

DEVELOPMENT OF PACKAGING TRAY FROM SUGAR PALM FIBER (MECHANICAL PROPERTIES)



BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS & TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology



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Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "Mechanical Properties of Sugar Palm Fiber Composite For Packaging Application" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.



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 (Process & Technology) with Honours.

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DEDICATION

Praise God for providing me with the strength, direction, and knowledge I needed to finish my

thesis. &

To my adoring parents and relatives for their unwavering support and encouragement.

&

To my supervisor TS Kamal Bin Musa, and Dr. Ridhwan Bin Jumaidin for their help and



ABSTRACT

Environmental concerns regarding non-biodegradable polymers are rapidly growing. Several ecologically friendly materials have been developed to solve these critical problems. Biopolymer is a substance that can help since it biodegrades faster and is more environmentally friendly. Due to abundant availability, low cost, biodegradability and renewability, starch is used in biodegradable polymers. Thermoplastic starch (TPS) polymers are developed from a variety of natural sources that are biodegradable and compostable. TPS has gained popularity, yet it differs from other polymers in linear and branching topologies, resulting in considerable changes to its properties. Fibers are also used in fiber-reinforced composite materials, providing structure strength and stiffness. Natural fibers are mostly agricultural waste, which is useless to burn as fuel, exacerbating environmental concerns. Sugar palm fibers (SPF) are obtained from trunk, bunch, frond, and trunk surface, known as Ijuk, have been identified as a potential reinforcing element for the production of bio-based composites. In this research, the objectives are to develop a packaging tray by using thermoplastic cassava starch (TPCS) reinforced with various amounts of SPF, by investigating the material's mechanical and thermal properties. TPCS reinforced with SPF composite was made by mixing at high speeds, followed by a hot press. Several tests were performed to evaluate different properties. A thermogravimetric analysis (TGA) test was performed for the thermal properties of the composite, tensile and flexural testing to examine the mechanical properties. Fourier Transform Infrared Spectroscopy (FTIR) and a Scanning Electrode Microscope (SEM) to examine the chemical interaction and morphological characteristics. The results shown in TGA that the TPS has lost the most weight, reducing overall thermal stability of the polymer matrix system, and as the SPF content increases, the thermal stability improves, which proves that composites with SPF of 40wt% and 50wt% has better thermal stability than the rest. In FTIR, the existence of O-H bonding in starch and fiber was indicated by the highest peak in the curve, which was at 3200–3500cm⁽⁻¹⁾. The highest tensile strength achieved shown in tensile testing is when SPF content reaches 50%, whereas for modulus elasticity for tensile and flexural strength is achieved at the highest when SPF content at 40%. In SEM, it has shown that a high sample fiber loading has a good adhesion to the TPCS matrix but when it reaches the limit due to weak bindings between TPCS and SPF. This has proven that the TPCS reinforced with SPF composite outperforms the matrix material in terms of feature function. The SPF composite reinforced TPCS tray can be expected to be used as a biodegradable tray in the packaging industry. At the end of this study, an actual prototype of the packing tray is constructed successfully and can be considered as a fully functional prototype.

ABSTRAK

Kesedaran mengenai alam terutama disebabkan oleh polimer yang tidak terbiodegradasi kini berkembang pesat. Beberapa bahan mesra alam telah dianalisis untuk menyelesaikan masalah kritikal ini. Biopolimer adalah bahan yang dapat membantu kerana biodegradasi lebih cepat dan lebih mesra alam. Oleh kerana ketersediaan yang banyak, kos rendah, biodegradasi dan kebaharuan, kanji digunakan dalam polimer yang boleh terurai secara biodegradasi. Polimer kanji termoplastik (TPS) dibangunkan daripada pelbagai sumber semula jadi yang terbiodegradasi dan kompos. TPS telah mendapat populariti, tetapi berbeza dengan polimer lain dalam topologi linier dan bercabang, yang mengakibatkan banyak perubahan pada sifatnya. Serat juga digunakan dalam bahan komposit bertetulang serat, memberikan kekuatan dan kekukuhan struktur. Serat semula jadi kebanyakannya adalah sisa pertanian, yang tidak berguna untuk dibakar sebagai bahan bakar, memperburuk masalah alam sekitar. Serat liuk (SPF) diperoleh dari permukaan batang, tandan, pelepah dan batang, yang dikenali sebagai Ijuk, telah dikenal pasti sebagai elemen penguat yang berpotensi untuk pengeluaran komposit berasaskan bio. Objektif penyelidikan ini adalah untuk membuat biodegradasi tray thermoplastik dengan campuran lilin lebah yang diperkuat dengan pelbagai jumlah ratio SPF. TPCS yang diperkuat dengan komposit SPF dibuat dengan dicampurkan pada kelajuan tinggi, diikuti dengan tekan panas pada suhu 155 °C. Beberapa ujian dilakukan untuk menilai sifat yang berbeza. Uji analisis termogravimetri (TGA) dilakukan untuk sifat terma ujian komposit, tegangan dan lenturan untuk memeriksa sifat mekanik, dan Spektroskopi Infrared Fourier Transform (FTIR) dan Mikroskop Elektrod Pengimbasan (SEM) untuk memeriksa interaksi kimia dan morfologi ciri. Hasil kajian ditunjukkan dalam TGA bahawa TPS telah kehilangan berat yang paling banyak. mengurangkan kestabilan haba keseluruhan sistem matriks polimer, dan apabila kandungan SPF meningkat, kestabilan haba bertambah baik, yang membuktikan bahawa komposit dengan SPF 40wt% dan 50wt% mempunyai kestabilan haba yang lebih baik daripada yang lain. Di FTIR, kewujudan ikatan O-H dalam kanji dan serat ditunjukkan oleh puncak tertinggi dalam lengkung, iaitu pada 3200–3500cm⁽⁻¹⁾. Kekuatan tegangan tertinggi yang dicapai ditunjukkan dalam ujian tegangan adalah ketika kandungan SPF mencapai 50%, sedangkan untuk keanjalan modulus untuk kekuatan tegangan dan kekuatan lenturan dicapai pada tahap tertinggi ketika kandungan SPF pada 40%. Di SEM telah menunjukkan bahawa pemuatan serat sampel yang tinggi mempunyai lekatan rendah pada matriks TPCS ketika mencapai had kerana pengikatan yang lemah antara TPCS dan SPF. Ini telah membuktikan bahawa TPCS yang diperkuat dengan komposit SPF mengungguli bahan matriks dari segi fungsi ciri. Dulang TPCS dengan campuran komposit SPF diharapkan dapat digunakan sebagai dulang biodegradasi dalam industri pembungkusan. Pada akhir kajian ini, prototaip sebenar dulang pembungkusan dibina dengan jayanya dan boleh dianggap sebagai prototaip yang berfungsi sepenuhnya.

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LIST OF SYMBOLS AND ABBREVIATIONS

SEM	-	Scanning Electron Microscope
SPS	-	Sugar palm starch
TPS	-	Thermoplastic starch
TPCS	-	Thermoplastic cassava starch
TGA	-	Thermo-gravimetric Analysis
РМС	-	Polymer Matrix Composite
NFTC	-	Natural Fiber Reinforced Thermoplastic Composites
SPF		Sugar Palm Fiber
SPFC	kun	Sugar Palm Fiber Composites
FTIR	T USA	Fourier Transform Infrared Spectroscopy (FTIR)
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CHAPTER 1

INTRODUCTION

1.1 Background

In current times, plastic pollution has remained being one of the issues at the core of the challenges infecting the current situation of this universe. Annually, higher than anticipated of eighty million tons of plastic related wastes are dumped into the sea. There is about 5 trillion pieces of plastic trash are disposed and found in all the water reservoirs in the whole world (Godswill & Gospel, 2019). An alternative method to produce more ecofriendly polymer to handle the current issue is by using green materials and fully biodegradable composite which can most likely solve polymer waste disposal problems (Sahari et al., 2013b).

Composite is defined as a fusion of different materials with unsimilar physical and chemical characteristics (Jogur et al., 2018). Research from Yashas Gowda et al., (2018) found that composite materials are one of the materials which properties improve and enhance in terms of stiffness, strength, cost effective, density and sustainability. In today's time, starch, an example of a natural resource, has become popular and highly demanded for the development of biopolymer to replace the conventional polymer, mainly because of its renewability, biodegradibility, cost-effective and attainability (M. L. Sanyang et al., 2016).

Due to starch's potential to show good mechanical characteristics and attribute, shear stress and thermoplastic behaviour under high temperature, it is considered as the most ideal source for producing bio-degradable polymer and composite (Lomelí-Ramírez et al., 2014; Mo et al., 2010; M. L. Sanyang et al., 2016). In addition, fibers are the key components of reinforcements that play a crucial role in the mechanical properties of a material. Natural fibers have numerous advantages, such as low cost, high density, recyclability biodegradability and con-siderable efforts are being made to tap their full potential (Edhirej et al., 2017).

The recyclable nature of these materials is a benefit since it reduces disposable waste and therefore costs less (Gowda et al., 2018). Glycerol is the most often used plasticizer for starch. Thus, a recent study into the impact of glycerol concentration on the physical and thermomechanical characteristics of starch revealed that starch with an appropriate quantity of plasticizer showed improved mechanical qualities (Sahari et al., 2012)(Muhammed L. Sanyang et al., 2015).

1.2 Problem Statement

Environmental issues have risen to the top of the priority list in today's society. One of the sources of these environmental problems is packaging waste. Packaging waste accounts for a significant portion of solid waste, raising environmental concerns. One of the most difficult problems the packaging industry has in its attempts to create bio-based primary packaging is the development of a polymer with durability that matches the shelf-life of the product being packaged. In order to be effective during storage, the bio-based packaging material must maintain its mechanical and barrier characteristics while being stable. It must also operate effectively throughout the whole storage period till disposal. (Kumar, 2017).

In addition, According to (Nik Baihaqi, 2021) Sugar palm fiber is a by product of the agricultural sector.Furthermore, agro-waste may be utilised as a source of reinforcement in a range of biomaterial applications. Sugar palm fiber may be found in a wide range of goods and applications. Sugar palm fiber, in particular, can be utilised to create composite materials.

Starch is a naturally occurring element with easily degradable properties. It does, however, have a number of shortcomings, most notably in terms of mechanical and thermal performance. (Zuo, 2015) Meanwhile, sugar palm fiber may aid in the improvement of the mechanical and thermal strength of starch when used in conjunction with it (Nik Baihaqi, 2021). The development of biodegradable goods derived from sugar palm fiber and starch is thus necessary.

As a result, the primary objective of this research is to create a biodegradable thermoplastic cassava starch/beeswax composite that is reinforced with Sugar Palm leaf fibre. The objective of this research, apart from that, will be to investigate the mechanical and thermal properties of a biodegradable thermoplastic cassava starch/beeswax composite reinforced with Sugar Palm fibre. As a consequence of this study, the amount of waste generated by sugar palm will be decreased, and the trash will be transformed into new biodegradable material.

1.3 Research Objective | TEKNIKAL MALAYSIA MELAKA

The primary goals of this thesis and analysis are as follows:

- I. To produce biodegradable tray from thermoplastic cassava starch reinforced with Sugar Palm fiber composite.
- II. To investigate the mechanical properties of biodegradable thermoplastic cassava starch reinforced with Sugar Palm fiber composite.
- III. To determine the thermal properties of biodegradable thermoplastic cassava starch reinforced with Sugar Palm fiber composite.

1.4 Scope of study

Cassava starch, sugar palm fiber, beeswax, and glycerol were the primary organic materials utilized in this investigation. By referring to the required percentage of formulation, a Cassava starch, sugar palm fiber, beeswax, and glycerol were the primary organic materials utilized in this investigation. In this study, the plasticizer is glycerol. Beeswax is added to the cassava starch and glycerol mixture at the appropriate proportion for the formulation. The purpose of beeswax is to act as a protective agent reduce the water absorption and moisture. Then, corresponding to the desired amount of percentage for this study, sugar palm fiber is added as a reinforcement to the combination of three basic materials. The hot compression moulding process will be used to create a thermoplastic starch composite with beeswax reinforcement and sugar palm fiber. Tensile, flexural, and density tests will be used to investigate mechanical properties, while thermogravimetric analysis (TGA) will be used to determine thermal properties and Fourier-Transform Infrared Spectroscopy (FTIR) will be used to determine the chemical structure of the material composite and scanning electron microscopy (SEM) is to observe the morphology of a ERSITI TEKNIKAL MALAYSIA MELAKA material composite.

1.5 Structure of Thesis

This research is formatted in accordance with the guidelines developed by Universiti Teknikal Malaysia Melaka (UTeM) for the publication of this report. This article is divided into six sections: an introduction, a review of a literature, a methodology section, results and discussion, and a conclusion. The layout is detailed as follows:

Chapter 1

This chapter discusses the study's purpose in detail and highlights the issue that prompted this report. This chapter discussed the importance and nature of the research and function.

Chapter 2

This chapter justifies the extensive literature review conducted by a previous report on the subject of this thesis. Additionally, this chapter discusses the research void identified by an analysis of previous studies.

Chapter 3

This chapter discussed the methods utilized in this study in terms of material planning, testing procedures, and data collection.

Chapter 4

This chapter summarized the findings and discussion of the thermoplastic cassava starch reinforced with sugar palm leaf fiber composite testing. The chapter discusses the outcome in depth. **ERSITI TEKNIKAL MALAYSIA MELAKA** *Chapter 5*

This chapter summarizes On Thermoplastic Cassava Starch Reinforced by Sugar Palm Fiber Composite, the results of the thesis are discussed, as well as suggestions for further investigation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of many types of research and development on the biodegradable product have been made by the researcher and scientist all over the world. Oceans, land, and waterways can all be affected by plastic waste. Every year, between 1.1 and 8.8 million metric tonnes of plastic trash are expected to reach the world ocean from coastal towns (Godswill & Gospel, 2019). Most marine or aquatic animals are harmed because of mechanical effects., for example, like harmful physical structure of plastic wastes and issues concerning the marine animals ingesting plastic wastes.

Nowadays, many people are concerned and aware of the creation of biodegradable products. This is because they realize it as one of the solutions that may help to minimize waste and save the animals from extinction. The development of tray packaging biodegrades the researchers. Biodegradable thermoplastic starch product is eco-friendlier where it is easy to be degraded and has a low production cost. Besides that, the application of biodegradable thermoplastic starch is widely used in many industries such as the automotive industry, packaging industry, and others. The purpose is to make a general overview of the introduction of the materials used and establish the foundation to explain the research gaps found for this thesis's research work. Moreover, packaging tray biodegradable thermoplastic is an innovation in engineering materials, which is reasonable for knowing its properties and important to save the world from pollution.

2.2 Composite

Composites are the key element in the industrial field. Composite materials were initially utilized overseas in the 1950s, and it has been used as domestic means since the 1960s. (Wang et al., 2011). In general, composite is best known as a mixed combination of numerous materials with different characteristics and forms via a process known as a compound. It does not only preserve the primary characteristics of the original material but also reveals a new characteristic that does not possess any at all by the original material.

According to Harker (2018), Composites are materials that have been blended in such a way that we may make better use of their benefits while minimizing the impacts of their flaws to some extent. It is a material made up of a matrix and reinforcing material in a multiphase system. Furthermore, it is constructed of a polymer matrix reinforced with an engineering, man-made, reinforced material, and natural fiber. The loading capacity of composite materials will not be lost in the short run and will not break if there are any faults or cracks in them.

Furthermore, composite materials have a considerable amount of eigenfrequency, and resonance is difficult to achieve in general. Simultaneously, the interlinking of fiber and milieu in composite materials where it has a high potential to absorb energy that vibrates, resulting in high damping vibration of material. It is possible to halt the process when it vibrates in a short amount of time if it occurs. Composite materials are also versatile materials with mechanical and physical characteristics that are able to be modified to fit a specifically appropriate application and to fulfil its requirements. Furthermore, composites have good Young's modulus, strength, and thermal expansivity, but they have average density, fracture energy, and thermal conductivity when compared to other engineering materials (Ji & Gao, 2004).

According to research by Begum et al. (2020), The following characteristics of composite materials should be present: in terms of microscopic characteristics, it is a non-homogeneous material with a specific interface, where significant distinctiveness are present in the production of component materials, formed materials should have a significant improvement in terms of performance, and the component materials' fraction of volume should be greater than that of the composite materials.

Fiber reinforced composites (FRP) are commonly referred to in the industry as materials with outstanding integrated performance that are composed of reinforcement that is high in terms of strength, modulus, and brittleness, and a matrix material that has low modulus and toughness, which is achieved through a specific processing procedure. In contemporary materials science, fibre, sheet, and particle reinforced composite materials, as well as self-reinforced polymer matrix, ceramic matrix, and metal matrix composites, are all being investigated further.

2.2.1 Classification of composite

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Research from Markovičová & Zatkalíková (2016) state that composites are usually classified by the type of material used for the matrix and its structure, and this research are supported by Qian (2009), that stated that metal matrix composites (MMC), ceramic matrix composites (CMC), carbon/carbon composites (C/C), and polymer matrix composites (PMC) or polymeric composites are the four types of matrix composites that can be found as shown in Figure 2.1.



Figure 2.1 Classification of composites

Composites are made up of fibres arranged in a matrix structure, and they are classified according to the length of the fibres in the matrix structure. Composites are divided into three groups based on their structural characteristics (Altenbach, 2018; Rajak et al., 2019). Composites made of continuous fibre reinforcement typically have long fibre reinforcements, while hybrid fiber-reinforced composite materials consist of two or more fibres reinforced in a single matrix structure and discontinuous fiber-reinforced composite

materials consist of shorter fibre reinforcements. Unidirectional continuous fibre reinforcement is distinguished from bidirectional continuous fibre reinforcement by the direction of fibre flow. It is possible to distinguish between two kinds of discontinuous: oriented in an aligned fashion and randomly oriented.

2.3 Polymer Matrix Composite (PMC)

Because it employs organic polymer as the matrix and fiber as the reinforcement, polymer matrix composites (PMC) have been gaining popularity practically worldwide due to their low cost and easy production process. The loading bearing members principle was used by PMC, with the matrix acting as a provider for binding and retaining the reinforcement together into a solid. The fibers of PMC make it the primary load-bearing component. Furthermore, the increased environmental impact of synthetic-fiber-based polymer composites' manufacture, disposal, and recycling has prompted the creation of ecofriendly composites, making PMC the best and most prevalent answer for environmental concerns (Begum et al., 2020; Wang et al., 2011).

PMC is now a vital part of a process that is commonly employed in industrial production. It was due to its ease of processing, lightweight nature, increased production, and lower cost. To accommodate the high strength modulus, PMC is currently modified with fillers and fibers. The natural fiber is one of the fibers used in PMC, and it is derived from a variety of plant and animal sources. Currently, the majority of research and product development efforts are focused on the utilisation of plant-based natural fibres as a reinforcing component in polymer composites. Natural fiber-reinforced polymer matrix composites have the potential to be less costly, more durable, and more ecologically friendly than conventional polymer matrix composites; nevertheless, their potential for use in polymer composites has not yet been fully explored (Yashas Gowda et al., 2018).

2.3.1 Characteristics of PMC

PMC has its own set of characteristics. In fiber polymer composites, one of its properties is that it acts as a glue, binding the high stiffness, high strength fibers together firmly and stably. Because it is lightweight and strong, and it offers a wide range of design options, it is also simple to make and mould in any shape or size. According to Balakrishnan et al., the low density, high stiffness, and strength of the raw materials were necessary for PMC to achieve the desired performance (Balakrishnan et al., 2016). PMC's expansion coefficient is typically substantially higher than fibers (Wisnom et al., 2006). PMCs are made up of a range of organic polymers with short or continuous fibers and various reinforcing agents, allowing them to improve qualities, including fracture toughness, high strength, and stiffness.

The PMC is built in such a manner that the fibres are able to withstand the mechanical stresses that are applied to them. What the matrix does is keep the fibres together, allowing load to be transmitted between them as effectively as possible. A polymer matrix reinforced with natural fibres has a greater resilience than a conventional polymer matrix. Because of the interfacial link that exists between them, their chemical and mechanical identities are preserved. The fibres are the primary components of the charge carrier ensemble, and the matrix is responsible for keeping them in place. When the prop is positioned correctly, it transfers energy between them and protects them from environmental harm. In comparison to ceramic matrix composites, carbon matrix composites, and metal matrix composites, PMC production is less complicated and more accessible due to the ease with which it is produced. When it comes to PMC, one of the most significant disadvantages is that they are nonbiodegradable after use. However, this may be reduced to some extent by mixing polymers with natural fibres to form composite materials (Chung, 2017; Zhang et al., 2016).

The strength and modulus of fibre, in addition, are much greater than those of the matrix material that is usually used in the construction of a polymer matrix composite. As a result, fibres take on the role as the main load-bearing component. However, in order for fibres to be securely connected, a matrix material with excellent adhesive properties is required. Aspects of polymer matrix composite materials that are particularly noteworthy are the high specific strength and specific modulus that they possess. The specific strength is defined as the ratio of strength to density, and the specific modulus is defined as the ratio of modulus to density, with both lengths serving as the dimensions or units of measurement. Fibers with high performance and low density are used to reinforce composite materials, resulting in composite materials having high specific strength and specific modulus.

Not only that, but PMC has excellent ablation resistance and strong instantaneous temperature resistance. Only 1% of metal materials have the same heat conductivity as fiberglass reinforced polymers. It may also be produced into materials with high specific heat, high melting heat, high vaporisation heat, and excellent chemical corrosion resistance and strong friction properties. According to reports, it has unique optical, electrical, and magnetic capabilities (Dang et al., 2017).

In addition, PMC excels in processing fibers, matrix, and other raw materials that are selected to meet the product's condition and performance requirements. The material may be designed using the moulding process, which allows it to be tailored to the product's shape, size, and quantity. By reducing the number of assembly pieces, integrated moulding can save time, material, and weight. Thus, there is advantages and disadvantage of PMC as shown in Table 2.1.

Table 2.1 Advantages and Disadvantages of PMC. (Dang et al., 2017; Wang et al.,2011)

Advantages	Disadvantages	
	Automation and mechanization processes	
Low modulus	have a modest degree of automation and	
	mechanization.	
High density	Consistency of the material properties poor	
Lower specific modulus	Stability of product quality poor	
High specific heat, melting heat, and	Long-term high-temperature resistance	
vaporization heat, good friction properties and		
chemical corrosion resistance.		
It has a strong temperature resistance in the short term and a good ablation resistance.	Ageing resistance are poor	

2.3.2 Classification of PMC

The polymer can be divided into four different types. The first is a linear polymer, which is made up of chains of molecules. Thermoplastic polymers were then categorised as linear or branched based on whether or not the molecular chains were connected. Thermosetting polymers are also included in the polymer classification because they are strongly cross-linked to form a robust three-dimensional network structure. According to studies, an elastomer is a type of polymer with elastic deformation of more than 200 percent. Based on Figure 2.2, showing the classification of polymer. However, there are two types of polymers. Thermosets and thermoplastics are the two types most commonly used (Fischlschweiger et al., 2017). The interest in thermoplastic polymer composites is growing in sustainable development and circular economy since thermoplastic polymers are recyclable (Chegdani & Mansori, 2018).



Figure 2.2 Classification of polymer (Fischlschweiger et al., 2017).

According to research by Begum et al. (2020), Fiber-reinforced composites and particle-reinforced composites are the two types of PMC. The two most common Fiberreinforced plastics are glass fiber reinforced plastics (GFRP) and carbon fiber reinforced plastics (CFRP). Long fiber thermoplastics and short fiber thermoplastics are two types of polymer-based composite materials. This demonstrates that PMC classification is defined in a slightly different manner.

2.3.3 Structure of PMC

PMC structure resembles the shape of a wave, as shown in Figure 2.3.



Figure 2.3 Structure of PMC

2.3.4 Application of PMC

Nowadays, PMC is extensively used in the manufacturing sector. PMC has been used in a variety of situations and applications throughout the world. As a consequence, the PMC has gained popularity in high-strength, high-modulus applications such as aerospace, automotive, sports goods, and other high-modulus applications. Furthermore, as a result of extensive research conducted in the area of carbon fibre technology in recent years, the cost of carbon fibre has been steadily decreasing, allowing it to be used in a wider range of building applications. (Das et al., 2019).

Aside from that, To replace traditional metal alloys, the industry is concentrating on the use of polymer composites, thermosets, or temperature-resistant and high-strength thermoplastics, among other materials. Note that this is not only a trend in the automotive industry, but rather a need (Koniuszewska & Kaczmar, 2016). Tires, different belts and hoses, and automobile bodywork are mostly samples of PMC applications in the automotive sector. Bugatti, for example, uses PMC as the primary building material for the car's body.

PMC is also developed in aerospace vehicles to store aircraft tires and interiors. PMC is used in auto parts, for example, as a building material in high-performance sports gear. Composite material developments have significantly impacted the evolution of new ships designed for the maritime industry. The lightweight of marine constructions is critical for reduced fuel consumption and mobility, while polymer-based composite materials offer essential water and corrosion resistance properties. In earlier years, the job of PMC of materials was often employed in the automotive, aerospace, marine, and military sectors. Composite materials are examples of a material in which the final characteristics may be altered by altering the components. This helps create composite materials that are stronger, lighter, and less expensive for applications, including aircraft, automobiles, roofing structures, and interiors.

PMC has shown to be an effective reinforcement in polymer matrices and is possibly user-friendly. PMC also has exceptional corrosion resistance, excellent formability, and mechanical vibration-damping properties. The comparatively high specific strength of PMC allows for weight reduction in final elements of automobile structures in the automotive sector. The same trend may be used in the aircraft industry. Materials with better mechanical characteristics, such as those required in the construction of military aircraft, military land vehicles, warships, and military troops' equipment such as bulletproof vests, are in high demand in the military sector. (Koniuszewska & Kaczmar, 2016).

2.4 Thermoplastics Composite

They have one- or two-dimensional molecular structures and a melting point that is exaggerated at high temperatures, making them thermoplastics. Additionally, the softening process at high temperatures may be reversed to let the compound to recover its characteristics when it cools, making it simpler to mould the compounds using conventional compress methods. These are polymers that can flow when heated to a temperature higher than that of melting or vitrification, and they are also known as thermoplastics. Because of their high molar mass, entanglements, linkages, and chain branching, plastic deformation occurs, resulting in viscous flow, which is often associated with rheology. (Shanks & Kong, 2011).

Thermoplastic composites may be classified into three types, as shown in Figure 2.4When compared to synthetic-fiber based thermoplastic composites, natural-fiber reinforced thermoplastic composites have lower impact strength, poorer durability, and better moisture absorption. Following that, synthetic fibres are often utilised in structural applications due to their better material properties when compared to traditional steel and aluminium. When it comes to mechanical properties, hybrid composites are defined as those that depart either favourably or negatively from the behaviour of a rule of mixes. The impact may be either positive or negative depending on the relative volume percentages of two kinds of fibres, the design of the layers, and the loading patterns used (Jogur et al., 2018).

Incorporating natural fibre into a composite reinforcing system is not a new idea. It was first employed approximately a century ago, mostly in wood items with basic and relatively low-cost components, and it is still in use nowadays (Kandola et al., 2018). Furthermore, Gironès et al. (2012) stated that natural fibres generated from plants have a number of advantages over glass fibres, including minimum density, low abrasive wear, global availability, renewable and biodegradable nature, cost-effective manufacturing, and recyclability, to name a few. A few of the drawbacks include poor compatibility with hydrophobic polymer matrices, poorer tensile strength than glass fibres, heat sensitivity at compounding process temperatures, moisture absorption, and flammability, among other things.

It is becoming more common for industry to request the use of NFTC, especially in the automotive and aerospace sectors. In many industrial applications where great structural performance is not required, high-strength steel is a viable option that is becoming more popular. A significant demand exists in the industrial sector for sustainable development
materials such as natural fibres, especially plant fibres. This is primarily due to the many advantages that natural fibres provide in terms of mechanical, economic, and environmental performance(Chegdani & Mansori, 2018).



2.4.1 Natural Fiber Reinforced Thermoplastic Composites (NFTC)



Natural Fibers

Figure 2.5 Type of natural fiber and synthetic fiber (Rajak et al., 2019).

Nowadays, the use of natural fiber composites is focused on structural applications that require high mechanical performance, especially long plant fiber reinforced polymer composites, which are becoming increasingly popular. Furthermore, the usage of natural fiber composites is concentrated on structural applications that demand high mechanical performance, particularly long plant fiber-reinforced polymer composites, which are becoming increasingly popular. Based on research conduct by Thomason & Rudeiros-Fernández (2018), The growing interest in NFTC has been fuelled by factors such as the increasing demand for natural raw materials, cost competitiveness, the large amounts of energy required in the production of synthetic fibres, environmental regulations and growing environmental awareness in society. Because of their specific properties, numerous academic researchers have concluded that NFTCs can compete with mineral or inorganic fibre- and filler-reinforced composites in certain applications. A common argument for NFTC is that they are more environmentally friendly. The fibre example for natural fibres and synthetic fibres is shown in Figure 2.5.



Figure 2.6 Starch.

Starch is a natural polymer. Starch is one of the elements in the composite, also known as amylum. According to Breuninger et al. (2009), Starch is often generated by plants in their green leaves to store extra glucose produced during photosynthesis, which acts as a food reserve for the plants. Energy is stored in the form of grains in the chloroplasts and storage organs of plants such as the cassava plant's root, potato tubers, the pith of the sago palm's stem, and the seeds of cereal crops such as seed corn, wheat and rice, to mention a few.

When required, starch is broken down into its component monomer glucose units in the presence of certain enzymes and water, and the resulting glucose units diffuse out of the cell to feed the plant tissue around it. Cereal plants and tubers, for the most part, have a high concentration of starch as part of their overall composition. As shown in Figure 2.6, Starch is a stereo-regular polymer characterized by chirality, chain directionality, branching, white colour, and a high density of hydrogen bonding. Starch may be used to make biodegradable plastics without the need for additional processing. It is positioned to capture a larger proportion of the plastics business as consumers become more environmentally conscious. However, because starch is soluble in water, materials manufactured from starch can expand and distort when exposed to moisture, severely restricting their use.

Moreover, because starch is a low-cost, plentiful, edible, and biodegradable polymer, it has gained a great deal of interest in recent years. Native starch is found in nature in the form of semi-crystalline granules, and it is made up of two components: amylose and amylopectin. There has been a great deal of interest in developing starch-based bioplastics as an ecologically benign, biodegradable alternative to hydrocarbon-based plastics (Abral et al., 2019). Polysaccharide starch is a polysaccharide that is acquiring significant relevance in various fields, including new materials and the environment. In addition to increasing the biodegradability of microorganisms, the kind of starch employed in the production of polymeric blends can directly impact the characteristics of the polymer.

2.5.1 Characteristics of Starch

During photosynthesis, plants create starch, a white, granular carbohydrate that acts as the plant's energy storage (Breuninger et al., 2009). According to Bashir & Aggarwal (2019), it has a semi-crystalline structure and is found in granular form in the chloroplasts of green leaves, as well as in the amyloplasts of tubers and grains, among other places.

Research from Sahari et al. (2013) demonstrates that starch, when mixed with a plasticiser and heated to a high temperature, may be used as a thermoplastic material. Although the starch particles from various sources are chemically similar, the granules from each source vary in terms of size, shape, and the molecular components that make up the starch particle. Because it is plentiful, renewable, and affordable, starch is positioned to play an increasingly greater role in producing sustainable plastics and other bioproducts in the future (Glenn et al., 2014). Nevertheless, Starch is fragile and has weak mechanical and water barrier characteristics, making it a poor choice for food applications. A further change of the material's characteristics is required in order to get more acceptable material properties.

2.5.2 Classification of Starch

The starch can be classified into three categories, as shown in

Figure 2.7. Native starch, can be include starch in this category if it has not been treated in any way after being extracted from its source and is white, odourless, and colourless in powder or liquid form after being extracted from its source. The phrase "modified starch" refers to starch that has had one or more of its original characteristics altered or modified. Additionally, hydrolused starch is starch that has had one or more of the native starch's inherent properties changed or modified (Bashir & Aggarwal, 2019).



Figure 2.7 Classification of starch.

When investigating starch structure, the most effective method starts with visual features and proceeds to chemical bonding as the structure is examined. Starch is made up of granules, and the granules are divided by cell walls, which are present in plants and are responsible for the structure of starch. Throughout each cell, crystal bundles are interwoven with amorphous starch, lipids, and waxes. Then, inside each cell, there are different crystalline portions that may be distinguished (Shogren et al., 2009).

2.5.3 Application of Starch

The use of starch has been around for a long time, and is particularly prevalent in the food manufacturing sector. Tapioca starch is a popular application since it is used in the production of sweeteners and other related goods. Furthermore, It can be used to make a variety of products, including monosodium glutamate, alcohol, maltodextrin, lysine, citric acid, glucose syrup and crystallised glucose, maltose rich malt, litchi and lake fruit preserves, paper and cardboard for packaging, candy and instant noodles. It can also be used to make

vermicelli and pasta, potato flour and rice paper for packaging, and pearl nuts for packaging. (Defloor et al., 1998).

Starch is also notable for its lack of taste contribution to food systems, which allows for complete and quick detection of the taste of the meal itself. The paper industry, as well as the food sector, are significant users of starch. Along with binding fibres, starch helps retain additives and increases the overall strength of the fibres in a fabric. Notably, even if the granules are not completely distributed, strength improvements are still possible, and the rate of draining on the forming wire is not slowed or completely stopped (Breuninger et al., 2009).

Research from Abral et al. (2019) found that starch films are used in food packing. This is because it is very clear, strong, and has a low moisture absorption rate, all of which contribute to its ability to extend the shelf life of food. Additionally, tapioca starch has been utilised as a carrier component in corrugating formulations after being partially swelled with alkali and then terminated with acid. Apart from textile manufacturing, starch is widely used in printing, finishing, and sizing operations. It is often used as a warp size to provide strength and resistance to abrasion to the yarn during the weaving process. Typically, starch is modified and has a wide range of applications.

2.5.4 Structure of starch

The chemical formula for starch is ($C_6H_{10}O_5$) as shown in Figure 2.8 Structure of starch (Bashir & Aggarwal, 2019). It is a homopolymer of glucopyranose units. Amylose and amylopectin are two kinds of polymer chains found in starch. Amylopectin has a branching structure with glycosidic connections 1–4 and 1–6, while amylose has a linear structure with glycosidic connections 1–4 and 1–6. as



Figure 2.8 Structure of starch (Bashir & Aggarwal, 2019).



2.6 Cassava or Tapioca Starch

Figure 2.9 Cassava or tapioca root and starch.

Currently, cassava is grown in less than 100 countries worldwide with very different farming scales with 230 million tons of cassava output. This dramatic increase in output by the ethanol biofuel industry used cassava as an input material in Southeast Asian countries and increased food demand in Africa. Nigeria, in particular, is the world's leading cassava producer. Indonesia, the Congo Republic, and Thailand are the next three countries with the largest cassava production. The rest of the world's top 10 cassava countries include Angola, Ghana, Vietnam, India, and Mozambique. The top 10 cassava-producing countries account for 75% of the total cassava production worldwide.

Tapioca, also known as yucca in Central America, mandioca or manioca in Brazil, and cassava or cassada in Africa and Southeast Asia, is a highly cultivated plant in Malaysia. It is one of the most widely grown food crops on the planet, accounting for about a quarter of global production. Tapioca refers to the starch and other goods derived from the tapioca plant's roots, while cassava refers to the plant's roots.

In addition to its ease of planting and cheap input requirements, cassava is a shrubby perennial crop well-known for its high yields. All soil types are suitable for the plant's growth. However, for root development loose-structured soils such as light sandy loams and loamy sands are preferred. Both infertile and acid soils are incapable of supporting development, while an alkaline soil is incapable of supporting growth. It takes just 9 to 12 months to propagate well when using mature plant stakes planted vertically about 10cm below the soil surface and with a 100cm circle spacing between each stake. (Breuninger et al., 2009). Even though the basic features of this starch are well understood, much more research is needed to understand the changes in composition and functional qualities between different varieties. The cassava roots are the starch-reserve meat, and the starch concentration of the root's carbohydrate is 26-35.7, the moisture is from 61.92 -70.25 % ant other more content. Cassava is a root vegetable that grows in tropical climates. It is classified as a tuber crop, along with potatoes and yams. Cassava roots have a form that is similar to that of sweet potatoes, as shown in Figure 2.9. It is a plentiful and reasonably priced source of carbohydrates. It has the potential to deliver more calories per acre of the crop than cereal grain crops, making it a particularly beneficial crop in underdeveloped countries.

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Table 2.2 Contents in Cassava roots (Breuninger et al., 2009)

Properties	Range of value
Moisture (% wet basis)	61.92-70.25
Carbohydrate (% wet basis)	26-35.7
Protein (N \times 6.25 % wet basis)	0.70-1.18
Fat (% wet basis)	0.08-0.41
Ash (% wet basis)	0-1.00
Crude fiber (% wet basis)	0.60-1.11
Potassium (mg/kg)	0-0.26
Phosphorus (mg/kg)	0-400
Vitamin (mg/kg)	0-252

2.6.1 Characteristics of Cassava Starch

Cassava is the world's fifth-most largely produced starch crop and the third most extensively eaten food source in tropical regions.. The starch in cassava is the most important component. The granules of cassava starch are spherical, with a truncated end and a welldefined hilum on one end. The granules of cassava starch are spherical, with a truncated end and a well-defined hilum on one end. The size of the granules ranges between 5 and 35 microns.

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It is usually manufactured by the wet milling of fresh cassava roots. However, it is also manufactured from dried cassava chips in some countries, such as Thailand, where it is referred to as "cassava starch." Tubers that are mature and of good quality may produce about 25% starch. It is feasible to generate about 60% starch from dried cassava chips and approximately 10% dry pulp from dried cassava pulp per 100 kg of cassava roots. The value of harvested cassava may be enhanced by processing it to produce cassava starch, which contributes to rural economies' development.

Starch, along with other natural polymers, has become one of the most promising ecologically friendly materials in recent years due to its cheap cost, widespread availability, and biodegradability. Cassava pulp, often known as bagasse, is one of the most important byproducts of cassava starch. The residual starch in cassava bagasse (CB), according to studies conducted by Edhirej et al. (2017), ranges between 50 and 60%. There was a wide range of amylose content in the starch samples, ranging from 17.9 to 23.6 %. For samples taken during the dry season, particle sizes varied between 9.5 and 12.7 mm, while particle sizes varied between 11.8 and 13.6 mm for samples taken during the rainy season. Cassava starch has a better amylose average DP than 3000 compared to another source of starch. This study conduct by Breuninger et al.,2009 refer to Table 2.3 show that Cassava large amylose average that is 3000 compare to others type of starch. No systematic changes in particle size distribution as a function of crop age at harvest were observed (Defloor et al., 1998). Based on Sriroth et al. (2000), in Malaysia and Singapore, the first wave of cassava processing technology arrived, which was intended for small-scale production of meal and flour.

Table 2.3	Comparison	of tapioca/cassa [·]	va starch	with	other s	tarch	(Breuninger	et
al.,2009).	F						61	
· · ·	-							

Source	Cassava	Potato	Corn	Waxy Corn	Wheat
Granule diameter (µm)	4-35	5-100	2-30	2-30	1-45
Average diameter (μm)	15	27	S-10	10	bimodal
Amylose content (%)	RSITI TEKNII	KAL MALA	YSIA ₂₈ MEL/	AKA 0	28
Amylose average DP	3000	3000	800	Not available	800
Tg (glass transition temperature) $^{\circ}$	65-70	60-65	75-80	65-70	80-85
Phosphorus (%)	0.01	0.08	0.02	0.01	0.06
Ash (%)	0.2	0.4	0.1	0.1	0.2
Protein (%)	0.10	0.06	0.35	0.25	0.40
Lipid (%)	0.1	0.05	0.7	0.15	0.8

2.6.2 Cassava starch composites from various studies.

Cassava starch composite research is accelerating and gaining popularity each year. as shown in Table 2.4

Table 2.4	Cassava	starch	composites	from	various	studies.

Study about	Product / application	Reference
Utilising the cassava starch casting method	Cassava/sugar palm fiber reinforced cassava starch hybrid composites.	(Edhirej et al., 2017)
Cassava starch	Food and industry	(Breuninger et al., 2009)
Cassava starch with Lycium ruthenicum Murr's anthocyanins	Packaging films	(Qin et al., 2019)
Starch-based films	Starch-based film	(Dieulot & Skurtys, 2013)
Cassava Starch Technology	Cassava starch improved processing technology	(Sriroth et al., 2000)
Cassava bagasse cellulose nanofibrils	Cassava bagasse cellulose nanofibrils	(Teixeira et al., 2009)
Cassava Starch Physico- Chemical Properties	The amylose contents of the starch	(Defloor et al., 1998)
Biocomposites based on cassava starchburied	Degradation of cassava (tapioca) starch based composite films	(Maran et al., 2014)
Cassava starch and anthocyanins from Lycium ruthenicum Murr	Packaging films were	(Waqas et al., 2019)
Cassava/sugar palm fiber reinforced cassava starch hybrid composites	Hybrid composite	(Edhirej et al., 2017)
Effect of mechanical on structure of cassava starch	Cold-water solubility and rheological	(Huang et al., 2007)
Water sorption and mechanical properties of cassava starch films	Moisture sorption characteristics of cassava starch films	(Mali et al., 2005)
Utilization of Indigenous Biodegradable Plastics	Potato tuber, cassava tuber, and gabi tuber as a biodegradable plastic.	(Cataquis et al., 2019)

2.7 Thermoplastic starch (TPS)

Informing TPS, Starch granules degrade significantly and transition to a new continuous phase in the form of thick melting substance. TPS exhibited flexibility as a result of the plasticiser effect, which resulted in the breakdown of inter and intramolecular hydrogen bonds along the polymer chains, an increase in intermolecular spacing, and a rise in the molecular mobility of the starch chain., as shown in Figure 2.10 (Zuo et al., 2015). TPS has garnered considerable interest despite the fact that the structures disturbed are more complicated than those of synthetic thermoplastics, owing to its thermoplastic-like processability at high temperatures and shear rates. TPS is similar to other polymers in terms of linear and branching topologies, molar mass, glass transition temperature, plasticizer modification, crystallinity, and melting point.



Figure 2.10 TPCS structure.

2.7.1 Thermoplastics Starch (TPS) Characteristics

Thermoplastic starch polymers are made from a number of natural sources, including wheat, rice, maize, potato, pea, and tapioca, and are biodegradable and compostable. (Frost, 2010). Based on research from Abral et al. (2019) and Ilyas et al. (2019), TPS has a lower glass transition temperature and is more flexible. TPS, on the other hand, has a number of faults, including low tensile strength and severe deformations, as well as water resistance, which limit its potential as a packaging material (Altayan et al., 2020; Palm et al., 2020).

Thus, natural fibres, such as cellulosic fibres, whiskers, and nanofibers, have been utilised to strengthen TPS and have been proven to overcome TPS drawbacks, and have been used to create novel and inexpensive starch bio-composites. (Altayan et al., 2020; Nazrin et al., 2020; Pérez-Pacheco et al., 2016). Natural fibres may be produced from agricultural crop wastes such as sugar palm, oil palm, pineapple, and banana, which together account for billions of tonnes of trash. The relationship between the components of starch and the resulting TPS properties. Amylose content in TPS has an effect on its rheological, structural, thermal, and mechanical properties (Altayan et al., 2020).

2.7.2 Classification of Thermoplastics Starch

Blends, composites, and chemically modified starch systems are the three types of thermoplastic starch materials available, as shown in Figure 2.11. Blends are made up of two or more polymers formed from distinct monomers that can be miscible, immiscible, compatible, or incompatible .Starch-poly(ethylene) (PE) materials are an example of a blend in which poly(ethylene) is the predominant phase and starch is added to make the product biodegradable. Composites are polymers that include a filler or secondary phase, such as glass particles, silica, carbon, or natural fibres, distributed throughout. Alteration of the base material is very common, and it may be accomplished in batch reactors or through reactive extrusion. The hydroxypropylation of starch is one such example (Frost, 2010).



Figure 2.12 Sugar Palm Tree (Huzaifah et al., 2016)

The sugar palm tree is a vital part of Malaysia's flora. It is a member of the Palmae family and is naturally a forest plant, making it one among Malaysia's most useful and adaptable trees. Arenga pinnata is also known as Areng palm, black fibre palm, Gomuti palm, Aren, Irok, Bagot, and Kaong. The image of the Sugar palm tree is shown in Figure 2.12. The sugar palm tree's fruits may also be used to produce juice. The white fruits, which were taken off the fruit bunch, are edible. They may be bottled in a thick syrup or cooked in a sugary syrup for desserts.

Sugar palm fiber is organically interwoven in the trunks of sugar palm trees from the bottom to the top. The fiber was chopped with an axe and then ground to a finer size of 2 mm using a Fritsch Pulverisette mill. The outer half of the stem is made of highly robust and sturdy wood. It can be used to make flooring, furniture, and tool handles. The roots of the sugar palm are also said to have medicinal properties. Researchers are now concentrating their efforts on the generation of bioethanol from Neera sugar using a fermentation method.

From Taiwan to Southeast Asia, sugar palms are cultivated in nations such as the Philippines, Indonesia, Papua New Guinea, India, Northern Australia, Malaysia, Thailand, Burma, and Vietnam. It has been suggested that it may serve as a source of natural fibres and biopolymers (Huzaifah, Sapuan, Leman, & Ishak, 2017). The main structural component of sugar palm fibers (SPF) is cellulose (66.5%), contributing to their excellent mechanical qualities. Sugar palm's ability to make biopolymers is another appealing feature. The starch collected from sugar palm tree trunks may be used to make biodegradable polymers, which can then be reinforced with natural fibres to form biodegradable composites.

The advantages of this composite are its accessibility, cheap cost, renewable nature, and, most importantly, its biodegradability (Atikah et al., 2019). Sugar palm fibre was formerly utilised as a substitute for glass fibre in advanced engineering applications such as soil stabilisation in road building, reinforcing polymers, as a matrix composite in material

engineering, and undersea cables as a replacement for glass fibre (Nurazzi et al., 2020). A study related to the chemical and physical characteristics of various parts of sugar palm tree was conducted by Sahari et al. (2012) and (Huzaifah, Sapuan, Leman, Ishak, et al., 2017) show that Sugar Palm Trunk fiber has the greatest diameter and highest percentage of water absorption, followed by Sugar Palm Bunch, Ijuk, and Sugar Palm Frond fibers.

Part	Ijuk	Sugar Palm Bunch fiber	Sugar Palm Trunk fiber	Sugar Palm Frond fibers	References
Water absorption percentage (%)	103.8	123.7	132.8	61.4	(Huzaifah, Sapuan, Leman,
Diameter (µm)	17n/221	254.7	115.4	592.2	Ishak, et al., 2017)
Holocellulose (%) UNIV	/ERSITI	TEKNIKAL	MALAYSI	A MELAKA	
Cellulose (%)	52.3	61.8	40.6	66.5	(Sahari et al., 2012)
Lignin (%)	31.5	23.5	46.4	18.8	

Table 2.5 Parts of type of Sugar palm fiber with its diameter and its water absorption percentage.

2.8.1 Sugar palm starch (SPS)

Numerous research on sugar palm starch film have been reported in Malaysia, one of the most promising sugar palm starch producers. However, Poeloengasih et al. (2016), based on a research on sugar palm starch's use in medicine, especially as a gelatine substitute

in capsule shell manufacturing. Sugar palm starch has it owns properties, as shown in Table 2.6. It's made up of 37.60 percent amylose, which may be used to replace gelatine. As a consequence, it has a high potential for film formation. While many previous studies produced sugar palm starch films with starch concentrations of less than 9% w/w, the present research produced a sugar palm starch film recipe with a high sugar palm starch content.

Table 2.6 Sugar palm starch properties (Atikah et al., 2019; Ilyas et al., 2019).

Properties	Specification		
Density (g/m ³)	1.54		
Ash (%)	0.20		
Amylose (%)	37.60		
Protein (%)	0.19		
Fat (%)	0.27		
Water content (%)	15.00		
Palm Fiber (SPF)	JIEM		

2.9 Sugar I

Sugar palm fibre is categorised according to the section of the tree from which it originates, including black sugar palm fibre (Ijuk), Sugar Palm Bunch fibre (SPB), Sugar NIVERSITI TEKNIKAL MALAYSIA MELAKA Palm Frond fibres (SPF), and Sugar Palm Trunk fibre (SPT) (SPT), as shown in

Figure 2.13.



Figure 2.13 Classification of SPF.

2.9.1 Characteristics of SPF

In sectors that formerly depended largely on synthetic fibres, natural fibres are increasingly outnumbering synthetic fibres in terms of demand and usage. In terms of cost, density, availability, eco-friendliness, non-toxicity, flexibility, renewable, biodegradable, abrasion resistance, high strength and modulus, and simplicity of processing, natural fibres outperform synthetic fibres.

However, Natural fibres, on the other hand, have a number of recognised drawbacks, including poor impact strength and a high water uptake in the absorption characteristics component. Because of its amazing characteristics, such as high strength and firmness when loaded, recyclability, superior corrosion resistance, and environmental resistance, thermoplastic composites are as competitive in dominating industry demand and application as Fiber-Reinforced Plastic (FRP) (Atiqah et al., 2018).



Figure 2.14 Sugar palm fiber (Ijuk).

Sugar palm fibers (SPF) shown in Figure 2.14 is renowned for its excellent durability and resistance to saltwater, which are two of its most important advantages. Sugar palm fibres were historically utilised to make ropes for ship cordages since they had been shown to perform well in saltwater. Because no additional procedures, such as water retting or mechanical decorticating, are needed, the manufacture of such fibres is easy. In the field of material engineering, SPF has been used as reinforcement in polymer matrix composites. Sugar palm fibres, like other natural fibres, have shown promise in many investigations for use in composites. (Edhirej et al., 2017).

Sugar palm fibres such as kenaf, jute, oil palm, sugarcane bagasse, pineapple leaf, and banana pseudo-stem have shown potential in a variety of composite applications. (Edhirej et al., 2017). When compared to other natural fibres, sugar palm fibre has the following characteristics. This fibre has been the subject of much study, particularly in terms of its physical, mechanical, and environmental characteristics. Commonly, the physical properties table shown in Table 2.7 of SPF where it has a small diameter, low density, significant water absorption, and low water content. While for the mechanical properties, the tensile strength, stiffness, and elongation are higher compared to other natural fiber as shown in

Table **2.8**.

Physical Properties	Value
Diameter (mm)	0.4 ± 0.079
Density (g/cm ³)	1.4623 ± 0.0121
Water absorption (%)	161.96 ± 34.04
Moisture content (%)	6.45 ± 1.07

Table 2.7	Physical	propertie	s of SPF :	from Kuala	Jempol,	Negeri	Sembilan	Malaysia
(Huzaifah	, Sapuan	Leman, I	shak, et a	al., 2017).		-		-

 Table 2.8 Mechanical properties of SPF from Kuala Jempol, Negeri Sembilan (Atiqah et al., 2018).

Mechanical Properties	Value
Tensile strength (MPa)	15.5
Stiffness (GPa)	0.49
Elongation at break (%)	5.75

Sugar palm fiber has been shown to have several important advantages as research progresses. SPFs are well-known for their long durability and resistance to seawater, two of their main benefits (Edhirej et al., 2017). Sugar palm fiber is well-known for being low-cost, biodegradable, and abundant in nature, among other things. In terms of qualities, sugar palm fiber has demonstrated high mechanical strength, low density, and excellent thermal characteristics (Atiqah et al., 2018).

Moreover, according to Nazrin et al. (2020), Nanocellulose fibres produced from sugar palm fibres have generated considerable attention owing to their unique properties, which include a large surface area, a high aspect ratio, a low density, and a high aspect ratio when compared to comparable commercial fibres. Sugar palm fibre has a variety of drawbacks, including non-adhesion to polymer matrices, excessive wetness, poor modulus, and low strength, in addition to the shortcomings stated before. As a consequence, chemical treatment was employed to enhance the attraction between the two components in the composite (Ilyas et al., 2019).

2.9.2 Sugar Palm Fiber Composites (SPFC)

In terms of durability, tensile strength, and moisture and heat resistance, sugar palm fibre outperforms coir fibre. Numerous studies on the use of sugar palm fibres as reinforcement in polymer composites have been performed. The optimal matrix for the job reduces money, improves performance, and is compatible with fibre. Three types of polymer resins are classified: thermoset, thermoplastic, and bio-based. SPFC is a starch-based film capable of being cast in a variety of methods.

Despite the fact that starch-based films have a lower moisture barrier than other types of films due to their hydrophilic nature, they have good oxygen, carbon dioxide, and lipid barrier properties. When it comes to starch films, plasticizers are often used to reduce brittleness and enhance film flexibility by increasing intermolecular space. This is because starch films are brittle in their natural state. Sugar palm fibre outperforms coir fibre in terms of durability, tensile strength, moisture and heat resistance, among other characteristics. There has been a great deal of study on the use of sugar palm fibres as reinforcement for polymer composites.

The best matrix for the job saves money, improves performance, and is compatible with fibres and other materials. Three types of resins are distinguished: thermoset resins, thermoplastic resins, and bio-based polymers (biopolymers). Due to the fact that SPFC is composed of starch, there are many ways to cast it. Due to their hydrophilic nature, starch-based films exhibit good oxygen, carbon dioxide, and lipid barrier characteristics, despite their lower moisture barrier effectiveness. To reduce the brittleness and enhance the flexibility of the starch film, a plasticizer is often used to expand the intermolecular space inside the starch film, resulting in greater flexibility. SPF and SPC composite research is growing rapidly and becoming more popular every year, as shown in Table 2.9 .

Table 2.9 SPF and SPS composite various studies.

Study about	Product / application	Reference
Sugar Palm Starch-Based Composites	Packaging Applications	(Muhammed L. Sanyang et al., 2015)
Mechanical, Physical and Thermal Properties Sugar palm nanocellulose fiber	Bio nanocomposites	(Nazrin et al., 2020)
Biodegradability and mechanical behaviour of	Sugar palm starch based biopolymer .	(Sahari et al., 2014a)
Physico-chemical and Thermal Properties	Starch Derived from Sugar Palm Tree (Arenga pinnata)	(Sahari et al., 2014b)
Effect physical properties	Thermoplastic sugar palm starch/agar (TPSA) blend when incorporated with seaweed.	(R. Jumaidin et al., 2016)
Sugar palm & (Wurmb.) Merr) cellulosic fiber	Isolation of nanofibrillated cellulose	(Ilyas et al., 2019)
SPF and SPS	Biocomposites.	(Sahari et al., 2013c)
Its fibers, polymers and composites	New biodegradable	(Ishak et al., 2013)
ornhusk/sugar palm fiber	Hybrid composite	(Ibrahim et al., 2020)

2.10 Plasticizer

Plastics made from natural plant polymers such as wheat or starch have easily attacked and degraded molecules by bacteria. Water is the most often used plasticizer. It is, however, too volatile to be utilised as the only plasticizer in TPS because to its high volatility. Glycerol, pentaerythritol, polyols, sugar alcohols, poly(oxyethylene)s, poly(oxypropylene)s, non-ionic and anionic surfactants, as well as poly(oxyethylene)s and poly(oxypropylene)s, are examples of less volatile plasticizers. The best choice is polar liquids that form hydrogen bonds with one another. Anti-plasticisation may be seen in plasticizers that are more sensitive to water, such as glycerol, at certain concentrations that are usually low in relation to the amount of water present in the mixture.

Plasticiser activity related to water sorption isotherms that provide molar sorption enthalpies of starch–plasticiser complexes. Competitive plasticization was studied using glass transition temperature models. Starch plasticizers work in the same way that synthetic polymer plasticizers do. In addition to these functions, starch plasticizers create a hydrogenbonding compound with the starch, which prevents retrogradation, which results in cracking as a result of delayed recrystallization.

The proper term for a plasticizer that is also a polymer was allowed, and as a result, a polymer mix, as described in the following section, was created. Because amylose forms V-type crystals, retrogradation is more severe in starches with high amylose content. It is possible to undergo retrogradation when starch granules are combined with water and boiled until gelatinization occurs, which results in retrogradation. Figure 2.15 Process retrogradation of starch is formed.

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Figure 2.15 Process retrogradation of starch is formed.

However, the amylose starch with the highest amylose content is the best for forming TPCS. To provide consistent characteristics throughout time, additives are essential to stabilize TPCS against retrogradation The physical characteristics (density, moisture content, water absorption, and thickness) of plasticized SPS declined as the glycerol concentration rose in a research performed by Sahari et al., (2013a) on SPS plasticized using glycerol as a plasticizer. More study is required to determine the best plasticizer concentration and ratio combination.

In the production of TPCS, glycerol is used as a plasticizer because of its unique properties, which include cheap cost, nontoxicity, a high boiling point, and an abundance of hydroxyl groups. In light of these properties, the glycerol-plasticized TPCS is appropriate for usage in applications where the polymer will come into close contact with foods and drinks, such as single-use packaging materials. Amorphous homogeneous phase (amorphous homogeneous phase = amorphous homogeneous phase + water) was chosen as a co-plasticizer in conjunction with glycerol because water plays an important role in improving

the thermoplasticization process by enhancing granule transformation to the amorphous homogeneous phase. The co-plasticizers water and glycerol have both been identified as coplasticizers on numerous occasions.

According to many studies, the most important rationale for adopting this plasticization technique is that its components act as lubricants, enabling polymer chains to move freely and preventing TPCS products from degrading. When compared to other plasticizers, it was found in additional tests that, in addition to the advantages previously stated, this co-plasticizers system reduced shear stress values during the plasticization process (Altayan et al., 2020).

As little nonrenewable resources as feasible should be used. However, in the event that this is not feasible, the ideal packing material should be reusable and recyclable in nature. Additionally, the usage of biodegradable packaging materials contributes to the decrease of trash in landfills. Biodegradable packaging (bio packaging) as shown in Figure 2.16 can be produced either from renewable raw materials or synthesized from petrochemical sources. (Natalia Czaja-Jagielska, Katarzyna Lemanska, Dominik Paukszta, 2011).

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Figure 2.16 Example of biodgradable packaging.

2.10.1 Biodegradable plastics

Nowadays, biodegradable plastic is very common as it is one of the alternative ways that is beneficial and good for the environment. Biodegradable packaging is more widespread as a replacement for traditional plastics, mainly as foils and rigid, disposable packaging containers. Among many products, pioneering efforts to create more eco-friendly packaging can be found in horn, confectionery, dairy, fruit and vegetable, or beverage industry. The renewability, sustainability, and compatibility of biodegradable plastic have encouraged manufacturers to invest in it for single-use applications such as kitchen bags, food protection films, plates, cups, and a variety of other culinary utensils and packaging items (Natalia Czaja-Jagielska, Katarzyna Lemanska, Dominik Paukszta, 2011).

According to several experts, the primary reason for the development of this plasticization system is that its components act as a lubricant, facilitating the movement of polymer chains and delaying the retrogradation of TPCS products.(Altayan et al., 2020). Oxo-biodegradable and hydro-biodegradable plastics are the two most frequent forms of biodegradable polymers (Co et al., n.d.) as shown in Figure 2.17. In many cases, oxy-biodegradable plastics are made from oil by-products, but they include an additive that enables them to breakdown in the presence of oxygen and be eaten by microorganisms, which basically implies that they decompose much more quickly than conventional plastics. As the name implies, hydro-biodegradable polymers are starch-based plastics that disintegrate via hydrolysis or moisture.



Figure 2.17 Classification of biodegradable pastics.

Oxo-biodegradable plasticshown in Figure 2.18 is recyclable if it has not decomposed. It may be recycled alongside conventional plastic and doesn't produce methane. The serviceable life Plastic bags that are oxo-biodegradable are the same as traditional plastic bags. It degrades due to exposure to the elements such as sunshine, heat, and bacteria, and takes an estimated two years to deteriorate under normal conditions. Depending on the quantity of exposure, the time required for a bag to decompose will be longer or shorter.



Figure 2.18 Oxo-biodegradable plastics bag.



Figure 2.19 Hydro-biodegradable food freezer bag

Hydro-biodegradable plastics shown in Figure 2.19 is type of plastics that breakdown and biodegrade at a faster rate than oxo-biodegradable plastics, but the carbon dioxide emitted by hydro-biodegradable ones is higher than oxo-biodegradable ones. When deposited in a landfill, hydro-biodegradable ones will release methane and will only decompose in a high-microbial environment with higher moisture, where hydrolysis will take place actively. Despite this, the ultimate result is the same since both kinds of bags are transformed to carbon dioxide, water, and biomass. Industrial composting is possible using hydro-biodegradable polymers. However, unlike oxo-biodegradable polymers, which can be processed with standard machines, it requires specialised equipment. The comparision between both of biodegradable plastics are shown in Table 2.10.

Made from fossil fuel-derived polymers and starch	Usually made from a by-product of oil-refining	
Damages recycle stream unless extracted from feedstock	Can be recycled as part of a normal plastic waste- stream	
Cannot be made from recyclate	Can be made from recycled plastic	
Emits CO ₂ rapidly while degrading	Emits CO ₂ slowly while degrading and forms biomass	
Can emit methane in landfill	Inert deep in landfill	
Needs special machinery	Can use same machinery as for conventional plastic	
Not suitable	Suitable for use in high-speed machinery	
Compostable	Can be compostable	
Four or five times more expensive than conventional plastic	Little or no on-cost	
Weaker than conventional plastic	Same strength as conventional plastic	
Heavier	Same weight as conventional plastic	
Prone to leakage	Leak-proof	
Degrades only in high-microbial environment	Degrades anywhere on land or sea	
Cannot be controlled	Time to degrade can be set at manufacture	
Safe for food contact	Safe for food contact	
No PCB's Organo-chlorines, or "heavy metals"	No PCB's Organo-chlorines, or "heavy metals"	
Can be incinerated, but lower calorific value	Can be incinerated with high energy-recovery	
Production uses fertilisers, pesticides and water	Production uses no fertilisers, pesticides or water	

Table 2.10 Comparison of hydro-biodegradable and oxo-biodegradable plastics (Co et al., n.d.)

2.11 Waxes

Waxes are produced by a wide range of plants and animals. Waxes are composed of long-chain aliphatic hydrocarbons. Typically, natural waxes are fatty acid esters or long-chain alcohol esters. Animal wax esters are often prepared using a variety of carboxylic acids and fatty alcohols. It is a simple lipid that is produced when a long-chain alcohol is esterified with a fatty acid. At 20 degrees Celsius, waxes vary in texture from soft and sticky to hard and plastic or breakable. Most waxes have a low viscosity. They are insoluble in water and soluble in organic solvents at a temperature-dependent rate (Tinto et al., 2017).

Moreover, natural and synthetic waxes can be distinguished. Natural waxes are further divided into renewable and non-renewable categories as shown in Figure 2.20. Mineral waxes derived from lignite or brown coal, whether crude or refined, are nonrenewable natural waxes that are derived from fossil fuels. Natural waxes that have been chemically altered, such as via hydrogenation and re-esterification, as well as natural waxes that have not been chemically altered are available (Tinto et al., 2017).



Figure 2.20 Classification of waxes.

Oil-binding waxes are used in a variety of products, including shoe polish and lipsticks, water repellency in draggers and industrial coatings, release performance in bakeries and plastics, scratch resistance in car polish and inks, plasticizing in hot-melts and chewing gum, dispersing in mascara and toners, and release performance in agricultural and pharmaceutical matrices.



2.11.1 Beeswax

UNIVERSITI TEFigure 2.21 Beeswax. SIA MELAKA

Bee is an animal that produce honey inside the hive. When compared to other insects that make waxes, beeswax is the most well-known. Honeybees create beeswax, which is a naturally occurring wax. Honeybees use it to form honeycomb cells, which is produced by worker bees in a hive. An empty honeycomb is melted in hot water to extract the wax. The ester myricyl palmitate, which bees use to build honeycombs, is a significant component of beeswax. When honey is harvested and refined, the wax is collected as a by-product (Points & Terms, 2021).



Figure 2.22 Generic structure formula of bee waxes (Points & Terms, 2021).

It is composed mostly of complicated mixtures of paraffinic hydrocarbons, free fatty acids, esters of fatty acids and alcohol, and diesters. It is a suitable for decreasing the absorption of water as it act as wax. Beeswax is collected from honeycombs using a centrifuge process after the honey has been removed. Beeswax is used to make candles and other household items (Bonvehi & Bermejo, 2021). The composition of beeswax varies somewhat depending on where it is produced, the melting point ranges between 62 and 65 degrees Celsius refer to Figure 2.22 Generic structure formula of bee waxes (Points & Terms, 2021). Newly created beeswax is pure white because to propolis and pollen pigments, but it becomes yellow, dark yellow, and brownish after being handled by honeybees. Overheating and chemical bleaching may damage the odor of beeswax. Light-colored wax is more valuable than dark-colored wax in general.(Bogdanov, 2016).

Characteristics	Properties
Colour	Yellow or dark yellow
Odour	Honey-like
Consistency	Sticky
Melting point (°C)	61- 65
Density (g/m ³)	0.950-0.965
Refracture index at 75 °C	1.440-1.445

 Table 2.11 Physical characteristics of beeswaxes (Points & Terms, 2021)

Beeswaxes have commonly been used since long time ago, based on research conducted by Bogdanov, (2016) as shown in Figure 2.23. Besides its use for foundation, which is probably the primary use, wax is also used for cosmetics, pharmaceutical products, candles, and other purposes. Furthermore, beeswax is used to manufacture wax foundations and has a broad variety of commercial applications, including candle production, metal casting, and modelling, as well as cosmetics, food processing, industrial technologies, textiles, varnishes, and polishes, among others (Bonvehi & Bermejo, 2021).



Figure 2.23 Beeswaxes used in various fields (Bogdanov, 2016).

2.12 Glycerol



Figure 2.24 Image of glycerol.

Glycerol has been shown to be a common plasticiser in the production of thermoplastic starch-based composites in recent study, which has been verified in practise. Glycerol's compatibility with amylose enables it to enter starch molecules, enhancing and improving the thermoplastic polymer's flexibility and workability. Glycerol is a small organic molecule with three hydroxyl groups that may permeate starch molecules, strengthening and improving the thermoplastic polymer's flexibility polymer's flexibility and workability. Because glycerol is non-toxic and may be utilised as an emulsion, it is an excellent choice for the food sector (Balakrishnan et al., 2016).

Glycerol is produced mostly from fats and oils found in plants, such as vegetables, and animals. In certain contexts, glycerol was used interchangeably with glycerine and glycyl alcohol. A pleasant taste is known to be linked with glycerol's physical state, which is that of a colourless, odourless liquid with no detectable odour. Glycerol is situated between lipid and carbohydrate metabolism in the biological system because the rest of carbohydrate is converted to a long chain fatty acid and esterified by three-hydroxyl groups. Glycerol has the chemical formula C3H5(OH)3.



Figure 2.25 Structure of glycerol (Katryniok et al., 2010).

Glycerol's three-hydroxyl group inhibits the absorption of moisture from the air, resulting in a hygroscopic molecule. This is one of the reasons why glycerol is well-suited for usage in the cosmetics industry, since it may retard the drying process of the material and render it permanently wet. Its structure is shown in. Figure 2.25.

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2.13 Summary

Based on the literature review done on natural fiber, composite, starch, thermoplastic starch including waxes and plasticiser, the conclusion has been made as follows:

i. The involvement of natural fiber in composite gives a positive impact on the environment in terms of reusing the waste from natural fiber such as sugar palm fiber and form into a valuable product.

ii. TPCS reinforced by natural fiber helps to reduce the damage towards nature since it is biodegradable component which can degrade easily in the soil.

iii. SPF is a valuable material that can be utilised as a thermoplastic starch reinforcement.

iv. Inclusion of beeswax into a TPCS will reduce its water vapour permeability.

As a result, since many studies on thermoplastic starch have been conducted, it has been discovered that a few research has been conducted on the integration of sugar palm fiber into thermoplastic cassava starch or beeswax.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains this study's entire research activity, from the selection of raw materials to the fabrication of thermoplastic cassava starch reinforced by sugar palm fiber. The testing of product that will be conduct includes strength, hardness, Young Modulus, ductility or brittle of the materials testing, and how the material performs under different temperature conditions. Because of this, there are procedures will be carried out to execute these two properties tests on the new material to get the data analysis of the new material and to reach a conclusion on the results obtained. The flow chart of study are shown in the Figure 3.1.

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Figure 3.1 Flow of the study

3.2 Material

3.2.1 Sugar Palm Fiber

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Sugar palm fiber was supply by Adha enterprise which originated from Jempol, Negeri Sembilan. The sugar palm fiber was cut from the sugar palm tree. Next, the contaminant such as soil, small stone and dry leaf was removed from the sugar palm fiber. The fiber can be extracted easily and more defined fiber was obtained by this method. Next, SPF then cut into small pieces to ease the process of the grinder by using the dry grinder. The grinder will grind the fiber until the fiber composition becomes small in the range of about 0.1-0.3 cm. Then, the SPF that have been grind filtered by using a small net to remove the dust and store in the container. The process are shown in Figure 3.2.

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Figure 3.2 Processing of cleaning and grinding SPF.

3.2.2 Cassava Starch



In this study, the base material used was cassava starch. Cassava starch physically appears in white powder form just like other starch. Table 3.1 shows the general properties of cassava starch that obtained from the characterization of cassava starch.

Table 3.1	General	properties	of	cassava starch.	ALAYSIA	MEL/	AKA
I GOIC CII	Gener m	properties					

Properties	Value/Characteristics	
Moisture	10.4 ± 0.08	
Ash Content at 900 °C	25% to 42%	
pH Value	4.8 to 5.2	
Acidity	0.0002 to 0.0004	
Colour	White	
Form	Powder	
Gelatinization Temperature (°C)	68-70	

3.2.3 Glycerol



Figure 3.4 Glycerol

Glycerol is used in this study as the plasticizer for the fabrication of starch thermoplastic. It is vital as it helps in the formation of a thermoplastic cassava starch. Glycerol was provided and was beforehand bought at QReC Chemicals. Table 3.2 shows the specifications of glycerol.

· · · ·	. O. V
Specification	Composition
Assay (acidimetric)	Min 99.5%
Insoluble in water	Passes test
Acidity/alkalinity	Passes test
Halogen Compounds (as CI)	Max 0.003%
Chloride (CI-)	Max 0.001%
Sulfates (S04)	Max 0.001%
Ammonium (NH4)	Max 0.0015%
Arsenic (As)	Max 0.0001%
Copper (Cu)	Max 0.001%
Heavy Metals (as Pb)	Max 0.0005%
Iron (Fe)	Max 0.0005%
Lead (Pb)	Max 0.001%
Nickel (Ni)	Max 0.0005%
Zinc (Zn)	Max 0.001%
Aldehydes (HCHO)	Max 0.0005%
1,2, 4-butanrial (G.C)	Max 0.02%
Sulfated Ash	Max 0.01%
Water	Max 2%

Table 3.2 The specifications of glycerol.

3.2.4 Beeswax



Figure 3.5 Beeswax

Beeswax is also vital in the fabrication of thermoplastic starch as it reduces the

thermoplastic starch to be moisture. This property is important in a thermoplastic starch as it lowers its rate of decomposition. The beeswax provided was bought from Aldrich Chemistry. Table 3.3 shows the specification of the beeswax.

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Table 3.3 Specification of beeswax.

Test	Specification
Appearance (Color)	Faint Yellow to Yellow-Tan
Appearance (Form)	Solid
Infrared Spectrum	Conforms to Structure
Melting Point	62.0 - 65.0 °C
Ester Value	72-79
Ester/Acid Ratio	3.3-4.2

3.3 Preparation of samples

3.3.1 Preparation of Thermoplastic Cassava Starch (TPCS)

The preparation of thermoplastic cassava starch consists of two parts: weighing and mixing cassava starch and glycerol and hot press machine. In the weighing and mixing of cassava starch and glycerol part, the glycerol was weighted with ratio 30 while the starch was with ratio 70 according to mixture as shown on Table 3.4 . The weighed cassava starch and glycerol undergoing manual dry mixing until the mixture was evenly distributed. After that, the mixture undergoing the high-speed dry mixing by using dry blender with speed of 1200 rpm for 3-5 minutes until the mixture was blended homogeneously, Figure 3.6 Process making shown the Process making TPCS.

Table 3.4 The ratio mixture of thermoplastic cassava starch.

	1/ / 3					
Thermoplastics Cassava Starch						
Mat	erial	Ratio				
LINIVERSITI 1	Cassava Starch	VSIA MEI70 KA				
2	Glycerol	30				
То	tal	100				



Figure 3.6 Process making TPCS

3.3.2 Preparation of TPCS with Beeswax

The preparation of thermoplastic cassava starch with beeswax will be the continuity of the preparation of thermoplastic cassava starch until the high-speed dry grinding part. The most suitable amount of ratio for beeswax is 2.5 of the whole mixture of beeswax need to be added in the mixture of the thermoplastic cassava starch with 97.5 as shown on Table 3.5.

The beeswax preparation that needs to be weighed and added to the pure thermoplastic cassava starch will be done by cutting the beeswax into small pieces. Since the beeswax condition that in solid state and big size for it to be mixed well with the pure thermoplastic cassava starch, the beeswax need to be cut in small pieces and shred by using the shredder. Then, the shredded beeswax will be weighed 10 % from mould and dry mix with the pure thermoplastic cassava starch which 90 %. After that, the mixture of thermoplastic cassava starch and beeswax is undergoing the high-speed dry mix by using dry blender with 1200 rpm speed for 3 - 5 minutes until mixed well. Figure 3.7 shown the process mixing of TPCS and beeswax.

Thermoplastic Cassava Starch With Beeswax					
No	Name	Amount (%)			
1	Pure TPCS	97.5			
2	Beeswax	2.5			
	Total	100			

Table 3.5 The r	atio of mixtur	e for TPCS	with	beeswax.
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Figure 3.7 Process mixing TPCS and beeswax.

3.3.4 Preparation of TPCS with Beeswax Reinforced by SPF .

The thermoplastic cassava starch with beeswax from the previous process was been prepared. In this part, the mixture of TPCS with beeswax will be incorporated with the SPF. The preparation of the SPF that done from previous process and the fiber that was stored in the tight container in order to prevent the absorption of moisture from surrounding to the fiber. In this section, the incorporation of SPF is based on the specified percentage which consist of 0 wt.%, 10 wt.%, 20 wt.%, 30 wt.%, 40 wt.% and 50% fiber. The 0 wt.% of SPF will be do on the previous section. The 10 wt.% of SPF need the mix with TPCS with 90% beeswax according to the mould. The steps will need to be repeat for 20%,30%,40% and 50% the next percentage of SPF, respectively.

The process of TPCS with Beeswax Reinforced by SPF are shown in Figure 3.8. The modification of the thermoplastic cassava starch with beeswax reinforced SPF according to the percentage of fiber weight is shown in Table 3.6.

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Table 3.6 Percentage of the mixture in making TPCS with beeswax and SPF.

Mixture	Percent (%)				
SPF	10	20	30	40	50
TPCS+Beeswax	90	80	70	60	50
Total			100		



Figure 3.8 TPCS reinforce with SPF

3.3.5 Preparation of TPCS SPF TRAY

The process of development TPCS SPF tray are the process of TPCS with beeswax will be incorporated with the SPF.In this section, The development of thermoplastic composite with fibre content of 20 wt.% is applied for the fabrication of a tray. Similar to the fabrication of the thermoplastic samples, the thermoplastic samples, all the components of the materials are mixed until homogenous using a dry mixer. The mould for the tray is lined with mylar film to ensure easy removal of the final product from the mould. After placing the thermoplastic mixture into the mould, it is then placed into the hot press of 155 °C pressed at 30 tons for 1 hour. The mould is then cooled for another 20 minutes, before removal of the tray. The process of development of TPCS SPF TRAY are shown Figure 3.9.





SPF Tray

mould **Figure 3.9 Process making SPF Tray**

press

3.3 Equipment 3.3.1 Thermal Testing

3.3.1.1 Thermo-gravimetric Analysis (TGA)



Figure 3.10 Scanning electron microscope.

Thermo-gravimetric analysis has been performed to classify the material's thermal degradation activity in relation to weight loss due to the increasing temperature. TGA has been conducted at the Fakulti Teknologi Kejuruteraan Mekanikal Pembuatan (Universiti Teknikal Malaysia Melaka, UTeM) with a Mettler-Toledo AG, Analytical (Schwerzenbach, Switzerland) as shown in figure 3.10. The specimen was weighing in the range of 10±2 mg. The testing is performed in aluminium pans in the temperature range of 25 to 900 ° C at a heating rate of 100C min-1 under a dynamic nitrogen atmosphere.

3.3.1.2 Tensile Test



Figure 3.11 Tensile Test On Universal Testing Machine (INSTRON 5969).

The specimens for tensile testing have been required to be cut refer to the ASTM D638. By using a Universal Testing Machine (INSTRON 5969) shown in Figure 3.11 with a 5 kN load cell, 3 samples were cut to perform this test; the crosshead speed is maintained at 5 mm / min. The measurement has been set at 23 ± 1 ° C room temperature and 50 ± 5 % relative humidity (ASTM D638).

3.3.1.3 Flexural Test



Figure 3.12 Flexural Test On Universal Testing Machine (INSTRON 5969).

The specimens for flexural tests should be cut refer to ASTM D790 at a temperature of 23 ± 1 ° C and a relative humidity of 50 ± 5 %. Using the Universal Testing Machine (INSTRON 5969) with a 5kN load cell, 3 to 5 samples could be cut to conduct this test; the crosshead speed is maintained at 2 mm / min. The length of the support span has been set at a ratio of 16:1 to the sample thickness (ASTM D 790). The dimension of the samples is 130mm (L) x 13mm (W) x 3mm (T). Figure 3.12 shows the Flexural test on Universal Testing Machine (INSTRON 5969).

3.3.2 Chemical Interaction and Morphological Characteristic



3.3.2.1 Fourier Transform Infrared Spectroscopy (FTIR)

Figure 3.13 IR spectrometer (Nicolet 6700 AEM).

FTIR is an efficient analytical method for functional group detection and covalent bonding knowledge characterization. In this research, FTIR is applied to expose the existence of functional groups that exists in sugar palm fibers. An IR spectrometer (Nicolet 6700 AEM) has been used to obtain the spectrum of the sample as shown in Figure 3.13 . The samples were obtained using jigsaw. The dimension of the samples is 10mm (L) x 10mm (W) x 3mm (T).

3.3.2.2 Scanning Electron Microscope



Figure 3.14 Scanning Electron Microscope (Zeiss Evo 18).

In order to produce an image, a scanning electron microscope (SEM) scans a directed electron beam over a surface. In this research, the samples has been obtained from the previous tensile test. SEM, model Zeiss Evo 18, is used to examine the morphology of tensile fractured surfaces with 10kv of acceleration voltage after the applied coating on the sample as shown in Figure 3.14.

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3.4 Summary

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This chapter presents the proposed methodology to develop a new, effective and integrated approach for the working process of developing on a new material follow by the good testing procedure and result collection. The goal of the proposed methodology is to obtain a simple, proper and efficient in such a way that the results of data analysis are the closest value to the real properties of the composite itself. The methods also aimed to exploit the network's widely accessible and restricted data on the testing method of new composite material. The ultimate intend of the method is to create a new composite material, which can be replace the petroleum-based polymer by containing the traditional polymer properties in thermal and mechanical phase as much as getting special effects which can reduce the pollution on the environment.

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CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter examined the anticipated impact of Thermoplastic cassava starch beeswax reinforced with sugar palm fiber composite using thermal and mechanical tests. Fourier Transfer Infrared Spectroscopy (FTIR) and Scanning Electron Microscope (SEM) are two more physical tests that are included. Thermal analysis is performed using thermogravimetric analysis (TGA). Mechanical testing was also performed, which includes a tensile and flexural test. The results of each testing were evaluated and discussed in this chapter.

4.2 Thermal Analysis

4.2.1 Thermo-gravimetric Analysis (TGA)

The changes in a sample's weight while heated or cooled at a controlled temperature was analyzed by TGA, with the changes being consistently analyzed. The temperature control programmed could be isothermal, where the temperature remains constant or nonisothermal. A situation in which the temperature remains unchanged is described as isothermal. Yet, non-isothermal corresponds to a situation in which the heating rate remains unchanged, attributed to a linear change in temperature over time (Huzaifah, Sapuan, Leman, & Ishak, 2017). TGA studies were first carried out by heating samples to a specified temperature and then weighing them after removing them from the sampling head at specific time intervals.

The result of this testing in Figure 4.1 shown that on the first of weight loss in between temperature 30°C to 330°C was attributed to the evaporation of moisture from

water. According to Carlsson et al., (2013) research, thermoplastics have lost the most weight, which supported the result. This was caused by replacing certain unsaturated polyester matrices with less thermally stable sugar palm fibers, reducing the overall thermal stability of the polymer matrix system. These results were similar to Ahmad et al., (2011) research, which found that thermoplastics lost the most weight. This was caused by replacing certain unsaturated polyester matrices with less thermally stable sugar palm fibers, reducing the overall thermal stability of the polymer matrix system (Nurazzi et al., 2020). Compared to a composite with 0% fiber content, the composite with the highest fiber content, 40 % and 50%, has better thermal stability. This discovery was consistent with recent studies on sugar palm fiber Cassava/sugar palm fiber reinforced cassava starch hybrid composites (Edhirej et al., 2017; Mo et al., 2010).

In addition, the result was supported by research Maqsood & Rimasauskas (2020), that stated the fiber's adherence to the starch matrix increases heat stability because fibers and matrix adhere effectively, leading to minimal mass loss in the study. According to the results, the sugar palm fibers' fiber-fiber interaction may have had a role in the higher initial temperature that at the 30 and 40 weight percent fiber loading occurs the 70 and 30 weight percent ratio when compared to the other loadings. It was shown that the fiber-fiber interaction is greater than the fiber-matrix interaction when sugar palm fiber loadings are higher. Because of the non-limited mobility, it is possible that the decomposition temperature will be reduced even more (Syafri et al., 2019). This statement support by Balachandar et al., (2019) , which stated that the first decomposition of natural fiber takes place between 30 °C to 110 °C. In this study, moisture evaporation in sugar palm fiber occurred from 30 °C to 330 °C. In this phase, the fiber burns slowly, and the increased temperature makes the fiber become lighter due to the evaporation of the water-bound and volatile extractives.



4.1.2 Derivative Thermogravimetry (DTG)

DTG is a type of thermal analysis in which the rate of material weight changes upon heating is plotted against temperature and used to simplify reading the weight versus temperature thermogram peaks which occur close together (Karak, 2012). Meanwhile, DTG curves give clearly transformation of the composite degradation characteristics. Referring to Figure 4.2, it can be seen that the similar trends of degradation of the overall trend. The first peak of the composites (maximum decomposition) was shift to higher temperature following the incorporation of SPF which is agreement with the result shown in TGA curve, suggesting improved the thermal stability.

The weight loss of the composites at the maximum decomposition phase decreased following the increase of fibre content. This finding is in agreement with Balachandar et al., (2019) which reported that TGA results of weight loss percentage with increasing temperature showed two to three stages of characteristics depending on the natural fiber, chemical treatment conditions, and immersion time . From the peak of the DTG curve, the maximum degradation decomposition temperature for 40 % fiber of the composites was observed to be in the range 330°C to 370°C.



Figure 4.2 DTG result of TPCS reinforced with SPF .

4.3 Mechanical analysis

It is important to understand the mechanical properties while selecting it for an engineering product or application. Mechanical properties are those of a material that involves a reaction to an applied load. The mechanical properties of metals define a material's range of applicability and its estimated service life. Mechanical properties also enhance material classification and identification.

4.3.1 Tensile testing

The material's tensile properties describe how it will respond to tension forces. Tensile test, or also known as tension test, is a basic mechanical test that involves loading a properly prepared specimen in a controlled way until it fails completely. The applied force and the specimen's elongation over a given distance, on the other hand, are measured. Tensile tests are used to determine the tensile strength, modulus of elasticity, elongation, elastic limit, decrease in area, proportional limit, yield strength, yield point, and other tensile characteristics.

The different composition of SPF that are 0-50% and TPCS were tested, and their strength strain behaviour is shown in Figure 4.3. The result shown that 50% TPCS with beeswax react with 50% SPF have higher value of tensile testing. This was because in most practical composites, brittleness is a characteristic of high-performance reinforcing fibers. This result was supported with research from Sanyang et al., (2015) that found out ratio of 50:50 research SPS50-PLA50 manifested significant improvement in physical, mechanical, and water barrier properties in Sugar Palm Starch-Based Composites for Packaging Applications research. From the curve, it is apparent that the strength increased with the increase of strain value and then experienced failure at a certain point where in this observation is shown in ratio 40:60.

According to Ishak et al., (2013), the failure may be attributed to poor strength of fiber when the fiber is pulled under the action of applied forces. 50% fiber had the highest average tensile strength of 10.3 ± 1.075208 MPa, while 40% and 30% fibres were 8.4 ± 1.422096 MPa and 8.58 ± 0.888183 MPa, respectively. These results are compatible with the cellulose content of the fibers where the highest cellulose content had the highest strength properties (Huzaifah, Sapuan, Leman, & Ishak, 2017). Ishak et al., (2013) agreed

that cellulose is the main structural component providing mechanical strength and stability to the fiber.



The tensile strength, and elasticity of sugar palm fiber with different composition are compared in Figure 4.3 and Figure 4.4. As shown in Figure 4.4, 40% fiber had the highest average tensile modulus of 1993.723 \pm 100.7209MPa, while 50% were 1959.947 \pm 66.3382MPa which have not much different with 50% and for 30% fiber 1561.54 \pm 177.5409 MPa respectively.For the elastically at break, 0% fiber had the lowest percentage, which was 116.5855 \pm 46.41383. They elastically deform to failure, with little or no nonlinear deformation. The unreinforced matrix in metal and polymer-matrix composites is usually capable of irreversible plastic deformation, and the matrix failure strain is usually much greater than that of the fibers (Harker, 2018).



Figure 4.4 Tensile Elasticity of TPCS reinforced SPF

ANOVA technique is employed to study the influence of tensile strength and tensile modulus. The means and standard deviations of shear bond strength values are shown in Table 4.1 Multifactorial ANOVA showed that tensile strength and tensile modulus $p \le 0.05$ which had a significant effect on the bond strength values.

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Table 4.1 Summary Of Anova For Tensile Properties On TPCS Reinforces Spf.

Variable	df	Tensile strength	Tensile modulus
Mixture	5	2.69E-06	7.45E-11

*Note: significant difference at $p \le 0.05$.

4.3.2 Flexural Testing

The flexural test measures the amount of force required to bend a beam under three-point stress. The data is often used to choose materials for load-bearing parts which doesn't flex. When the stress in the outer fibers on the tensile face approaches the composite's tensile strength when loaded in bending, the composite will fail. Across the other hand, early flexural testing often produced tensile strength values considerably lower (Harker, 2018).

The result for this testing has proven that 40% TPCS reacted with beeswax and 60% SPF have higher value. According to Koniuszewska & Kaczmar (2016), the few main factors influencing composite performance include fiber and matrix power, as well as fiberto-matrix interactions. Fiber-reinforced plastics are made from brittle resins that are reinforced with strong, brittle fibers that may be stiff (like carbon) or flexible (like nylon) (eg. glass or aramid polymers). There was an interesting study carried by Silviana et al., (2018) they have completed an experiment on the effect on glycerol content on cassava starch composite films with the similar results. According to them, fiber and matrix power, fiber-to-matrix interfaces are the few main factors influencing composite performance.

The result that was conducted by Silviana et al., (2018) revealed that higher of the glycerol content in the film resulted greater of elongation to break. Natural fiber reinforced hybrid polymer composite is the subject of this amazing discovery. The lower strength may be related to a higher fiber content (Ilyas et al., 2019). The flexural strength of cassava starch reinforced sugar palm fiber increased with fiber content from pure cassava starch firm to 6% sugar palm fiber reinforcement, but decreased from 8% sugar palm fiber reinforcement, according to a previous research (Edhirej et al., 2017). This prove that flexural strength rose as the amount of sugar palm fiber in the component grew, but it decreased when the quantity of fiber was exceeded. This result was similar to Kumar & Thakur, (2017) earlier's research.



Figure 4.5 Flexural strenght TPCS reinforced with SPF.

From the Figure 4.6 it shows the results for maximum stress flexural. The Figure 4.6 show that, 50% fiber had the highest maximum stress flextural value, at 36.40913 ± 3.050771 MPa, while 40% was 31.79577 ± 0.798801 MPa which have not much different with 50%. Then the third highest maximum stress flextural was 30% at a value of 15.9402 ± 177.5409 MPa, which also not much difference with 10% and 20%, with value of 11.4441 ± 1.6627481 MPa value 20% and 11.14742 ± 1.896445 MPa and value 10% respectively. Finally, 0% fiber had the lowest percentage, which was 4.688493 ± 1.260543 MPa.



Figure 4.6 Maximum stress flexural of TPCS reiforced with SPF.

ANOVA technique is employed to study the influence of flexural strength and maximum stress flexural. The means and standard deviations of shear bond strength values are shown in Table 4.2 where Multifactorial ANOVA showed that flexural strength and maximum stress flexural the $p \le 0.05$ which had a significant effect on the bond strength values.

Table 4.2 Summary of ANOVA for flexural properties on TPCS reinforces SPF .

ANOVA

Source of Variation	df	F	P-value
Flexural strength	5	26.66142	4.17E-06
Maximum stress flexural	5	156.718	1.69E-10

*Note: significant difference at $p \le 0.05$.

4.4 Chemical Interaction and Morphological Chareteristics

4.4.1 Fourier Transform Infrared Spectroscopy (FTIR)

The chemical structure of the material composite will be determined using Fourier-Transform Infrared Spectroscopy. The chemical bonding characteristics of a material composite, such as fiber and starch in this instance, are also determined using FTIR. The majority of biological resource samples showed the same peaks in their FT-IR spectra as the previously discovered peaks.

Figure 4.7 shows that the existence of O–H groups in starch and fiber was suggested by strong peaks at 3200–3500cm⁻¹, showing that starches are particularly sensitive to water molecules due to the presence of hydroxyl groups (Edhirej et al., 2017). This can be explained by Jumaidin et al., (2017), who found that cellulose and hemicellulose in natural fiber contribute to the presence of the O-H band. The existence of O-H groups in fibers was revealed by the strong peaks at 3200–3500cm⁻¹, as predicted by FTIR, owing to the presence of hydroxyl groups in cellulose, hemicellulose, and lignin.

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4.4.2 Scanning Electron Microscope (SEM)

The purpose of scanning electron microscopy (SEM) is to observe the morphology of a material composite. SEM is a flexible device that may be used to verify and examine microstructure morphology and chemical composition characterisation (Nazrin et al., 2020). SEM micrographs can also reveal the interaction between the matrix and fiber of the composite material (Edhirej et al., 2017).According to Ibrahim et al., (2020), SEM micrographs of starch-based composites revealed a few types of failure, including fiber fracture, matrix failure, and fiber-matrix interfacial failure. They revealed that the samples with 60 percent date palm and flax fiber content have more voids and fiber pull-outs. SEM detects these interactions and transforms them into a picture (Abbasi et al., 2018). The addition of glycerol and the starch melt mixing have enhanced starch plasticization (Ridhwan Jumaidin et al., 2017). This research supports the findings of Edhirej et al., (2017), who discovered that when examined under SEM micrographs, pure cassava starch films exhibit a compact structure and homogeneous surface.

Figure 4.8(a) and figure 4.8(b) presented different magnification for the specimen, 20x and 200x. From the result, it can be seen that in the specimen there was no fiber, only the matrix composed of starch and beeswax can be found. In this photomicrograph, there was a remarkable finding that a part of the mixture between starch and beeswax has formed a granular structure like a glossy According to the research, the rationale that can be inferred in relation to the uniform surface was related to the application of the beeswax emulsion sheet (Putra et al., 2019).



Figure 4.8 Different magnification for SEM micrography of tensile fracture surface of TPCS: (a) 20x magnification (b) 200x magnification.

Figures 4.9(a) and 4.9(b) show the scanning electron microscopic (SEM) fractography of the tensile-tested fracture surface for 10% of SPF contained on TPCS composite specimen. The

result does not show the evident of the good adhesive structure but showed the fiber and the matrix are separated, indicating a weak interfacial bonding between the SPF and the matrix. Crack and void also apperead.



Figure 4.9 SEM 10% figure of TPCS reinforced SPF.

The result was that the high sample fiber loading of sugar palm have a great adhesion to the TPCS Matrix. This was attributed to improve tensile strength due to strong adhesion between TPCS matrix and fibers. In this photomicrograph, it was discovered that a portion of the starch and beeswax combination had produced a granular structure with a glossy shape. This study agreed with (Putra et al., 2016), who discovered a similar structure in creating beeswax/multi-walled carbon nanotubes. Besides, owing to the low reinforcing agent, the specimen with 50% of SPF revealed a structure of voids and defective interaction between the matrix and fiber which showed in Figure 4.10(f). When it reach the of limit adhesion, TPCS cannot longer bind the SPF .This finding is in line with the research on gelatin content on potato starch green composite films, where the voids on the surface of the highest gelatin content composite films are more visible (Balachandar et al., 2019)



Figure 4.10 SEM micrograph of fracture surface of TPCS blended with different ratio .(a) 0wt%, (b) 10wt%, (c) 20wt%, (d) 30wt%, (e) 40wt%, and (f) 50wt%

4.5 **Product Innovation**

The biodegradable sugar palm fiber tray (SPF Tray) was developed successfully as a possible application using the SPF-reinforced TPCS composite that was illustrated in this report. Figure 4.11 demonstrate the SPF Tray invention.



Figure 4.11 Tray from TPCS reinforced SPF.

It offers a green alternative to the traditional packaging tray with the design of this product, which has caused significant environmental contamination. The mechanical characteristics of this material are similar to the synthetic polymer in terms of physical properties, i.e., polyester, nylon, etc., which makes it a highly feasible alternative to replacing the conventional packaging tray. The use of the biodegradable sugar palm fiber tray (SPF Tray) as a small tools packaging tray and a potable stationary tray as an alternative to the existing packaging on the market was shown in Figure 4.12 and Figure 4.13.


Figure 4.12 Snack tray of TPCS reinforced SPF.



Figure 4.13 Portable stationary tray of TPCS reinforced SPF.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It is undeniable that many efforts have been made on the production of environmentally friendly polymers as an alternative to synthetic polymers. These studies are important as it is to configure the composition of thermoplastic starch that has physical properties that are on par with synthetic polymers while capable of biodegradation. This study is being carried out based on the three main objectives. Below is stating the objectives and the finding from this study.

- i. To determine the mechanical properties of biodegradable thermoplastic tray cassava starch reinforced with sugar palm fiber composite.
 - The mechanical properties of TPCS reinforced with SPF composite have been successfully tested. The addition of SPF substantially increased the tensile strength and tensile modulus of the composite. The incorporation of SPF has also been shown to improve flexural strength and flexural modulus.

Nevertheless, the better properties are 40% of SPF reinforced in the composite, starting from 50%, the data showed a decline. These finding were consistent with the results of the FT-IR and SEM that demonstrate the compatibility of the TCAS/beeswax and the SPF and managed to create a homogeneous structure. The FT-IR spectroscopy helps in identify the water in the samples and position of the O-H band as the fiber material enhances conformity with the matrix and fiber's strong adhesion. Therefore, the good uneven distribution of SPF in the matrix contributes to improves the composite's strength.

ii. To investigate the thermal properties of biodegradable thermoplastic tray cassava starch reinforced with sugar palm fiber composite.

• The thermal properties of TPCS reinforced with SPF composite have been successfully tested. The TGA test reveals that the addition of SPF greatly increased the composite's thermal stability. This is clarified that the composite with the highest fiber content, 50% of SPF, has better thermal stability compared to pure thermoplastic cassava starch. High thermal stability is based on decomposition temperature.

iii. To produce biodegradable thermoplastic tray cassava starch reinforced with sugar palm fiber composite.

• For the preparation of the material specimen, this analysis introduces a new biopolymer. Using cassava starch, glycerol as the plasticizer, modified with the addition of beeswax and finally the presence of SPF as the reinforcing agent, TPCS reinforced with SPF composite has been successfully developed. These raw materials were successfully processed using the method of highspeed mixing and hot-pressing. The application of fiber to the TPCS matrix has led to a increment in the strength component of thermoplastic cassava starch.

5.2 Recommendation for future research

The recommendation for future is to ensure to ensure that there is a constant dispersion of sugar palm fibre in the starch matrix. Futhermore ,It is recomment to study the production of material using machines of high productivity such as the injection moulding machine.In addition, The Compare the effect of the adhesion with the starch matrix using treated cassava starch and untreated sugar palm fibre and the properties of the thermoplastic material by incorporating different types of plasticizer is required as recommendation for future research and study.

5.3 **Potential of the Product**

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The potential usage of fabrication of the tray using the thermoplastic material can be show in Figure 5.1. Potential usage of this thermoplastic tray includes tool tray, stationary tray, and snack plate. Cost analysis on the production of a single unit of the tray is shown in Table 5.1.





Figure 5.1 Potential usage of this thermoplastic tray includes stationary tray(b), Sause tray (c), and snack plate (d).

5.4 Commercialisation Potential

The potential usage of fabrication of the tray using the thermoplastic material can be show in Figure 5.1. Cost analysis on the production of a single unit of the tray is shown in Table 5.1.

Table 5.1 Cost analysis on the SPF tray.

	alund all	15	Price per kg	Price per	Price per tray
Material		Weight (g)		gram (RM)	(RM)
Cassava Sta	arch	13.52	2.3	0.0023	0.031
Glycerol		1.35	2.6	0.0026	0.0035
Beeswax		36.89	3	0.003	0.11
Sugar Palm	Fiber	15.81	2	0.002	0.032
Total cost					0.1765

Positive feedback is given by potential consumers through a survey to determine the willingness of the consumers to purchase a product using this material. With the material cost of this product to be around RM 0.18, the acceptable price range for consumers to

purchase the product is at RM1.00 -3.00 as shown in Figure 5.3. Another factor that contributes to the consumers willing to purchase this product is due to its biodegradability property. The consumers do realise the importance of using biodegradable material to preserve the environment for future generations, hence, they are willing to purchase biodegradable products as an alternative to conventional polymers. The survey was conduct along consumer as shown in Figure 5.2.





Figure 5.2 Survey with consumers at (a) Kuih keria gula melaka, (b) bahulu warisan, and (c) MD putu bamboo.

	Survey form for potential end consumers
COMMERCIALIZATION OF	THERMOPLASTIC STARCH WITH POTENTIAL END
CONSUMERS KOMERSIALISASI TERMOP POTENSI	LASTIK KANJI DENGAN PENGGUNA AKHIR
Name/ Nama: Siti Novs	Jahirah Bt Mohd Zanzuri
Company Name/ Name Syaril	Kat: MO PUTU BAMBU WORLD
MALAYSIA MA	
 If this product is marke Kalau produk ini didap Yes/Ya How much are you will Harga berapa yang and 	ted, are you willing to purchase this product? ati di pasaran, adakah anda rela untuk membelinya? No/Tidak Hing to pay for this product? a rela bayar untuk produk ini?
5) RM 1.00 RM 2.00	اونيۇىرسىتى تىكنىكا
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Rm 4.00	
 Do you think packagii Adakah anda fikir sya 	ng companies would be willing to buy such products? arikat pembungkusan bersedia membeli produk tersebut?
Yes/Ya	NoTidak
	The above statements are true and correct Maklumat diatas adalah benar and terrat
	liv
	citi nussahirat 11+ 20m2n

Survey form for potential end consumers
COMMERCIALIZATION OF THERMOPLASTIC STARCH WITH POTENTIAL END CONSUMERS KOMERSIALISASI TERMOPLASTIK KANJI DENGAN PENGGUNA AKHIR POTENSI
Name/ Nama: Multiminged 20/10219
Company Name/ Name Syarikat: Bahdo warisan
 If this product is marketed, are you willing to purchase this product? Kalau produk ini didenati di pasaran adakah anda rela untuk membelinya?
Yes/Ya TAAY SIA
2) How much are you willing to pay for this product? Harga berapa yang anda rela bayar untuk produk mi? RM 2.00 RM 3:00 Rm 4.00 3) Do you think packaging companies would be willing to buy such products? Ability (and FEE LED BUT FORMALL)
Yes/Ya
The above statements are true and correct, Maklumat diates adalab been and to be a statement of the statemen
IPie
701/102 9.



Figure 5.3 the feedback of the potential user with consumers at (a) MD putu bamboo, (b) bahulu warisan, and (c) Kuih keria gula melaka

5.5 Lifelong Learning

Lifelong learning refers to the process of gaining knowledge and acquiring new skills throughout our lives. It is self-evident that practical and soft skills are acquired throughout the course of this thesis' completion. Interpersonal communication is an example of a soft skill that has developed. Proper verbal communication between coworkers is critical during this study time, notably during the preparation of TPCS samples and weekly talks with our supervisor. Following the conclusion of this study report, it is clear that appropriate time management is also essential. During this thesis writing phase, I discovered that I had improved my time management skills. This thesis will not be completed by the deadline if time management is not properly managed during the research period. Soft skills learned during this time are applicable not just to our academic lives, but also to our future professional lives. These are the skills that keep the world running. Aside from that, practical skills are acquired throughout this time. Practical abilities such as utilising a scanning electron microscope, a hot press machine, or an FT-IR machine, for example, will be useful in the future. A system that instils practical skills in kids like us assists us in preparing for life after school in the workplace.

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APPENDICES

APPENDIX A Gantt chart for PSM 1

Milest	one
Chapter 1	WEEK 12
Chapter 2	WEEK 7
Chapter 3	WEEK 11
Chapter 4	WEEK 13
Final Report	WEEK 16

APPENDIX B Gantt chart for PSM 2

Project Activities								w	cek							
Bachelor's degree Project 2	1	2	3	4	5	6	7	8		10	11	12	13	14	15	16
Briefing PMS 2	10.110	1.00														
Meeting with Supervisor																
Fabrication of sample (10%, 20%, 30%, 40%, 50%)			. •													
Sample testing			100						1							
Mechanical testing			Y.													
Tensile																
Flexural 🔀			A.						¥							
Density					0				μ <u>β</u>							
Thermal and others testing	100 million								60							
TGA									Ť.							
FTIR 24									15							
SEM								0	₩.							
Produce packaging tray									E.							
Producing pakaging tray					1	1			5	0						
CHAPTER 4: RESULT & DISSCUSION									DTER							
Colleting Data	1.1								5		0					
Chapter 4 writing									-		0					
Chapter 5 writing				1		d.						0				
Submission First Draft Report PSM 2	Law.	ul		-	Ri	6	2	5 7	in	1 0	ŝ	4	0			
Slide preparation										11	1	1				
Presentation	100	199							1.0	100						0
Report Correction PSM 2								1.0								
Submission Final Report PSM 2																0
UNIVE	RSI	TIT	EK	NI	(AL	. M/	ALA	YS	IA I	IEL	.AK	A				

Milestone	
Accomplishment of fabrication of sample	WEEK 3
Accomplishment of Mechanical testing	WEEK 5
Accomplishment of Thermal and others testing	WEEK 8
Accomplishment of produce packing tray	WEEK 10
Accomplishment of collecting data	WEEK 11
Accomplishment of Presentation PSM 2	WEEK 16
Accomplishment of Submission Final report PSM 2	WEEK 12

APPENDIX C Survey form for potential end consumers.

Survey form for potential end consumers

COMMERCIALIZATION OF THERMO CONSUMERS KOMERSIALISASI TERMOPLASTIK F POTENSI	<u>PLASTIC STARCH WITH POTENTIAL END</u> KANJI DENGAN PENGGUNA AKHIR
Name/ Nama:	
Company Name/ Name Syarikat :	
ALAYS/A.	
 If this product is marketed, are you Kalau produk ini didapati di pasara 	willing to purchase this product? n, adakah anda rela untuk membelinya?
Yes/Ya 2) How much are you willing to pay for Harga berapa yang anda rela bayar	No/Tidak.
RM 1.00 RM 2.00	
کل ملیہ ۲۹ (RM 3.00 Rm 4.00	اونيومرسيتي تيكنيد
3) Do you think packaging companies Adakah anda fikir syarikat pembun	KAL MALAYSIA MELAKA would be willing to buy such products? gkusan bersedia membeli produk tersebut?
Yes/Ya	No/Tidak

The above statements are true and correct, Maklumat diatas adalah benar and tepat,

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: DEVELOPMENT OF PACKAGING TRAY FROM SUGAR PALM FIBER (MECHANICAL PROPERTIES)

SESI PENGAJIAN: 2021/22 SEMESTER 1

Saya ABIGAIL LIVAN MUSI

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

- 1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
- 2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
- 3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
- 4. **Sila tandakan (✓)

SULI

TERHAD

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

ABIGAIL LIVAN MUSI

Cop Rasmi:

Alamat Tetap:

No 7, Blok H,

<u>Uma Daro Sungai Asap Belaga,</u> <u>96900 Belaga Sarawak.</u>

Tarikh: <u>18/01/2022</u>

Tarikh: _____

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

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Tuan

WALAYS/4

PENGKELASAN TESIS SEBAGAI TERHAD BAGI TESIS PROJEK SARJANA MUDA

Dengan segala hormatnya merujuk kepada perkara di atas.

 Dengan ini, dimaklumkan permohonan pengkelasan tesis yang dilampirkan sebagai TERHAD untuk tempoh LIMA tahun dari tarikh surat ini. Butiran lanjut laporan PSM tersebut adalah seperti berikut:

Nama pelajar: ABIGAIL LIVAN MUSI (B091810160) Tajuk Tesis: DEVELOPMENT OF PACKAGING TRAY FROM SUGAR PALM FIBER (MECHANICAL PROPERTIES)

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULITIA MELAKA

Sekian, terima kasih.

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