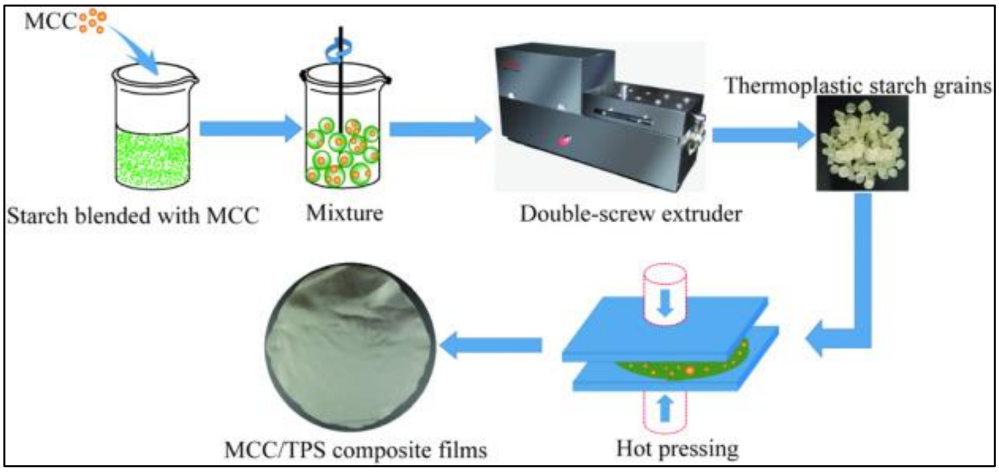


Figure 2.13: The preparation process of MCC/TPS composite films (Chen et al, 2020).

2.6 Polypropylene

Plastics can be classified into four main types based on their properties: thermoplastics, elastomers, thermosets, and polymer compounds as shown in figure 2.14. Each type possesses a distinct macromolecular structure and exhibits unique physical characteristics. (Hisham A. Maddah, 2016).

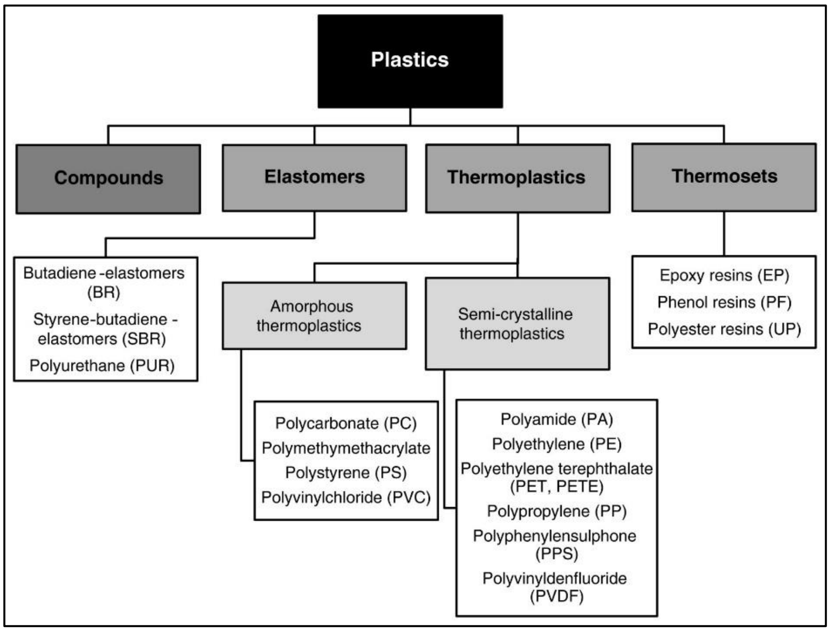


Figure 2.14: Classification of plastics (Hisham A. Maddah, 2016).

Thermoplastics, including polypropylene (PP), can exist in either amorphous or semi-crystalline forms. PP, discovered in 1954, rapidly gained popularity as a low-density commodity plastic. It showcases excellent chemical resistance and can be effectively processed through injection molding and extrusion techniques. The outstanding high temperature resistance of PP makes it a desirable choice for sterilizable items in clinical settings, such as instrument trays, bottles, and jars (Hisham A. Maddah, 2016).

Polypropylene is a petrochemical product derived from propylene through addition polymerization, where propylene molecules form long polymer chains. Various methods such as solution, suspension, bulk, and gas-phase polymerization can enhance the polymerization process. The characteristics of polypropylene are influenced by process conditions, copolymer components, molecular weight, and distribution. (Hisham A. Maddah, 2016).

2.6.1 Application of Polypropylene

The global demand for plastics has reached a staggering 245 million tons annually, and it is projected to continue increasing as a result of growing public demand. Figure 2.15 provides an overview of the overall demand for plastics in 2006, revealing that it constituted approximately 90% of the total demand (Hisham A. Maddah, 2016).

An Extensive Examination of Major Commodity Plastics encompasses a comprehensive investigation of five prominent commodity plastics, namely polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET). The discovery of polypropylene (PP) can be attributed to Giulio Natta in 1954; however, commercial production did not commence until 1957 (Hisham A. Maddah, 2016).

PP distinguishes itself as the most extensively utilized thermoplastic due to its advantageous attributes of affordability and molding flexibility. Following PP, polyethylene (PE) emerges as the second most prevalent plastic material. Various grades of polyethylene include linear low density (LLDPE), low density (LDPE), medium density (MDPE), and high density (HDPE) (Hisham A. Maddah, 2016).

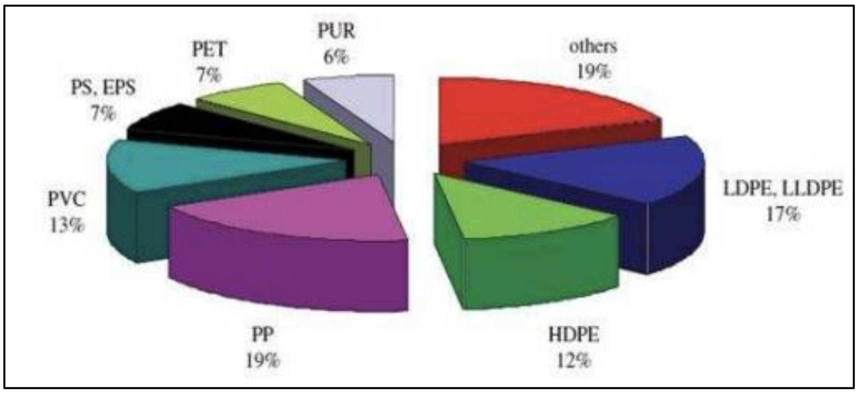


Figure 2.15: World plastics demand by resin types 2006 (49.5 million tons) (Hisham A. Maddah, 2016)

Polypropylene is widely recognized as a prominent thermoplastic renowned for its exceptional stiffness and high melting point, attributed to its crystalline structure. The presence of methyl groups within its molecular chains significantly contributes to its inherent rigidity. Possessing a density of 0.90 g/cm³, polypropylene exhibits extensive utilization across diverse industries. However, it is important to note that polypropylene is not suitable for applications below 0°C. Experimental findings underscore its favorable physical, mechanical, and thermal properties at room temperature, exemplifying remarkable rigidity, low density, and impressive impact resistance. As a cost-effective thermoplastic material, polypropylene showcases outstanding characteristics such as flame resistance, transparency, high heat distortion temperature, dimensional stability, and recyclability, rendering it highly versatile for a wide range of applications. (Hisham A. Maddah, 2016).

2.6.2 Types and Properties of Polypropylene

Polypropylene (PP) exhibits three distinct stereo-specific topologies, atactic, syndiotactic, and isotactic. The atactic configuration refers to an irregular arrangement of methyl groups within the polymer structure. In contrast, syndiotactic PP features alternating methyl groups positioned on both sides of the polymer backbone. Isotactic PP, on the other hand, displays a consistent placement of methyl groups on one side of the polymer chain. In particular, syndiotactic PP with a crystallinity level of 30% demonstrates a melting point of 130°C. In comparison, completely isotactic PP exhibits a higher melting point of 171°C. (Hisham A. Maddah, 2016).

Polypropylene (PP) possesses a range of exceptional properties, rendering it highly desirable for petrochemical companies. Notably, PP exhibits semi-rigidity, allowing for structural stability, while its translucency provides versatility in various applications. The material demonstrates robustness, enabling it to withstand chemical exposure and endure fatigue over extended periods. Moreover, PP exhibits excellent heat resistance, making it suitable for applications requiring thermal durability. Its high glass transition point and strong resistance to bending stress further enhance its mechanical integrity. Furthermore, PP showcases low water absorption, ensuring dimensional stability and mitigating the risk of water-induced damage. The material's good electrical resistance makes it well-suited for electrical and electronic applications. Its lightweight nature contributes to ease of handling and transportation. Additionally, PP exhibits high impact strength, enabling it to endure external forces without significant deformation. Importantly, PP is non-toxic, making it a safe and reliable choice for various consumer products. (Hisham A. Maddah, 2016).

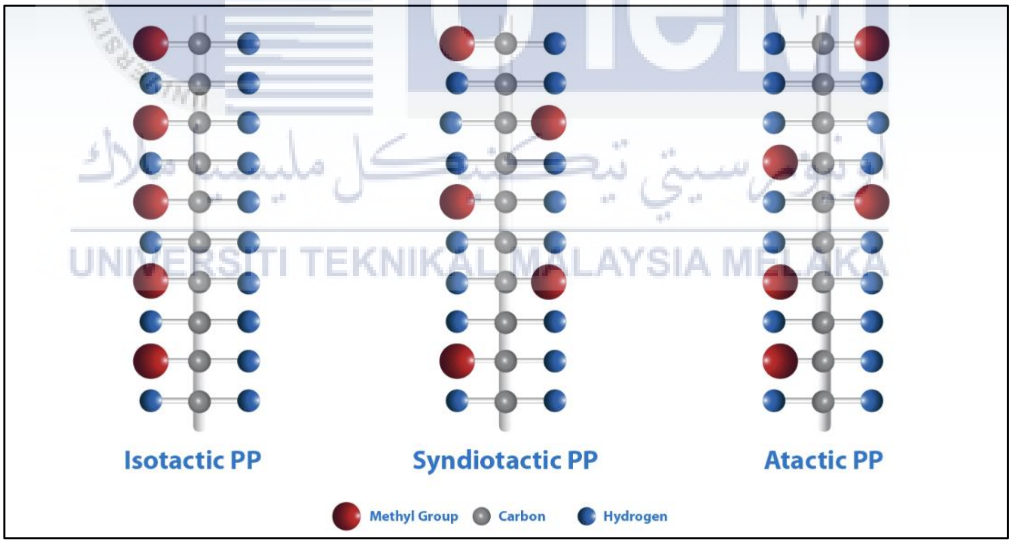


Figure 2.16: Polypropylene (PP) exhibits three distinct stereo-specific topologies, atactic, syndiotactic, and isotactic (Hisham A. Maddah, 2016).

This analysis focuses on the three varieties of polypropylene (PP) and their distinguishing characteristics. The first type is homo-polymer polypropylene (HPP), which consists solely of propylene monomer and exists in a semi-crystalline solid state. The second type is random copolymer polypropylene (RCP), where ethylene is incorporated as a co-monomer in PP chains at concentrations ranging from 1% to 8%. Lastly, the third type is impact copolymer polypropylene (ICP), which is a variation of HPP that contains a co-mixed RCP phase with an ethylene content of 45% to 65%. Co-polymers are generally referred to as polymeric compounds that contain more than one type of monomer in their chains, while homo-polymers consist of identical monomers throughout their chains. (Hisham A. Maddah, 2016).

2.7 Palm Wax

Palm wax, derived from palm oil obtained from the Elaeis guineensis tree, possesses unique properties and environmentally friendly characteristics as figure 2.17. Its chemical composition, rich in long-chain saturated fatty acids, contributes to its hydrophobicity. With a lower melting point than other waxes, palm wax is suitable for incorporating thermosensitive active compounds. Moreover, its abundance of saturated compounds enhances its oxidative stability. Palm wax finds applications in candle manufacturing and food coatings, offering high melting points and fragrance-holding capacity (Syahida et al, 2020).

However, the sustainability of palm wax production raises concerns such as deforestation and habitat loss. Initiatives like the Roundtable on Sustainable Palm Oil (RSPO) aim to promote responsible practices within the industry. To address ongoing debates, further research is needed to explore sustainable alternatives and ensure responsible sourcing and utilization of palm wax, mitigating the environmental and social impacts associated with palm oil production (Syahida et al, 2020).

Figure 2.17: Palm Wax ((Syahida et al., 2020).

2.8 Effect of Natural Fibre on Environment Properties

2.8.1 Moisture Content

Moisture content testing is a method used in thesis analysis to determine the amount of moisture present in a material or substance. It involves measuring the percentage of water or moisture by weight in relation to the total weight of the material (Sarsari et al, 2016).

In this paper review analysis, the Kamaruddin et al, (2023) investigated the effect of Cymbopogan citratus fibre (TCPS/PW/CCF) on the moisture content of thermoplastic cassava starch/palm wax composites. The study found that the moisture content of the composites without Cymbopogan citratus fibre was the highest at 11.04% as shown in figure 2.18. This high moisture absorption could be attributed to strong hydrogen interactions between the hydroxyl groups in starch and free water molecules. However, the inclusion of Cymbopogan citratus fibre in the composites resulted in reduced moisture content, ranging from 5.65% to 11.04%. The increase in CCF content from 10% to 60% led to a slight decrease in moisture content. This reduction can be explained by the strong hydrogen bonds formed between the Cymbopogan citratus fibre and the starch matrix, which limit the availability of hydroxyl groups for water absorption. The study suggests that the inclusion of components such as palm wax in the composites can enhance water resistance by reducing starch hydrophobicity and improving processability.

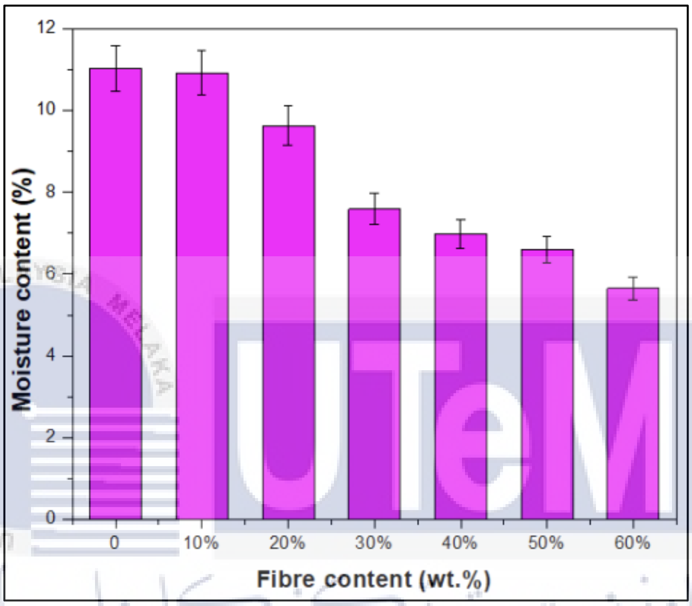


Figure 2.18: Moisture content of TPCS/PW/CCF biocomposites (Kamaruddin et al, 2023).

Jumaidin et al, (2021) investigated the effect of cogon grass fibre (CGF) on the moisture content of thermoplastic cassava starch (TPCS) composites. Different concentrations of CGF (1%, 3%, and 5%) were incorporated into the TPCS matrix, and the moisture content of the resulting composites was examined. The results, presented in Figure 2.19, demonstrated that the inclusion of CGF had minimal impact on the moisture content of the composites. The moisture content slightly decreased from 6.4% for the TPCS matrix to 5.9% for TPCS/CGF-1, followed by a slight increase to 7.9% for TPCS/CGF-5. However, these changes were not significant and could be attributed to small variations in the composite formulations. Furthermore, the moisture content of TPCS/CGF-3 was similar to that of the neat TPCS. The slight increment observed in TPCS/CGF-5 (approximately 1% higher than the neat TPCS) was deemed insignificant. These findings indicate that incorporating CGF at concentrations of 1% to 5% does not considerably affect the moisture content of the composites. This lack of significant impact on moisture content can be attributed to the relatively non-hydrophilic nature of CGF compared to the neat TPCS. Overall, these results contribute to the understanding of moisture behavior in TPCS composites and highlight the potential of CGF as a reinforcing material without compromising moisture resistance properties.

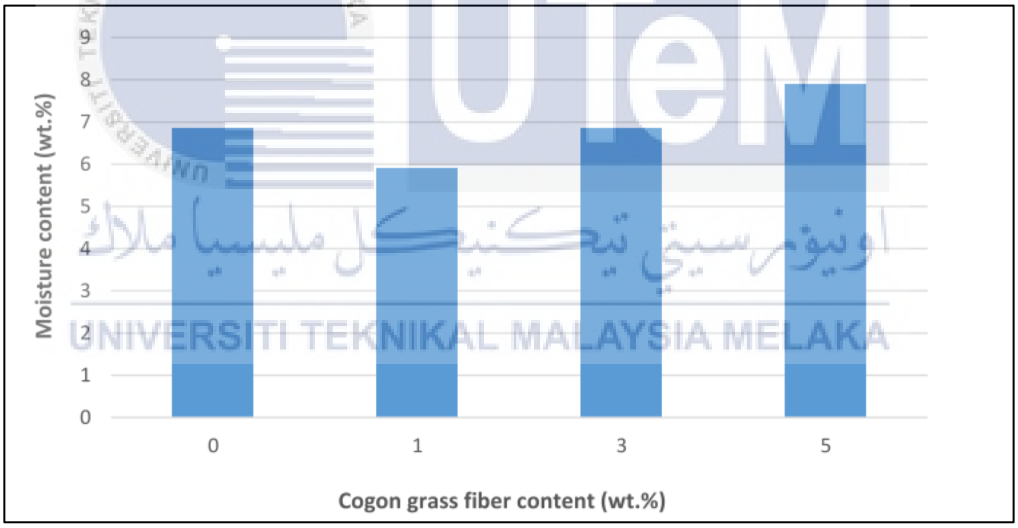


Figure 2.19: Moisture content of TPCS with cogon grass fibre composites ((Jumaidin et al., 2020).

2.8.2 Water Absorption

Water absorption test refers to a procedure conducted to evaluate the ability of a material or composite to absorb water when immersed in or exposed to a water environment.

The test involves submerging the sample in water for a specific duration and then measuring the amount of water absorbed by the material. The water absorption percentage is calculated by comparing the weight of the sample before and after the immersion (Radzi et al, 2019).

The study conducted by Wan Zarina et al, (2018) investigated the water absorption behavior of Mengkuang Reinforced Thermoplastic Natural Rubber Composites. The presence of O-H groups in lignocellulosic fibres makes them susceptible to water absorption. After a 24-hour immersion in distilled water, the impact of fibre content on water absorption was observed. The lowest absorption rate was found at 10% fibre content, with minimal reduction when fibre size decreased. Increasing the fibre content to 20% and 30% resulted in significantly higher absorption rates. Analysis revealed that 500 µm fibres show the highest water absorption, followed by 125 µm fibres, while 250 µm fibres had the lowest absorption across all fibre contents. Moreover, fibre bonding and the formation of fibre bundles contributed to increased water absorption by creating larger microcracks. These findings offer valuable insights into the water absorption behaviour of lignocellulosic fibre composites, highlighting their practical implications as shown in figure 2.20.

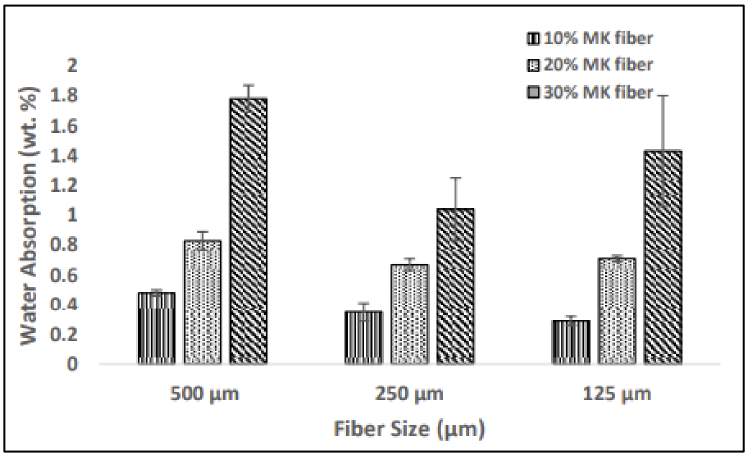


Figure 2.20: Effect of fibre size and fibre content (%) on water absorption of mengkuang reinforced 60/40 HDPE/NR composites (Wan Zarina et al., 2018).

In Kaewtatip (2012), conducted research to investigate the water absorption behavior of composites made from thermoplastic starch (TPS) reinforced with luffa fibre. The study revealed that as the fibre content increased in the TPS/luffa fibre composites, there was a noticeable decrease in water absorption. Specifically, when the luffa fibre content increased from 5 wt.% to 20 wt.%, a significant reduction in water absorption was observed. This decrease can be attributed to the hydrophilic nature of starch compared to cellulose, as well as the presence of the fibre, which contributes to decreased hydrophilicity.

Moreover, the strong adhesion between the TPS matrix and luffa fibre played a vital role in limiting the free volume of starch molecular chains, thus impeding water penetration. The enhanced interaction between the TPS matrix and luffa fibre reinforced the composite structure and restricted the movement of water molecules within the material. As a result, the water absorption capability of the TPS/luffa fibre composites was effectively reduced. These findings highlight the significant influence of Fibre content and adhesion on the water absorption behavior of the composite materials. Figure 2.21 illustrates the decrease in water absorption with an increase in luffa fibre content.

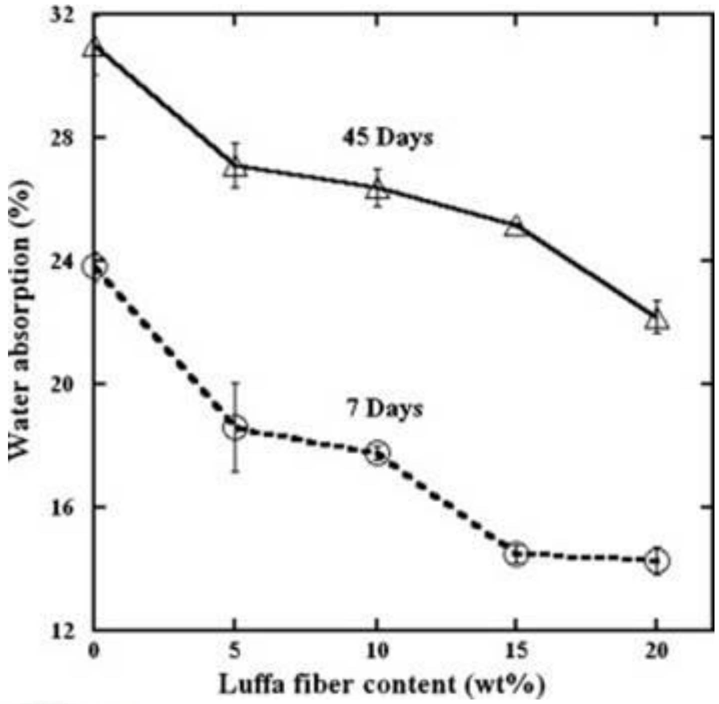


Figure 2.21: Water absorption with Luffa fibre content (wt%) (Kaewtatip et al., 2012).

2.8.3 Water Solubility

Water solubility test is a method used to evaluate the solubility of a material or composite in water. It provides valuable information about the water resistance and stability of the tested material when immersed and stirred in water (Nazri et al, 2020).

Zakaria et al, (2020) conducted an analysis of the characteristics of thermoplastic corn starch composites reinforced with short pineapple leaf fibres using the laminates method, specifically focusing on the water solubility test. Figure 2.22 displays the water solubility of PALF/TPCS bio-composites, which provides insights into both the water resistance and degradation behavior of the composites when immersed and continuously stirred in water. It was observed that the water solubility of PALF/TPCS bio-composites significantly increased from 25.08% to 36.83% with the addition of PALF at fibre content ranging from 20 to 60 wt.%. These findings suggest that lower fibre content contributes to reduced water solubility, while higher fibre content leads to increased water solubility. This indicates that PALF has the ability to enhance the solubility of PALF/TPCS bio-composites, thereby improving their degradability in water, which is advantageous for sustainable waste disposal. However, it is important to note that higher water solubility also indicates a weaker resistance of the bio-composites when exposed to water.

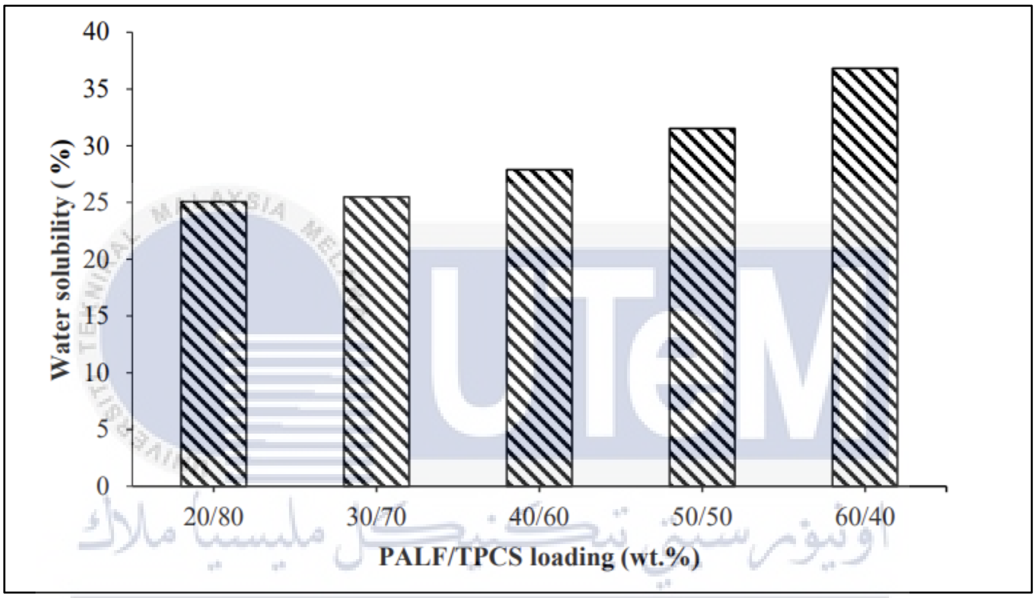


Figure 2.22: The water solubility for PALF/TPCS bio-composite (Zakaria et al, 2020).

According to Jumaidin et al, (2019) the physical properties of Cogon Grass Fibre (CGF) Reinforced Thermoplastic Cassava Starch (TPCS) Biocomposite explored the water solubility of TPCS/CGF composites. The results showed in figure 2.23 that the inclusion of CGF reduced the solubility of the composite in water compared to neat TPCS. The solubility percentages of TPCS/CGF-1, TPCS/CGF-3, and TPCS/CGF-5 were 28.70%, 28.90%, and 28.48% respectively, lower than the 36.3% solubility of neat TPCS. The water resistance of CGF played a significant role in hindering water absorption, preventing disintegration and dissolution of the materials. The incorporation of CGF resulted in the formation of a fibre network within the composites, indicating strong interactions between CGF fibres and TPCS starch chains at the fibre-matrix interface. The abundance of hydroxyl groups in CGFs and the hydrogen bonding with the starch matrix facilitated the interaction between CGF and starch chains, providing resistance and stability to TPCS/CGF. These interactions also enhanced the cohesive properties of the biopolymer matrix, reducing water sensitivity. Similar findings were reported when hybrid composites of cassava bagasse and sugar palm fibre were added to the TPCS matrix, leading to decreased water solubility of the films.

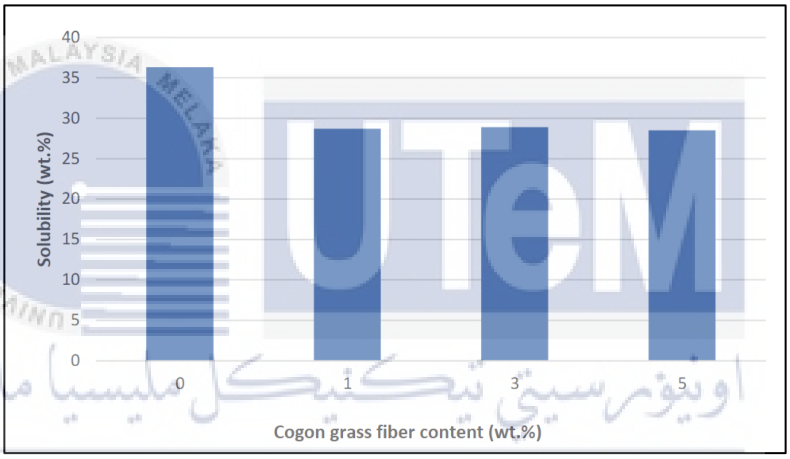


Figure 2.23: Solubility of TPCS/cogon grass fibre composite (Jumaidin et al, 2019)

Hafila et al, (2022) conducted a review analysis on the water solubility characteristics of thermoplastic cassava starch (TPCS) composites containing palm wax at different loadings. The addition of palm wax to the TPCS matrix resulted in a significant improvement in water resistance, as evidenced by a decrease in solubility from 33.82% to 23.39%. in figure 2.24. This enhancement can be attributed to the hydrophobic nature of palm wax and its interaction with starch, forming a strong network that limits the access of water molecules to hydroxyl groups. Consequently, the hydroscopic nature of the bio composites is minimized. It was observed that increasing the palm wax content further decreased the water solubility of the TPCS/palm wax composites. Palm wax, being insoluble in water, contributes to the formation of hydrophobic interactions, reducing the availability of binding sites. Similar results have been reported in studies involving palm wax in other bio composite systems. Notably, palm wax not only improves water resistance but also maintains the structural integrity of the composites when immersed in water. These findings highlight the potential of palm wax as an effective additive for enhancing water resistance and preserving the integrity of TPCS-based bio composites.

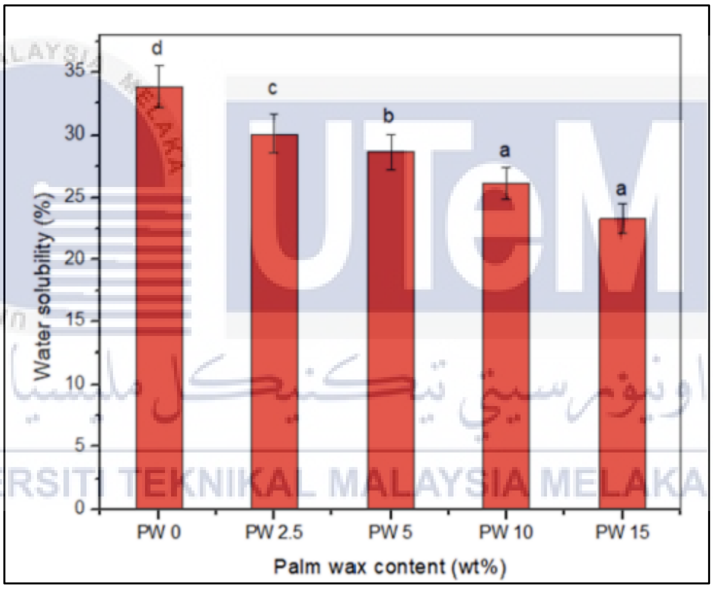


Figure 2.24: Water solubility of TPCS with different amounts of palm wax (Hafila et al, 2022).

2.8.4 Soil Burial

Soil burial test refers to a method used to assess the biodegradation or decomposition behaviour of materials or samples when buried in soil under controlled laboratory conditions.

The test involves burying the specimens in soil and monitoring their degradation over a specific period (Magalhães & Andrade, 2009).

Sarsari et al, (2016) thesis focused on using walnut shell flour (WSF) as a substitute for wood in walnut shell flour/thermoplastic starch (WSF/TPS) composites. The weight loss of the composites was studied in a soil burial degradation test in figure 2.25, and it was found that the weight loss increased with higher starch content. However, the inclusion of walnut shell flour significantly improved the durability of the composites. The high lignin content in walnut shell flour played a role in reducing weight loss by protecting the composites from degradation. The breakdown of starch structures also contributed to lower weight loss. Overall, incorporating walnut shell flour in WSF/TPS composites not only enhanced their physical properties but also increased their biodegradability, highlighting the potential of walnut shell flour as a sustainable filler in thermoplastic starch composites.

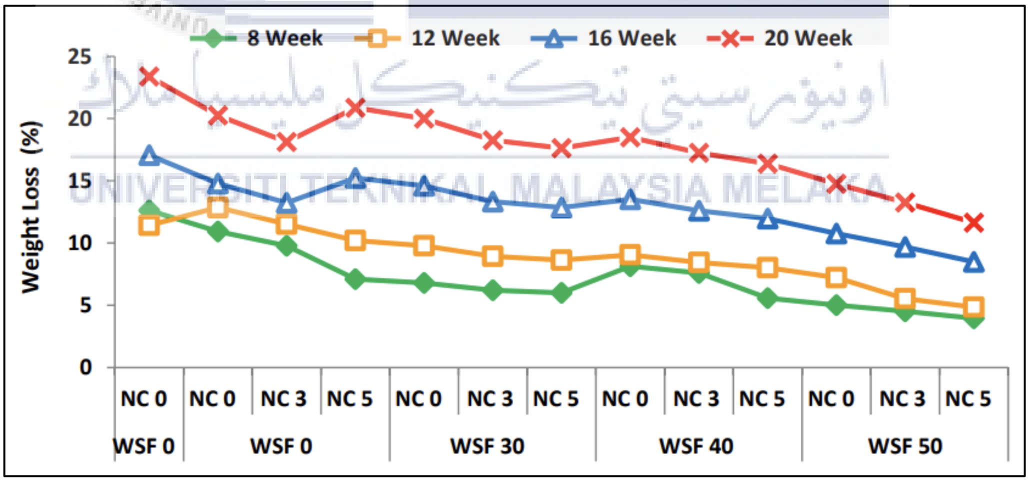


Figure 2.25: Weight loss of sample buried in soil for 8, 12, 16, and 20 weeks (Sarsari et al, 2016).

Nazrin et al, (2022) study of the research paper was on the physical stability of sugar palm crystalline nanocellulose reinforced thermoplastic sugar palm starch/poly (lactic acid) blend bio nanocomposites using a soil burial test. The weight loss of the blend bio nanocomposites was observed to determine their biodegradation behavior. The results showed in figure 2.26, an increasing trend in weight loss percentage with the addition of thermoplastic sugar palm starch (TPS) within the blend. Active degradation was observed in the first 30 days, followed by lower degradation rates in the next 90 days. The presence of amylopectin in the blend promoted water diffusion and microorganism growth, leading to weight loss. The adaptation of microorganisms and the homogenous composition of PLA60TPS40 reduced the degradation rate. Samples with higher TPS content experienced significant weight loss, with PLA40TPS60 showing the highest increase. The physical condition of the samples varied, with some maintaining their shape while others shrunk and displayed surface cavities. The choice of plasticizers also influenced the degradation rate, with lower moisture content affecting the interaction between starch, water, and sorbitol. This research highlights the importance of understanding the factors influencing the degradation of bio nanocomposites and the role of composition and plasticizers in the physical stability.

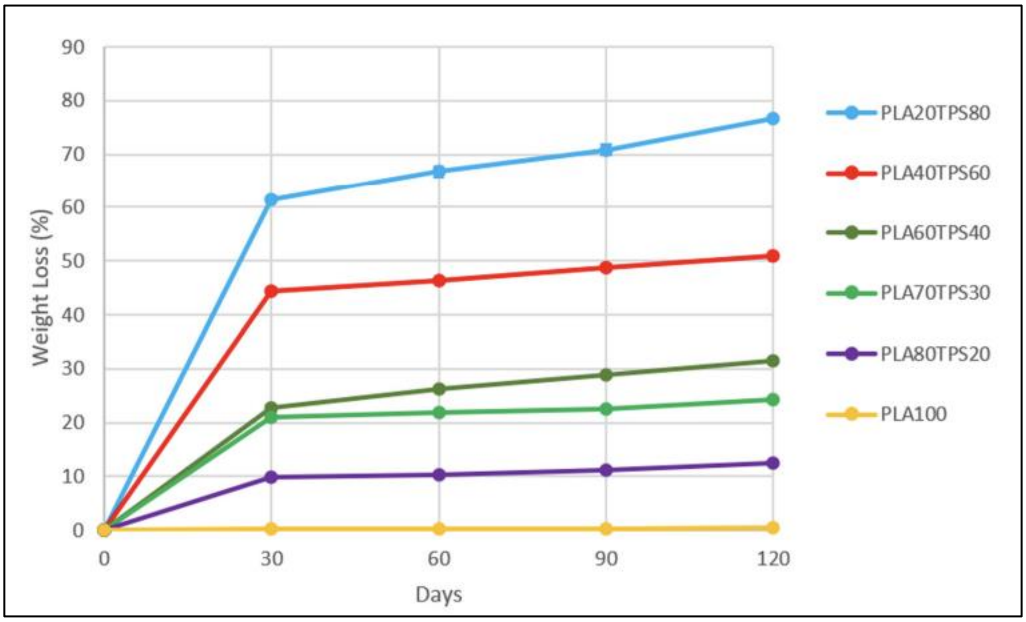


Figure 2.26: Weight loss against time of PLA100 and PLA/TPS blend bionanocomposites (Nazrin et al, 2022)

In this Sivakumar et al, (2022) analysis, the study aimed to evaluate the impact of incorporating banana leaf fibre (BLF) on the mechanical and thermal properties of thermoplastic cassava starch (TPCS) through a soil burial test. The biodegradation rate, influenced by soil moisture and microorganisms, was assessed by measuring the weight loss of the materials over time. Results showed that all composites experienced greater weight loss after three weeks compared to two weeks, indicating increased microbial activity during the longer burial period in figure 2.27. The addition of banana leaf fibre to the TPCS matrix resulted in a lower percentage change in weight compared to TPCS alone. Specifically, the TPCS/BLF-50 wt.% composite show a lower weight loss than the TPCS matrix after two weeks, but a higher weight loss after three weeks. This observation can be attributed to the higher hydrophilicity of the fibre, which contributed to the reduced weight loss of TPCS/BLF composites after two weeks of soil burial.

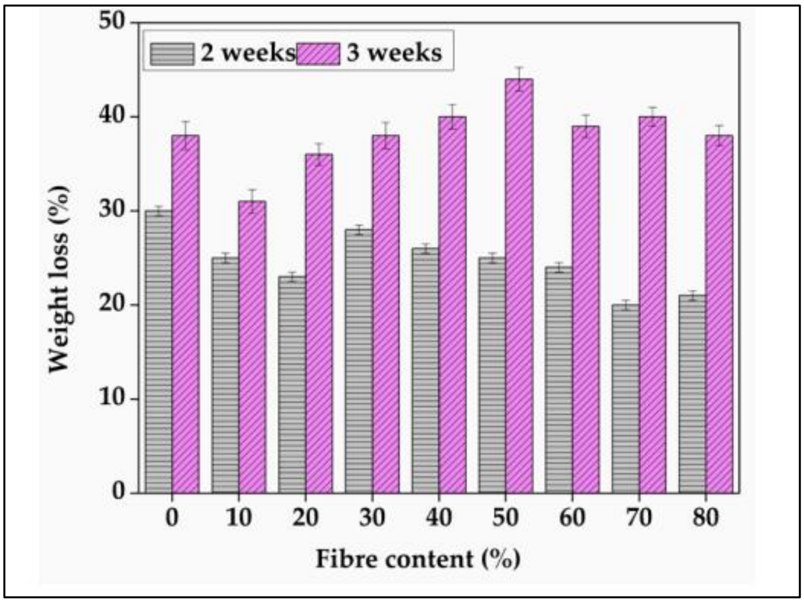


Figure 2.27: Weight loss of composites after soil burial (Sivakumar et al, 2022).

2.8.5 Density

Density testing refers to the measurement of the density of a material or substance. Density is the mass per unit volume of a material and is typically expressed in grams per cubic centimeter (g/cm³) or kilograms per cubic meter (kg/m³). The density test involves determining the mass of a sample and measuring its volume using various techniques such as displacement or instrumental methods (Wan Zarina et al, 2018).

In this review analysis, the Kamaruddin et al., (2023) focused on the preparation of thermoplastic cassava starch/palm wax blends incorporated with Cymbopogan citratus fibre (TCPS/PW/CCF) bio-composites at different concentrations of CCF. The density test was performed on fabricated samples, which were dried in an oven. The results showed that the density of the bio composites decreased as the CCF loading increased in figure 2.28. This reduction in density can be attributed to the low density of the added CCF compared to the control sample. The decrease in density was found to be 6.87%, indicating a decrease in the proportion of bio composite mass when CCF was added. This trend of decreasing density with increasing fibre loading has been observed in previous studies with different fibre-reinforced composites. The lightweight nature of the composites provides practical benefits in terms of material weight reduction.

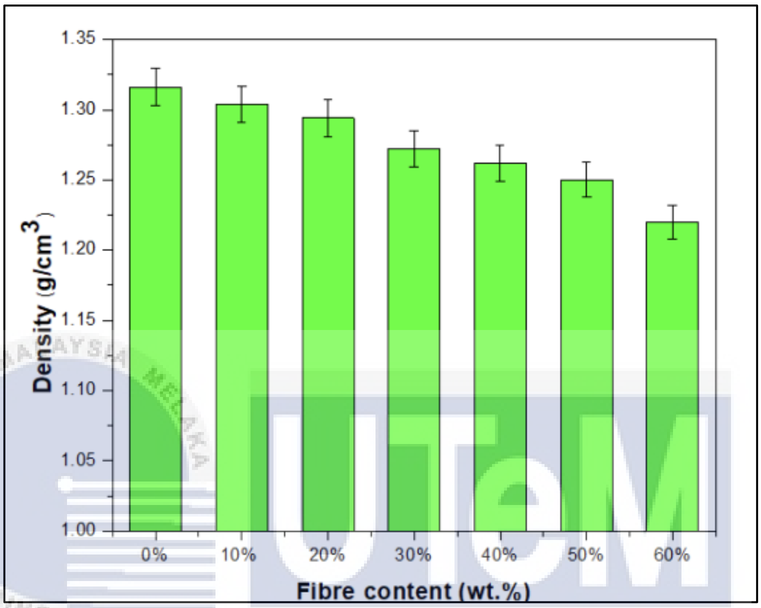


Figure 2.28: Density of TPCS/PW/CCF biocomposites (Kamaruddin et al., 2023).

Zakaria et al, (2020) conducted an analysis of the characteristics of thermoplastic corn starch composites reinforced with short pineapple leaf fibres using the laminates method, focusing on density measurements. The density results of PALF/TPCS bio-composites at various fibre loadings are presented in Figure 2.29. Overall, the density of the bio-composites consistently decreased as the PALF loading increased. The highest density value was observed at a 20 wt.% fibre loading, measuring approximately 1.32 g/cm3. On the other hand, the lowest density values of 1.23 g/cm3 were obtained at 50 and 60 wt.% fibre loadings, respectively. The reduction in density between the highest and lowest values was approximately 7.32%. These observations indicate that the density of PALF/TPCS bio-composites is significantly higher in the matrix (TPCS) than in the fibre (PALF).

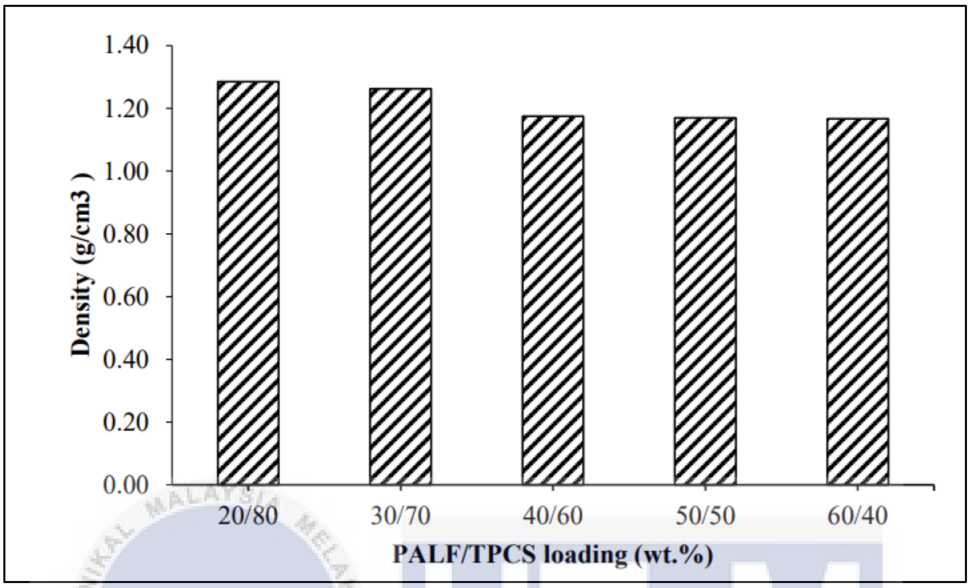


Figure 2.29: The density testing for PALF/TPCS bio-composite (Zakaria et al, 2020)

2.8.6 Thickness Swelling

Thickness swelling refers to a measurement that assesses the dimensional change of a material when it absorbs moisture or is exposed to a liquid. It is commonly used to evaluate the swelling behavior of composite materials, particularly those made of natural fibres or wood. The test involves immersing the material in a liquid or exposing it to a humid environment and measuring the change in thickness over a specified period.

Sarsari et al, (2016) conducted a thickness swelling test on walnut shell flour/thermoplastic starch (WSF/TPS) composites. The composites were immersed in water for 2 hours and 24 hours, resulting in TS ranging from 5.36% to 10.87% and 6.97% to 16.57% respectively in figure 2.30. Higher WSF content led to increased thickness swelling, in line with previous research on wood-plastic composites. The correlation between thickness swelling and water absorption was observed. Composites without nano clay (NC) and with 50% WSF had the highest TS, while those with NC showed lower TS at a constant WSF level. These findings offer valuable insights for optimizing WSF/TPS composites, aiding applications requiring moisture resistance and dimensional stability.

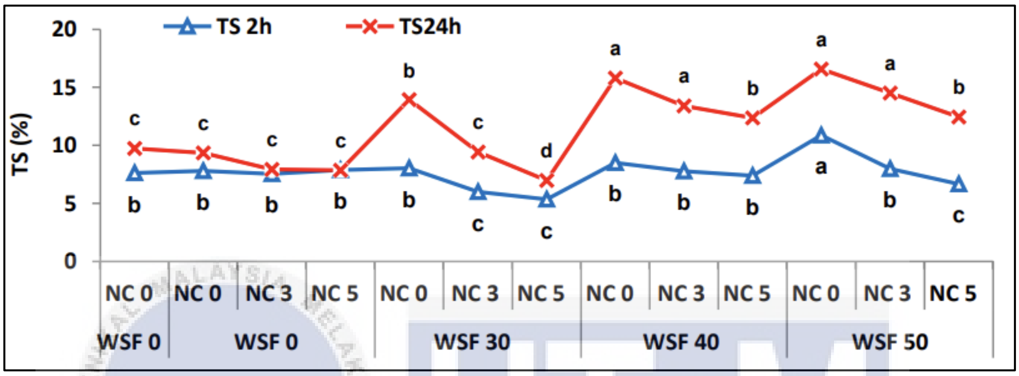


Figure 2.30: Means of thickness swelling after 2 h and 24 h (TS 2 h & TS 24 h) in WSF/TPS composites (Sarsari et al, 2016)

A review article analysis was conducted by Sari & Suteja, (2020) on Corn husk Fibre reinforced polyester composites, focusing on thickness swelling behaviour. The composites were immersed in water for 24 hours and 72 hours, and the thickness swelling was evaluated. The results showed in figure 2.31 that the swelling of CHF/polyester composites increased with increased water absorption, indicating a correlation between water uptake and thickness swelling. Additionally, the rate of swelling change was found to increase with longer immersion time. The presence of CHF in the polyester matrix influenced the swelling thickness, likely due to differences in water uptake between CHF and polyester components. The mechanism of thickness swelling was found to be similar to that of water uptake. These findings contribute to understanding the behaviour of CHF/polyester composites in relation to moisture absorption and dimensional changes.

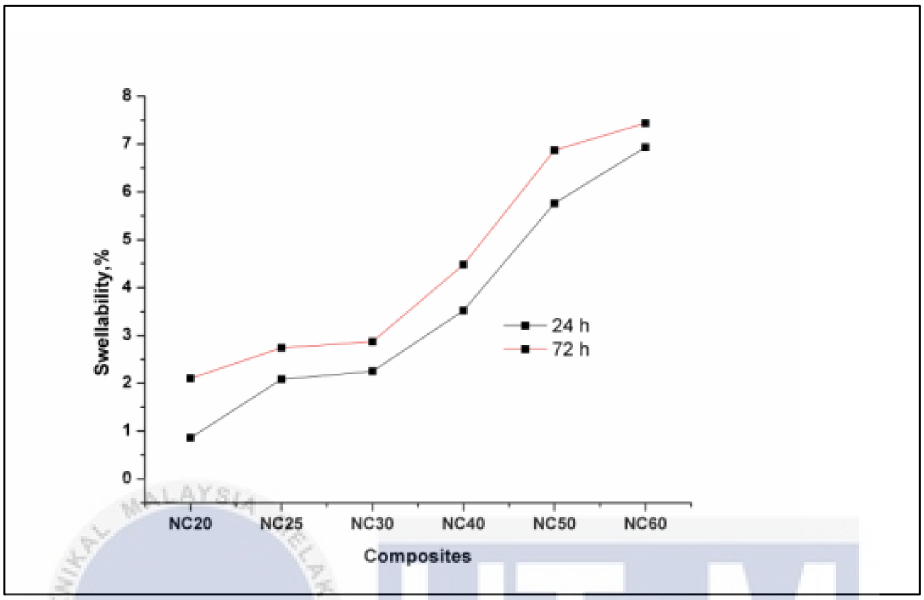


Figure 2.31: Swelling of polyester/corn husk fibre composites (Sari & Suteja, 2020).

2.8.7 Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) is used to examine the surface morphology of a material composites. SEM micrographs can be used to visualize the contact between the matrix and fibres of the composite material.

In this review analysis, (Hafila et al., 2022) focused on the effect of palm wax on the mechanical, thermal, and moisture absorption properties of thermoplastic cassava starch composites. The images from SEM of the fractured TPCS/palm wax composite surfaces are recognized in figure 2.32. The control surface (fig. 2.32) contains a homogenous surface with no visible phase separation, propose a good interaction between starch and glycerol. However, after the palm wax incorporation into TPCS, it was discovered that the samples' surfaces show less homogeneity, resulting in a non-uniform and stiff structure with an irregular surface as shown in figure 2.32. Besides, the structure was observed to be less constant, and fragile interface or stress concentration sites for crack initiation and propagation were appearance, resulting in the easy failure of composites under applied tensile strength.

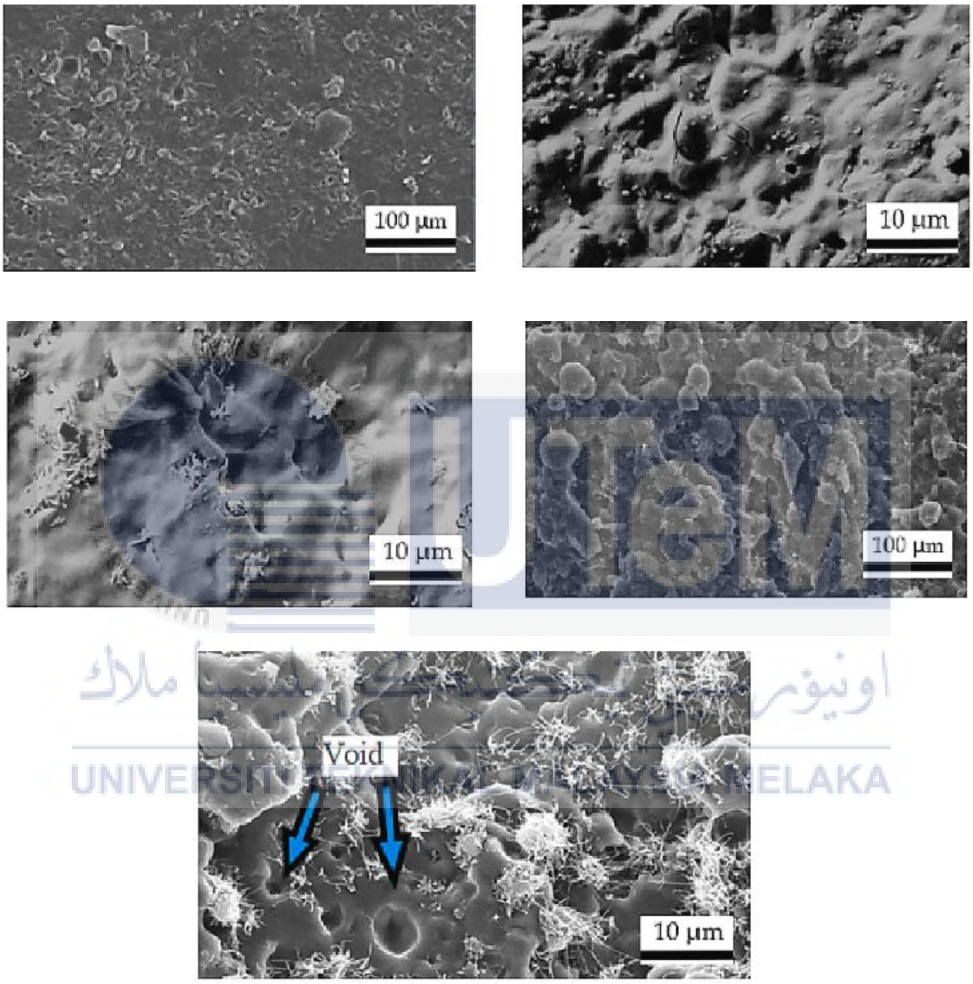


Figure 2.32: SEM micrograph of fracture surface of TPCS blended with different ratios of palm wax (0wt%, 2.5wt%, 5wt%, 10wt%, and 15wt% (Hafila et al., 2022).

A review article analysis was conducted by Ahmad, (2020), on effect on the thermal, mechanical, and biodegradable properties of thermoplastic cassava starch bio composite. Fig. 2.33 show the SEM micrograph of the tensile fractured surfaces of TPCS composite with different ratio of cogon grass fibre. Rough surface of CGF apparently good adhesion between the cogon grass fibre and TPCS matrix. The fibre fracture can be distinct appeared on the surface of tensile fracture structure. This result suggests strong stress-transfer from TPCS biopolymer matrix to CGF which shown reinforcement effect to the composites. Besides, starch granules in TPCS shape and stretch out at determine level with glycerol. Fibre pull-out is visible from the micrograph and CGF are found to be more broken in Fig. 4d. Besides, it can be recognized that TPCS and CGF are distinctly reconcilable which show through good fibre wetting by the matric (Fig. 2.33b).

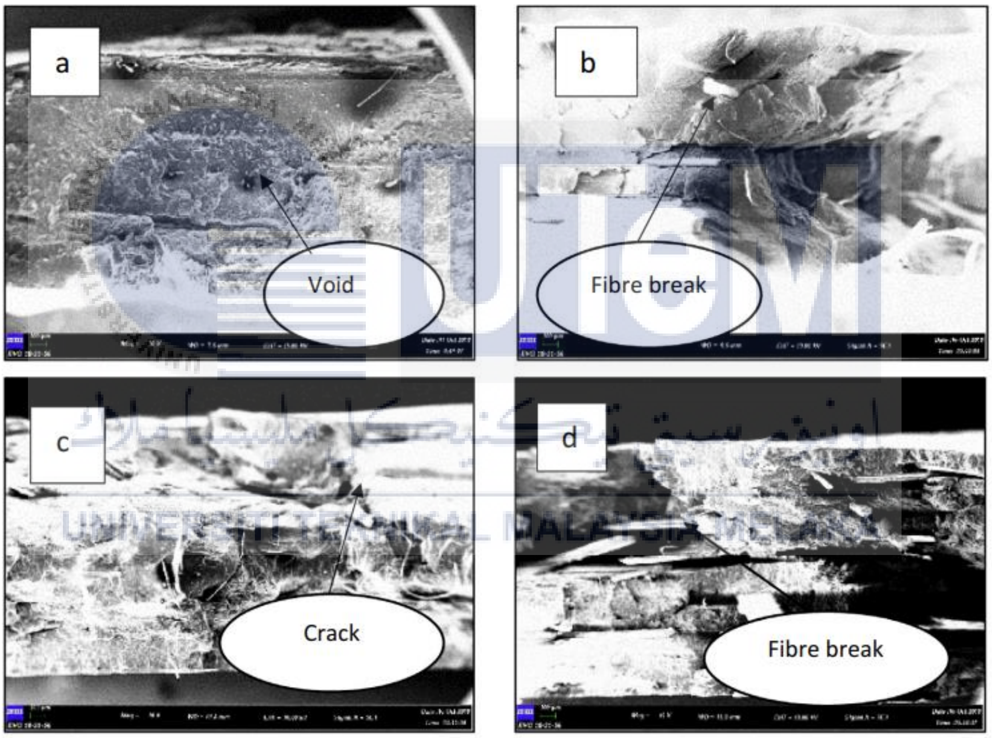


Figure 2.33: SEM micrograph of fracture surface of TPCS blended with different ratio of cogon grass fibre (a) TPCS, (b) TPCS/CGF-1, (c) TPCS/CGF-3, and (d) TPCS/CGF-5 (Ahmad, 2020)

2.9 Summary

Chapter 2 of the research paper provides a comprehensive literature review focusing on composite materials made with natural fibres:

- This chapter highlights the extensive research conducted on utilizing corn husk, an inexpensive and biodegradable agricultural waste, in composite materials. Numerous studies have explored the application of corn husks in various composite materials, data analysis findings and results. The insights and analysis presented in this review offer valuable perspectives on the development of eco-friendly and sustainable products, benefiting both humanity and the environment.
- The study showed that corn husk (CH) can be successfully utilized together with thermoplastic starch (TPS) in CH/TPS composites with useful physical and mechanical properties.
- The incorporation of corn husk fibre and polypropylene into a composite material offers an opportunity to enhance its properties by combining the strength and durability of polypropylene with the renewable and biodegradable nature of corn husk fibre. These composites hold promise as a sustainable and cost-effective solution for a wide range of applications.
- The incorporation of PP and Thermoplastic Starch with fibre enhances the graph result, countering the decrease caused by fibre's moisture-absorbing properties.

2.10 Literature Review Critique

This thesis explores the use of cost-effective and environmentally friendly corn husk in composite materials, aiming to strengthen the analysis, particularly when combining it with thermoplastic starch. The investigation of sample journals provides details on research methodology, data sources, and analysis techniques. The study reveals a consistent decrease in water affinity, physical testing, environmental testing, and other properties as the natural fibre concentration reaches 40%. The improvements observed in integrating corn husk with thermoplastic starch underscore its effectiveness in composite production. In conclusion, this study improves understanding of comprehensive analysis, specific data inclusion, and transparent methodology. Applying these insights in future steps get brings closer to the objectives.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter specifically examines the raw material, the production process of thermoplastic starch reinforced with corn husk fibre and thermoplastic cassava starch (TPCS), and the testing procedures required to evaluate the characteristics of the raw material. The research and methodology utilized in this study are visually presented in Figure 3.1, illustrating the sequence of steps involved.

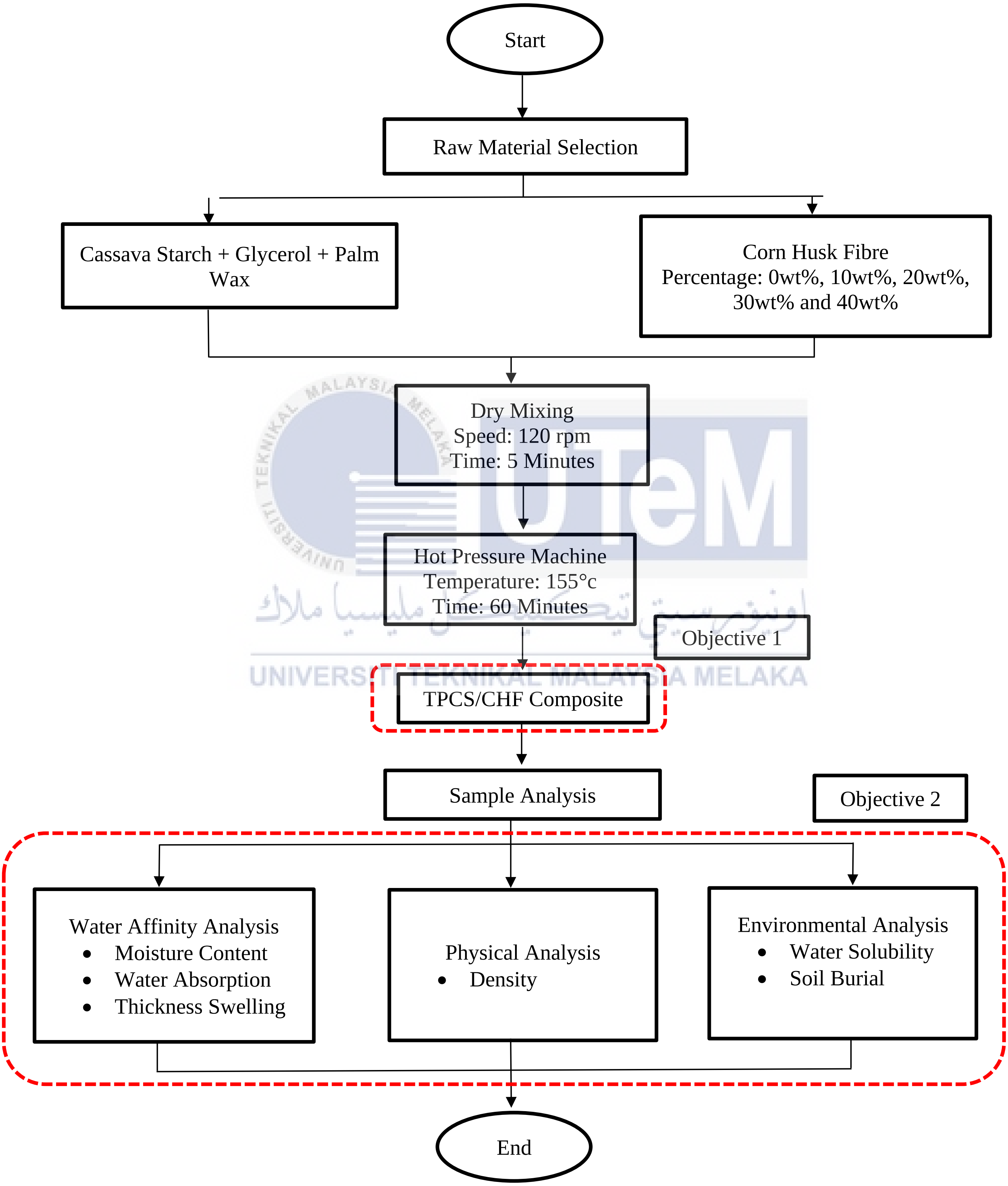


Figure 3.1: Flow of Research Methodology

3.2 Material

3.2.1 Corn Husk Fibre

Cornhusk has been obtained from the Sunggala market, Port Dickson, Negeri Sembilan. To maintain uniformity, corn husks are selected and picked based on the same stall. Corn husks range in size from 13.5 cm to 15.2 cm in length and width. Figure 3.1 shows the corn husk Fibre to be used in this experiment. Following that, corn husk fibre was blended using a grinder machine in preparation for the hot press process. Subsequently, the corn husk was soaked for two weeks to ensure proper seasoning.

Figure 3.2: Corn Husk Waste

Figure 3.3: Soaked corn husk

Figure 3.4 : Corn Husk Fiber

3.2.2 Cassava Starch

Cassava starch from the provider Antik Sempurna Sdn. Bhd. is the primary ingredient of this project. In essence, cassava starch is a white powder that resembles other starches in appearance. The cassava starch that will be used in this study is shown in Figure 3.2.

Figure 3.5: Cassava Starch

3.2.3 Glycerol

Glycerol was used as a plasticizer after purchases from QReC (Asia) Sdn Bhd. Glycerol, also known as glycerin, glycerin, or propanetriol, is a type of polyol. The glycerol from QReC Chemical had a molar weight of 92.10 g/mol and was 99.5% AR grade. Glycerol is a thick, tasteless liquid that is non-toxic, colorless, and odorless as shown in figure 3.3.

Figure 3.6: Glycerol

3.2.4 Palm Wax

The significance of palm wax, a resinous wax, is emphasized in this study. Palm wax exhibits a color spectrum ranging from pale yellow to yellow tan in figure 3.4. The moisture-repellent characteristics of palm wax play a crucial role in preventing the degradation of thermoplastic cassava starch when exposed to moisture.

Figure 3.7: Palm Wax

3.3 Preparation of Sample

3.3.1 Preparation of Thermoplastic Cassava Starch with Palm Wax

The manufacturing process of thermoplastic cassava starch involves two steps which were weighing and combining cassava starch and glycerol, followed by pressing the mixture using a hot press machine.

The ratio of cassava starch to glycerol used in the study was 100 g and 30 g, respectively. The cassava starch and glycerol were carefully weighed, dried, and evenly distributed before undergoing high-speed dry mixing for 3-5 minutes using a dry blender set at 1200 rpm.

After weighing the mixed cassava starch and glycerol at 58.20g, the mixture was placed into the mold, which was then inserted into the preheated hot press machine set at 155 °C. To facilitate the removal of the sample mixture from the mold, a Mylar sheet was lined inside the mold.

The Mylar film not only prevented the sample mixture from sticking to the mold during the hot press process but also compressed the mixture within the mold. Once the hot press machine reached the temperature of 155 °C, the mold containing the mixed sample was placed inside for an hour-long duration. This process resulted in the production of 100% thermoplastic cassava starch, as depicted in Figure 3.6, illustrating the preparation steps of the material.

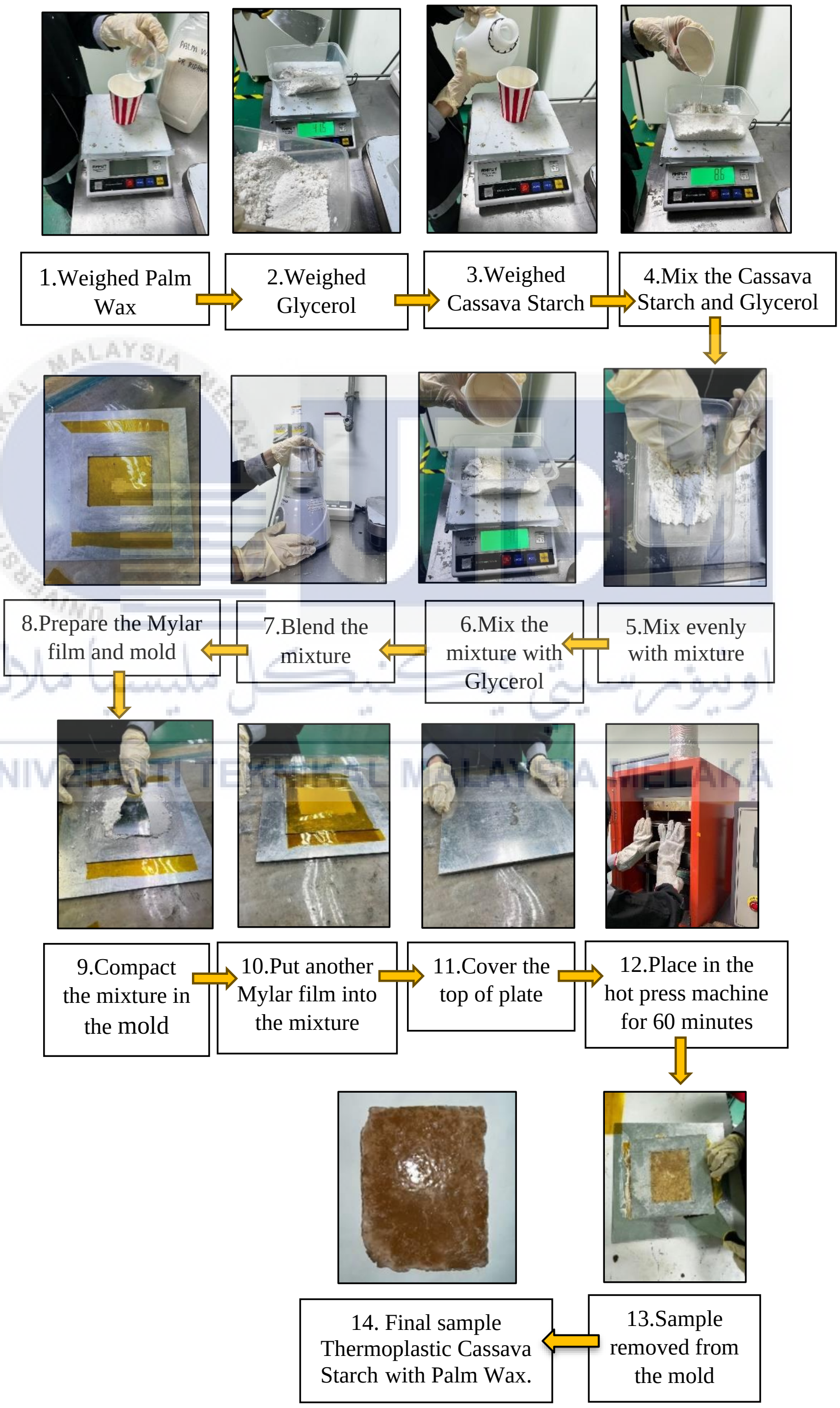


Figure 3.8: Fabrication and preparation of Thermoplastic Starch with Palm Wax

3.3.2 Preparation of Thermoplastic Cassava Starch Reinforced with Corn Husk Fibre

The process was conducted to produce thermoplastic cassava starch composites with varying proportions of corn husk fibre. The study involved combining thermoplastic cassava starch with different percentages of corn husk fibre (0%, 10%, 20%, 30% and 40%). The mixture was prepared by calculating the appropriate ratio of corn husk fibre to thermoplastic cassava starch based on the desired percentage. For instance, a 20% corn husk fibre composition required 11.64g of corn husk fibre and 46.56g of thermoplastic cassava starch. Subsequently, the mixture was thoroughly blended and placed into a mold, which was then subjected to hot pressing at 155°C for 60 minutes. This procedure was repeated for each of the different fibre percentages.

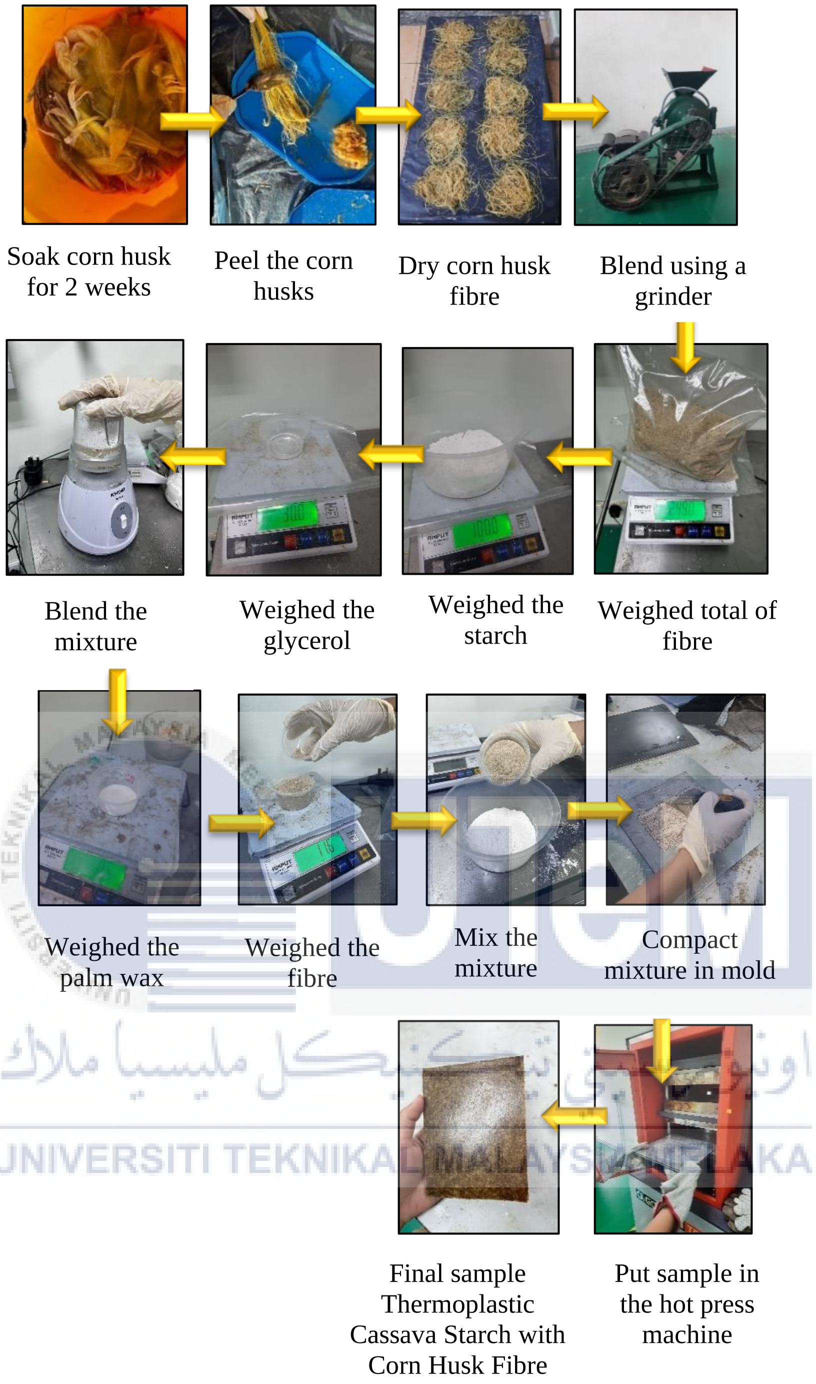


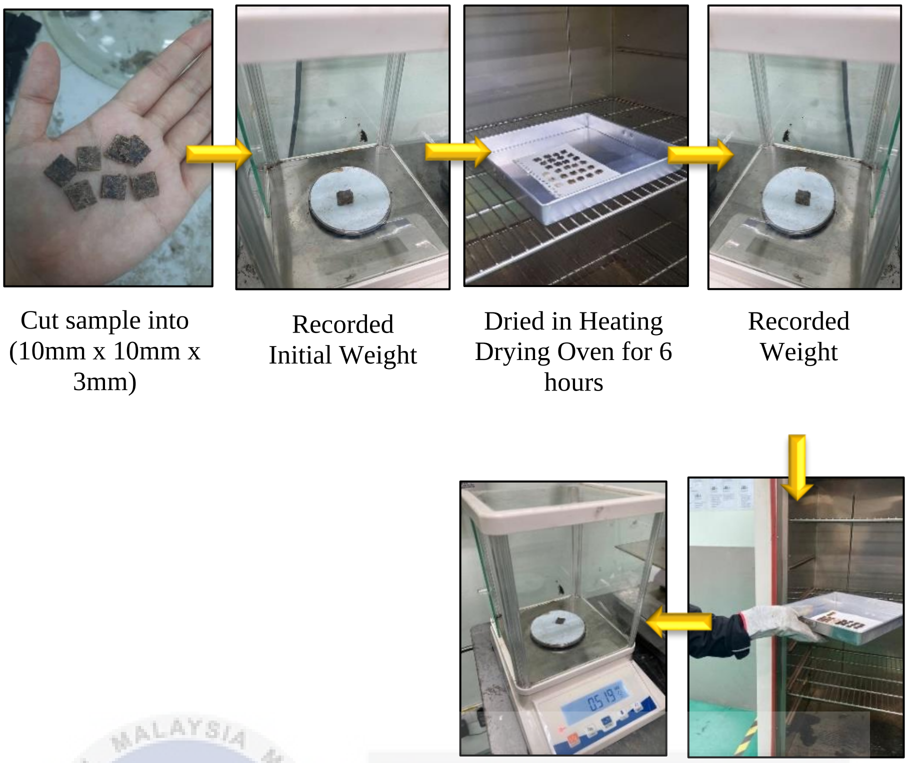
Figure 3.9: Fabrication and preparation of Thermoplastic Starch with Corn Husk Fiber

3.4 Characterization of Sample

3.4.1 Moisture Content

The objective of this study is to outline the standardized procedure for evaluating the moisture content in samples. This procedure has been conducted in a manner consistent with previous tests. Three sample pieces, each measuring 10mm x 10mm x 3mm, will be prepared for analysis. Weighing balances have been utilized to determine the initial weight (Wi) of the samples. Subsequently, the samples have been subjected to a drying process in an air circulation oven set at a temperature of 80 °C for a duration of 6 hours. Upon completion of the drying period, the samples have been carefully removed from the oven to prevent them from absorbing moisture from the surrounding environment during the subsequent weighing process. The final weights (Wf) of the samples have been promptly determined to ensure accurate measurements. To ascertain the moisture content, the percentage of moisture present in the samples have been calculated according to the following procedure.

$$\textit{Percentage of Moisture Content}\ (\%) = \frac{Wf - Wi}{Wi} x\,100\%$$



Cut sample into (10mm x 10mm x 3mm)

Recorded Initial Weight

Dried in Heating Drying Oven for 6 hours

Recorded Weight

Recorded Final Weight

Dried again for 1 hour more because the weight doesn't constant

Figure 3.10: Testing of moisture content

3.4.2 Water Absorption

This procedure has been conducted in a manner consistent with previous tests. Three sample pieces, each measuring 10mm x 10mm x 3mm, have been prepared for analysis. Weighing balances have been utilized to determine the initial weight (Wi) of the samples. Subsequently, the samples have been subjected to a drying process in an air circulation oven set at a temperature of 80 °C for a duration of 2 hours. Upon completion of the drying period, the samples have been carefully removed from the oven to prevent them from absorbing moisture from the surrounding environment during the subsequent weighing process. The final weights (Wf) of the samples have been promptly determined to ensure accurate measurements. To ascertain the moisture content, the percentage of moisture present in the samples have been calculated according to the following procedure.

$$\textit{Percentage of Water Absorption } (\%) = \frac{Wf - Wi}{Wi} \, x \, 100\%$$

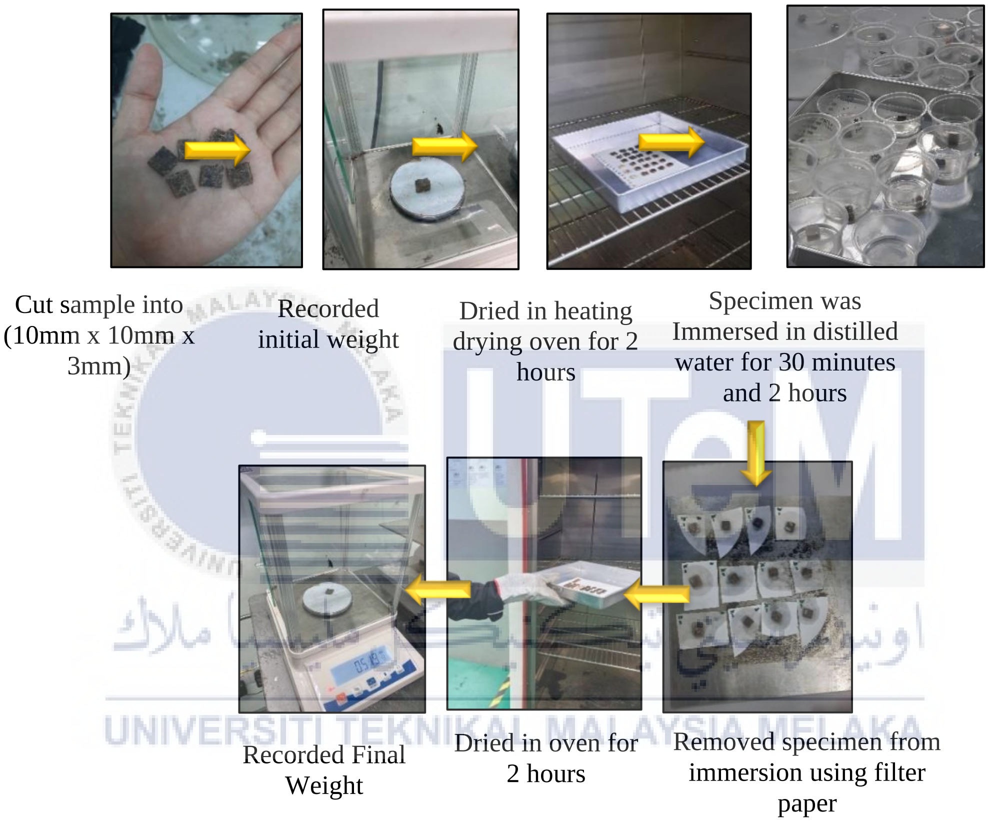


Figure 3.11: Testing of water absorption

3.4.3 Thickness Swelling

This study focuses on conducting a thickness swelling test on thermoplastic cassava starch samples reinforced with palm wax, adhering to the guidelines specified in the ASTM D570-98 standard. However, slight modifications have been made to the sample dimensions to ensure compatibility with the testing procedure. The samples, with dimensions of 10 mm x 10 mm x 3 mm, have been sliced accordingly. In this study, to eliminate any residual moisture, the samples have been placed in an air circulation oven set at a controlled temperature of 80°C for a drying period of 2 hours. After the drying process, the initial thickness of the samples has been measured using a Vernier Caliper Mitutoyo model, with a precision of 0.01 cm (Ti). Subsequently, the samples have been immersed in water at room temperature (23 °C±1) for two different time intervals: 0.5 hour and 2 hours. Following each immersion period, the final thickness of the samples has been measured using the same Vernier Caliper (Tf). The percentage of thickness swelling have been calculated using a formula obtained from the ASTM D570-98 standard.

$$\boldsymbol{Percentage\ of\ Thickness\ Swelling}\ (\%) = \frac{\boldsymbol{Tf - Ti}}{\boldsymbol{Ti}}\ \boldsymbol{x\ 100\%}$$

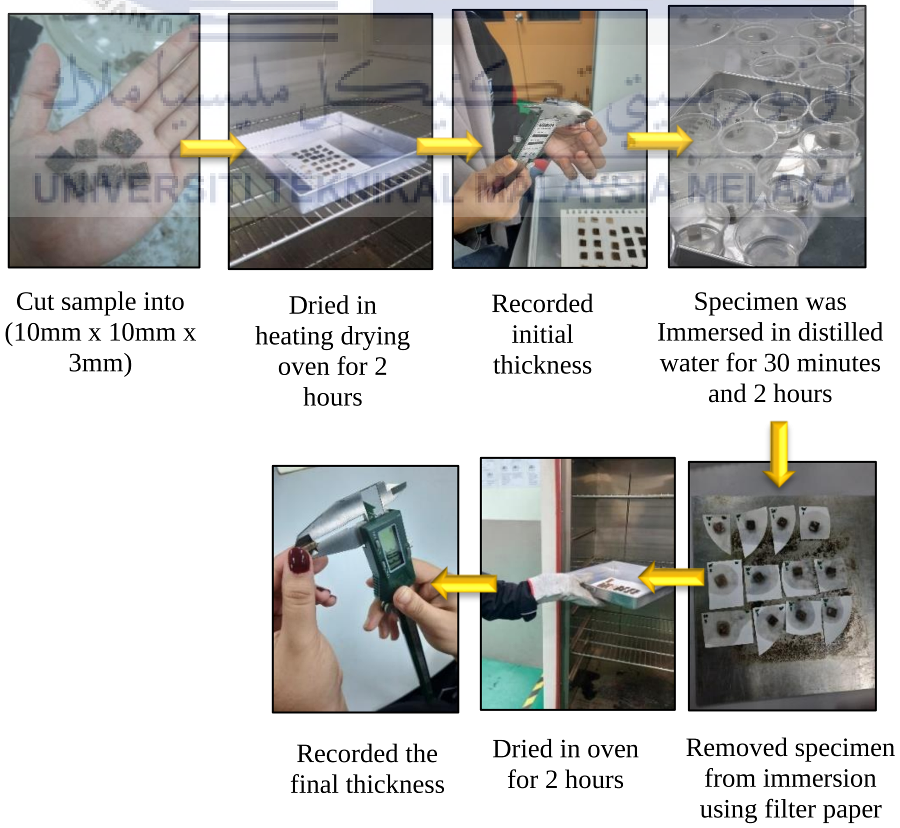
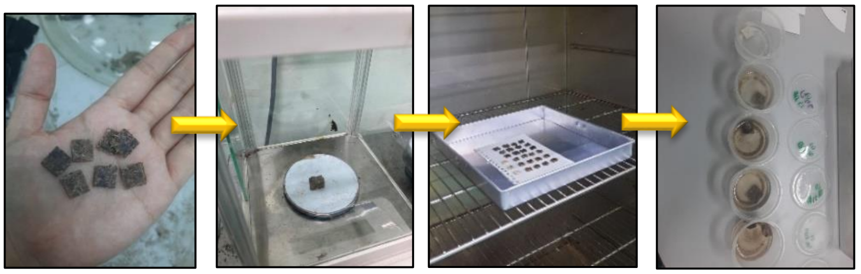


Figure 3.12: Testing of thickness swelling

3.4.4 Water Solubility

In order to conduct the testing, the specimen have been undergo initial preparation by being cut into dimensions of 10mm x 10mm x 3mm. The initial weight (Wi) of the specimen have been determined using a precise weighing scale. Next, the samples have been subjected to a drying process in an air circulating oven for a duration of 2 hours, at a controlled temperature of 80 °C. Following this, the samples have been immersed in 30 ml of distilled water and gently stirred. After 24 hours, the samples have been carefully removed from the container, and any remaining water on the sample surface have been absorbed using filter paper. The samples have been undergo an additional 2 hour drying period in an air circulating oven at the same temperature of 80 °C±2. The final weight (Wf) of the samples have been determined, and the weight reduction percentage have been calculated using the following formula.

$$\textbf{\textit{Percentage of Weight Reduction}}\ (\%) = \frac{Wf - Wi}{Wi} x\ 100\%$$

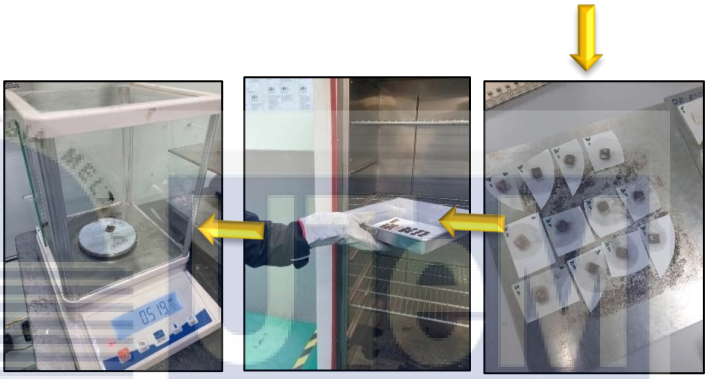


Cut sample into (10mm x 10mm x 3mm)

Recorded initial weight of sample

Dried in heating drying oven for 2 hours

Specimen was immersed in distilled water for 24 hours



Recorded final weight of sample

Dried in oven for 2 hours

Removed specimen from immersion using filter paper

Figure 3.13: Testing of water solubility

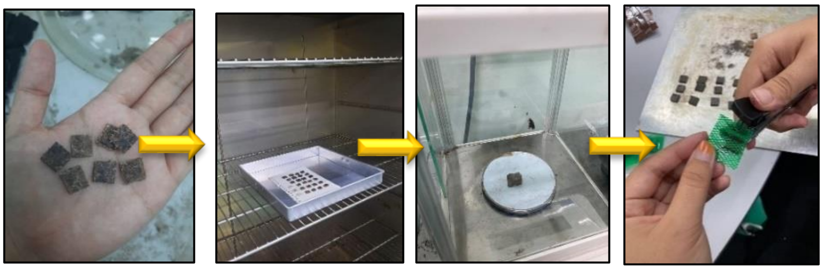
3.4.5 Soil Burial

The soil burial test has been conducted on three samples for each formulation. The samples have been approximate dimensions of 10 mm x 10 mm x 3 mm and have been buried at a depth of approximately 10 cm in the soil. Unlike other tests, the samples have been divided into three equal-sized pieces measuring 10 mm x 10 mm x 3 mm. The initial weight (Wi) of each sample have been measured using a weighing balance after being the subjected to a drying period of 2 hours in an air circulating oven set at a temperature of 80 °C.

For the soil burial test, a 50/50 mixture of sand and soil have been used, and the temperature have been maintained at 30 °C. To maintain the initial water content of the soil, 400 ml of water have been added every day to each 1250 g mixture. To facilitate the removal of samples from the soil burial process, plastic mesh has been employed. The use of plastic mesh has ensured that microorganisms and moisture remain in contact with the soil samples.

The experiment has been designed to conduct two types of determinations, one lasting four weeks and another lasting eight weeks. At the end of each duration, the soil samples have been carefully extracted and washed with distilled water to eliminate contaminants. Subsequently, the samples have been dried for 2 hours in an air circulating oven at a temperature of 80 °C, followed by weighing to determine the final weight (Wf). The percentage weight loss has been calculated using the methodology outlined in ASTM D 6003-96, which is specifically designed for assessing mass loss during soil burial tests.

$$\text{Weight loss } (\%) = \frac{Mi - Mf}{Mi} \times 100$$



Cut sample into (10mm x 10mm x 3mm)

Dried in oven for 2 hours

Recorded initial weight

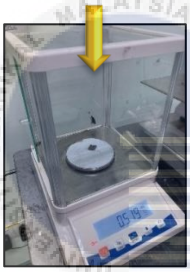
Plastic mesh has been put on sample

Dried in oven for 2 hours

400 ml of water was watered daily

400 ml of water was watered daily

The samples were planted 10 cm deep in the ground.



Recorded final weight

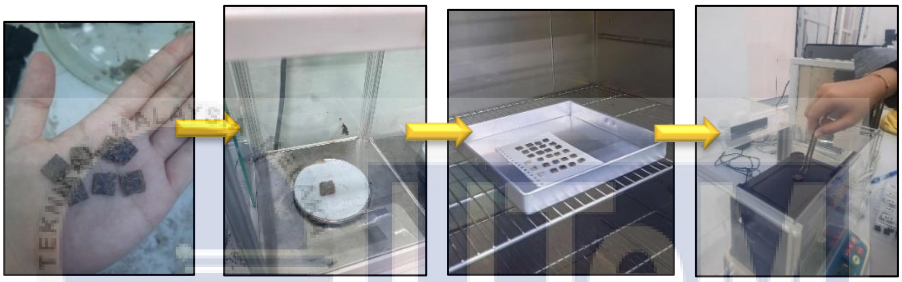
Figure 3.14: Testing of soil burial

3.4.6 Density

The density testing method employed in this study have been adhere to the guidelines outlined in the ASTM D 1895 standard. This study to ensure compatibility with the testing conditions, the samples have been chopped to a size of 10mm x 10mm x 3mm. Subsequently, the samples have been undergo a drying process in an air-circulating oven set at a controlled temperature of 80 °C for a duration of 2 hours.

After the drying period, the samples have been placed in a desiccator containing granulated silica gel to ensure their chilled state. The chilled samples have been weighed and the volume will be determined volumetrically. The density of the samples has been determined by calculating the ratio of their weight to the volume. To measure the weight and volume, a Vernier Caliper Mitutoyo model with an accuracy of 0.01 cm have been used. The weight and volume data obtained for density determination have been computed using the provided formula.

$$\boldsymbol{Density}\ \frac{(g)}{cm3} = \frac{mass\ (m)}{volume\ (v)}$$



Cut sample into (10mm x 10mm x 3mm)

Recorded initial weight of sample

Dried in heating drying oven

Recorded Volume Specimen

Figure 3.15: Testing of density

3.4.7 Scanning Electron Microscope (SEM)

The scanning electron microscope (SEM) from Germany is employed to investigate the morphology of samples consisting of thermoplastic cassava starch reinforced with Corn Husk Fibre. The primary objective of utilizing SEM equipment is to analyse and characterize the structural features of the composite material. Samples derived from the tensile test were positioned in a transparent container and embedded in clay at different concentrations ranging from 0%, 20%, 30%, 40%, and with a separate singular of CHF. Following the sample preparation, an in-depth analysis was carried out using scanning electron microscopy (SEM) to extract detailed information from the images.

Figure 3.16: SEM machine

Figure 3.17: Sample of Corn Husk Fiber of SEM analysis

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this section, a summary is presented regarding the initial findings and hypotheses derived from the fabrication of samples and the outcomes of diverse tests conducted throughout this study. The research concentrates on three principal domains: environmental testing, water affinity testing, and physical testing. Environmental testing encompasses evaluating material performance and durability across various environmental conditions, while water affinity testing seeks to comprehend the interaction between the material and water. Additionally, physical testing, particularly the density test, offers insights into the material's compactness and its suitability for specific applications. These comprehensive tests contribute to a holistic comprehension of the materials' behaviour, properties, and potential applications.

4.2 Water Affinity Testing

4.2.1 Moisture Content

Moisture content was tested to determine the presence of water in TPCS samples reinforced with Corn Husk Fibre (CHF). Fig. 4.1 shows the moisture content result for TPCS/CHF composites based on the fibre loading (wt.%). It can be noticed from the figure that the increasing of CHF content in TPCS/CHF composite is constantly decreasing the moisture content from 24% to15% respectively.

In addition, this is consistent with previous research by Kamaruddin et al., (2023) where the finding also reported a significant drop in the moisture content of Cymbopogan citratus fibre (TCPS/PW/CCF) bio-composites blends incorporated with thermoplastic cassava starch/palm wax. The presence of a statistically significant difference between the mean data for one composite level and another is indicated in Table 4.1 through the analysis of variance (ANOVA) for moisture content. This is evident as the P-value is below 0.05.

This indicates that adding CHF at a concentration of 10% to 40% has a significant impact on the moisture content of the composite material. The observed variation in moisture content could be explained by the difference in water affinity, as CHF shows a lesser tendency to absorb water compared to the TPCS matrix. This stands as a probable causative factor for the observed fluctuations in moisture content (Kamaruddin et al., 2023). The conclusion drawn is consistent with Zakaria et al., (2020) observations on thermoplastics starch, revealing a decrease in moisture content as fibre content increases.

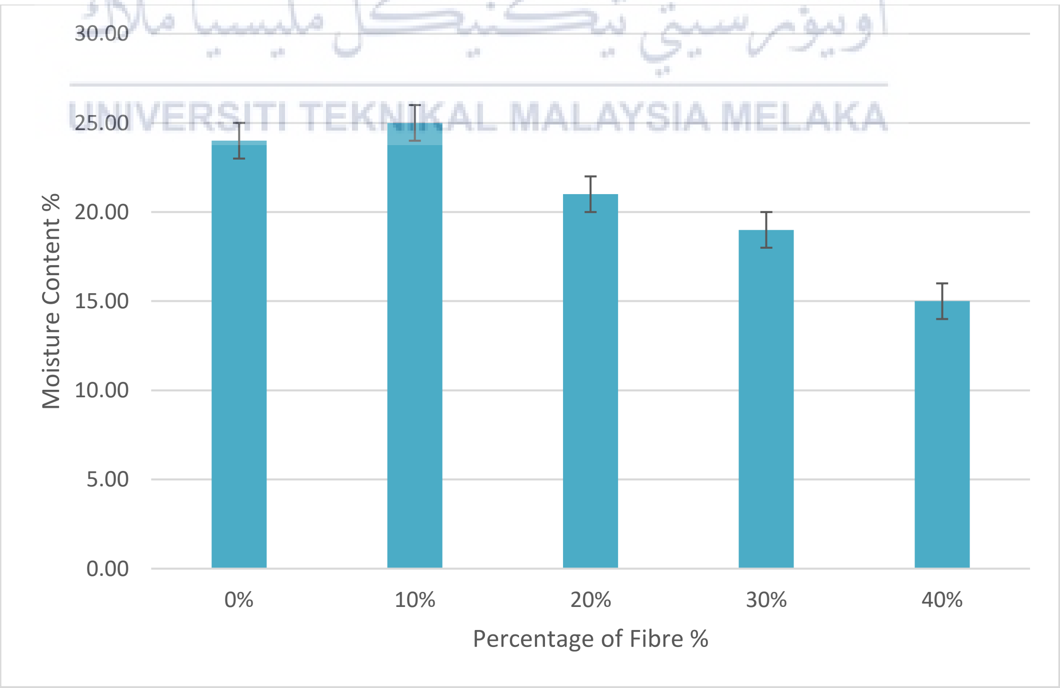


Figure 4.1: Percentage of moisture content of TPCS/CHF with different fibre

Table 4.1: The Analysis of variance (ANOVA) of moisture content

Variables	**Df**	**Moisture Content**
Mixture	4	<0.001

4.2.2 Water Absorption

Water absorption of the thermoplastic starch-based composite is another important characterization in humidity environment because these properties can determine their performance. Figure 4.2 shows the water absorption capacity of both the TPCS matrix and its composite after being immersed in water for 30 minutes and 2 hours.

The result indicates that the percentage of water absorbed decrease with increasing fibre content for 30 minutes and 2 hours soaking times. According to the graph, a fibre concentration of 0% for 0.5 and 2 hours indicates that 43% and 73% of water is absorbed. However, the proportion changes when CHF is included. The presence of fibre reduces the amount of water absorbed as the graph show that the lowest fibre concentration of 40% for 0.5 and 2 hours decreased to 25% and 56%.

This phenomenon might be attributed to higher amount of corn husk fibre inside the matrix that led to excessive swelling and eventually weakened the filler-matrix bonding of the composites. It shows similarity as compared to the result pattern of the previous study by Wan Zarina et al., (2018) on water absorption behavior of Mengkuang Reinforced Thermoplastic Natural Rubber Composites.

However, an increase in water absorption for 30 minutes and 2 hours soaking times was observed for specimens with 20 wt% fibre, attributed to the existence of empty voids resulting from the insufficient presence of fibres. Statistical analysis showed that the water absorption was significantly different ($P < 0.05$) for TPS/CHF composites at various contents of CHF and palm wax fillers. Generally, the presence of CHF in TPCS/CHF composite causes water absorption to decrease dramatically. This finding revealed that the composite has better water resistance than TPCS matrix.

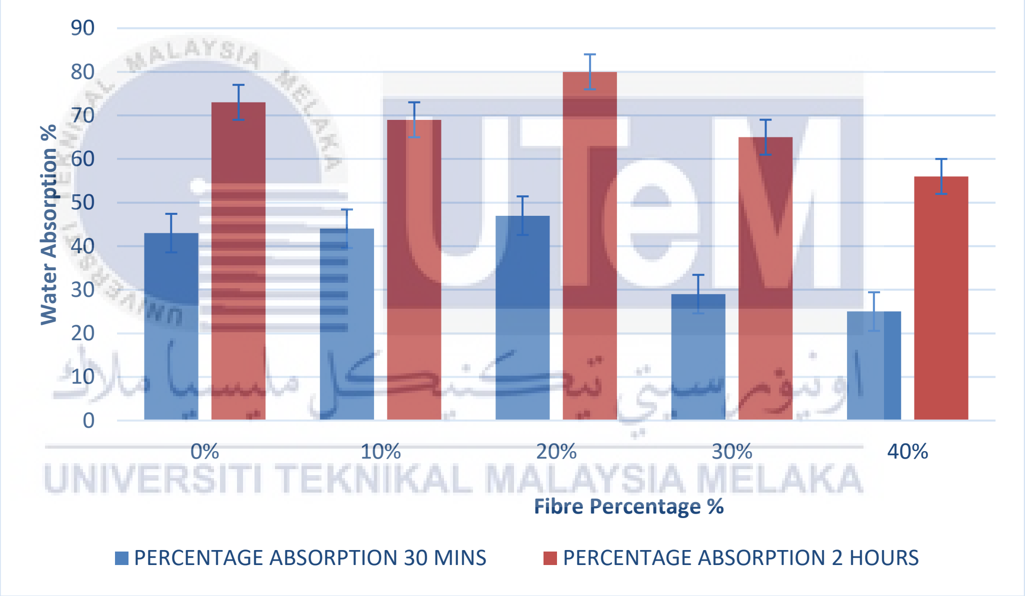


Figure 4.2: Percentage of Water Absorption of TPCS/CHF with different fibre.

Table 4.2: The Analysis of Variance (ANOVA) of Water Absorption

Variables	Df	30 Minutes	2 Hours
Mixture	4	<0.001	<0.001

4.2.3 Thickness Swelling

The dimensional stability of a material can be determined by observing the extent to which it expands or contracts because of moisture entering or exiting the material. Figure 4.6 displays the thickness swelling capacity of both the TPCS matrix and its composite after being immersed in water for 30 minutes and 2 hours.

The graph depicts the decreasing percentage of thickness swelling as the fibre loading increases. Thickness swelling of TPS/CHF composites ranged from 22% to 7% after 30 minutes and 41% to 23% after 2 h water immersion, respectively. Furthermore, the sample that contained a low fibre loading was more swollen than the ones that contained a high fibre loading consistent with Kamaruddin et al.'s (2023) study on Cymbopogan citratus fibre's impact on starch preparation.

Statistical analysis showed that the thickness swelling was significantly different ($P < 0.05$) for TPS/CHF composites at various contents of CHF and palm wax fillers. Furthermore, composites with higher percentages of CHF were more susceptible to the thickness swelling. This effect might be due to the increase of CHF content in the composite formulation. In the contrary, low swelling index are preferable for many applications because they indicate improved water resistance.

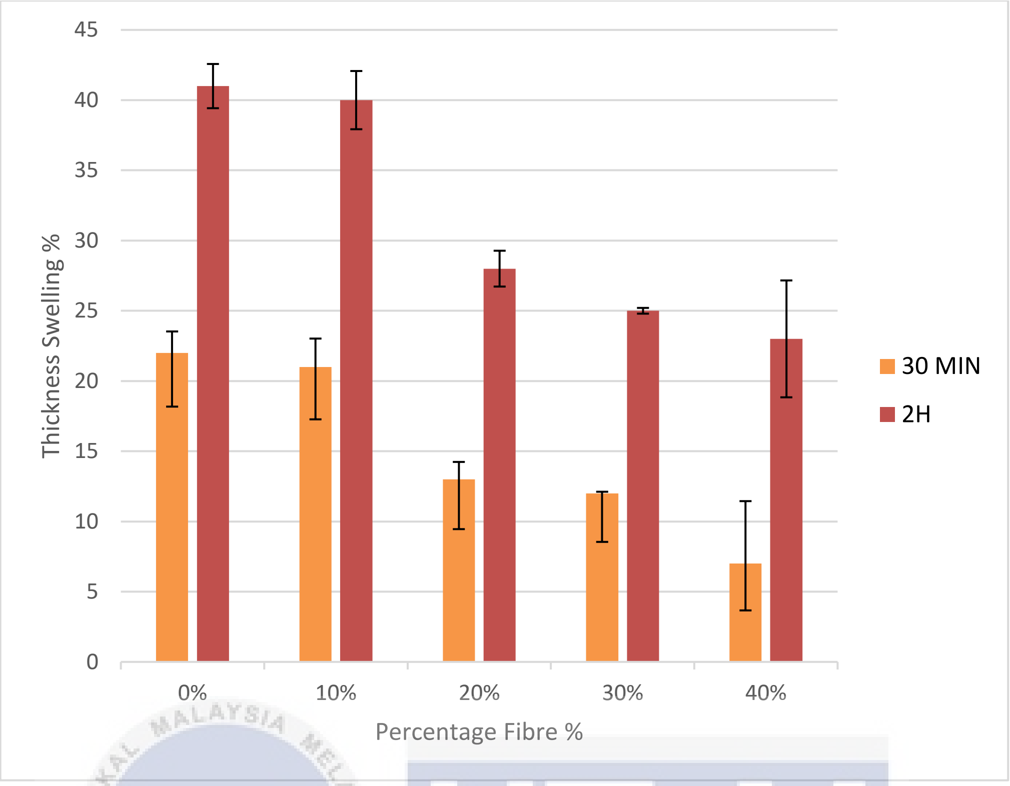


Figure 4.3: Percentage of Thickness Swelling of TPCS/CHF with different fibre.

Table 4.3: The Analysis of Variance (ANOVA) of Thickness Swelling

Variables	Df	30 Minutes	2 Hours
Mixture	4	<0.001	<0.001

4.3 Environmental Analysis

4.3.1 Water Solubility

The water solubility test is a method employed to assess how much a material or composite dissolves in water. Figure 4.3 shows the TPCS/CHF bio composites' water solubility. This solubility demonstrates the effect of water immersion with continuous stirring on the composite samples. It was observed that the solubility of thermoplastic TPCS slightly decreased from 41% to 29% after the addition of fibre (0 to 40 wt%). However, an increase in moisture content was observed for specimens with 10 wt% fibre, attributed to the existence of empty voids resulting from the insufficient presence of fibres.

This result suggests that CHF has the ability to decrease the solubility of TPCS/CHF bio-composites. This phenomenon was attributed to the less hydrophilic behaviour of CHF and TPCS in this bio-composite. Similar findings were obtained when a Thermoplastic Cassava Starch (TPCS) Bio composite and Cogon Grass Fibre (CGF) was added to the TPCS matrix, reducing the films' water solubility (Jumaidin et al., 2019). This is shown in table 4.3 by the analysis of variance (ANOVA) of water solubility. A statistically significant difference exists between the mean data for one composite level and that of another level, as indicated by the P-value being less than 0.05.

Based on the results obtained, it can be concluded that higher fibre content corresponds to lower levels of water solubility. Furthermore, increased amount of corn husk could enhance the matrix's water resistance, compared Jumaidin et al.'s (2016) findings of increased water solubility in thermoplastic cassava starch with added seaweed. Nevertheless, it should be noted that higher water solubility also indicates weak resistance of material when exposed to water (Jumaidin et al., 2016).

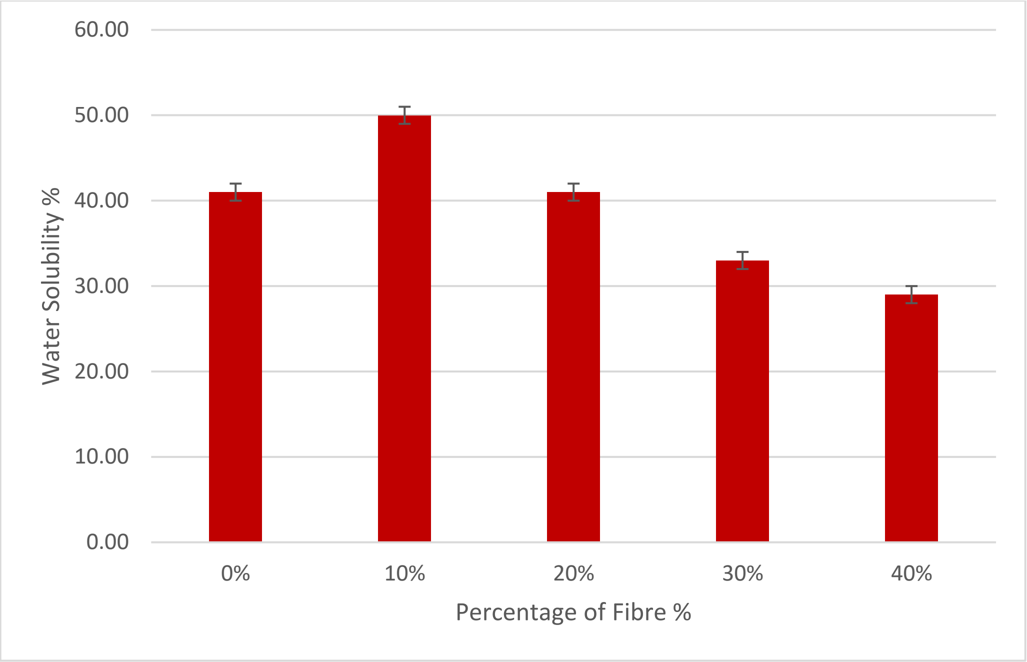


Figure 4.4: Percentage of Water Solubility of TPCS/CHF with different fibre.

Table 4.4: The Analysis of Variance (ANOVA) of Water Solubility

Variables	**Df**	**Water Solubility**
Mixture	4	<0.001

4.3.2 Soil Burial

According to (Zakaria et al., 2020), suggest that the primary indicator of the biodegradation process during the soil burial period by moisture and microorganisms is the weight loss of the material. The weight loss of TPCS/CHF bio composites during soil burial occurs in two separate periods of four (4) and eight (8) weeks, as shown in Figure 9. As expected, the bio-composites exhibited greater weight losses during the eight (8) week soil burial compared to the four (4) week burial period.

As expected, higher weight losses of soil burial were shown in all bio-composites for 8 weeks as compared with the burial of 4 weeks. This phenomenon is due to the higher amount of microorganism activity occurred at a longer soil burial time, which led to the increase in the weight loss of the composites. Figure 4.4 shown that loading of TPCS/CHF from 0 wt.% to 40 wt.% has decreased the weight loss of bio-composites from 52% to 29.6% and 81.7% to 67.7% after soil burial for 4 and 8 weeks, respectively.

The increased weight loss of the composites can be attributed to the greater level of microorganism activity observed during an extended period of soil burial. This is in agreement with the results of Sarsari et al., (2016) where the lower fibre content was associated with greater reduction in the weight. The analysis of variance (ANOVA) of soil burial demonstrates this in Table 4.4. due to the fact that there is no statistically significant difference between the mean data for one level composite and the mean data for another level composite. Therefore, this study indicates that the CHF is very effective at speeding up the biodegradation process of bio composites.

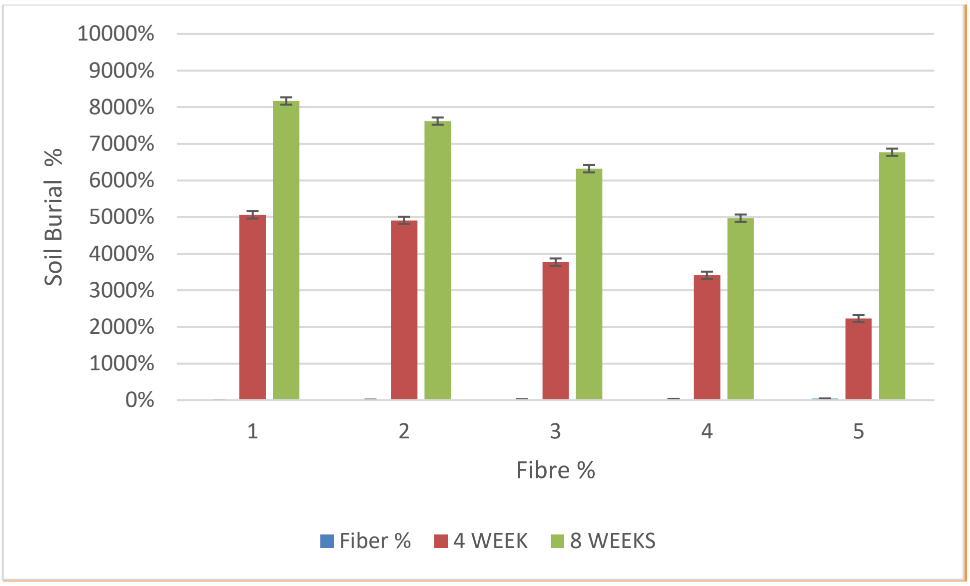


Figure 4.5: Percentage of Soil Burial of TPCS/CHF with different fibre.

Table 4.5: The Analysis of Variance (ANOVA) of Soil Burial

Variables	Df	4 Weeks	8 Weeks
Mixture	4	<0.001	<0.004

4.4 Physical Analysis

4.4.1 Density

The density test includes assessing the mass of a sample and determining its volume through diverse methods like displacement or instrumental techniques, as outlined by Wan Zarina et al. in 2018. Fig. 4.5 shows the density of TPCS/CHF composite and the highest density is at 0 wt.% of fibre loading, which is about 0.390 g/cm3. However, the density results are slightly decreasing with the increment of CHF content and the lowest value is 0.3 56g/cm3 at 40 wt.% of fibre loading.

This specifies that the decreasing trend in density value might be associated with the reduction in the proportion of bio composite mass when CHF is added, as the percentage of the TPCS/CHF matrix is reduced while the volume remains constant. This finding agreed with a previous study Kamaruddin et al., (2023), on developing Cymbopogan citratus fibre (TCPS/PW/CCF) bio-composites reinforced thermoplastic cassava starch/palm wax, where the biocomposites' density values decreased as fibre loading was added.

In table 4.5, the analysis of variance (ANOVA) of soil burial reveals this. Due to the lack of a statistically significant difference between the mean data for one level composite and the mean data for another. From the observations, it can conclude that the density of TPCS/CHF bio-composites are significantly higher in the matrix (TPCS) than in fibre (CHF).

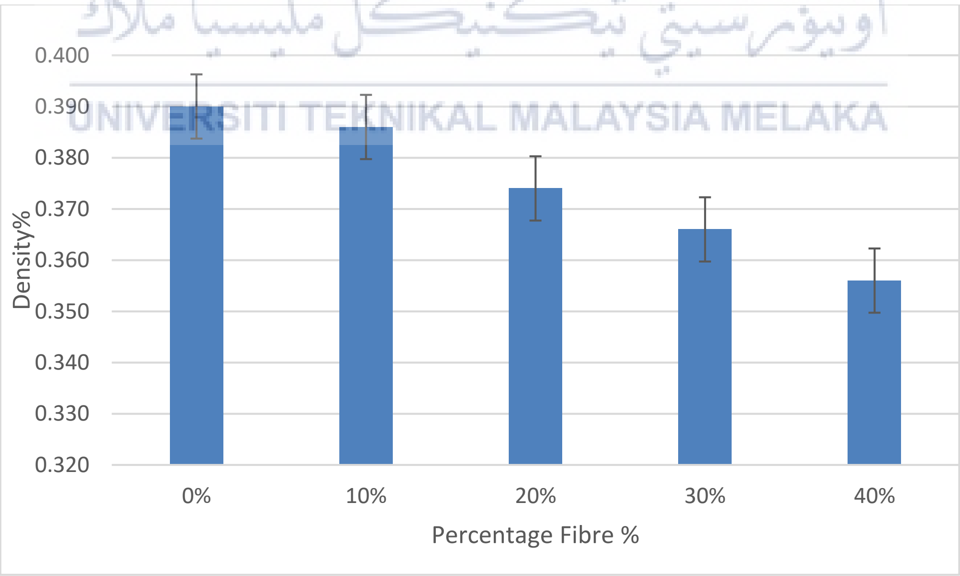


Figure 4.6: Percentage of Density of TPCS/CHF with different fibre.

Table 4.6: The Analysis of Variance (ANOVA) of Density

Variables	**Df**	**Density**
Mixture	4	<0.001

4.5 Other Analysis

4.5.1 Scanning Electron Microscopy (SEM)

SEM micrographs can be used to visualize the contact between the matrix and fibres of the composite material. The device used to observe and examine the morphology of microstructures is the scanning electron microscope (SEM). The SEM micrographs of TPCS containing 0%, 10%, 20%, 30%, and 40% CHF are shown in Figure 4.8, Figure 4.9, Figure 4.10, Figure 11, and Figure 4.12. The SEM micrograph of CHF is shown in Figure 4.7.

In Figure 4.8, the SEM micrograph displays the sample with 0% corn husk fibre. The image shows the approximate texture of a 0% TPCS/CHF composite under SEM microscopy, with only the matrix of starch and palm wax visible. Further, the fabrication with 0% fibre content has a consistent surface free of obvious air pockets.

Figures 4.9 and 4.10 illustrate the presence of fibre breakage and micro voids observed in composite samples containing 10% and 20% fibre content. The appearance of voids upon the addition of TPCS with various fibres signifies a fragile interfacial bonding between the CHF and the matrix. The fibre breakage in all composites shows tensile fracture, indicating effective stress transfer from the matrix to the Fibre, strengthening the composites (Jumaidin et al., 2017b).

In figure 4.11 and 4.12 shows the SEM micrograph of TPCS containing 30% and 40% corn husk fibre. This image shows the presence of void, indicating insufficient mixing between the fibre and matrix. According to Hafila et al, (2022) state that this can be attributed to the excessive amount of filler and the challenge of hydrophilic starch forming a proper bond with hydrophobic wax matrices.

Although there are voids, the image also finds a generally good adhesive structure. Moreover, it is observed that TPCS and CHF exhibit a high degree of compatibility, evident from the excellent wetting of the fibre by the matrix, as shown in Figure 4.11. This behaviour may be attributed to the shared hydrophilic properties of TPCS and CHF, contributing to good adhesion in the presence of some voids.

The findings indicated that the structural composition of corn husk fibre demonstrated positive attributes and exhibited a favorable trend during the analysis. The evaluation of the corn husk fibre structure revealed commendable characteristics, suggesting its suitability and advantageous qualities for the intended application or purpose.

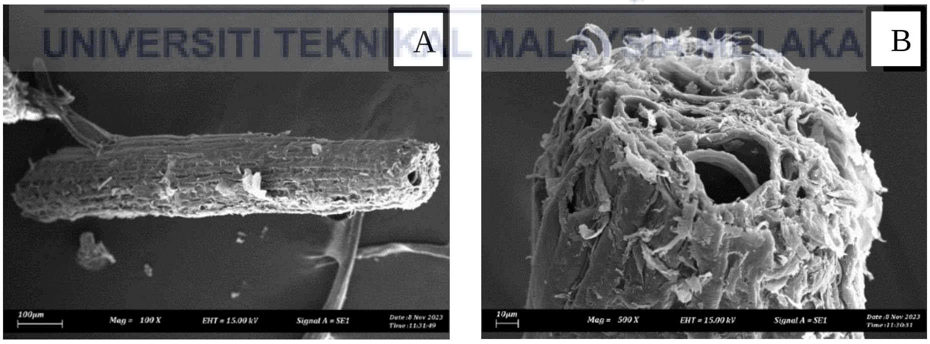


Figure 4.7: (A) Overview and (B) Close View of CHF fibre

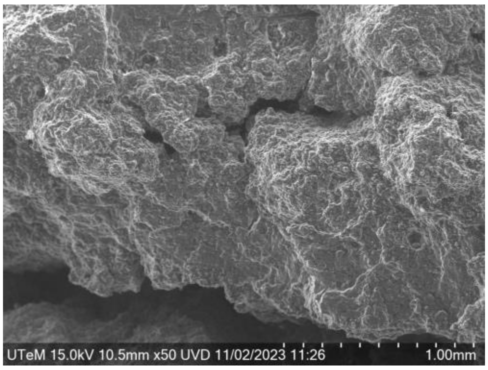


Figure 4.8: 0% fibre content

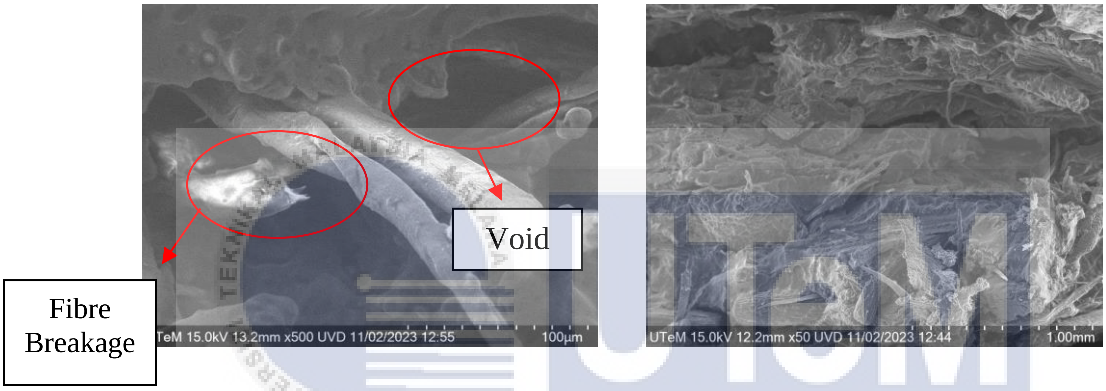


Figure 4.9: 10% fibre content

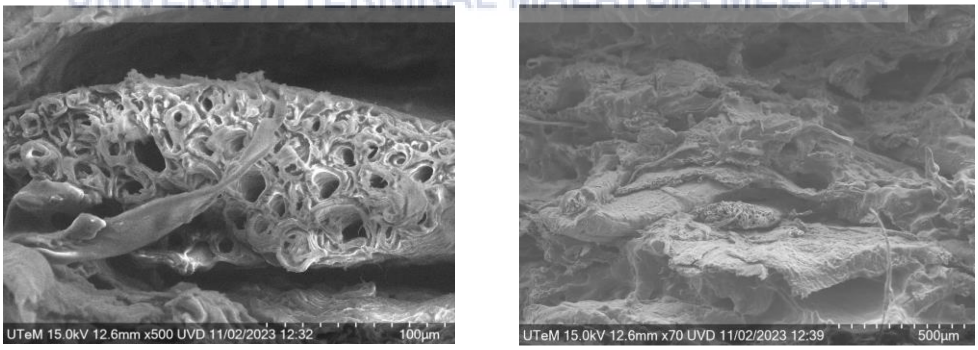


Figure 4.10: 20% fibre content

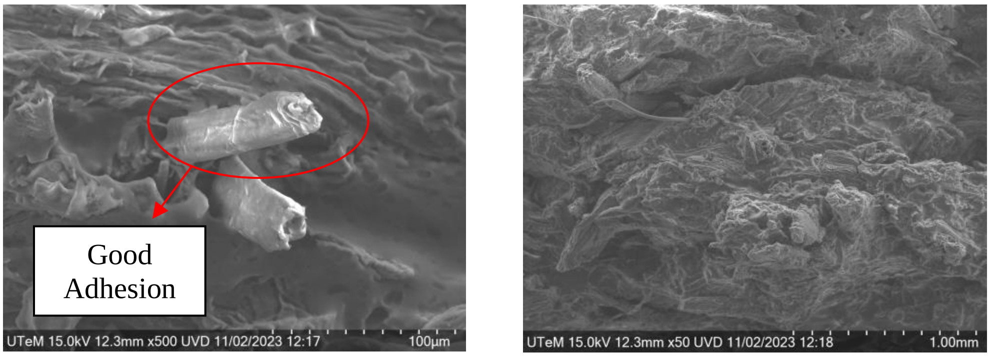


Figure 4.11: 30% fibre content

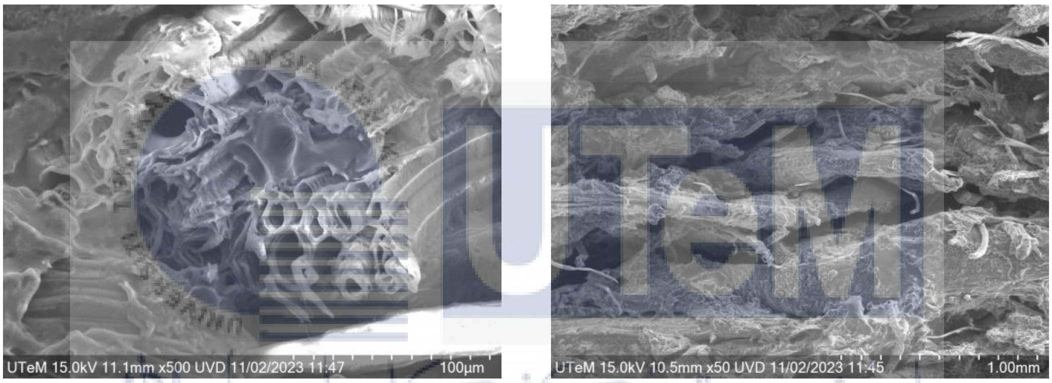


Figure 4.12: 40% fibre content

4.6 Product Fabrication of Packaging Tray

This research has been developed using TPCS/palm wax composites reinforced with CHF to create biodegradable packaging trays for potential applications. The trays were produced by hot pressing at 115 °C for 60 minutes, followed by a cooling period of 20 minutes. Next, this study involved four main components such as corn husk fiber, glycerol, palm wax, and cassava starch that were physically mixed and blended. The process carried out in making the tray has shown good results as in the analysis of material test samples.

The resulting packaging tray, with dimensions of 120 x 120 x 3 (mm), has become an environmentally friendly alternative so that it can contribute to the reduction of environmental pollution. Therefore, having good environmental properties comparable to synthetic polymers such as polyester and nylon, this material has proven to be a suitable replacement for conventional packaging trays. So with that, the production of this packaging tray product has been able to show the achievement of the object to be achieved in this study.

Figure 4.13: TPCS/CHF composite with 30% fibre sample product

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Conclusion

Several researchers have concentrated on the development of materials that are both environmentally friendly and sustainable, stressing the urgent need for new biodegradable products to preserve nature. The objective of this study is to document the progress of an innovative material that is made from cassava starch, outline three main objectives, and present the following conclusions:

i. **To produce biodegradable thermoplastic cassava starch reinforced with Corn Husk Fibre composite.**

The production of the biodegradable thermoplastic composite was achieved produced through the application of dry mixing and a hot-pressing machine. It was generated from cassava starch with the addition of CHF. The physical and environmental parameters for each percentage were determined using TPCS with CHF composite samples that were made at different fibre loading percentages.

ii. **To investigate the water affinity properties and the environmental properties of the biodegradable thermoplastic cassava starch reinforced with Corn Husk Fibre composite.**

The study on a thermoplastic cassava starch composite reinforced with Corn Husk Fibre revealed that higher fibre content led to decreased moisture content and water absorption, reaching a minimum of 40%. Improved thickness swelling enhanced water resistance. Soil burial results showed lower values at 4 and 8 weeks with increasing fibre content. Water solubility reached a minimum of 29% at 40% fibre content. Physical analysis indicated a decrease in sample density with higher fibre content, reaching a minimum of 0.356%. SEM analysis highlighted enhanced structural characteristics, including more voids, fibre breakage, and good adhesion.

iii. **To fabricated biodegradable packaging from Corn Husk Fibre**

Corn Husk Fibre packaging tray has been developed. The prospective product's dimensions are 12cm x 12cm x 1cm. The packaging design features a star from the Malaysian flag in the centre, symbolizing unity among the country's 13 states and federal government.

5.2 Recommendation for Future Research

i. To investigate an appropriate coating method to improve the material's moisture characteristics.

ii. To search cost-effective methods for large-scale production of innovative composite materials.

iii. To study the potential applications and performance of composite material in real-world scenarios.

iv. To investigate the material's resistance to various environmental factors, such as UV radiation and temperature fluctuations.

v. To explore the potential for incorporating recycled materials into the composite for a circular economy approach.

5.3 Project Potential

In this study, products developed with minor changes to the existing manufacturing process, this product emerges as an attractive alternative to synthetic plastics, offering a sustainable solution. This advanced development exhibits great potential for commercialization within various industries as a versatile disposable single-use tray.

Figure 5.1 showcases an adapted tray reinforced with CHF, serving purposes such as organize items while Figure 5.2 showed the prospective outcomes of the innovative material.

Figure 5.1: TPCS with 20% CHF sample tray.

Figure 5.2: Application of TPCS/CHF as organiser items.

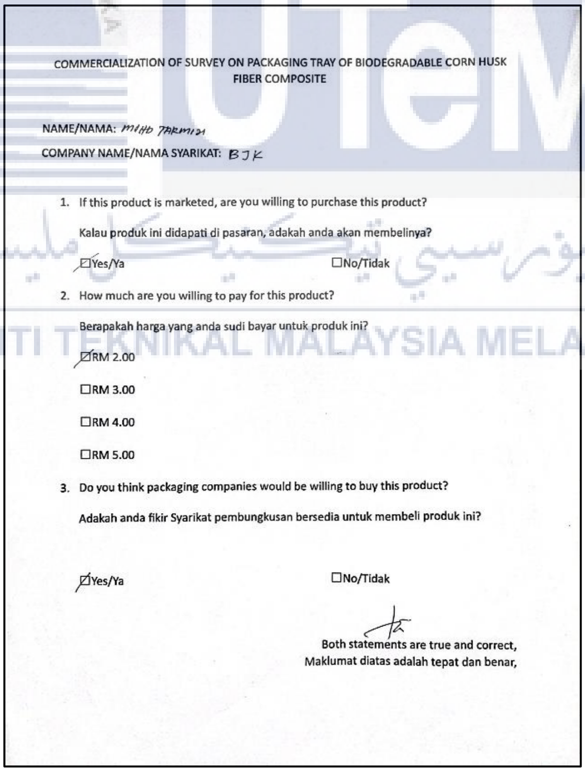
Table 5.1: Prospective outcomes of the innovative material

	Material	**Weight (g)**	**Price per kg (RM)**	**Price per gram (RM)**	**Price per tray**
1.	**Cassava Starch**	40.00	3.00	0.003	0.11
2.	**Palm Wax**	8.16	2.60	0.0026	0.03
3.	**Glycerol**	17.14	2.60	0.0026	0.02
4.	**Corn Husk fibre**	16.33	1.00	0.001	0.01
			Total		0.17

An additional aspect contributing to the product's appeal is the cost-effectiveness of the raw materials used. The financial analysis presented in Table 5.1 reveals that the production cost of TPCS reinforced with CHF is approximately RM0.17. This cost estimation positions the product in a competitive stance alongside other non-biodegradable bio-plastic composites in the market. This affordability enhances the economic viability of the innovative tray, making it an attractive option for businesses seeking sustainable and cost-effective alternatives to traditional plastic products.

In Figure 5.3, a project potential survey was conducted at Brother John Kopitiam. Encik Tarmizi, the proprietor of Brother John Kopitiam expressed a willingness to purchase the packaging tray at a price of RM 2.00. This valuable insight from a potential customer underscores the practical appeal of the product in the market and provides a tangible indication of its acceptance and affordability within specific business contexts, such as local enterprises like Brother John Kopitiam.

Figure 5.3: Survey on potential project with the owner Brother John Kopitiam



COMMERCIALIZATION OF SURVEY ON PACKAGING TRAY OF BIODEGRADABLE CORN HUSK FIBER COMPOSITE

NAME/NAMA: MOHD TARMIZI
COMPANY NAME/NAMA SYARIKAT: BJK

1. If this product is marketed, are you willing to purchase this product?

   Kalau produk ini didapati di pasaran, adakah anda akan membelinya?

   ☑Yes/Ya ☐No/Tidak

2. How much are you willing to pay for this product?

   Berapakah harga yang anda sudi bayar untuk produk ini?

   ☑RM 2.00
   ☐RM 3.00
   ☐RM 4.00
   ☐RM 5.00

3. Do you think packaging companies would be willing to buy this product?

   Adakah anda fikir Syarikat pembungkusan bersedia untuk membeli produk ini?

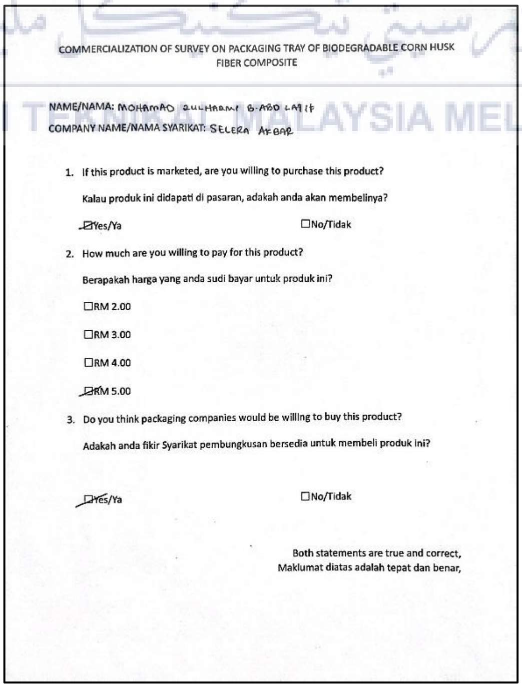
   ☑Yes/Ya ☐No/Tidak

Both statements are true and correct,
Maklumat diatas adalah tepat dan benar,

Figure 5.4: Survey question at Brother John Kopitiam

In Figure 5.4, a project potential survey was conducted at Selera Akbar, Encik Zulharmi bin Abd. Latif expressed a willingness to purchase the packaging tray at the price of RM 2.00. This survey result signifies a positive reception of the product within different business settings, extending its market potential beyond specific enterprises. Encik Zulharmi bin Abd. Latif willingness to buy at the specified price further reinforces the product's attractiveness and indicates its versatility in meeting the needs of businesses such as Coffeology.

Figure 5.5: Survey on potential project with the owner Selera Akbar



COMMERCIALIZATION OF SURVEY ON PACKAGING TRAY OF BIODEGRADABLE CORN HUSK FIBER COMPOSITE

NAME/NAMA: MOHAMAD ZULHARMI B.ABD LATIF
COMPANY NAME/NAMA SYARIKAT: SELERA AKBAR

1. If this product is marketed, are you willing to purchase this product?
   Kalau produk ini didapati di pasaran, adakah anda akan membelinya?
   ☑Yes/Ya ☐No/Tidak
2. How much are you willing to pay for this product?
   Berapakah harga yang anda sudi bayar untuk produk ini?
   ☐RM 2.00
   ☐RM 3.00
   ☐RM 4.00
   ☑RM 5.00
3. Do you think packaging companies would be willing to buy this product?
   Adakah anda fikir Syarikat pembungkusan bersedia untuk membeli produk ini?
   ☑Yes/Ya ☐No/Tidak

Both statements are true and correct,
Maklumat diatas adalah tepat dan benar,

Figure 5.6: Survey question at Selera Akbar

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APPENDICES

APPENDIX A GANTT CHART: PSM 1

TASK / PLANNING	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PSM 1: PROJECT BRIEFING	■								MID SEM BREAK					
CHAPTER 2: LITERATURE REVIEW														
Literature Survey		■	■	■	■	■	■	■						
Report Writing		■	■	■	■	■	■	■						
CHAPTER 3: METHODOLOGY														
Preparation of Composites										■	■	■		
Report Writing										■	■	■		
CHAPTER 4: PRELIMINARY RESULT & DISCUSSION														
Previous Study Finding												■	■	
Report Writing												■	■	
CHAPTER 1: INTRODUCTION														
Report Writing											■			
OTHERS PREPARATION											■			
Format Thesis														
Gantt Chart	■	■	■	■	■	■	■	■		■	■	■	■	■
Slide Presentation Preparation													■	
Presentation														■
Submit Final PSM 1 Report													■	

APPENDIX B GANTT CHART: PSM 2

TASK / PLANNING	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Receive Previous Project	■								MID SEM BREAK					
Supervisor Meeting Discussion	■	■	■	■	■	■	■	■		■	■	■	■	■
WATER AFFINITY TESTING														
Moisture Content Testing		■	■											
Water Absorption Testing			■	■										
Thickness Swelling Testing				■	■									
ENVIRONMENTAL TESTING														
Water Solubility Testing					■	■								
Soil Burial Testing					■	■								
PHYSICAL TESTING														
Density Testing						■	■							
PRODUCT FABRICATION														
Production of Packaging Tray								■		■	■			
OTHERS PREPARATION														
Report Writing	■	■	■	■	■	■	■	■		■	■	■		
Format Thesis													■	
Slide Presentation Preparation													■	
Presentation														■
Submit Final PSM 2 Report														■

APPENDIX A List of distribution netwok parameters.

Milestone for Gantt Chart PSM 1:

Description	Point	Week
Completition of Introduction	M1	13
Completition of Literature Review	M2	8
Completition of Methodology	M3	11
Completition of Preliminary Result	M4	13
Submission of Final Proposal Report	M5	14

Milestone for Gantt Chart PSM 2:

Description	Point	Week
Completition of Water Affinity Testing	M1	5
Completition of Environmental Testing	M2	6
Completition of Physical Testing	M3	7
Completition of Product Fabrication	M4	11
Submission of Final Report	M5	14