BIODEGRADABLE PACKAGING DERIVED FROM COCONUT LEAF FIBER : MECHANICAL PROPERTIES

CHE AMIMI YASMIN BINTI CHE ASUDIN

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

2022

Faculty of Mechanical and Manufacturing Engineering Technology

BIODEGRADABLE PACKAGING DERIVED FROM COCONUT LEAF FIBER: MECHANICAL PROPERTIES

Che Amimi Yasmin Binti Che Asudin

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

2022

BIODEGRADABLE PACKAGING DERIVED FROM COCONUT LEAF FIBER: MECHANICAL PROPERTIES

CHE AMIMI YASMIN BT CHE ASUDIN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "Biodegradable Packaging Derived From Coconut Leaf Fiber : Mechanical Properties" is the result of my own research, with the exception of the references. The thesis has not been accepted for any degree and is not being submitted concurrently with another degree's candidature.

Signature :
Name : Che Amimi Yasmin Binti Che Asudin
Date : 18 January 2022

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.

Signature : ....
Supervisor Name : Dr. Ridhwan Bin Jumaidin
Date : 18/1/2022

DEDICATION

Alhamdulillah

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

&

To my beloved parents, families and my friends for every support that was given to me.

&

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

&

To all people who support me throughout my journey.

ABSTRACT

Nowadays, environmental awareness has increased in society that involving new materials and goods. This awareness is related to creating petroleum-based products, particularly those used to produce short-life products such as disposable eating utensils, food packaging, and bags with an indirect environmental impact. Furthermore, this issue arises because the use of non-biodegradable plastic contributed to environmental issues such as water pollution, air pollution, and landfill problems. Hence, the need to create more environmentally friendly products is crucial, and the development of the quality of the materials increased from days to days to overcome this problem. Numerous studies have been conducted on biopolymers derived from renewable resources because they are one of the most promising materials for replacing petroleum-based polymers.The objective of this study is to produce biodegradable thermoplastic cassava starch reinforced with coconut leaf fiber composite. Second, to investigate the thermal testing and mechanical testing of biodegradable thermoplastic cassava starch reinforced with coconut leaf fiber composite and to produce biodegradable packaging from the coconut leaf fiber. Natural fibre is a biodegradable natural fibre that is used as a reinforcement in polymeric composites mostly due to its low production costs, improved hardness, excellent fatigue resistance, good thermal and mechanical resistivity, and biodegradability.Hence, all materials were uniformly mixed before being fabricated with hot compression moulding at 155 °C for 60 mins. The fundamental properties of TPCS reinforced by coconut leaf fibre biopolymer composites were next studied in order to evaluate their potential as biodegradable reinforcements. The appearance of coconut leaf fibre was discovered to have an effect on the attributes of the samples. The incorporation of beeswax and coconut leaf fiber improves the weaknesses of cassava starch biopolymer, and the composition ratio is 10 – 40 wt.%. Moreover, it is expected to improve mechanical properties. This research investigates mechanical testing by using such as tensile and flexural test while thermal testing consist thermogravimetric analysis (TGA). For other testing consists Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) against the behavior of TPCS reinforced by coconut leaf fiber composite. In generally, a similar trend in the tensile and flexural characteristics of the TPCS coconut leaf fiber composite was observed. Addition of fiber at 30% shows the maximum tensile and flexural strength and modulus while tensile strain, it was found that at 10% shows the maximum and for the flexural shows that, at 20% shows the maximum result. Besides that, the characterization of TPCS reinforced with coconut leaf fiber was done by using SEM and FTIR. The presence of chemical bonding in the samples is shown by FTIR. Hence, it was found that there the present of O-H, C-H and C-O bands in the samples. Moreover, microstructures of the composite are shown by SEM micrographs as fiber concentration increases. The presence of fiber break which aid in the improvement of the mechanical properties. Hence, in term of thermal, the properties were improved with addition of the fiber, as shown by higher residue content. In conclusion, the study presented potential application fields of TPCS reinforced by coconut leaf fiber biopolymer composites, particularly in packaging applications. As a result, this material has the potential to be a viable replacement for non-biodegradable bioplastics in the future, and natural waste can be fully exploited.

ABSTRAK

Pada masa kini, kesedaran alam sekitar telah meningkat dalam masyarakat yang melibatkan bahan dan barang baru. Kesedaran ini berkaitan dengan mencipta produk berasaskan petroleum, terutama yang digunakan untuk menghasilkan produk jangka pendek seperti peralatan pakai buang, pembungkusan makanan, dan beg dengan kesan persekitaran tidak langsung. Tambahan pula, isu ini timbul kerana penggunaan plastik tidak terbiodegradasi menyumbang kepada isu alam sekitar seperti pencemaran air, pencemaran udara, dan masalah tapak pelupusan. Oleh itu, keperluan untuk mencipta lebih banyak produk mesra alam adalah penting, dan pembangunan kualiti bahan meningkat dari hari ke hari untuk mengatasi masalah ini. Banyak kajian telah dijalankan ke atas biopolimer yang diperolehi daripada sumber yang boleh diperbaharui kerana ia adalah salah satu bahan yang paling menjanjikan untuk menggantikan polimer berasaskan petroleum. Objektif kajian ini adalah untuk menghasilkan termoplastik kanji ubi kayu terbiodegradasi diperkukuh dengan komposit gentian daun kelapa. Kedua, untuk menyiasat ujian haba dan ujian mekanikal termoplastik kanji ubi kayu terbiodegradasi diperkukuh dengan komposit serat daun kelapa dan untuk menghasilkan pembungkusan terbiodegradasi daripada serat daun kelapa. Gentian asli ialah gentian semula jadi terbiodegradasi yang digunakan sebagai tetulang dalam komposit polimer kebanyakannya disebabkan oleh kos pengeluarannya yang rendah, kekerasan yang dipertingkatkan, rintangan lesu yang sangat baik, kerintangan terma dan mekanikal yang baik, dan kebolehbiodegradan. Oleh itu, semua bahan dicampur secara seragam sebelum dibuat. dengan acuan mampatan panas pada 155 °C selama 60 minit. Sifat asas TPCS yang diperkukuh oleh komposit biopolimer gentian daun kelapa dikaji seterusnya untuk menilai potensinya sebagai tetulang biodegradasi. Penampilan sabut daun kelapa didapati mempunyai kesan ke atas sifat-sifat sampel. Penggabungan lilin lebah dan serat daun kelapa memperbaiki kelemahan biopolimer kanji ubi kayu, dan nisbah komposisi ialah 10 – 40 wt.%. Selain itu, ia dijangka meningkatkan sifat mekanikal. Penyelidikan ini menyiasat ujian mekanikal dengan menggunakan seperti ujian tegangan dan lentur manakala ujian haba terdiri daripada analisis termogravimetrik (TGA). Untuk ujian lain terdiri daripada Fourier Transform Infrared Spectroscopy (FTIR) dan Scanning Electron Microscopy (SEM) terhadap tingkah laku TPCS yang diperkukuh oleh komposit serat daun kelapa. Secara amnya, trend yang sama dalam ciri tegangan dan lenturan komposit gentian daun kelapa TPCS telah diperhatikan. Penambahan gentian pada 30% menunjukkan kekuatan dan modulus tegangan dan lenturan maksimum manakala terikan tegangan, didapati pada 10% menunjukkan maksimum dan bagi lenturan menunjukkan bahawa, pada 20% menunjukkan hasil maksimum. Selain itu, pencirian TPCS yang diperkukuh dengan sabut daun kelapa dilakukan dengan menggunakan SEM dan FTIR. Kehadiran ikatan kimia dalam sampel ditunjukkan oleh FTIR. Oleh itu, didapati terdapat kehadiran jalur O-H, C-H dan C-O dalam sampel. Selain itu, struktur mikro komposit ditunjukkan oleh mikrograf SEM apabila kepekatan gentian meningkat. Kehadiran pemecah gentian yang membantu dalam peningkatan sifat mekanikal. Oleh itu, dari segi terma, sifat telah diperbaiki dengan penambahan gentian, seperti yang ditunjukkan oleh kandungan sisa yang lebih tinggi. Kesimpulannya, kajian membentangkan bidang aplikasi berpotensi TPCS yang diperkukuh oleh komposit biopolimer gentian daun kelapa, terutamanya dalam aplikasi pembungkusan. Akibatnya, bahan ini berpotensi untuk menjadi pengganti yang berdaya maju untuk bioplastik tidak terbiodegradasi pada masa hadapan, dan sisa semula jadi boleh dieksploitasi sepenuhnya.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Merciful

First and foremost, I would like to thank and praise Allah s.w.t for giving me the strengths and his blessing in completing this thesis. This project would not be possible without His love and guidance in giving us strength, patience, and grace.

With the deepest gratitude I would like to give a million appreciations to everyone who helped me during the period of my research. Especially to my respectable supervisor Dr. Ridhwan Bin Jumaidin, I would express my sincere honour for his guidance, critics, and willingness in giving a helping hand and advice through this research. I deeply appreciate his hospitality, intelligence, and knowledge from the beginning of the semester until now.

I do like to express my heartfelt appreciation to our beloved parents, who have always provided moral and physical support, encouragement, and motivation to help me complete this final project, as well as to the rest of my family for their prayers, love, motivation, and encouragement, which inspire me to work harder to achieve my dreams. And successfully complete this subject. Finally, I dedicate it to my colleagues who assisted me in resolving the issues that arose while completing this thesis.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

Ma - Absorbed Water
Mb - Bound Water
cm - Centimeter
cm^2 - Centimeter Cube
cm^3 - Centimeter Cubic
CMC - Ceramic Matrix Composite
CLF - Coconut Leaf Fiber
Td - Decomposition Temperature
℃ - Degree Celsius
FTIR - Fourier Transform Infrared Spectroscopy.
g - Gram
J - Joule
kg - Kilogram
MPa - Mega Pascal
MMC - Metal Matrix Composite
µm - Micrometer
mg - Milligram
mm - Millimeter
SiO2 - Nano Silica
% - Percentage
PVC - Poly (Vinyl Chloride)
PE - Polyethylene
PMC - Polymer Matrix Composite
PP - Polypropylene
PS - Polystyrene
SEM - Scanning Electron Microscopy
NaOH - Sodium Hydroxide
TGA - Thermogravimetric Analysis
TPPS - Thermoplastic Potato Starch
TPS - Thermoplastic Starch
Tg - Transition Temperature
Wt.% - Weight Percent
XRD - X Ray Diffraction

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Environmental awareness has increased in society in recent years, involving new materials and goods. This awareness is related to creating petroleum-based products, particularly those used to produce short-life products such as disposable eating utensils, food packaging, and bags that have an indirect environmental impact (Paiva et al., 2018). Furthermore, this issue arises because of the nonrenewable waste accumulation impact. Green materials as an alternate approach without hurting the ecological environment was a solid move to address this developing problem (Jumaidin et al., 2019).

According to Ncube et al., (2020) state that, packaging is the largest and fastest-growing user of synthetic plastics. Likewise, the majority of consumer products on the market today are made of some form of plastic. Every year, nearly 280 million tons of plastic materials are produced worldwide, with most of them ending up in landfills or the oceans (Asuquo, 2018). Apart from that, the use of non-biodegradable plastic contributed to environmental issues such as water pollution, air pollution, and landfill problems (Folino et al., 2020).

All of these concerns have prompted new research. Hence, new progress in the development of biodegradable plastics, primarily from renewable natural resources, have resulted in the production of biodegradable materials with similar functionality to oil-based polymers. Increased use of bio-based materials has the potential to have a number of benefits for greenhouse gas balances and other environmental impacts over entire life cycles, as well as the use of renewable resources rather than finite resources. The use of biodegradable materials is intended to contribute to sustainability while reducing the environmental impact of disposing of oil-based polymers (Song et al., 2009).

Since starch is abundantly available, inexpensive, and biodegradable, it is regarded as one of the most promising biopolymers. Starch is a semicrystalline polymer that is the primary form of carbohydrates stored in plants. Starch is a mixture of two polysaccharides that include -D glucopyranosyl repeating units: an essentially linear carbohydrate called amylose and a highly branched polymer called amylopectin. One of the primary disadvantages of granular starch is its restricted processability, which can be enhanced with the use of plasticizers (Fekete et al., 2018).

Apart from that, according to Carvalho, (2008) state that on previous study, thermoplastic starch is semi-crystalline substance consisting of restructured starch and one or more plasticizers. Thermoplastic starch is produced by destroying starch granules in the presence of plasticizers under controlled conditions. The most extensively used plasticizers are polyols such as glycerol, glycols, and water (Fekete et al., 2018). Hence, although thermoplastic starch are biodegradable, thermoplastic starch has been found to have weak mechanical qualities, which has limited the scope of its possible applications (Jumaidin et al., 2019).

According to Pestaño & Jose (2016) found that the coconut leaf is one of the largest in the plant world. Hence, in Malaysia, coconut leaves are a readily available biomass source. Coconut shells and leaves are generated as a result of coconut's use in the food industry. Coconut leaves are high in lignin and can be used in place of wood as a source of activated carbon. Cocoanut leaves contain approximately 38.7% lignin, which is more than the lignin content of coconut sheath (29.7%).

1.2 Problem Statement

The use of non-biodegradable materials in various packaging applications has raised environmental pollution concerns (Ncube et al., 2020). Plastic are one type of waste that is placed in landfills and has negative effects on the environment. Plastic are created from nonrenewable resources such as petroleum, take hundreds of years to disintegrate, and often include pollutants that harm the environment (Adamcová et al., 2017).

In addition to enforcing environmental standards, building a product base made of biodegradable materials is necessary. Many researchers and studies have employed starch in thermoplastic starch. However, few have declared that thermoplastic starch has used in the production of biodegradable products. The biggest limitation of starch as a possible packaging material is its highly sensitive to environmental factors, particularly moisture, brittleness, and extremely poor miscibility with hydrophobic synthetic polymers. As a result, the thermoplastic starch qualities are insufficient, necessitating further research to improve thermoplastic starch qualities (Carballo et al., 2019).

Many researchers and studies have employed starch in thermoplastic starch, however few have declared that thermoplastic starch is used in the production of biodegradable products. since the qualities of thermoplastic starch are poor, more study is needed to improve the properties of thermoplastic starch (Carballo et al., 2017) .

According to Mendagri (2008) state that, coconut is one of the most popular fruits in Malaysia, with approximately 611 million coconuts consumed each year. Due to Malaysia's high consumption of coconut, a large amount of coconut waste was produced. The usage of this agricultural waste is based on the idea that it can replace the present material used in the commercial product in order to cut costs or improve the mechanical qualities of the composite material (Ganiron et al., 2017). However, the use and application of coconut leaf in industry is limited, and the leaf eventually becomes a waste (Nathanael, 1961).

According to Zheng et al., (2013) state that on previous study, since demand for coconut products has grown in recent years, the scale of coconut agriculture has grown, resulting in a significant amount of waste from the growing and processing of coconut. These wastes are thrown or burned immediately, not only harming the natural environment but also wasting a large amount of resources.Thus, learning and understanding the complete usage of coconut leaf waste, as well as analysing existing challenges, is important in supporting the development of comprehensive usage procedures for coconut leaf waste. The overproduction of coconut leaf need to be fully utilize as some part of the coconut plant can be used as coconut fiber especially coconut leaf in produce composite materials.

This study aims to to develop biodegradable packaging from coconut leaf fiber and thermoplastic starch by investigating the thermal and mechanical properties of the material. Aside from that, in this study aim to develop a material that positively impacts the environment and creates a superior material substitute for petroleum-based products. This research will provide information on coconut leaf fiber, allowing overproduction of coconut leaves used as new biodegradable material.

1.3 Objective of Study

The main objectives of this research and study are as follows :

a) To produce biodegrable thermoplastic cassava starch reinforced with coconut leaf fiber composite.

b) To investigate the thermal and mechanical properties of biodegradable thermoplastic cassava starch reinforced with coconut leaf fiber composite.

c) To produce biodegradable packaging from the coconut leaf fiber.

1.4 Significance of Study

The justification of this study are as follows:

1.4.1 The outcomes of the recent study might deliver a new information regarding to the biodegradable thermoplastic cassava starch/beeswax reinforced with coconut leaf fiber composite.

1.4.2 The problem related to the environmental pollution might be reduced by applying the fully bio-composite material started from coconut leaf fiber and thermoplastic cassava starch/beeswax.

1.4.3 The problem caused by the conventional thermoplastic also can be diminished by introducing the new material from cassava starch and coconut leaf.

1.4.4 More value added to the existence of coconut leaf fiber by implemented it as new reinforcement material in producing bio-composite product.

1.5 Scope of Study

The primary raw materials used in this study are cassava starch, coconut leaf fiber, beeswax, and glycerol. The thermoplastic cassava starch mixture formed by combining cassava starch with glycerol at the appropriate percentage of formulation. In this study, glycerol serves as a plasticizer. In the appropriate percentage of formulation, beeswax is added to a mixture of cassava starch and glycerol. Then, due to the percentage required for this study, coconut leaf fiber is added as reinforcement to the mixture of three raw materials. The Hot press machine method was used to create the thermoplastic starch composite with beeswax reinforcement and coconut leaf fiber. In thermal testing, the machine that will be used are thermogravimetric Analysis. For mechanical testing are Tensile Test, and Flexural Test while for other testing Fourier Transform Infrared (FTIR), and Scanning Electroscopy Microscope (SEM).

1.6 Structure Thesis

This thesis is structured in accordance with the format established by Universiti Teknikal Malaysia Melaka (UTeM) for the publication of this study. The following sections comprise this report: introduction, literature review, methodology, results and discussion, and conclusion. The following are the specifics of the structure:

Chapter 1

This chapter describe clearly about the objective of the study and highlighted the problem that initiated to this research. The significance scope of the study and work were elaborated in this chapter.

Chapter 2

This chapter justify the comprehensive review of the literature conducted by a previous study in relation to the subject of this thesis. Additionally, this chapter discusses the research gap identified through a review of previous studies.

Chapter 3

This chapter described the methodology used in this study for material preparation, testing procedures, and data collection.

Chapter 4

This chapter summarised the result and discussion on the testing that have been done on the thermoplastic Cassava Starch Reinforced by Coconut Leaf Fiber Composite that will be tested. The chapter discusses the result in detail.

Chapter 5

This chapter present the overall conclusion of the study with recommendation and improvement for further study according to Thermoplastic Cassava Starch Reinforced by Coconut Leaf Fiber Composite.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter highlights previous researchers' theories, knowledge, and findings in various development on biodegradable products. The term "biodegradable" refers to a product that can be broken down and converted into compounds found in nature by naturally occurring microorganisms. It is usually associated with an environmentally friendly product that can decompose into natural elements. In that case, reasonable modification and controllable degradation of biodegradable products can significantly reduce environmental pollution Nowadays, people are always alert and concerned about the natural condition such as pollution, and ecological health aspects have become increasingly important as public issues. In recent years, Biodegradable products derived from agricultural raw materials have made significant progress. As a result, various approaches to using starch as a natural biopolymer to produce biodegradable thermoplastics have been developed. Today, native starch can be processed under controlled high pressure and temperature to yield a thermoplastic product that can be quickly injected or blown moulded into a variety of products. As a result, agricultural foils, garbage or composting bags, and a variety of differently shaped starch foams with a wide range of applications for short-term uses in packaging are well-known starch end products that have already been developed in the industry (Song et al., 2009).

2.2 Polymer

Polymers are macro - molecules that are chemically linked together from smaller molecules or repeating groups of molecules called monomers. The number of monomers in a polymer molecule varies considerably, as does the degree of regularity in their order, relative orientation, and presence within the same polymer molecule (Gad, 2020).

In other definitions, Rajendra & Bhatu (2020) state that, the term of polymer is derived from two Greek words: poly and mers. Poly is an abbreviation for numerous, whereas mers is an abbreviation for unit or component. Polymers are large, high-molecular-mass molecules. They are also referred to as macromolecules because they are composed of numerous repeating structural units. The repeating structural units are composed of styrene monomers, which are reactive and straightforward molecules that are covalently linked together. It is composed of seven carbon atom backbones and three hydrogen atoms, as illustrated in Figure 2.1. As a result, polystyrene is composed of repeating units made up of four monomer styrene units, as illustrated in Figure 2.2 .

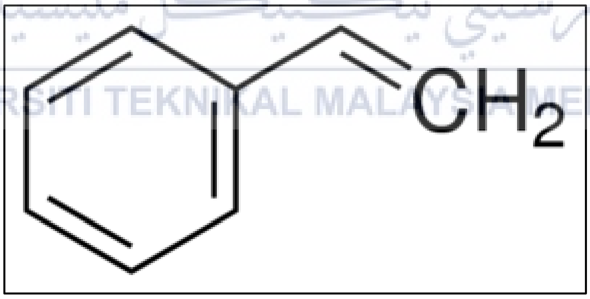


Figure 2.1 Chemical Structure of Monomer Styrene

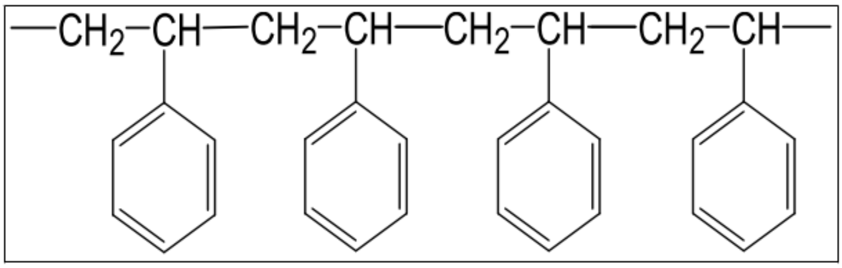


Figure 2.2 : Chemical Structure of Polystyrene (PS)

2.2.1 Classification of Polymers

Polymer has a high molecular weight. Due to the large number and variety of atoms found in their molecule, these materials come in various shapes and sizes (Sharma & Sharma, 2021). Polymers can have a variety of chemical structures, physical properties, mechanical behavior, and thermal characteristics, among other things, and they can be classified in a variety of ways based on these properties, as shown in Table 1 with the essential and broad classification of polymers listed in the following section.

Table 2.1 : Classification of Polymers

Basic of Classification Polymers type	
Origin	• Natural, Semi synthetic, Synthetic
Thermal Response	• Thermoplastic, Thermosetting
Mode of formation	• Addition, Condensation
Line structure	• Linear, Branched, Cross-linked
Application and Physical Properties	
Properties	• Rubber, Plastic, Fibers
Tacticity	• Isotactic, Syndiotactic, Atactic
Crystallinity	• Non crystalline (amorphous), Semi-crystalline, Crystalline
Polarity	• Polar, Non - polar
Chain	• Hetero, Homo-chain

2.2.2 Synthetic Polymer

Synthetic polymers, also known as artificial polymers. Hence, synthetic polymers are composed of carbon-carbon bonds and are commonly obtained in a controlled environment from petroleum oil. A trigger is a substance that is used to start or speed up a chemical reaction between monomers. Polyethylene (PE), polystyrene (PS), polyamides (nylon) and several others are examples of synthetic polymers (Sýkora & Švec, 2001).

According to Brinson & Brinson (2015) state that, over the last century, the development of synthetic polymers and the growth of the polymer industry has been phenomenal. Indeed, the market success of polymer-based products has created such a demand that total plastic production has surpassed total metal production for more than 20 years.

2.2.3 Thermoplastic

According to Cassagnau et al.,(2007) state that, Thermoplastics are produced in large quantities from plants and then converted chemically. A thermoplastic is a material that hardens when heated and softens when cooled. It can recycle because it can be heated and cooled many times. A thermoplastic melts when heated and freezes to a glassy state when cooled. In addition, the majority of thermoplastics have a high molecular weight. Intermolecular forces hold the chains together, but they weaken rapidly as the temperature rises. Because of these properties, thermoplastics can be reshaped using a variety of polymer processing techniques (Ching et al., 2017).

Moreover, the research study by Vlachopoulos & Strutt (2003) state that, Extrusion and injection moulding are the two most important polymer processing techniques. Extrusion necessitates a large amount of material, whereas injection moulding necessitates a large amount of labour. In both of these processes, the following steps are taken: (a) heating and melting the polymer, (b) pumping the polymer to the shaping assembly, (c) forming the melt into the desired shape and dimensions, and (d) cooling and solidifying the melt.

Polypropylene (PP), poly(vinyl chloride) (PVC), and polystyrene are some of the most important thermoplastics. These polymers are used in a variety of structural applications, including wire and light-duty utilities. Furthermore, thermoplastic polymers are used as natural and synthetic fibres (Cassagnau et al., 2007).

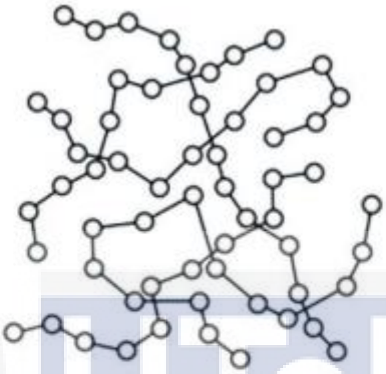


Figure 2.3 : Molecular Structure of Thermoplastic (Karuppiah & Engineering, 2016)

Apart from that, the structure of the molecules in thermoplastics allows them to be classified. Highly aligned molecules pack together more tightly, resulting in more robust plastic. The molecules in nylon, for example, are closely aligned, making this thermoplastic extremely solid. The degree to which the molecules are aligned also decides how transparent plastic is. Since thermoplastics with closely aligned molecules scatter light, they appear opaque. Thermoplastics with semi-aligned molecules disperse some light, giving most of these plastics a translucent appearance. Thermoplastics with random (amorphous) molecular arrangements are transparent and do not scatter light. Amorphous thermoplastics use in the manufacture of optical lenses, windshields, and other fine materials (Macosko, 1993).

In addition, according to Dynisco (2019) state that, thermoplastic materials are further classified into two types: semi-crystalline and amorphous. An amorphous thermoplastic material has no molecular structure and is typically a solid, transparent, rigid material with low shrinkages, such as polystyrene. In contrast, a crystalline polymer has a systematized crystal- structure, but it is often made of amorphous material. It is commonly referred to as a semi-crystalline thermoplastic element compared to amorphous thermoplastics; these plastics are usually more robust and less fragile. However, it is also normal for them to have a higher heat distortion temperature.

Furthermore, these plastics are transparent or opaque, and they have a high shrinkage and specific heat. Polyethylene is the most well-known semicrystalline, thermoplastic material. (Clear polystyrene is an amorphous polymer that often refers to as "crystal polystyrene.") This name, however, refers to the fact that it is "crystal clear" rather than a crystalline thermoplastic. Rheometry commonly uses to measure amorphous and semicrystalline thermoplastics. Hence, it widely uses in rheological studies (Dynisco, 2019).

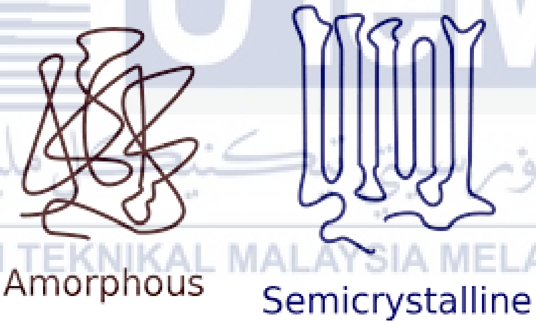


Figure 2.4 : Solid State Structure of Thermoplastics (Dynisco, 2019)

2.2.4 Thermosetting

According to Shrivastava, (2018) state that, Thermosets are materials that permanently harden when exposed to heat or certain chemicals. When exposed to heat, thermoset resin undergoes a chemical transformation, forming permanent chemical bonds between neighbouring molecular chains. These are called crosslinks, and the structure they create is similar to that of a molecular mesh network or a three-dimensional representation of a site. Since crosslinks are permanent, thermoset polymers do not soften during reheating and retain their shape. Because of this property, these materials are ideal for high-heat applications such as cooking utensil handles and silicone baking sheets.

When applied, thermosets become hard and brittle. Due to the high resistance to molecular movement caused by crosslinking, mechanical strength and elasticity are not temperature dependent, as they are with thermoplastics or elastomers. As a result, Thermosets cannot be melted and cannot be joined using thermal methods such as ultrasonic welding or laser welding. When the decomposition temperature (Td) is exceeded, the substance is chemically decomposed (Wang et al., 2018). Figure 2.5 shows that molecular structure of thermosetting while table 2.2 shows the comparison of thermoplastics and thermosets materials on a broad scale. It should remember that each material has distinct properties and applications.

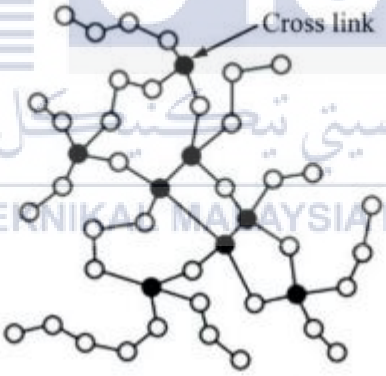


Figure 2.5 : Molecular Structure of Thermosetting (Karuppiah & Engineering, 2016)

Table 2.2 : Comparison Between Thermoplastics and Thermosets

Property	Thermoplastics	Thermosets
Flowability	Low	High
Raw material	Fully polymerized and supplied as solid pellets.	Not completely polymerized Supplied in the form of solid pellets.Typically supplied as a resinous liquid or semisolid.
Bonding between neighboring chains	Physical bonds, such as hydrogen bonds or van der Waals forces, hold neighbouring chains together.	Chemical linkages or crosslinks hold neighbouring chains toget
Processing	Shapes are formed in molten state then cooled to retain shape.	Shapes are formed in cold or warm state then heated to retain shape.
Processing equipment	Injection moulding and extrusion, for example, could be used with standard melt processing equipment.	Heat is introduced after the shapes are formed, necessitating the use of modified processing equipment.
Processing time	Short, as hardening could be performed quickly by cooling.	Long, as crosslinks require longer time to develop.

Recycling	Thermal recycling possible	Thermal recycling not possible
Dimensional Stability	Moderate	High
Common examples	Polyolefins, polyamides, polyesters, commodity, and engineering plastics are all examples of plastics.	Vulcanized rubbers, phenolic and epoxy adhesives, Bakelite, and advanced composites are all examples of vulcanised rubbers.

2.2.5 Application of Polymer

Many industries applied polymers such as automotive industry, computer industry, aerospace industry, building trades, and many other applications. Recently, bio-based polymers derived from renewable resources have piqued the interest of academic and industrial researchers as a possible replacement for petroleum-based polymers. The extensive use of fossil resources and reliance on them is becoming a problem in the polymer industry as a result of the challenges posed by the rapid depletion of fossil resources, regular price fluctuations, and rising demand for sustainable materials (Hastenreiter et al., 2020).

According to Zai (1988) state that, In agricultural applications, synthetic polymers are important as structural materials for creating an environment favourable to plant growth, such as mulches, shelters, or greenhouses, for fumigation and irrigation, and for transporting and regulating water distribution. Nevertheless, the primary necessity in the polymers used in these applications is their physical properties as inert materials, such as transmission, flexibility, permeability, or weatherability, rather than as active molecules.

A restriction change toward plastics characterizes the automobile industry. Thermoplastics have a wider variety of uses. In the thermoplastic classification, Nylon66 is a leaf. The materials used to make gears, sprocket wheels, chains, and other rotating spares determine by their strength and service conditions such as wear and noise. Because of its strong wear properties, excellent machinability, and ease of producing complicated shapes by casting process, cast iron and steels are widely used to manufacture rotating spares. Weight reduction can accomplish mainly using quality materials, design optimization, and improved manufacturing processes. Plastic materials are corrosion resistant, have low electrical and thermal conductivity, can be easily molded into complex forms, and come in various appearances, colors, and transparencies (Version et al., 2014).

2.2.6 Biopolymer

Biopolymers, which are polymeric substances formed by living organisms, have recently gained attention in research due to their unique properties (Macgregor, 2013) . In a simple word, they are polymeric biomolecules (Pattanashetti et al., 2017). Moreover, Biopolymers are chain-like molecules composed of repeating chemical blocks derived from renewable resources that can degrade in the environment (Macgregor, 2013).

According to Pattanashetti (2017) state that, Biopolymers perform an astounding variety of roles in our bodies. They connect cells to form tissues, send subtle chemical signals to cells to direct their behaviour, assist in maintaining the hydration and elasticity of the skin, and protect us from infection by forming the mucus gel that covers our eyes and respiratory tract. As a result, these biopolymers exhibit critical characteristics such as biodegradability, biocompatibility, and antimicrobial activity. Additionally, biopolymers have chemical structures and compositions that are very similar to those of macromolecules. As a result, it can be found outside the cell.

When used in situations where functionality and value are added, biopolymers have unrivalled advantages over conventional plastics. The use of these materials in living systems may mitigate the chronic inflammation, immunological reactions, and toxicity associated with the implantation of a synthetic polymer device into the host. Furthermore, chemically modified biopolymers can provide the necessary mechanical and electrical properties for specific applications (Pattanashetti et al., 2017).

2.2.6.1 Application of Biopolymer

Biopolymers can be categorized differently depending on the scale used. As shown in Figure 6, three forms of biopolymers can be differentiated based on their origin: natural, synthetic, and microbial biopolymer (Macgregor, 2013).

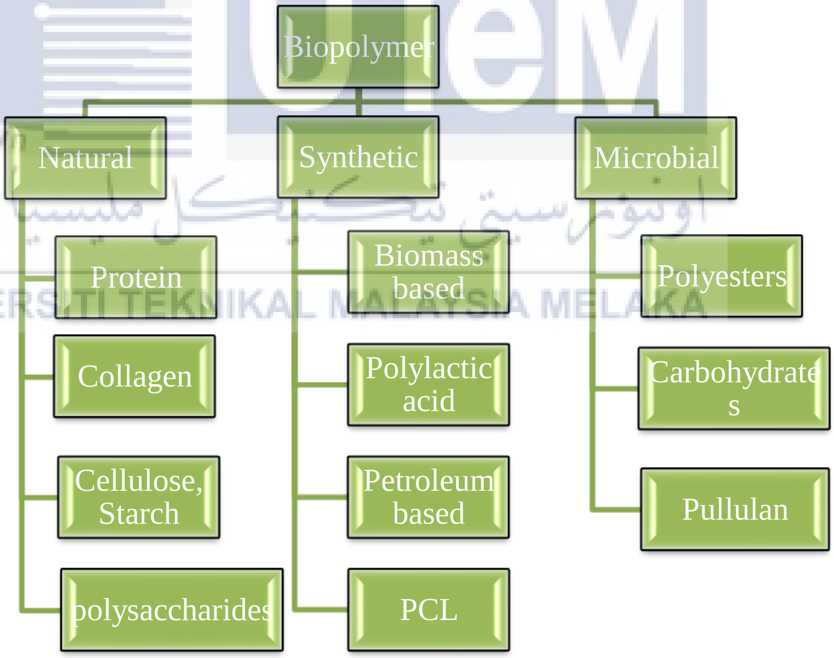


Figure 2.6 : Classification of biopolymers according to their origin (Macgregor, 2013)

2.3 Composite

A common composite material, known as a composition material. Hence, composite is a substance system made up of two or more constituent substances with significantly different physical or chemical properties when combined, can produce a substance with properties distinct from the individual components (Nagavally 2017).

According to Nagavally (2017) state that, a composite material is made up of reinforcementth at are embedded in a matrix. The reinforcement is retained by the matrix in order to form the desired shape, and the reinforcement improves the matrix's overall mechanical properties. If properly designed, the new composite material will outperform each material in terms of strength.

Composite materials are composed of reinforcement, a strong load-bearing material, and matrix, a weaker material. Reinforcement adds stiffness and strength to the structure, assisting in the support of structural loads. While composite materials retain their distinct identities, their properties are still related to the end product produced by their mixture. When compared to bulk materials, the primary advantages of composite materials are their high strength and stiffness combined with their low density, which enables weight savings in the finished part (Maha, 2017).

2.3.1 Classification of Composite

Composite materials are classified into two categories based on their composition: base material and reinforcement. Reinforcement is provided by natural or synthetic fillers, particles, fibres, or whiskers. The matrix is the base material that binds or retains the filler material in structure (Uygunoglu et al., 2015).

As illustrated in Figure 7, there are three major categories of composite materials: polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs), all of which are widely used in a variety of engineering applications. Depending on the type of reinforcement, composite materials can be classified as particulate composites, fiber-reinforced composites, or sheet moulded (Ibrahim et al., 2015).

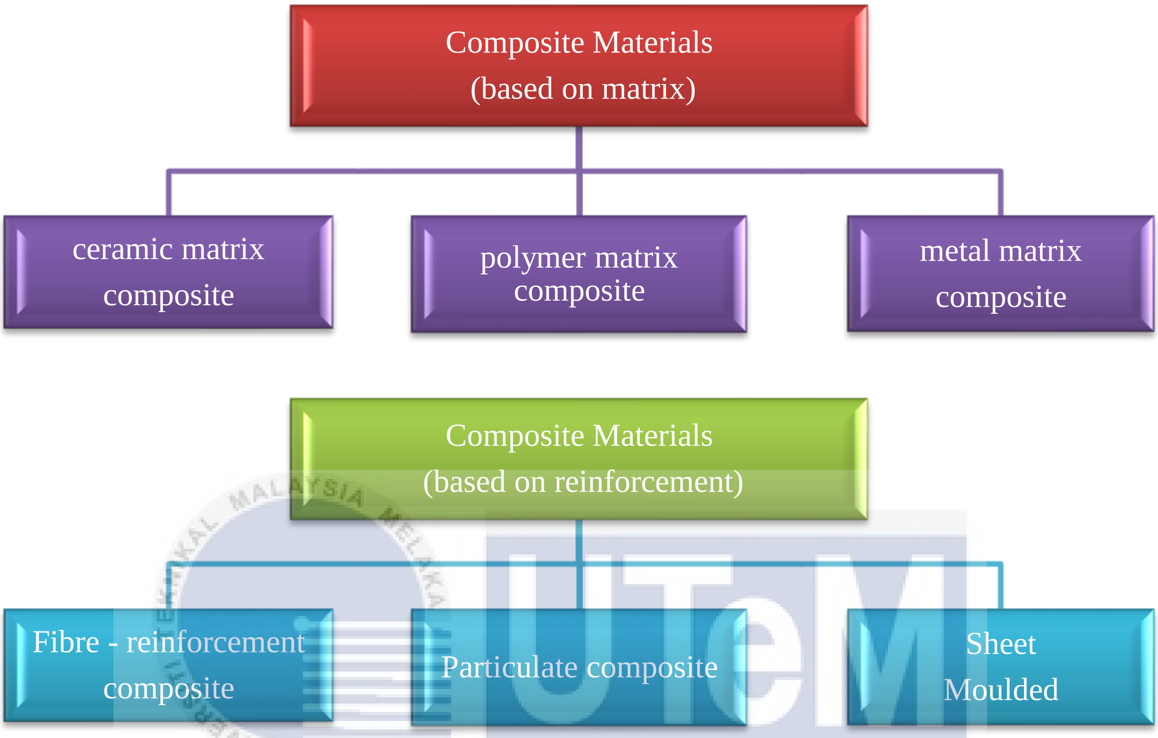


Figure 2.7 : Classification of composite materials (Ibrahim et al., 2015)

As illustrated in Figure 8: particle reinforced, fibre reinforced, and sheet moulded. Fiber Reinforced Composites (FRP) can be classified according to whether the fibres are discontinuous or continuous. Fiber Reinforced Composites are composite materials that contain fibres embedded within the matrix material. If the properties of the composite vary with the fibre length, it is referred to as a discontinuous fibre or short fibre composite.

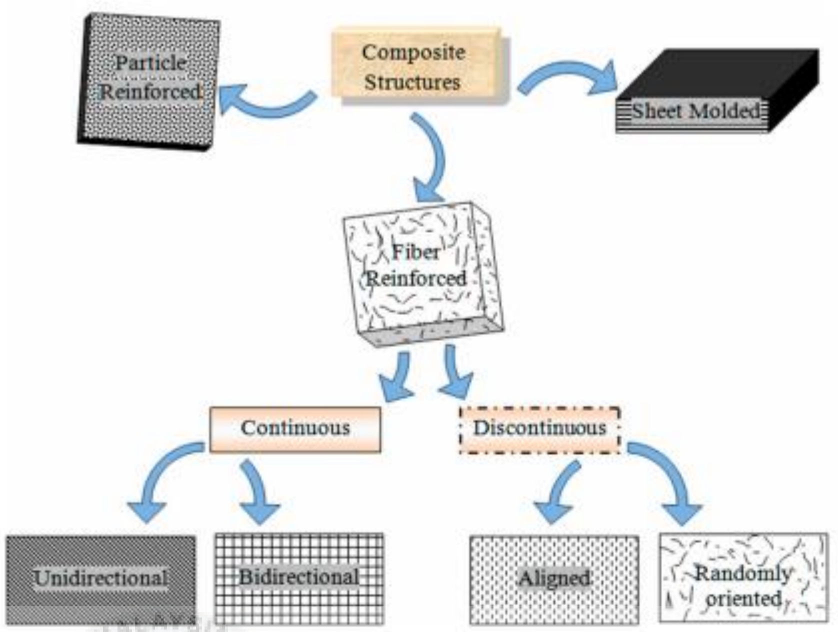


Figure 2.8 : Classification of composites structure (Rajak 2019)

2.3.2 Polymer Matrix Composite (PMC)

Polymer Matrix Composite contains a polymer (resin) matrix and a fibrous reinforcing dispersed phase. According to Yashas Gowda (2018), Polymer matrix composites (PMC) are made up of a variety of organic polymers containing short or continuous fibers and a variety of reinforcing agents, allowing them to enhance properties including fracture toughness and high tensile strength.

The matrix materials for composites are a diverse range of thermosetting and thermoplastic polymeric materials. The following table summarises several of the major advantages and disadvantages of resin matrices (Agarwal 2010).

Table 2.3: Advantages and limitations of polymer matrix composite (Agarwal 2010)

Advantages	**Limitations**
Low densities	Low transverse strength
Good corrosion resistance	Low operational temperature limits usually
Thermal conductivities that are inadequate	
Electrical conductivities are low	

Polymer Matrices Composites are frequently chosen due to their strength properties, heat resistance, chemical and moisture resistance, and other properties. The mechanical strength of the resin must be equal to that of the reinforcements. It must be simple to operate in the fabrication process chosen and able to withstand service conditions. Additionally, the resin matrix must be capable of wetting and penetrating the fibre bundles, reinforcing them, eliminating dead air spaces, and imparting physical properties that improve fibre performance (Agarwal 2010).

Polymer matrix composites (PMCs) primarily use in the aerospace industry. However, the decrement in the price of carbon fibers with time and the developments of low-cost reinforcement such as natural fiber have increased the applications of these composites in the area of automobile, marine, sports, biomedical, construction, and other industries also (Chauhan & Kumar Bhushan, 2017). PMC materials in the sectors applications reinforce with continuous or discontinuous carbon or glass fibers. The composition of these materials proves the light in weight of the component produced (N. Gupta & Doddamani, 2018).

2.3.3 Application of Composite

The growth of composite applications is due to several factors, the most important of which is that composite-fabricated products are more robust and lighter. Nowadays, it isn't easy to find any industry that does not benefit from composite materials. Technology and its requirements have changed over the last three to four decades. Many new needs and opportunities have arisen because of the changing environment, which can only meet by advancements in new materials and related manufacturing technologies. Several advanced manufacturing technologies and material systems have been introduced in the last decade to meet the needs of various market segments.

Composite dominantly use in the aerospace industry, transportation, construction, marine goods, sporting goods, and more recently infrastructure, with construction and transport being the largest. In general, high-performance but more costly continuous-carbon-fiber composites are used (Weber et al., 1987).

Generally, the invention of composites commonly used in the aerospace industry. Due to, the properties of the composite element are lighter, and it is suitable for making helicopters, small, military fighter aircraft, satellites, and vehicles. A variety of aircraft components made from composites such as spoilers, airbrakes, elevators, turbine engine fan blades, propellers, rear bulkhead, wing ribs, main wings, and others (Gupta et al., 2016).

2.4 Fiber

According to Fiore (2014) state that, fibers reinforce the matrix as the primary source of strength in composite material. Fiberglass has a high strength-to-weight ratio and a variety of exceptional properties, including high durability, stiffness, damping properties, flexural strength, corrosion resistance, wear resistance, impact resistance, and resistance to fire (

Menezes, et al., 2019). Fibers can classify into two categories which are natural fiber and synthetic fiber. Figure 9 shows that the classification of fiber.

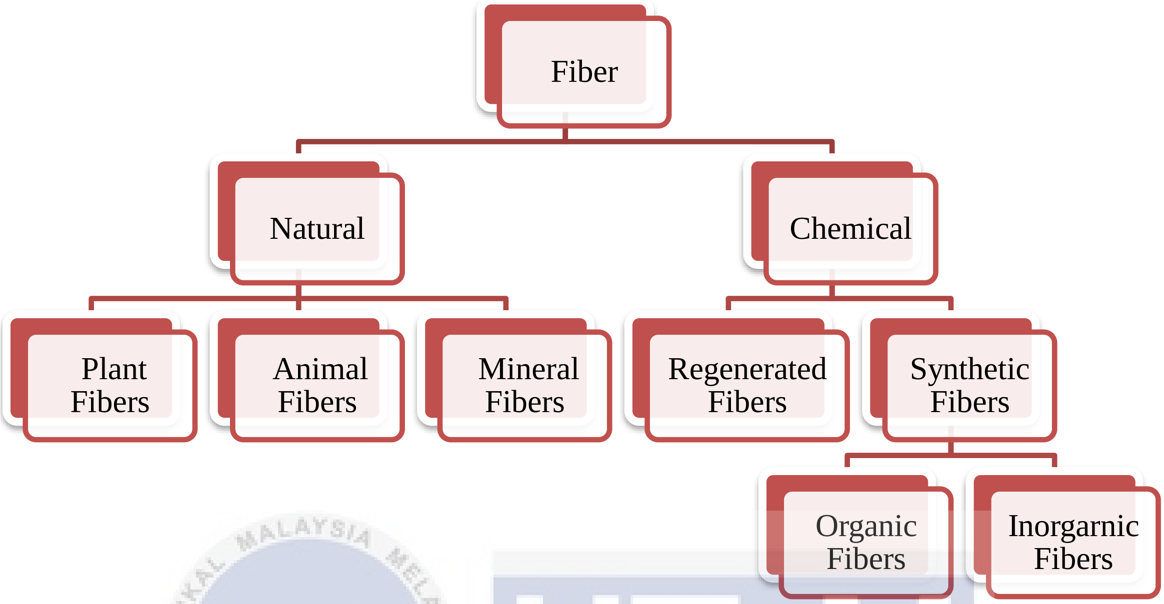


Figure 2.9 : Classification of Fiber (Menezes, et al., 2019)

2.4.1 Natural Fiber

The term "natural fiber" or reinforcements covers a broad range of vegetable, animal, and mineral fiber. The natural fiber is a new generation of reinforcements and supplements for polymer-based materials made from renewable sources (Ho 2012) . Due to increasing environmental consciousness, natural fiber composite materials or environmentally friendly composites have become a hot topic recently.

Natural fiber-reinforced polymer composites and resins derived from natural sources are increasingly being used in place of synthetic and glass fibre reinforced materials. Thus, the automotive and aerospace industries have been actively developing various types of natural fibres, primarily hemp, flax, and sisal, as well as bio-resin systems, for their interior components. Natural fiber composites appeal to different applications due to their high specific properties and low prices (Sanjay 2016).

According to Rajak (2019) state that, Natural fiber is one of the most common materials in industry because of its biodegradability, high strength, necessary stiffness, and low cost per unit volume. Natural fiber aids in weight reduction, toxicity reduction, environmental pollution reduction, cost reduction, and recycling. Natural fiber appears to be more prevalent than synthetic fiber due to these characteristics.

There are plenty of natural fibers that have been used in the research community to probe the availability of natural fibers and how they can use in the industry. Banana, bamboo, coir, cotton, flax, hemp, jute, kenaf, pineapple, ramie, and sisal are examples of natural fibers. All these examples of natural fibers are examples of standard fibers used in industry. Table 4 below explain detail about the type of natural fiber with detail description.

Table 2.4: Summary of Natural Fibers characteristics

Fiber	**Description**
Banana/ Abaca	Abaca, also called manila hemp, is a closely related plant to the banana. While the abaca plant resembles the banana, unlike the banana, its fruit is not suitable for human consumption due to its economic viability. Unlike bananas, abaca grows solely for the purpose of producing fibre.
Bamboo	Bamboo is a fast-growing plant that requires little water and is harvested at the base, leaving the root intact. Bamboo is a cylinder-shaped plant with a smooth fibre surface. Furthermore, it is more rigid and stronger than glass fibre.
Coir	Coir is appealing because it is more durable than most natural fibres, is chemical-free, has a high resistance to salt water, and is widely available.
Cotton	Cotton fiber has an excellent absorbency.
Hemp	Hemp fibre is extremely strong mechanically and has a high Young's modulus.
Jute	Has good insulation properties, a high aspect ratio, and a high strength-to-weight ratio.
Kenaf	Has low density and high specific mechanical properties.
Pineapple	Has excellent mechanical, physical and thermal properties
Sisal	An easy-to-grow plant with quick renewal times. The fibre has a high tensile strength and tensile intensity, as well as abrasion resistance, saltwater resistance, and acid and alkali resistance..

Figure 2.10 : Example of Natural fiber plants (Sanjay et al., 2016)

Natural fibers can classify according to their origin. Natural fibers are available from different sources and varieties. For instance, plant, animal, and mineral sources Fibers form hair-like material that comes in either continuous filaments or discrete elongated parts, like a thread. It is possible to spin them into filaments, lines, or rope. They can use in composite materials as a part. They can also be matted into sheets to create items like paper and felt. Figure 11 shows the classification of natural fibers (Bongarde & Shinde, 2014).

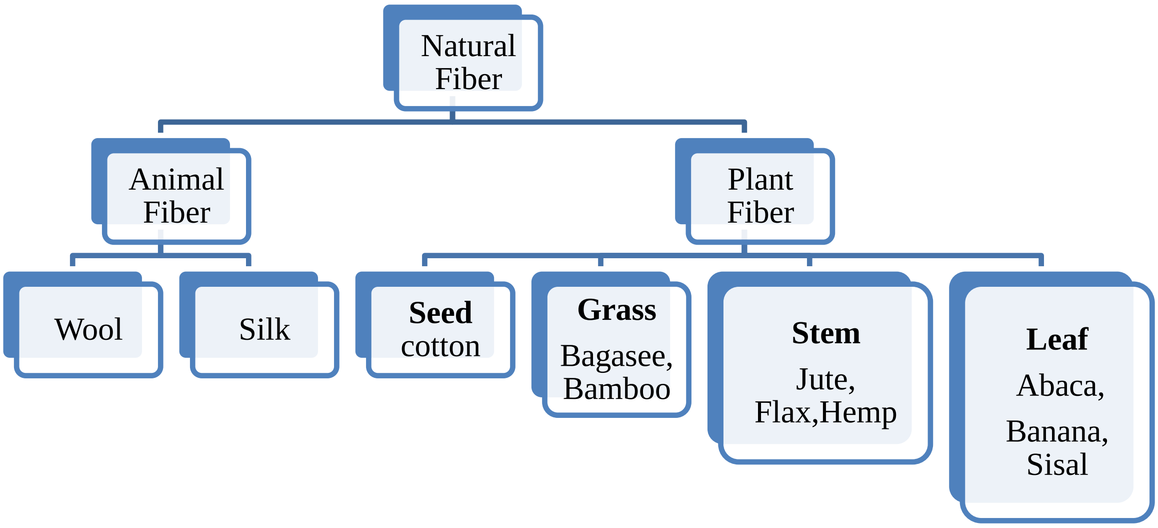


Figure 2.11 : Classification of natural fibers(Bongarde & Shinde, 2014)

Table 2.5 : advantages and disadvantages of natural fibers

Advantages	**Disadvantages**
Lightweight	Flammable
Recyclable	Dimensional instability
Improved specified mechanical properties.	High moisture absorption
Eco – friendly	Anisotropic behavior
Good thermal properties	Sensitive to UV
Good acoustic properties	Fugal attack and microbial
Low cost, availability	Low strength than synthetic fiber

2.4.2 Synthetic Fiber

The terms "man-made fibres" and "synthetic fibres" are frequently used interchangeably to refer to all non-natural fibres (Morgan, 1981). Synthetic fiber, also known as human-made fiber, is created by chemical synthesis and graded as organic or inorganic based on its material. The fiber material has a higher stiffness and strength than the matrix material (Kumar, et al., 2019).

Synthetic fibres are composed entirely of polymers that do not exist in nature and are produced in the laboratory, most frequently from petroleum byproducts. Synthetic fibres are composed of a variety of compounds, each of which possesses unique qualities. These polymers are used to manufacture nylon, polyesters, acrylics, and polyurethanes, among other fibres. Synthetic fibres are stronger and last longer than natural fibres. The three most often utilised synthetic fibres in the composites sector are Kevlar (aramid), carbon, and glass fibres, as shown in Figure 2.12 (Asim 2017).

Figure 2.12 : (A) glass fibers, (B) Kevlar fibers, and (C) carbon fibers (Asim 2017)

2.4.3 Comparison between natural and synthetic fibers

Table 2.6 : Comparison between natural and synthetic fibers

Criteria	Synthetic Fiber	Natural Fiber
Density	High	Low
Structure of Fiber	Can be modified.	Cannot be modified.
Nature	Hydrophobic	Hydrophilic
Durability, Usage and Cost	High	Low
Renewable and Recyclable	No	Yes
Biodegradability	No	Yes
Specific strength and Modulus	Low	High
Strength and Modulus	High	Low

2.5 Coconut Leaf

2.5.1 Coconut

In 2014, (Das & Biswas) published a paper in which they described Cocoanut is another name for the coconut palm. Cocos nucifera belongs to the palm family Arecaceae. In addition, according to Rana (2015) state that coconut palm is the only species recognized in the genus Cocos and it is a large palm with pinnate leaves 4-6 m long and pinnae 60-90 cm long and it consists old leaves break away cleanly, leaving the trunk smooth. It grows to 30 m tall and has a diameter of 60-70 cm. Furthermore, the coconut (Cocos nucifera L.) was introduced to a breeding programmed based on characteristics of the fruit and vegetative parts from different parts of the world by Spaniards in the 16th century (Zaremba & Smoleński, 2000).

Figure 2.13 : Cocos nucifera (Lima et al., 2015)

2.5.2 Coconut Leaf

According to Deepak & Jnanesh (2016) state that, coconut leaf residues are abundant in Karnataka because they are one of the cash crops grown. It is estimated that approximately 12 million people in India rely on the coconut sector in terms of cultivation, processing, and trading. Coconut contributes approximately 15,000 crores rupees to the nation's GDP with an annual production of around 21,892 million nuts. In addition, The Coconut (Cocos nucifera) is a benevolent tree, a gift from nature to mankind. The coconut tree provides clothing, utensils, and shelter, and thus is an important source of income for the people of coconut-growing states.

2.5.3 Characteristic of Coconut Leaf

According to an investigation by author Pestaño & Jose (2016) , In Malaysia, coconut leaves are a readily available biomass source. Coconut shells and leaves are generated as a result of coconut's use in the food industry. Coconut leaves are high in lignin and can be used in place of wood as a source of activated carbon. Cocoanut leaves contain approximately 38.7% lignin, which is more than the lignin content of coconut sheath (29.7%).

Moreover, the research study by Pestaño & Jose (2016) also found that the coconut leaf is one of the largest in the plant world. It is 6.1 m long on average and weighs 2.65 kg air-dry. Hence, the average amount of fallen leaves per hectare is 2507 per year. The petiole accounts for 91% of the leaf and is commonly used as fuel for cooking in villages. The leaf blade accounts for 7% of the total leaf weight, while the midribs account for 2%. The petiole (10% moisture) in one leaf weighs 2.17 kg dry.

Figure 2.14 : Coconut Leaf (Deepak & Jnanesh, 2016)

2.5.4 Coconut Leaf Fiber

Based on the previous study by Hemashree & Bhat (2017) state that, coconut leaves consist fiber content which is made up of the chemical compound’s cellulose, hemicelluloses, and lignin. Moreover, the primary constituents of biomass vary according to its type. In general, hemicellulose, and lignin make up 40%–60%, 20%–40%, and 10%–25% of the dry coconut leaf fibre, respectively (I. M. Rajendra et al., 2019).

Apart from that, according to Jishnu et al., (2019) state that, the characteristic behaviour of coconut leaves varies by country, season, and species. The coconut leaf's cellulose and lignin content contribute to its strength. Several studies have already been conducted over the last decade to investigate the mechanical behaviour of reinforced sandy soil under triaxial conditions.

In addition, I. M. Rajendra (2019) also found that, Thermal properties of cellulose, hemicellulose, and lignin are also known. Due to, the complexity of biomass conversion determines the variety of products, each composer's conversion must be investigated separately. Appropriate knowledge of the pyrolysis features of those three main components enables a better understanding of chemical conversion and thermal biomass conversion, which simplifies the selection of the most appropriate biomass sources and pyrolysis technique to achieve a desired products.

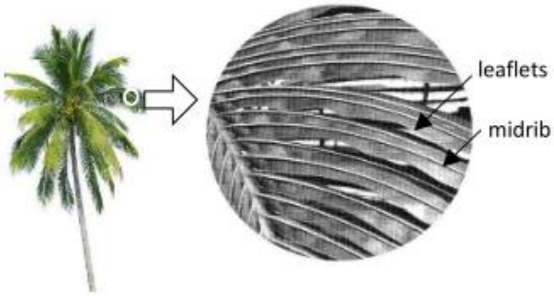


Figure 2.15 : Parts of Coconut Leaves (I. M. Rajendra et al., 2019)

According to this study, the structure of cellulose was determined using an extraction method consistent with ASTM D1107-96, and the composition of lignin, cellulose, and ash was defined utilising ASTM D1103-60, ASTM D1106-56, and ASTM D1102-84, respectively. To obtain a high validity value, a cellulose, hemicellulose, lignin, and ash evaporation was tested three times in a single sample and the results were averaged. Table 2.7 summarises the testing results (I. M. Rajendra et al., 2019).

Table 2.7 : Composition of dry biomass (I. M. Rajendra et al., 2019)

Leaf Part	**Cellulose**	**Hemicellulose**	**Lignin**
Leaflets	45.58	10.35	39.64
Midrib	60.75	11.42	22.10
Whole Leaf	56.71	10.66	28.44
Coconut Leaf	59.39	8.45	27.97

2.5.5 Coconut Leaf Composite

A study that have been carried out by Sulaiman (2016) state that, coconut leaves were used to generate activated porous carbon to be used as an electrode material in EDLCs. hence, CO2 was used as an activator in the preparation of activated carbon from coconut leaves, with varying temperatures of activation. The structure, morphology, and porous properties of CLACs were investigated. Additionally, coconut leaves were thermally analysed with a TGA. Then, the particle morphology was examined using field emission scanning electron microscopy (FESEM) (Sulaiman et al., 2016).

2.5.5.1 Field emission scanning electron microscopy (FESEM)

The morphology of coconut leaves, carbonised coconut leaves, and activated carbon were examined using FESEM. In Figures 15a and 15b, the surface morphology of coconut leaves was studied using FESEM. As seen by the micrographs, coconut leaves have a rough surface with some fractures and gaps. Additionally, the visible wood-grain pattern on the surface of the coconut leaves is a lignocellulosic material property. By contrast, as demonstrated in Figure 16, the surface of carbonised coconut leaves is devoid of lignocellulosic structures. Apart from that, activated carbon exhibited a spherical morphology with a foam-like structure, as seen in Figure 2.16 (Sulaiman 2016).

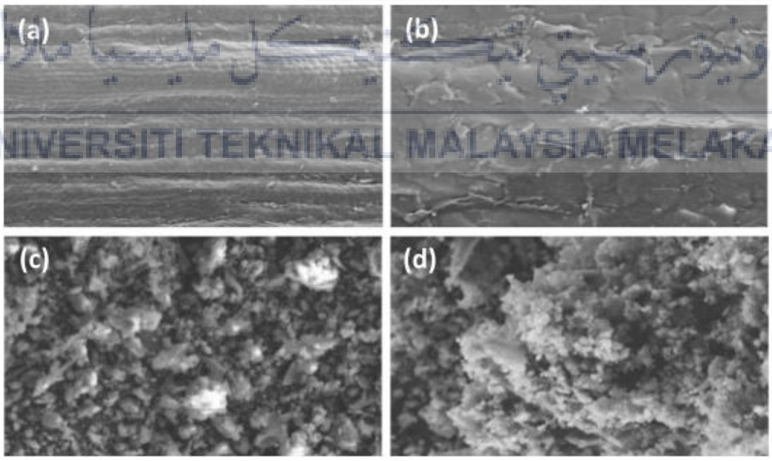


Figure 2.16 : FESEM image of coconut leaves (Sulaiman 2016)

2.5.5.2 Thermogravimetric analysis

Figure 2.17 illustrates the thermal breakdown of these compounds. Coconut leaves disintegrate at temperatures below 110°C owing to the corruption of any moisture or loosely bound water molecules associated with them; at temperatures above 110°C, the coconut leaf degrades due to the corruption of any moisture or loosely bound water molecules associated with them. Between 200 and 400°C, around 50% of weight loss occurs, which may be attributable to the breakdown of hemicelluloses and cellulose. Between 400 and 550°C, approximately 35% of the weight is lost as a result of lignin degradation. Thus, activated carbons synthesised from coconut leaves undergo a single breakdown process between 300 and 650°C, indicating the absence of loosely coupled water molecules. Weight loss happens as a result of hemicellulose and cellulose decomposition, as well as lignin degradation (Hemashree & Bhat, 2017).

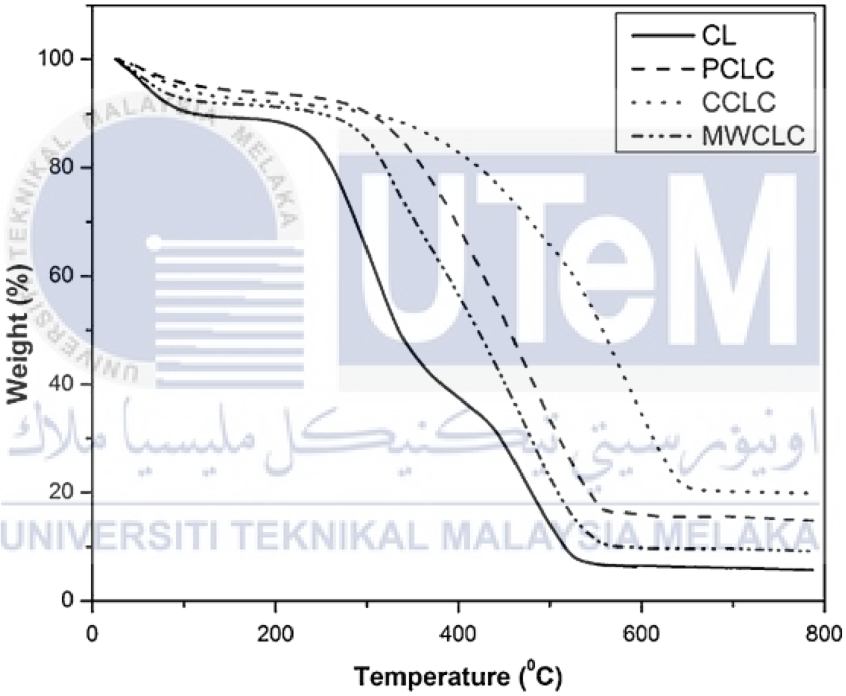


Figure 2.17 : TGA curves for coconut leaves (Hemashree & Bhat, 2017)

2.5.5.3 X ray diffraction (XRD)

The structural characteristics of coconut leaves, carbonised coconut leaves, and activated coconut leaves were investigated using X-ray powder diffraction. The XRD patterns of carbonised coconut leaves for b and activated carbon from 2=10 to 80° for c are shown in Figure 18. Coconut leaves contain two diffraction peaks at 16.28° and 22.18° that correspond to the crystalline structure of cellulose I, or native cellulose (Sulaiman 2016).

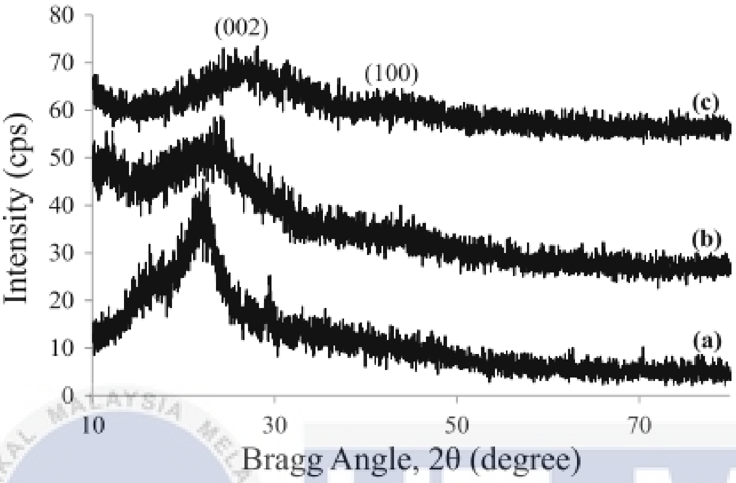


Figure 2.18 : XRD Pattern of a Coconut Leaves (Sulaiman 2016)

2.5.6 Application of Coconut Leaf

According to Gopal (2017) found that, there are numerous uses for coconut leaf fibre that benefit the user. Numerous enterprises utilise the waste of the coconut plant and convert it to fibre, which may then be used to create usable products. The coconut palm is referred to as 'Kalpavriksha,' which translates as 'the tree that contains everything necessary for existence. Each portion of the coconut is useful for something, whether it be food and beverage, medicine, cosmetics, industrial raw material, construction material, or cultural and religious functions. These arguments, however, just scratch the surface of the benefits that the coconut palm affords people, most notably in terms of food and money. The broader and more significant element of coconut cultivation is that it delivers not just financial benefits, but also conservation benefits, such as ecosystem services.

Apart from that, coconut leaves are frequently used to build brooms, temporary roofs, or are tossed and flared in farms, contributing to environmental pollution (Deepak & Jnanesh, 2016). Hence, Coconut leaves are also used to construct ketupat, which is a woven wrap made from two sections of young coconut leaf. It is preferable to use young leaves because they are more pliable and readily moulded (Rianti et al., 2018)

Figure 2.19 : The diamond shape of ketupat (Rianti et al., 2018)

2.6 Starch

Starch was the most affordable and abundant food biopolymer available anywhere on the planet. The starch content of food goods is the most essential factor in determining their overall quality (Mohamad Yazid et al., 2018). Additionally, starch is a critical biopolymer found in nature, with applications in both food and non-food industries. It is the most extensively used method of storing energy in plants. It is found in leaves, flowers, fruits, seeds, and many sorts of stems and roots, and accounts for between 70% and 80% of all calories consumed globally by humans. (Yoo, 2001). Hence, the majority of commercially accessible starches come from grains and tubers such as potato and tapioca. These cereals and tubers have a high starch content, often between 60% and 90% by dry weight. Tapioca and rice grow well in tropical regions, but corn, wheat, and potatoes grow well in cooler climates. Cereal and tuber starches have markedly different physical properties and application suitability (Shogren, 1998).

According to Alcázar-Alay & Meireles, (2015) state that, glucose molecules generated during photosynthesis in plant cells are a necessary component of the metabolic process that results in starch production. The chloroplasts of green leaves and the amyloplasts of tubers and cereals synthesise starch. The functioning of starch is largely owing to the presence of two high-molecular-weight components: amylose and amylopectin. The majority of starches include between 20% and 30% amylose, whereas amylopectin contains between 70% and 80%, depending on the source plant. Amylose molecules are made up of between 200 and 20,000 glucose units connected by 1,4 glycoside linkages in unbranched chains or coiled helixes, as illustrated in Figure 2.20 while Table 2.8 shows the ratio of amylose/amylopectin of different starches, depending on their source.

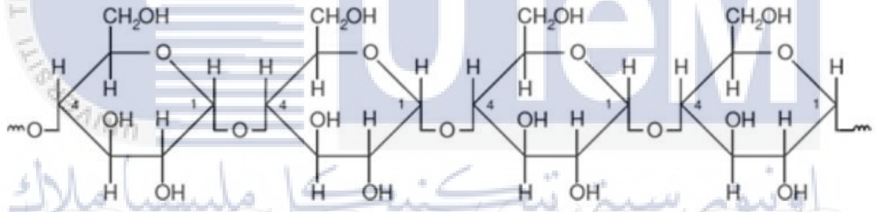


Figure 2.20 : Segment of an amylose molecule(Canyon Hydro et al., 2013)

Amylopectin's structure is clearly different from that of amylose as shown in Figure 21, amylopectin molecules contain glycosidic linkages of 1,4 and 1,6. The amylopectin chain has glycosidic linkages that connect the glucose molecules. Branches of the main chain are frequently found due to the 1,6 glycosidic interactions with additional glucose molecules. (Canyon Hydro et al., 2013).

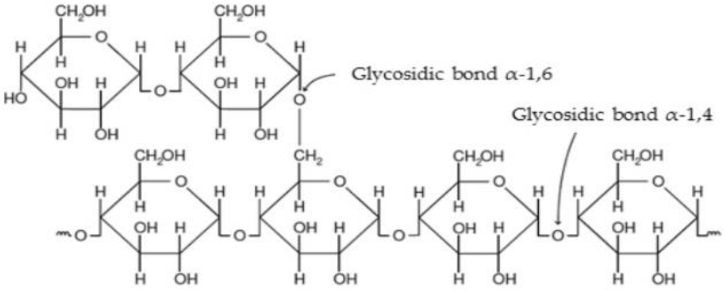


Figure 2.21 : segment of an amylopectin molecule (Canyon Hydro et al., 2013)

Table 2.8 : Contents of amylose and amylopectin (%) in starches derived from various sources (Muller et al., 2017)

Starch	**Amylose (%)**	**Amylopectin (%)**
Wheat	30	70
Corn	28	72
Potato	20	80
Rice	20 - 30	70 – 80
Cassava	16	84

2.7 Thermoplastic Starch

Thermoplastic starch is semi-crystalline substance consisting of restructured starch and one or more plasticizers. Hence, thermoplastic starch can be repeatedly softened and toughened, allowing it to be formed using common plastic industry techniques (Carvalho, 2008).

According to Canyon Hydro (2013) state that, a high water or plasticizer content, such as glycerol or sorbitol, is required to produce a starch-based film. Thermoplastic starches are materials that have been plasticized (through the use of mechanical and thermal energy). Thermoplastic starch is a new material for use as a biodegradable plastic, but it is one of the most extensively researched polymers in this field today. (Curvelo et al., 2001). Hence, the implementation and development of thermoplastic starch (TPS) are viewed as critical components of the effort to reduce total plastic waste (Ma & Yu, 2004).

Thermoplastic starch is a material created by the structural disruption (modification) that occurs inside the starch granule (Canyon Hydro et al., 2013). The techniques that have been used to process starch - based materials, such as extrusion, injection molding and film casting, are similar to those widely used in conventional polymers. However, it is important to note that, although starch processing is difficult, it is possible to achieve success if an effective formulation is formulated and adequate processing conditions are created (Liu et al., 2009).

2.7.1 Polymerization of Starch

Starch has a carbon, hydrogen, and oxygen ratio of 6:10:5 (C6H10O5), indicating that it is a carbohydrate chemical molecule. As a result, starch is a type of organic carbohydrate. Because starch has links between the glucose units generated during condensation, it is classed as a glucose polymer. By joining the carbon atom 1 of one glucose unit with the carbon atom 4 of the next glucose unit, an oxygen atom joins the glucose units. As a result, a lengthy chain of glucose units is formed. The glycoside bond is the connection between two glucose units via the C-1 oxygen atom (Nafchi et al., 2013).

According to Castillo et al., (2019) state that starch became plasticized as a result of the application of shear fields and the addition of plasticizers (polyols as the conventional additives). Glycerol acts as a plasticizer, enhancing the final characteristics of starch-based products. As a result, amylose and amylopectin are two different forms of polysaccharides that contribute to the starch granular structure. Due to the disturbance of the granular structure, part of the carbohydrate polymer molecules are replaced by amylose chains during the starch transformation. Thermoplasticization of starch entails a number of chemical reactions, including deconstruction, fragmentation, melting, and plasticization..

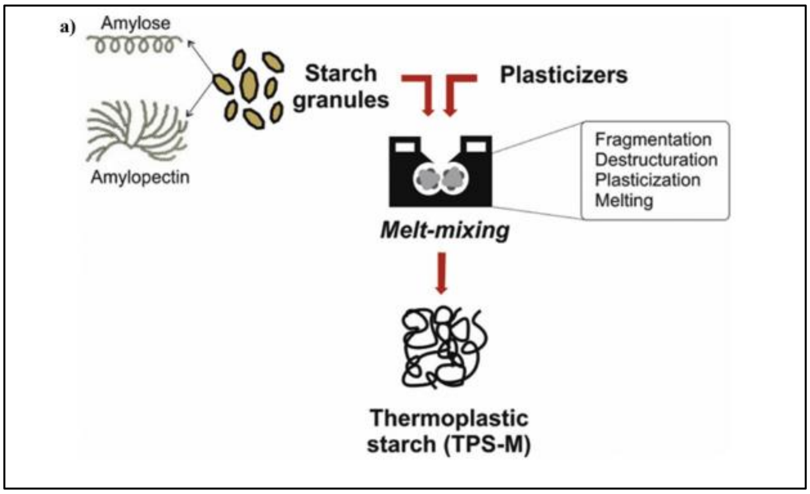


Figure 2.22 : Starch thermal processing melt-mixing (Castillo et al., 2019)

2.7.2 Thermoplastic Potato Starch

Zhang (2020) state that potatoes are a globally farmed carbohydrate crop. Global potato production was 388 million tonnes in 2017 and is likely to continue growing in the future. According to Bolcu & Stănescu, (2020) state that potato starch possesses a few unique properties that contribute to its molecular structure and granularity, which set it apart from other starches. There are several characteristics, including the granule's large and smooth structure, a considerable number of covalently bonded phosphate, a high molecular weight of amylose, and a long chain of amylopectin. As a result, amylopectin is a subtype of amylopectin. Additionally, the diameter of starch granules varies between 10 and 100 metres. It is composed of two polysaccharides, with glucose as the monomer. The glucopyranosyl residue is connected via -D-(1,4)-linkages chains and via -D-(1,6)-branches found at the reducing end side linked similarly to the other chains. Generally, the primary component of starches is amylopectin, which accounts for around 70% to 80% of the weight of the granules. Amylose is a minor component of starch and is significantly smaller in size than amylopectin.A study has been carried out to evaluate the functional properties of the native potato. The researcher used differential scanning calirometry (DSC), morphologic analysis by scanning electron microscopy (SEM), thermogravimetric analysis (TGA), X-ray diffraction (XRD), and rapid viscoamylograph analysis to perform thermal analysis (RVA). The humidity content, ash content, fiber content, fat quantity, and protein quantity were all determined using the proximal analysis. The potato starch extraction is the main raw material used in this analysis, and it is extracted using the conventional method. The outcome of proximal analysis is shown in Table 2.9 below (Velásquez Herrera et al., 2017).

Table 2.9 : Physicochemical properties of potato starch (Velásquez Herrera et al., 2017)

component	**%**	**Standard deviation**	**Coefficient of variation**
Fat	5.48	0.21	0.04
Ash	0.29	0.13	0.45
moisture	18.81	0.05	0.00
fiber	0.16	0.01	0.04
Protein	2.38	-	-
Carbohydrates	72.88	-	-

The result obtained in morphologic analysis is shown in Figure 2.23. Figure 2.23 shows the starch structure or starch granule of potato starch by sections. The left side of the figure shows the equatorial perspective micrograph while the right side shows the transversal perspective.

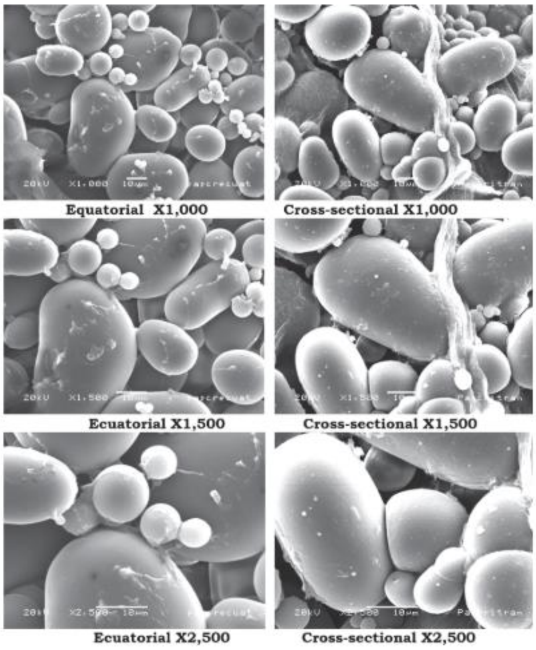


Figure 2.23 : Micrographs of potato starch (Velásquez Herrera et al., 2017)

Figure 2.24 shows the result that obtained from thermogravimetric analysis (TGA). The sample is shown in the figure without any water material (9.46 %). The sample then degrades by a significant percentage (68.40 %) at the second stage due to the temperature period with the highest degree of degradation. The other portion (21.13 %) is burned in the third level, when it is recombined with the inorganic material at a high temperature. As a result, it can be assumed that potato starch can preserve its structure at high temperatures which it is suitable to be used as thickener in cooking process. Potato starch also suitable to be used in packaging industry due to its low water absorption which it can be act as biodegradable polymer (Velásquez Herrera et al., 2017).

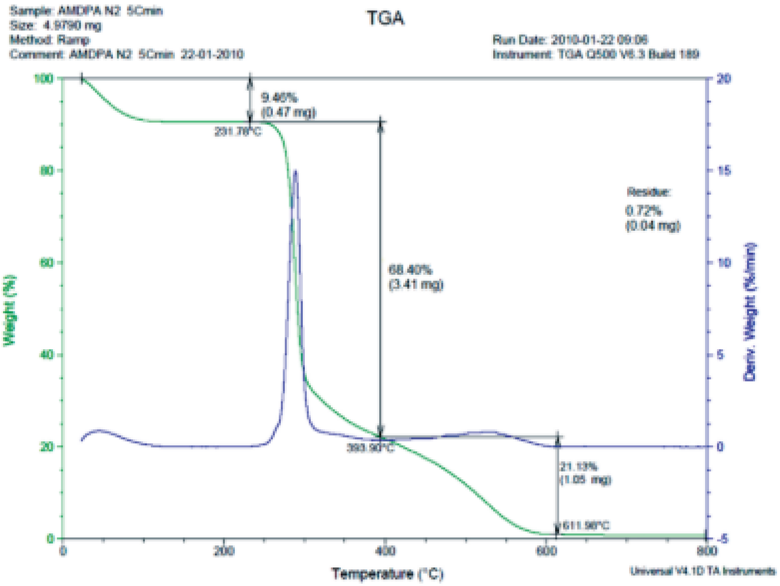


Figure 2.24 : Thermogravimetric analysis (TGA) (Velásquez Herrera et al., 2017)

2.7.3 Thermoplastic Cassava Starch

Cassava starch's functional qualities allow it to be employed in a wide range of food and industrial applications because of its versatility. A great deal more research is needed to fill in the gaps in our understanding of this starch's fundamental features. This is especially true for its varietal makeup and functional qualities, which are now under investigation. (Wheatley et al., 2003). Hence, cassava, often known as tapioca, manioc, or yuca, is a perennial woody shrub with tuberous roots belonging to the Euphorbiaceous family. As a result, it originated in South America and is now widely produced throughout Asia, Africa, and Latin America's tropical and subtropical regions as the third most important source of calories in the tropics, after rice and maize (Zhu, 2015).

Additionally, cassava is a staple food for over 800 million people globally, serving as the third largest carbohydrate source in tropical countries, behind rice and corn. Due to its ability to be left in the field for up to two years before harvesting, cassava is referred to as a food security crop. Although it is typically ingested raw, it is processed into a range of food and non-food products, including starch, flour, animal feeds, and textiles (Hasmadi et al., 2020).

According to Gunorubon & Kekpugile, (2012) state that, cassava starch was cross-linked using four different chemicals to achieve the desired results. A comparison was made between the modified starch and the native cassava starch in terms of functional qualities. As one of the crops that transforms the most solar energy per unit area into soluble carbohydrates, cassava is one of the most efficient. With roughly 40% more carbs per acre than rice and 25% more carbohydrates than maize, cassava is the most cost-effective source of calories for both human and animal nutrition. The cassava root's normal makeup is moisture (70 %), starch (24 %), fibre (2 %), protein (1 %), and other components, such as minerals, in addition to other nutrients (3 %)(Tonukari, 2004).

2.7.3.1 Starch Extraction Process

Cassava starch was primarily provided through the milling of fresh cassava. The extraction of starch from fresh cassava tuber was carried out in the manner depicted in Figure 23. When harvesting or selecting cassava tuber for starch extraction, age and tuber consistency are critical factors. Cassava tuber must be processed almost immediately after harvesting because they are extremely perishable and deteriorate in 1-2 days due to enzymatic processes.

Fresh tubers were cleansed, scraped, and cut into 1 cm cubes before being ground in a high-speed blender for 5 minutes. The pulp was suspended in tenfold its volume of water and stirred for five minutes before being filtered through double-fold cheese cloth. Before decanting and discarding the top liquid, the filtrate was allowed to stand for two hours to allow the starch to settle. Water was applied to the sediment, which was then stirred for 5 minutes. Filtration was repeated as before, and the filtrate starch could settle. The sediment (starch) was dried at 55°C for one hour after decanting the top liquid (Kaur et al., 2016).

Figure 2.25 : Extraction of starch from cassava tubers

2.7.4 Application of Thermoplastic Starch

The use of thermoplastic starch has numerous environmental benefits, including reduced soil and water pollution and resource conservation. In addition to saving energy, the use of thermoplastic starch in composites can reduce manufacturing costs and make the product more environmentally friendly. Since the environment has aged and a new substitute for traditional petroleum-based plastic is needed, thermoplastic starch is the best item to be substituted. The primary properties of each thermoplastic used in industry must be investigated. Since it is one of the thermoplastic applications in the packaging industry, it is mainly used in food packaging (Nafchi et al., 2013).

The commercialization of thermoplastic starch and polymers derived from starch is advancing. Because of starch products' inherent biodegradability, they are frequently used in packaging as films or sheets that can then be thermoformed into custom packaging specs.

Starch is best suited for dry product packaging; otherwise, there will be a diffusion transfer and equilibrium between the thermoplastic starch package and its contents. Thermoplastic starch foams are excellent for absorbing shock and protecting delicate materials. Thermoplastic starch compositions address the issue of packaging waste disposal because they degrade into environmentally friendly fragments depending on the quality of the non-starch components (Marcin Mitrus & Mościcki, 2011).

Apart from that, Thermoplastic starch is an important food commodity and a versatile biomaterial that is used in a wide range of industrial sectors around the world, including food, health, textile, chemical, and engineering. The physicochemical properties and functionality of starch play a significant role in its versatility in industrial applications. In its natural state, thermoplastic starch has minimal versatility and application. However, advances in biotechnology and chemical science have resulted in a wide variety of thermoplastic starch modifications for various purposes (M. Mitrus & Mościcki, 2009).

2.8 Thermoplastic Starch Composite

According to an investigation by Frost (2010) found that, composite refers to matrix polymers with dispersed conventional filler particles such as glass, fibers, talc, or clay particles. Nanocomposites are polymers that contain nanoscale fillers. The volume fraction of the filler, as well as its shape, size, and interfacial adhesion, all have an impact on the composite's properties.

In addition, according to Yin (2020) state that, because of its abundance and low cost, thermoplastic starch composite (TPS) has garnered considerable attention as a renewable bioplastic material, and it is widely considered the most environmentally friendly plastic. Thus, when compared to commercial plastics, thermoplastic starch composites have disadvantages such as poor mechanical and thermal properties and a high susceptibility to moisture, which severely limits the applications of starch plastic products.

According to a study conducted by Jumaidin (2019) state that, thermoplastic starch composite has the potential to be a viable alternative to non-biodegradable plastics. Because of its environmentally friendly properties, this biopolymer is an excellent candidate. Thermoplastic starch composite's mechanical properties and moisture sensitivity can be improved by modifying the material with natural fiber reinforcement and other types of polymer. Positive outcomes have been reported because of the thermoplastic starch composite modification work. This suggests that thermoplastic starch composite will likely replace petroleum-based polymers in the near future. The potential use of thermoplastic starch composite as a packaging material is viewed as one of the most promising solutions to the world's abundance of plastic waste. Table 1 shows the modification of TPS using various materials.

A study that have been carried out by Müller (2012) regarding to thermoplastic starch and nano clays produced by extrusion and thermopressing. The purpose of this research is to determine how various types of nano clays affect the crystallinity, and mechanical properties of TPS composite films produced by thermopressing. Furthermore, each film sample was subjected to scanning electron microscopy (SEM).

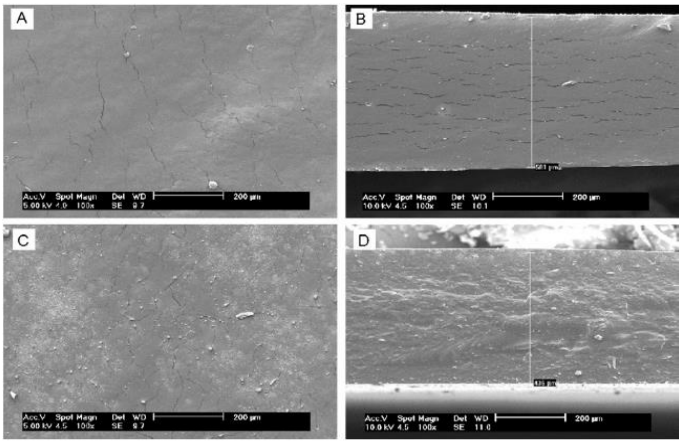


Figure 2.26 : Micrographs of the composite materials (Müller et al., 2012)

XRD is a well-established technique for determining the basal spacing of clay particles. When the polymer is injected into the organoclay galleries during melt intercalation, it forces the platelets apart and increases the d-spacing, causing the diffraction peak to shift to lower angles.

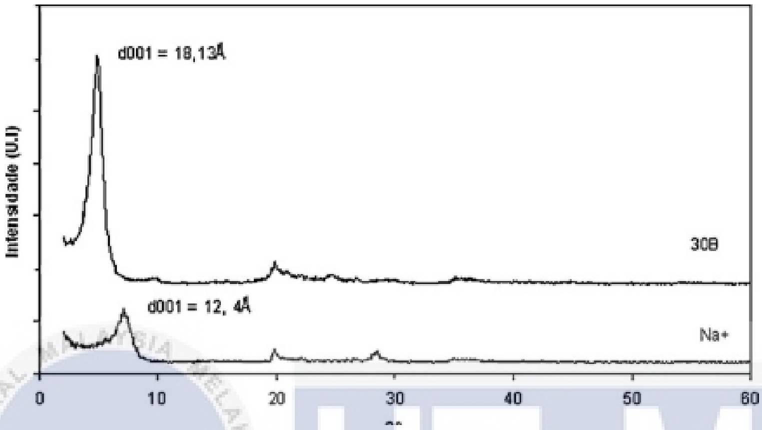


Figure 2.27 : Diffractogram of Cloisite B30 and Cloisite Na+ nano clays (Müller et al., 2012)

2.9 Waxes

Based on previous study by Asperger (1999) found that, waxes are a kind of substance that have been used for centuries in a variety of applications. According to the author, waxes are the fatty layer that covers the surface of leaves, animal bodies, and animal skins. On the other hand, technologists use the phrase to refer to any commercially valuable object made of fatty substances originating from natural, insect, or mineral sources. As a result, waxes are composed of aliphatic compounds with long chain lengths.

However, genetic and environmental factors have an effect on the nature and composition of waxes. Thus, wax sources influence the presence of their constituents, such as their chemical structure and degree of unsaturation. Without a doubt, waxes, regardless of their definition, have a wide variety of uses. This section addresses the numerous forms of wax and the sources of those waxes, which include animal, plant, and mineral sources. (Tinto et al., 2017).

According to Tinto et al., (2017) state that, at the temperature 20°C, waxes have a texture ranging from soft and sticky to hard and plastic or breakable. Most waxes have a low viscosity. They are insoluble in water and their solubility in organic solvents is temperature dependent.

2.9.1 Classification of Waxes

According to Author, Peleikis (2011) state that, There are two types of waxes: synthetic waxes and natural waxes. Natural waxes consists two types: renewable and nonrenewable. Mineral waxes such as montan and petrolatum, which are generated from lignite or brown coal and can be crude or refined, are nonrenewable natural waxes. Renewable natural waxes, such as animal and plant waxes, can be chemically changed via hydrogenation and re-esterification or left unaltered. The classification of waxes is depicted in Figure 2.28.

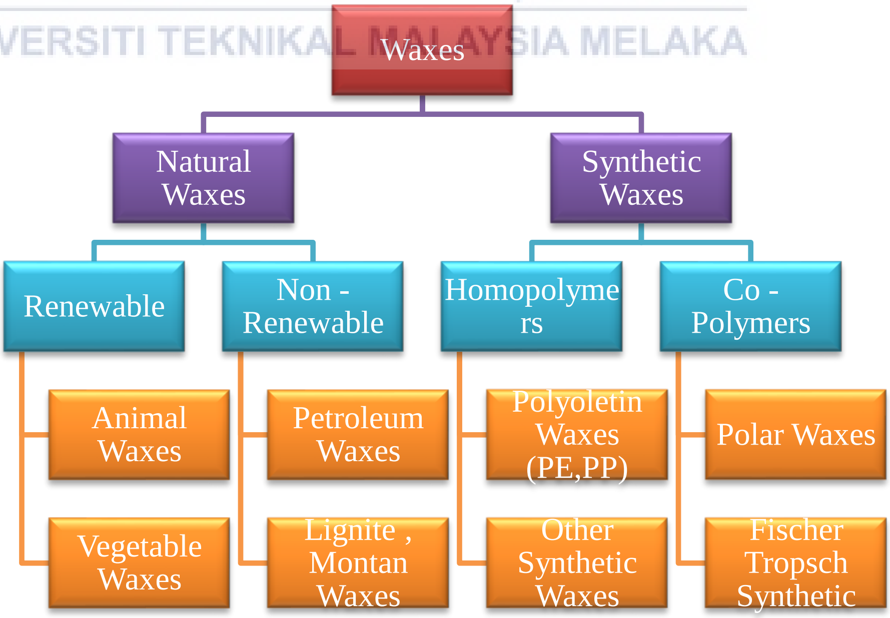


Figure 2.28 : Classification of waxes (Peleikis, 2011)

2.9.2 Synthetic Waxes

Synthetic waxes are a combination of natural and synthetic waxes with distinct melting points. A synthetic wax is composed of polyethylene with a low molecular weight. Natural waxes vary in composition and require more property monitoring than synthetic waxes, which are more uniform in composition. composition (Duru et al., 2019).

They are formed when long-chain fatty acids are diesterized or triesterized in ethylene glycol. Their melting points range from 60ºC to 75ºC, and, they can be employed to provide rigidity to sticks and to alter the crystallinity of the final product. Esters of alcohols and fatty acids are created for cosmetic uses. They have the same structure as waxes but are shorter in length. Straight chain esters such as cetyl palmitate and cetostearyl stearate, which are solid at room temperature, are used to improve the viscosity of emulsions. To generate products with outstanding spreading capabilities, liquid branched-chain esters such as isopropyl myristate or cetostearyl ethylhexanoate are employed. Furthermore, the ester utilised affects the solubility and spreadability of sunscreen agents, as well as their ability to penetrate the skin (Tinto et al., 2017).

2.9.3 Natural Waxes

According to Garriga, (2019)state that, natural waxes are effective protectors against mechanical stress, UV radiation, and parasites due to their inherent nature. Furthermore, it is well known that permeability for gas and water vapor is an important aspect for plants, and waxes play an important role in this aspect.

Moreover, the research study by Peleikis, (2011) also found that, Natural waxes are produced sustainably through biogenesis and are physically processed without the use of chemicals. Natural waxes are composed exclusively of long-chain, linear, and even-numbered aliphatic monoesters. Linear hydrocarbons (candelilla and bees wax), free wax acids (bees wax), free wax alcohols resembling polycosanoles, and other substances such as phytosterols and natural resins.

Additionally, animal and plant waxes are produced through a natural process called biogenesis and are composed mostly of waxy esters with different amounts of other chemicals such as fatty acids, fatty alcohols, and hydrocarbons. The following section discusses the chemical composition, characteristics, and applications of some natural waxes in further detail (Peleikis, 2011).

Because of their excellent oil binding properties and low cost, natural waxes are among the most valuable materials for this function. Furthermore, many waxes have been approved for use in food products (Silva et al., 2021).

2.9.4 Bee Waxes

Beeswax is a naturally occurring wax generated by honeybees A. mellifera in their nests. The wax is produced by bee glands found beneath the abdomen and is utilised to form the honeycomb. The wax is produced by eight glands in the abdomen portion of female worker bees. When honey is extracted and distilled, a byproduct is recovered: wax. Beeswax composition varies according to processing site, honeybee type employed, and wax age. Throughout the years, numerous tests with beeswax have been undertaken. years (Tinto et al., 2017).

Furthermore, beeswax is used to manufacture wax foundations and has a variety of commercial applications, including candle making, metal casting, and modelling, as well as cosmetics, food processing, industrial technologies, textiles, varnishes, and polishes. Paraffins, calf tallow, stearic acid, and carnauba wax were identified as adulterants in commercial Spanish beeswax. Thus, while freshly created beeswax is clear white, it transforms into yellow, dark yellow, and brownish colours originating from propolis and pollen after being managed by honeybees. Additionally, excessive heating and chemical bleaching might eliminate the aroma of beeswax. By and large, white wax is more precious than black wax. Additionally, if the wax becomes darkened as a result of the overheating process, its value is diminished greatly (Serra Bonvehi & Orantes Bermejo, 2012).

Bee wax is white and colorless when it is first exuded, but it will become colored over time as it collects and stores pollen and honey. The crude wax is refined using absorption technology to produce white Kahl wax 8104. Figure 2.29 shows that the bee wax in crude quality.

Figure 2.29 : Bees wax in crude quality (Peleikis, 2011)

Beeswax was obtained from the local market and melted inside the shell of the thermal storage unit. Scanning Electron Microscopy (SEM) was used to characterize the surface of beeswax at resolutions ranging from 5000X to 2000X (Dinker et al., 2017).

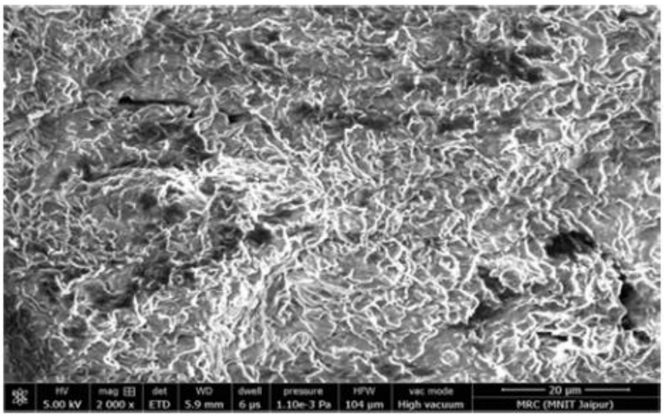


Figure 2.30 : SEM image of Beeswax (Dinker et al., 2017)

2.9.5 Application of Waxes

According to Tinto (2017) state that, the application of waxes is widely used in many industries because of its function, characteristics, and properties that suitable to the product that they produce. Waxes are widely used in Adhesive Manufacture, Barrier Coating, Cosmetics, and many others.

Additionally, beeswax has a variety of commercial uses, including candle making, metal casting, cosmetics, food processing, industrial technology, textiles, and polishes. Paraffins, cow tallow, stearic acid, and carnauba wax were discovered as adulterants in commercial Spanish beeswax (Tinto et al., 2017).

A mixture of honey, beeswax, and olive oil has been shown to be extremely effective in treating atopic dermatitis, psoriasis, and diaper dermatitis. All patients improved significantly after a month of three times daily local application. The mixture has been shown to be more effective than conventional medications used to treat the aforementioned diseases. Additionally, beeswax is frequently used in food packaging as a polishing agent E901 or as an edible coating in combination with polylactic acid PLA to protect cheese during seasoning (Fratini et al., 2016).

2.10 Plasticizer

According to an investigation by Suderman (2018), the term "plasticizer" refers to a polymer plasticizer system's desirable characteristics. In the film industry, it is defined as a material that provides flexibility, and increased film workability. Plasticizers are hydrophilic agents with a small molecular weight that are added to film-forming preparations to enhance the film's mechanical properties by interconnecting with the polymer network and competing for chain-to-chain hydrogen bonding along the polymer chains (Janjarasskul & Krochta, 2010).

In another study, However (2001) examined a plasticizer is a substance that softens and makes another material more flexible when added to it. Plasticizers are more precisely defined as materials that, when added to a polymer, increase the polymer's flexibility and workability by lowering the glass transition temperature of the polymer.

2.10.1 Glycerol

Glycerol refers to pure 1,2,3 propanotrial, whereas the "glycerin" refers to purified commercial products containing more than 95% glycerol (Coronado 2014). According to Author, (Chen & Liu, 2016) Glycerol is used in a wide variety of applications, including food and beverage production, pharmaceutical manufacturing, and cosmetics. The biofuel industry's rapid growth in recent years has resulted in a significant amount of crude glycerol being produced as a byproduct. Thus, glycerol was isolated in 2800 BCE by heating fat mixed with ashes to make soap (Quispe et al., 2018).

Similarly, Author Chen & Liu, (2016) found the bioethanol process produces glycerol, which accounts for up to 10% of total sugar consumed. Due to the excess crude glycerol generated in the biofuel industry, the price of glycerol has plummeted, rendering it a waste with a high disposal cost for many biodiesel plants. Converting crude glycerol into value-added products is a critical need and an excellent opportunity to bolster the biofuel economy's viability. To date, both chemical and biological methods have been investigated for converting glycerol into more useful products.

Glycerin is completely miscible with a wide variety of chemicals. Glycerin decomposes in acetone at a rate of 5% and in ethyl acetate at a rate of 9%. It is slightly soluble in dioxane and ethyl, but only very slightly in superior alcohol, fatty acids, and hydrocarbonate, as well as chlorinated solvents such as hexane, benzene, and chloroform.

Glycerin is extremely viscous: it remains a viscous liquid at room temperature even when concentrated to 100% (Quispe et al., 2018).

Moreover, the research study by Quispe (2018) also found Glycerol's volatility and vapour pressure are both low, and are proportional to its hygroscopicity. Temperature variations between 0 and 70 degrees Celsius have no effect on the vapour pressure of glycerin solutions. Glycerin, like other alcohols, has a lower vapour pressure than its molecular weight would suggest. Glycerin has a smaller effect on the vapour pressure of water than alcohol, which can be explained by molecular deformation, which occurs as a result of hydrate formation. Figure 2.31 shows structure of glycerol.

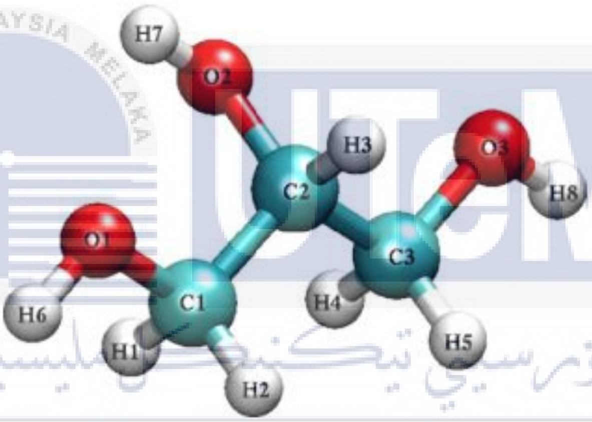


Figure 2.31 : Molecular structure of glycerol (Chen & Liu, 2016)

Table 2.10 : Physical and chemical properties of glycerol (Quispe et al., 2018)

Properties	Unit	(Morrison, 2000)	(Kreuter, 1996)	(Oecd, 2002)
Molecular Formula			$C_3H_5(OH)_3$	C_3H_8O3
Molar Mass	g/mol	92.09	92.09382	92
Relative Density	kg/m^3	1260	1261	1260
Viscosity	Pa s	1.41	1.5	1.41
Melting Point	ºC	18	18.2	18
Boiling Point (101.3 kPa)	ºC	290	290	290
	ºC	177	160	160

2.10.2 Sorbitol

In 2016 , (O. O. Ibrahim) published a paper in which they described Sorbitol is a sugar alcohol with the formula C6H14O6 that occurs naturally as a sweet component of several berries and fruits. Hence, Sorbitol is now commercially available as a byproduct of starch hydrolysis and catalytic hydrogenation. It is a common sweetener and humectant.

In another study by (Awuchi, 2017) examined Sorbitol, optionally called glucitol, is a sweet-tasting sugar alcohol that the human body slowly metabolises. It is synthesised by converting glucose to a hydroxyl group and aldehyde to a hydroxyl group. Additionally, while predominantly generated from corn syrup, Sorbitol is present in apples and peaches, where it is converted to fructose by Sorbitol-6-phosphate-2-dehydrogenase. Sorbitol is a sugar alcohol that is identical to mannitol; the hydroxyl group on carbon 2 is oriented differently. While the two sugar alcohols are structurally similar, their natural origins, melting points, and applications are quite distinct.The structure of sorbitol is presented in Figure 32.

Figure 2.32 : Structure of Sorbitol (Awuchi, 2017)

2.10.2.1 The Application of Sorbitol

According to an investigation by Chen & Liu (2016) Sorbitol is used as a sweetener. Sorbitol is a carbohydrate that acts as a sugar replacement. It may be indicated as an inactive component in some meals and products. As a result, the INS and E numbers for this vehicle are both 420. Sorbitol comprises approximately 60% of sucrose's sweetness. Sorbitol is referred to as a nutritive sweetener because it contains 2.6 kcal (11 kcal) of dietary energy per gramme, compared to the average of 4 kcal (17 kcal) for carbohydrates. It is widely found in diet goods (such as diet beverages and ice cream), mints, cough syrups, and sugar-free chewing gum, as well as occuring naturally in a range of stone fruits and berries belonging to the Sorbus genus of plants.

2.11 Packaging Material

In 2019, (Sangroniz) published a paper in which state that, due to their low cost, light weight, high performance, and processability, plastics are a popular packaging material. Plastic packaging production is expected to surpass 250 million metric tonnes by 20501. Despite the fact that the majority of plastics used in packaging are used for less than a week, their durability, one of their greatest advantages, is resulting in a massive increase in plastics disposed of as polluting waste.

As previously stated, packaging materials are classified into four types which are paper , plastic, metal, and glass packages. Hence, only paper/paperboard and a few plastic packages are biodegradable and thus recyclable (Kale et al., 2007).

In another study, Garriga (2019) examined packaging materials can used to create a variety of products. They can be used for food products such as fast food packages, frozen food, pet food, cereals, fresh fruits and vegetables, instant food, or other forms, as well as non-food products such as cosmetics, creams, electronics, sports equipment, boxes, envelopes, and toys. As can be seen, because of this broad classification, it is critical to determine which packaging material is best suited for its end-use properties, taking into account the advantages and disadvantages of each option.

2.11.1 Polypropylene PP

According to Author, Saravanan & Sulaiman, (2014) state that, Polypropylene is regarded as an essential polymer product that has begun to grow in a wide range among other plastics. In terms of cost and performance, the author also stated that polypropylene can effectively replace several materials such as steel, wood, glass, paper, and other metals. In addition, according to Author, Hisham A. Maddah, (2016) state that, Polypropylene has excellent chemical resistance and can be converted using a variety of methods.

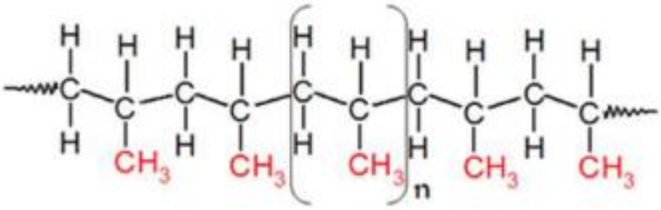


Figure 2.33 : Polypropylene Structure (Hisham A. Maddah, 2016)

Table 2.11 : Polypropylene's Benefits and Drawbacks (Hisham A. Maddah, 2016)

Advantages of PP		**Disadvantages of PP**
Homo-polymer	Copolymer	UV-degradable (Ultraviolet)
Process ability, Good	Process ability, High	Although combustible, there are retarded versions available.
Effect resistance, Good	Effect resistance, High	Attacked by chlorinated solvents and aromatics.
Stiffness, Good	Stiffness, High	Difficult to bond
Food contact, Acceptable	Food contact, Not preferable	The impact strength at low temperatures is insufficient.

Table 2.12 : Mechanical & Thermal Properties of Polypropylene (Hisham A. Maddah, 2016)

Property	Homopolymer			Copolymer	
Melt flow index	3	0.7	0.2	3	0.2
Tensile strength (MPa)	34	30	29	29	25
Elongation at break (%)	350	115	175	40	240
Flexural modulus (MPa)	1310	1170	1100	1290	1030
Brittleness temp. (°C)	+ 15	0	0	-15	-20
Vicat softening point (°C)	154 - 150	148	148	148	147
Rockwell hardness (R-scale)	95	90	90	95	88.5
Impact strength (ft Ib)	10	25	34	34	42.5

2.11.1.1 Polypropylene Applications

According to an investigation by Author, Saravanan & Sulaiman, (2014) Polypropylene is a petrochemical industry product. It is now considered one of the most widely used and versatile plastics, and it is used in commercial and specialized products for both long- and short-term applications.

Additionally, polypropylene is a widely utilised material in autos. It was initially used to line battery cases and air conditioning ducts. Due to the fact that PP is the lightweight thermoplastic with a weight of 0.9 g/mL, it accounts for a significant amount of the polymers in modern cars, as manufacturers attempt to minimise the overall weight of their vehicles in order to save customers money on petrol. Additionally, interior trim and a variety of exterior components are made entirely of polypropylene or polypropylene compounds. All interior trim, including walls, pillars and side panels, is made of PP. Because weight reduction is critical, PP has become a preferred material for vehicle exterior elements. Automobile bumpers are constructed with a well-known PP substance called thermoplastic olefin (TPO). TPO is also utilised in certain automobiles' air dams, body side claddings, rocker panels, and even grilles. The following table displays another intriguing application of polypropylene sheet foam in PP. Table 2.13 illustrates another interesting use of polypropylene sheet foam in PP (Hisham A. Maddah, 2016).

Table 2.13 : Applications of Polypropylene Sheet Foam (Hisham A. Maddah, 2016)

Transportation	Parts and accessories for automobiles, aerospace, and ships; glass and mirrors.
Furniture	Wooden office and home furnishings; steel, ceramic, and glass hardware; windows; and wood cabinets.
Technology	Components and parts for computers, televisions, audio systems, and radios
Injection	Blankets for drying concrete; extrusions of aluminium; functional and decorative hardware; protection for subterranean pipes

2.11.2 Polystyrene

In 2019, (Fernandes de Oliveira) published a paper in which they described Polystyrene, called Styrofoam in Brazil, is a synthetic aromatic polymer made from styrene monomer used in the petrochemical industry. It comes in rigid and foamed forms, but is most usually utilised in its white, hard, and brittle state. It is a low-cost resin that is frequently utilised as an excellent barrier against oxygen and water vapour due to its low melting point.

Polystyrene is a high-molecular-weight aromatic polymer produced from the monomer styrene. Unlike styrene, which is a liquid monomer, polystyrene can be solid or foamed. Polystyrene is a transparent, rigid, and brittle material used for a variety of purposes (GPPS). In terms of unit weight, it is a rather affordable resin. PS has a low melting point and is hence inefficient at holding oxygen and water vapour (Ho Thanh et al., 2018).

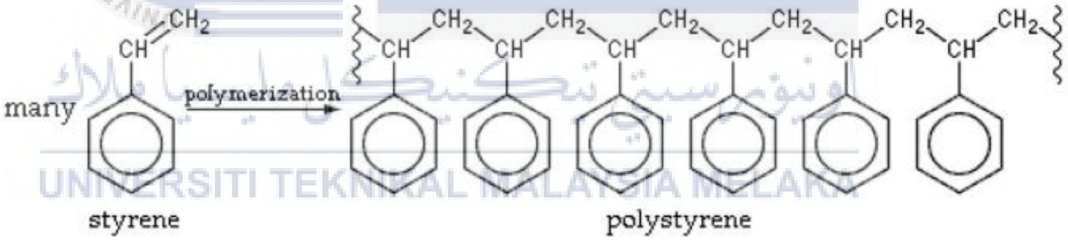


Figure 2.34 : Chemical formula of polystyrene (Ho Thanh et al., 2018)

Table 2.14 : Characteristics of polystyrene (Thomas et al., 2008)

Property	Value
Density [g/cc]	1.04–1.065
Poisson’s ratio	0.33
Solubility parameter [(cal/cm3)1/2]	18.6
Water absorption (ASTM)	0.05%
Softening temperature [°C]	108°C
Molecular weight (Mw)	218000

2.12 Summary

This chapter started by explaining the researchers' previous studies and concluding all the collected details. Thermoset, thermoplastic, and natural fibre are all polymer types that exhibit a high degree of mechanical resistance. Additionally, natural fibres can be classified into a variety of different categories based on their origin, plant or animal origin, or mineral form. Native Americans make use of a variety of plant fibres that are not commercially available. Plant fibres are used in a wide variety of industries, from textiles and paper to smart fabrics and lightweight automobile panels. The feasibility of using coconut leaf and its fibre reinforced epoxy composites in engineering applications is being investigated. Additionally, starch is a renewable and abundant natural resource that serves as the primary source of carbohydrate reserves in plants, whereas beeswax is used to make wax foundations and has a variety of commercial applications, including candle making, metal castings and modelling, cosmetics, food processing, industrial technology, textiles, varnishes, and polishes.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discuss the process flow and methodology that was adopted in this study to ensure all the objectives set can be achieved. The methods used to complete this research was explored in this methodology. The approach used to include the preparation of material, fabrication, and related experimental testing. The rationale for this methodology is to ensure that the experiment progress and procedures that is carried out in this study is on the right path and following the preparation plan accordingly to achieve the expected results.

3.2 An Overview of Methodology

This research started with the preparation of raw material following by the fabrication process and ending the workflow with the related testing method. This project is focused on producing biodegradable products that can be recycled and do not pollute the environment in the long term. The mechanical and thermal testing is performed after the fabrication process of sample is done. Thus, Figure 3.1 is the overall flow process of this study.

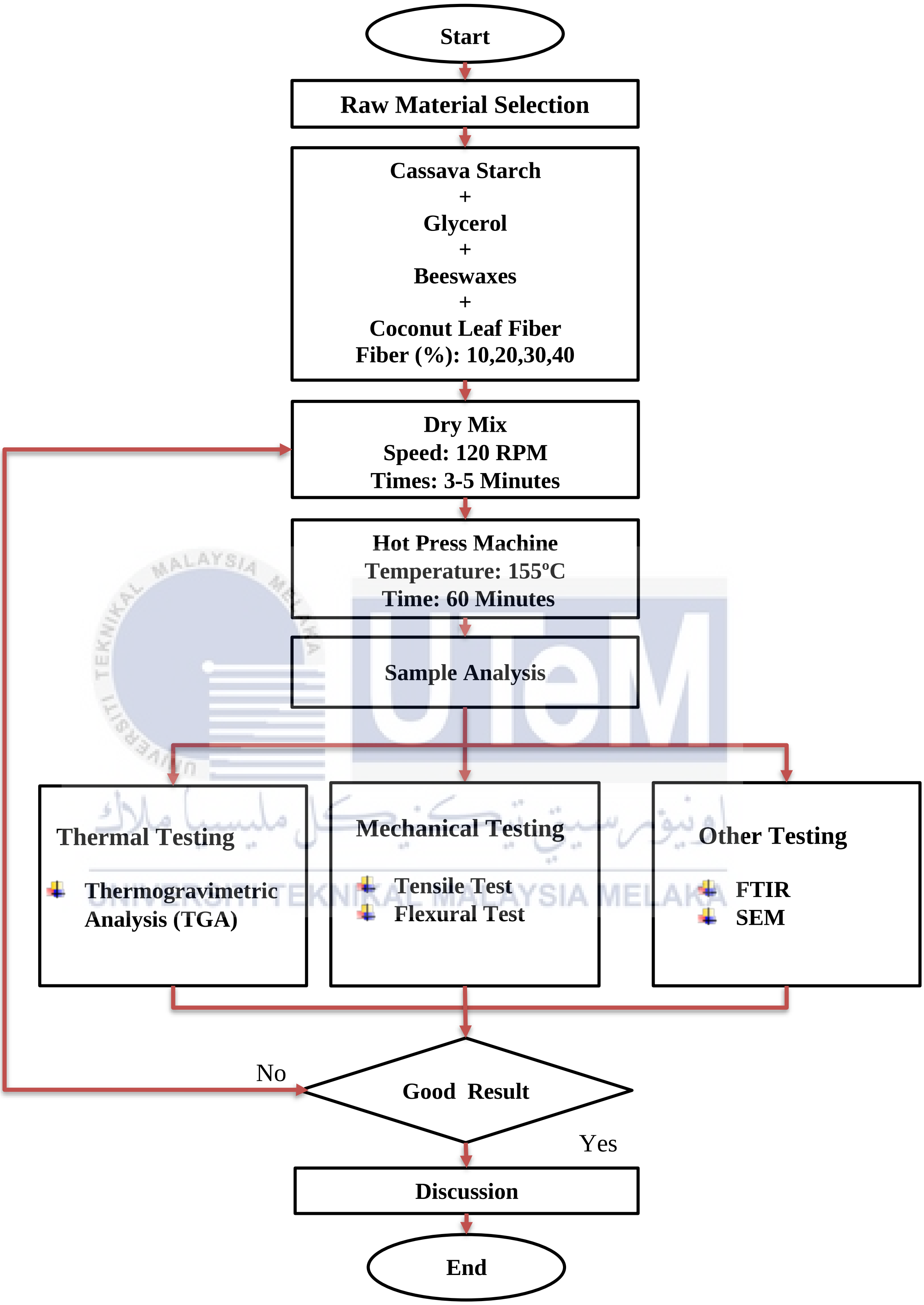


Figure 3.1 : Flow of Research Methodology

3.3 Material

3.3.1 Coconut Leaf Fiber

Coconut leaf was collected from a coconut plant that originated in Pasir Puteh, Kelantan. The leaf was cut from coconut palm and then the leaf was separated from the coconut leaf sticks and coconut midrib leaf. Then, the coconut leaf was soaked in water for 2 to 3 weeks during the water retting process. Water retting is the process of gaining and extracting fiber because the filler of the coconut leaf fiber was naturally digested by bacteria when leaving the fiber. Water retting is a traditional retting method for producing fibers at a low cost.

After soaking for 2 to 3 weeks, the coconut leaf was filtered to separate it from the soaking water. The fiber was collected by scraping the leaf's surface manually by using knife. Then, the fiber can be extracted easily in this manner, and a more defined fiber was obtained because of this method. The collected fiber was sun-dried for 7 hours until completely dry.

The dried fiber is then was cut into small pieces to facilitate the grinding process when using a dry grinder. The fiber was grounded in the grinder until it is in the form of a powder. The moisture content of the fiber has been removed.

Figure 3.2 : Process of Coconut Leaf Fiber

3.3.2 Cassava Starch

The base material used in this study was cassava starch, which was provided by the Antik Sempurna Sdn Bhd. Cassava is also known as 'ubi kayu' in Malay. Cassava starch, similar to other starches, appears as a white powder. Table 3.1 shows Proximate composition and pH of cassava starch derived from the previous study and Figure 3.3 shows cassava starch.

Table 3.1: Cassava starch's approximate composition and pH (Aviara 2010)

Parameter	**Value**
Moisture content (%)	12.5±0.11
Ash (%)	0.76±0.00
Crude fiber (%)	NIL
Crude fat (%)	0.16±0.00
Protein (%)	0.85±0.02
Granule size range (µm)	6.5-19
Average granule size (µm)	14.1±3.4
Amylose content (%)	23.45±0.03
pH	5.88±0.12

Figure 3.3 : Cassava Starch

3.3.3 Glycerol

The inclusion of plasticizer in the study can improve the product's flexibility and properties. Glycerol ($C_3H_8O_3$) was used as the plasticizer in this study, and it produced by QReC (Asia) Sdn Bhd. QReC Chemical's glycerol contained 99.5 % AR grade and 92.10 g/mol molar weight. Glycerol has a slightly viscous liquid and a transparent physical appearance. Glycerol's chemical composition is shown in Table 3.2 and Figure 3.4 shows Glycerol contained 99.5% AR grade.

Figure 3.4 : Glycerol contained 99.5% AR grade.

Table 3.2 : Chemical composition of glycerol from QReC Chemical

Chemical Composition	Percentage Value
Assay (Acidimetric)	Min 99.5%
Insoluble in water	Passes test
Acidity/Alkalinity	Passes test
Halogen Compounds (as Cl)	Max 0.003%
Chloride (Cl-)	Max 0.001%
Sulfates (SO4)	Max 0.001%
Ammonium (NH4)	Max 0.0015%
Copper (Cu)	Max 0.001%
Heavy Metal (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-butanorial (G.C)	Max 0.2%
Sulphated Ash	Max 0.01%
Water	Max 2%

3.3.4 Beeswax

Beeswax is one of the primary raw materials used in this study. The provided beeswax was obtained from Aldrich Chemistry and was in solid form. The color of beeswax ranges from pale yellow to yellow-tan, and it has a honeybee scent. Beeswax acts as a moisture repellent, preventing thermoplastic cassava starch from decaying due to the presence of water. The general properties of beeswax are shown in table 3.3 and figure 3.5 shown that beeswaxes.

Figure 3.5 : Beeswax

Table 3.3 : General properties of beeswax

Properties	**Specification**
Color Appearance	Faint Yellow to Yellow-Tan
Form Appearance	Solid
Infrared spectrum	Conforms to Structure
Melting Point	62.0 °C - 65.0 °C
Ester Value	72 – 79
Ester/Acid Ratio	3.3 – 4.2

3.4 Fabrication of Sample

3.4.1 Fabrication of Thermoplastic Cassava Starch with Beeswax

The thermoplastic starch preparation using beeswax was continued from the mixture that has been made previously until the high-speed dry grinding stage. Because the amount required to fill the mold is 58.20 g, the weighing ratio must be adjusted in order for the mixture to fit in the mold. The best amount of beeswax to incorporate in the thermoplastic starch mixture is 10% of the 58.20g of mold fill. The addition of 10% of the total mixture means that only 5.82 g of beeswax is required in the thermoplastic cassava starch mixture, and the weight for pure thermoplastic cassava starch is 52.38 g.

By cutting the beeswax into small pieces, the beeswax that was needed to be weighted and added to the pure thermoplastic cassava starch has been prepared. Because the beeswax was solid and large in size, it needed to be cut into small pieces and shred with a shredder in order to mix well with the pure thermoplastic cassava starch. The shredded beeswax then was weighed for 5.82g before dry mixed with pure thermoplastic cassava starch. Following that, the thermoplastic cassava starch and beeswax mixture were subjected to a high-speed dry mix using a dry blender set to 1200 rpm for 3 – 5 minutes, or until thoroughly combined. Next, line the mold with Mylar film and fill it with a 58.20 g mixture of thermoplastic cassava starch and beeswax. Placed the fill mold in the hot press machine at 155 °C for 1 hour of setting time.

Figure 3.6 : Fabrication of Thermoplastic Cassava Starch with Beeswax

3.4.2 Fabrication of Thermoplastic Cassava Starch Reinforced by Coconut Leaf Fiber

Due to the thermoplastic cassava starch with beeswax has been prepared in the previous process, the mixture of thermoplastic cassava starch with beeswax was incorporated with the coconut leaf fiber in this step. The coconut leaf fiber has been prepared earlier, and it was stored in a tight container to prevent moisture absorption from the surrounding environment.

The incorporation of coconut leaf fiber in this section was based on the specified percentages of 0 wt. %, 10 wt. %, 20 wt. %, 30 wt. %, and 40 wt. %. The 0-wt. % coconut fiber was achieved in the second section, which involved the preparation of thermoplastic cassava starch with beeswax, with the weight of thermoplastic cassava starch being 52.38 g and the weight of beeswax being 5.82 g. The 10-wt. % of coconut leaf fiber requires 52.38g of thermoplastic cassava starch mixed with beeswax, and the fiber is 5.82 g. The process was repeated for the next percentage of fiber. Table 3.4 shows the percentage of fiber weight modification of thermoplastic cassava starch with beeswax reinforced coconut leaf fiber.

Table 3.4 : The calculation for preparation of fiber and thermoplastic cassava starch with beeswax regarding to the different percentage.

Percentage of Fiber (%)	**Name of Substances**	**Weight (g)**	**Percentage Ratio (%)**
0	Pure thermoplastic cassava starch	52.38	90.00
	Beeswax	5.82	10.00
	Total	58.20	100.00
10	Thermoplastic cassava starch + beeswax	52.38	90.00
	Coconut leaf fiber	5.82	10.00
	Total	58.20	100.00
20	Thermoplastic cassava starch + beeswax	46.56	80.00
	Coconut leaf fiber	11.64	20.00
	Total	58.20	100.00
30	Thermoplastic cassava starch + beeswax	40.74	70.00
	Coconut leaf fiber	17.46	30.00
	Total	58.20	100.00
40	Thermoplastic cassava starch + beeswax	34.92	60.00
	Coconut leaf fiber	23.28	40.00
	Total	58.20	100.00
50	Thermoplastic cassava starch + beeswax	29.10	50.00
	Coconut leaf fiber	29.10	50.00
	Total	58.20	100.00

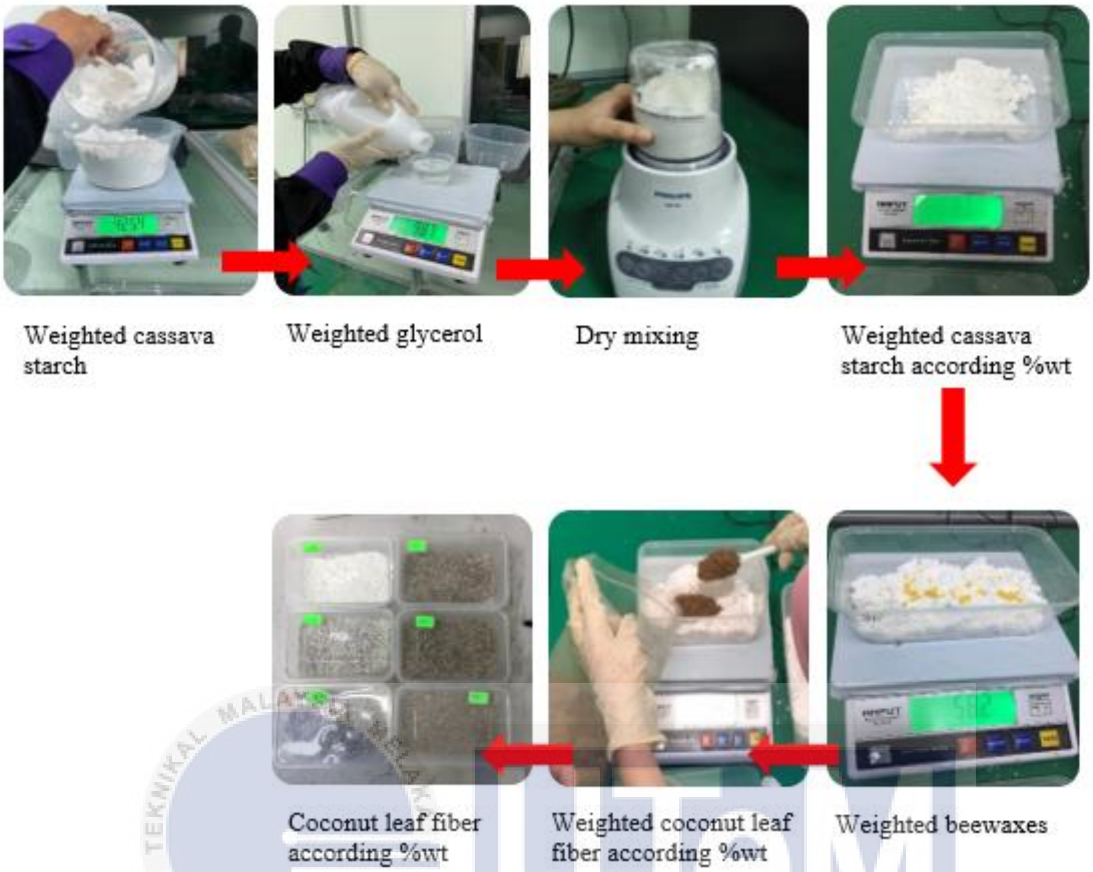


Figure 3.7 : Fabrication the Mixture of Thermoplastic Cassava Starch Reinforced by Coconut Leaf Fiber

Figure 3.8 : Fabrication of Thermoplastic Cassava Starch Reinforced by Coconut Leaf Fiber

3.5 Samples Testing

3.5.1 Mechanical testing

The mechanical test for this project has been performed on a composite material sample. This project focuses on mechanical testing to determine the durability of specimens. Tensile test and Flexural test are the type of mechanical testing used to determine the properties of materials.

3.5.1.1 Tensile Test

Tensile testing was used to determine the tensile strength, tensile strain and tensile modulus. This test determines both the amount of force used to break the specimen and its length. Utilizing ASTM D638 as a reference. Three samples are drawn from the specimens. The samples was tested on an INSTRRON 5969 Universal Testing Machine equipped with a 5 mm/min crosshead speed. Additionally, this test was carried out at a room temperature of 23 1°C and a relative humidity of 50%. (Measurement standard ASTM D638).

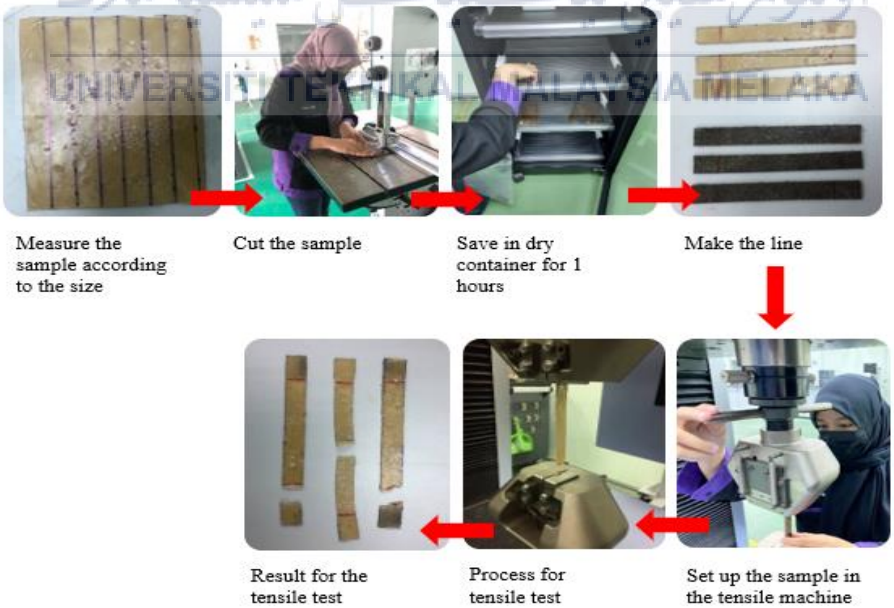


Figure 3.9 : Tensile Testing

3.5.1.2 Flexural Test

A flexural test was conducted to determine the flexural strength and modulus of the material. This test is conducted on a universal testing machine (INSTRON 5969) equipped with a load cell rated at 5 kN. ASTM D790 requires that the specimen be cut at a temperature of 23 1°C and a relative humidity of 50%. The specimen was cut to 10mm (L) x 13mm (W) x 3mm (T) and tested at a 2mm/min crosshead speed. While maintaining a constant crosshead speed, the support span length is set at a 16:1 ratio to the sample thickness (ASTM D790).

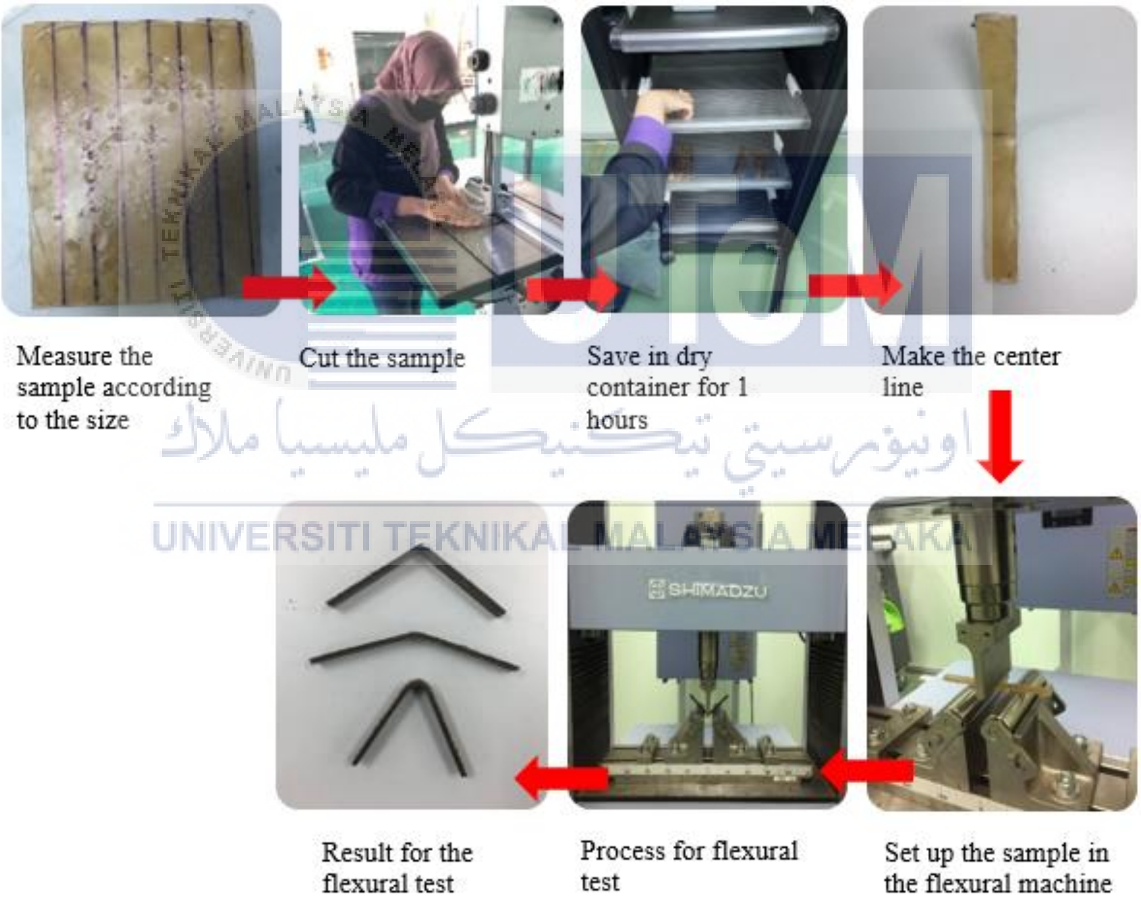


Figure 3.10 : Flexural Testing

3.6 Samples Testing

3.6.1 Thermal testing

3.6.1.1 Thermogravimetric analysis (TGA)

Thermogravimetric or thermal gravimetric analysis was performed to investigate the material's degradation and stability. This behavior can be identified as the weight of the material decreasing as the temperature rises. It is an analytical method used to evaluate the thermal stability and its fraction of volatile components by calculating the weight change occurring at a constant rate when the sample is heated. Figure 3.11 shown machine for the thermogravimetric analysis (TGA).

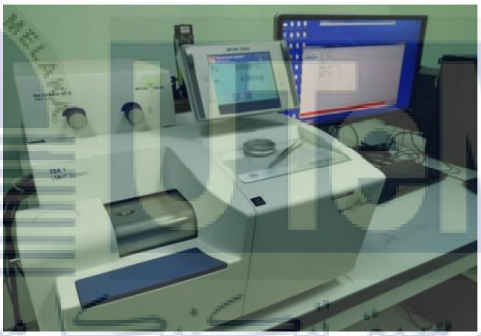


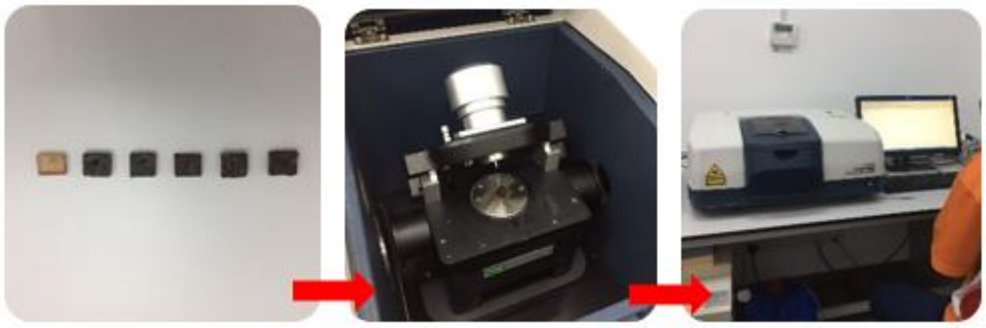
Figure 3.11 : Thermogravimetric analysis (TGA) machine

3.7 Samples Testing

3.7.1 Other testing

3.7.1.1 Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR test was performed to determine the presence of functional groups in coconut leaf fibre. Aside from that, the purpose of this test is to investigate the functional group and chemical properties of the material. The spectra of the material was obtained using an IR spectrometer (Nicolet 6700 AEM). The sample, which weighs 2mg and is in powder form, was mixed with potassium bromide (KBr) and pressed into a disc shape with a thickness of 1 mm. A sample of FTIR spectra was collected in the 4000 to 400cm-1 range. Figure 40 shows that FTIR Spectroscopy Testing.



Cut the sample

Put the sample in the FTIR machine

Wait a few minutes for the process

Figure 3.12 : FTIR Spectroscopy Testing

3.7.1.2 Scanning electron microscope (SEM) analysis

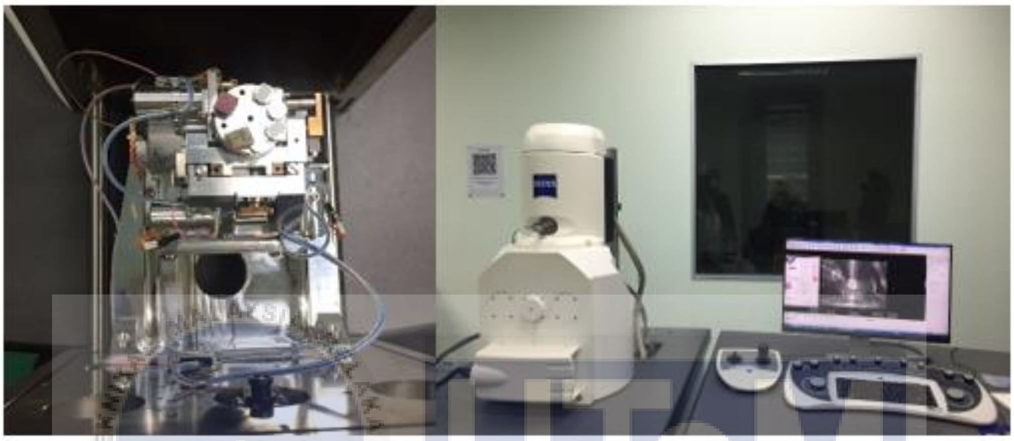
The purpose of implementing scanning electron microscopy (SEM) equipment is to detect the morphological view of thermoplastic cassava starch with beeswax reinforced by cconut leaf fibre samples, which is accomplished through the use of SEM equipment. It is a Zeiss Evo 19 Research SEM from Germany that was used for this project. According to Omidi (2017) state that on previous study, a scanning electron microscope is the method to examine the morphology and microstructure of tensile fracture surface of the material. Apart from that, it is a type of electron microscope in which images are collected by scanning the surface of a sample with a centrally focused electron beam. Electrons interact with the atoms in the sample, generating a variety of signals that provide information about the surface's topography and composition. A scanning electron microscope is the EM equivalent of a stereo light microscope due to its high depth of focus. It generates highly accurate images of cell surfaces and entire species that SEM cannot. Additionally, it can be used to count particles and calculate their sizes, as well as for process control (Omidi 2017). The scanning electron microscope (SEM) analysis machine is represented in Figure 41.

Cut the sample

Set up the sample for coating

Put in the coating machine

Result of coating



After coating, put the sample in the SEM machine.

Figure 3.13 : Scanning electron microscope (SEM) Testing

3.8 Process Production of Packaging Tray

The biodegradable packaging tray from the coconut leaf fiber composite was successfully manufactured using hot-pressing equipment 155°C for 60 minutes and cooling for 20 minutes. The fabrication of the packaging tray was comparable to the fabrication of material testing samples. The process started with the physical mixing of four basic ingredients: cassava starch, beeswax, glycerol, and coconut leaf fiber. Then, using the blender, continue blending until the liquid is uniform. In this case, a fiber mix of 20% was chosen throughout the fabrication process. The size of the packaging tray is 130 mm (L) x 80 mm (W) x 3 mm (T).

Figure 3.14 : Process Production of Packaging Tray

3.9 Summary

This chapter begins with the introduction of a flow chart for this project's methodology. Aside from that, this chapter describes chapters 1 and 2, which identify the problem and conduct a literature review, to demonstrate how each chapter is related. Following that, the use of materials such as coconut leaf and other ingredients such as cassava starch as a matrix in the production of composite and glycerol mixtures have been discussed. The entire process of producing coconut leaf fiber is also has been discussed.

The hot press machine was used to create the experiment's sample. The purpose is to make it easier to create a sample before testing it. Tensile and Flexural tests have been used to assess sample strength, while a thermogravimetric analysis (TGA) machine, FTIR and SEM will be used for thermal testing. All these machines have advantages of their own, and they were used to test the sample strengths based on their suitability to achieve the goal of this study.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter covers all about the results obtained from producing samples and all of the results for every test carried out. This research focuses on mechanical testing, thermal testing and other testing. The mechanical testing consists of Tensile Test and Flexural Test while thermal testing consists of Thermogravimetric Analysis (TGA) and other testing consists Fourier-Transform Infrared Spectroscopy (FTIR) and Scanning Electrons Microscopy (SEM). Hence, mechanical testing is to determine the material properties and structure. Meanwhile, thermal testing is a method to the ability of a substance to work safely at different temperatures, and other testing is used to obtain information about the surface topography and the composition.

4.2 Mechanical Testing

4.2.1 Tensile Testing

The tensile test is one of the mechanical tests used to determine and analyze composite material’s properties such as tensile strength, tensile modulus, and elongation at break of the material. This test determines both the amount of force used to break the specimen and its length. Utilizing ASTM D638 as a reference. Three samples are drawn from the specimens. The samples were tested on an INSTRON 5969 Universal Testing Machine equipped with a 5KN load cell and a 5 mm/min crosshead speed. Additionally, this test was carried out at a room temperature of 23.1°C and a relative humidity of 50% (Measurement standard ASTM D638) (Davis, 2004).

The average values of the five samples were analyse and recorded. The sample was cut in 10mm length x 13mm width x 3mm thickness by cutting machine. Figure 4.1 shown the sample attached to a tensile test machine.

Figure 4.1 : The sample attached to tensile test machine.

Figure 4.2, 4.3,4.4 shown the graph of the tensile properties of TPCS reinforced with coconut leaf fiber composites; that is, tensile strength, strain, and elastic modulus respectively. Table 4.1 shown the analysis of variance (ANOVA) of the tensile properties. Since the p-value was less than ($p<0.05$), there was a statistically significant difference in the mean tensile strength, strain, and modulus between the levels of composites. When various percentages of coconut leaf fiber were added, it was observed that the tensile strength, strain, and modulus significantly higher as the coconut leaf fiber content was increased.

According to Figure 4.2, the strength of the TPCS reinforced with coconut leaf fiber on tensile strength was observed that the ultimate tensile strength is increased significantly by stage from 0 wt.% to 30% fiber content, while the highest strength was obtained when 30% coconut leaf fiber was added. This demonstrated that the optimal amount of coconut leaf fiber required for reinforcing was 30% wt. because the strength is the highest compared with the other. In general, it can be observed that the change in the CLF structure has also contributed to a change in the material's tensile properties (Bharath et al., 2019).

Tensile strength of the composite is significantly increased with increasing CLF content. Tensile strength is particularly increased from 0.39 MPa until the highest one is 5.50 Mpa with 30 wt. % CLF in the composite. The increase in composite tensile strength can be attributed to many factors. Prachayawarakorn et al., (2013) stated that the tensile strength increase might be due to the similar chemical composition of natural fiber and starch. This is due to the resemblance of cellulose's main structure consisting of functional groups of hydroxyl for both natural fiber and starch (Prachayawarakorn et al., 2010).

However, when the coconut leaf fiber content exceeds 30% (i.e., 40%), the tensile strength decreases. The reduction in strength could be attributed to the higher fiber content, which led the fiber to agglomeration within the matrix at this point (Jumaidin et al., 2021). This was also supported by Luan et al., (2010) state that in previous study, this result can be attributed to the matrix discontinuity's effect on the matrix's high filler content, which resulted in a lack of stress transfer from matrix to filler. According to Radzi et al., (2019) in the previous study which state that, This could be a result of poor adhesion, a high void content, fiber pullouts, incompatibility, or agglomeration, all of which contribute to inefficient load transfer between the fiber and matrix. This finding was in agreement with a study by El-Shekeil et al., (2012) which state that in the previous study on kenaf fiber reinforced thermoplastic polyurethane composites, due to The matrix does not adequately moisten the fibers, and the increased fiber content resulted in agglomeration and blocking stress transfer from the matrix to the fiber. Hence, for the tensile strain, when fiber loading was increased, the strain demonstrated a decreasing trend. This is also a necessary consequence of high number of fibers with a low strain (El-Shekeil et al., 2012).

The tensile modulus of a stress–strain curve was determined by its initial slope and linear area. For the tensile modulus, the findings indicated a similar trend of increasing modulus from 0 to 30% of fiber loading but a minor decrement at 40% of fiber loading. (Edhirej et al., 2017) state that the tensile modulus of a material determines its stiffness, which means that a higher tensile modulus results in a stiffer composite material. Increased fiber loading results in a large increase in tensile modulus. As a result of the study, it was determined that the inclusion of coconut leaf fiber increased the tensile modulus. However, similarly as the tensile strength, the tensile modulus decreased at 40% wt. fiber. This trend was observed as a result of the high quantity of fibers with a low strain (El-Shekeil et al., 2012). This could may be due to structural changes in the arrangement of starch caused by the addition of fibers, resulting in a less compact matrix (Edhirej et al., 2017). This finding was in agreement with a study by Cheng, (2019) on properties of lignocellulosic fiber/CaCO3 /thermoplastic starch composites (0, 27, 54, and 81) g). Tensile strength and modulus increased as the LCF/CG hybrid dosage grew to 54 g, but then decreased when the dosage reached 81 g. This result was attributable to the fiber’s poor reinforcing action when the amount of fiber applied was high, which enhanced overall strength but decreased toughness.

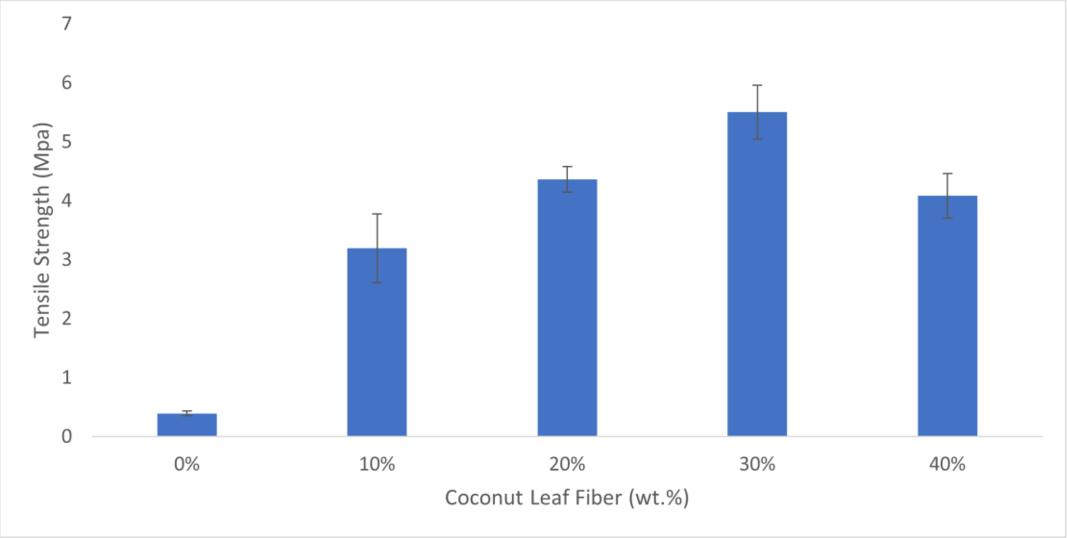


Figure 4.2 : Tensile strength (MPa) versus CLF loading (wt.%)

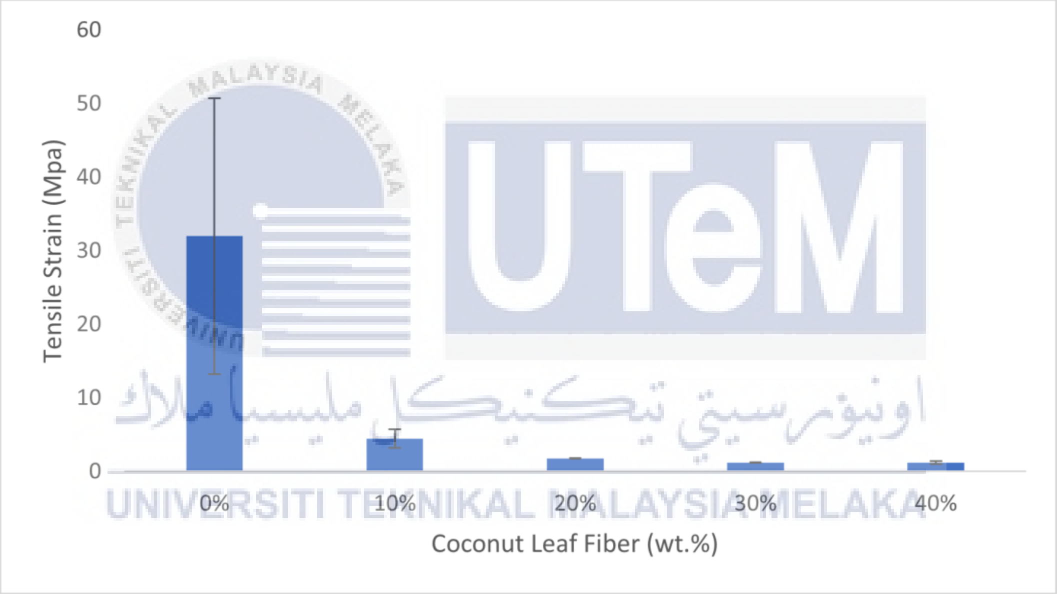


Figure 4.3 : Tensile strain (MPa) versus CLF loading (wt.%)

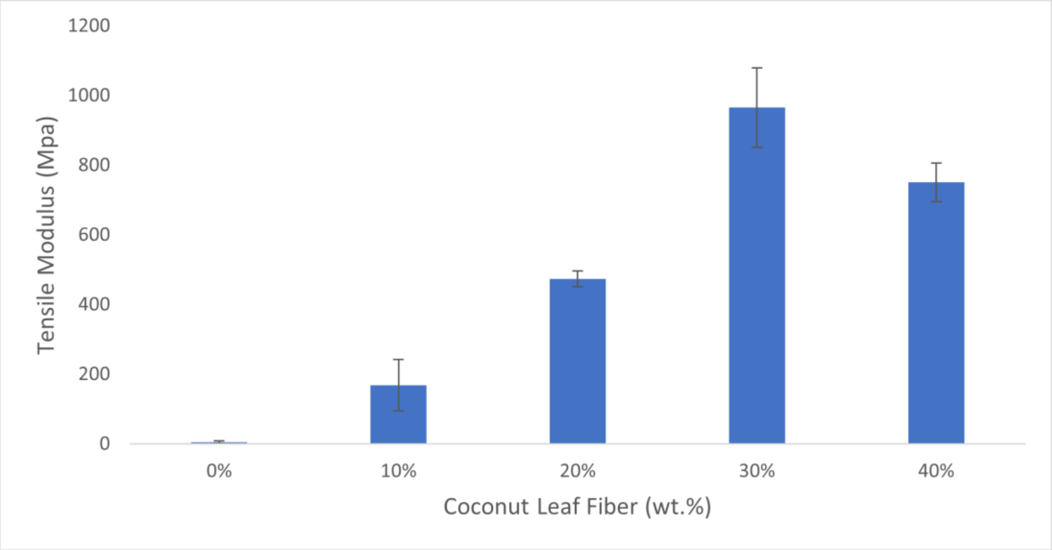


Figure 4.4 : Tensile Modulus (MPa) versus CLF loading (wt.%)

Table 4.1 : Summary of the analysis of variance (ANOVA) of tensile properties

Variables	df	Tensile Strength	Tensile Strain	Tensile Modulus
Mixture	4	0.00*	0.00*	0.00*

4.2.2 Flexural Testing

A flexural testing was used to determine the composite's flexural strength and modulus. The flexural strength of composite materials is determined by combining the compressive and tensile strengths (Ramesh et al., 2014). In specific applications, the flexural test is more critical than a tensile test to the benefits for material design or specification purposes (Zhou et al., 2011). Flexure characterizes the behavior of a slender structural element subjected to an external load applied perpendicularly to the element's longitudinal axis in engineering mechanics (Ahmed, Kumar & Muzammil, 2013).

The average values of the five samples were analyzed and recorded. The sample was cut in 10mm length x 13mm width x 3mm thickness by cutting machine. Figure 4.5 shown the sample attached to a flexural test machine.

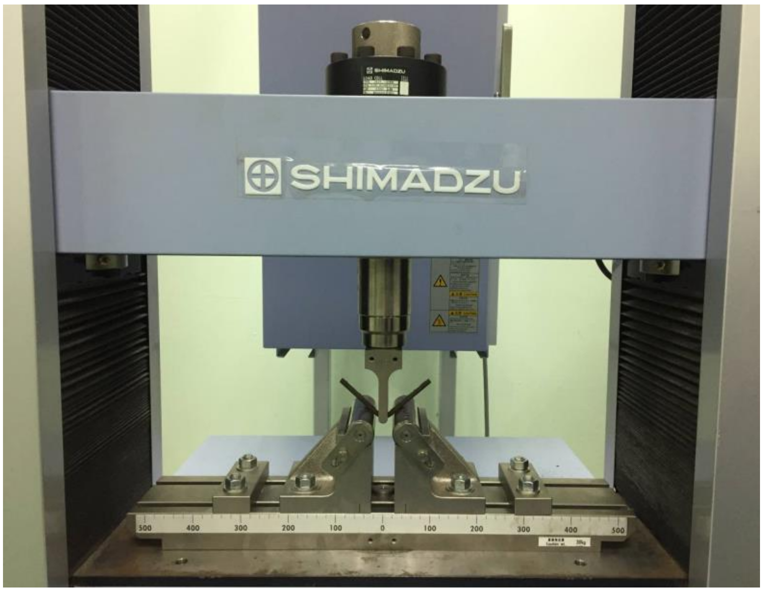


Figure 4.5 : The sample testing on flexural machine test.

Figure 4.6, 4.7,4.8 shown the graph of the flexural properties of TPCS reinforced with coconut leaf fiber composites; that is, flexural strength, strain, and elastic modulus respectively. Table 4.2 shown the analysis of variance (ANOVA) of the tensile properties. Since the p-value was less than ($p<0.05$), there was a statistically significant difference in the mean tensile strength, strain, and modulus between the levels of composites. In generally, a similar trend in the tensile and flexural characteristics of the TPCS reinforced with coconut leaf fiber composite was observed. When various percentages of coconut leaf fiber were added, it was observed that the tensile strength, strain, and modulus significantly higher as the coconut leaf fiber content was increased.

According to Figure 4.6, the flexural strength of the TPCS reinforced with coconut leaf fiber composite was observed to increased significantly by stage from 0 wt.% to 30% fiber content, while the highest strength was obtained when 30% coconut leaf fiber was added. This demonstrated that the optimal amount of coconut leaf fiber required for reinforcing was 30% wt. because the strength is the highest compared with the other.

According to Xia et al., (2016) state that, fibre-matrix interaction plays a key role in developing high-performance polymer/fibre composites. Flexural strength of the composite is significantly increased with increasing CLF content on the composite. Hence, Elanchezhian et al., (2018) state that, by integrating natural fibre into the TPCS matrix, the flexural strength and modulus can be increased. According to Ratna Prasad & Mohana Rao, (2011) state that, Flexural strength increases due to the improved adhesion between the matrix and the fibre. The flexural strength increase may be due to stronger bonding of CLF fibre with TPCS matrix and its strength.

From the highest flexural strength 30 wt.%, 10.29 Mpa the strength drops to 40 wt.%, 8.10 MPa. The strength decrease may be due to fibre integration and void presence, which may lead to a localised stress concentration point that helps propagate crack (Jumaidin et al., 2017). Hence, according to Radzi et al., (2019) state that the decreased in strength and modulus might be due to non-uniform interfacial bonding and poor distribution of fibers and matrix.

In addition, Senthilkumar et al., (2019) stated the reduction of flexural strength at 40 wt.% CLF loading due to increased inter-fibre interaction within the matrix and low fibre dispersion, non-uniform applied stress transfer between the fibre and matrix may be due. The reduction is caused by the inherent weak interfacial bonding of natural fibres, which produces partial spaces between the fibre and the polymer matrix, resulting in a poor transfer of stress and decreased composite strength (Siakeng et al., 2019).

Hussain & Rangadu, (2015) observed that the composite material's flexural strength is greater at a low fiber volume fraction than at a high fiber volume fraction. As a result, the flexural strength of the composite material increases as the fiber length decreases. Due to the fact that the fiber volume fraction is the primary factor affecting the flexural strength. In generally, a similar trend in the tensile and flexural characteristics of the TPCS/ coconut leaf fiber composite was observed. When various percentages of coconut leaf fiber were added, it was observed that the tensile strength, strain, and modulus significantly higher as the coconut leaf fiber content was increased.

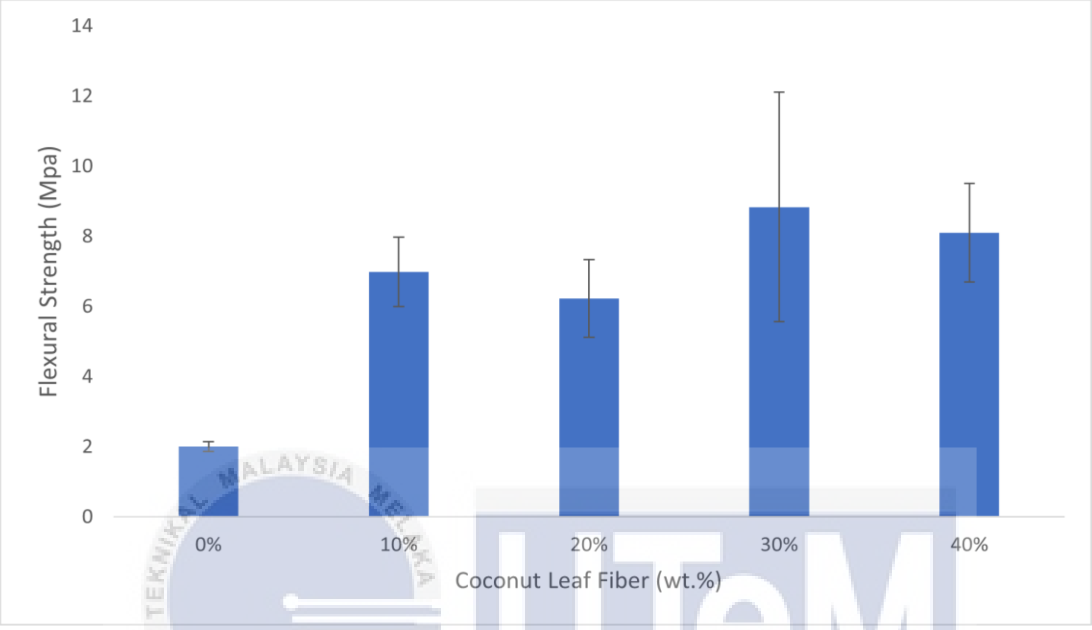


Figure 4.6 : The flexural strength (MPa) versus CLF loading (wt.%).

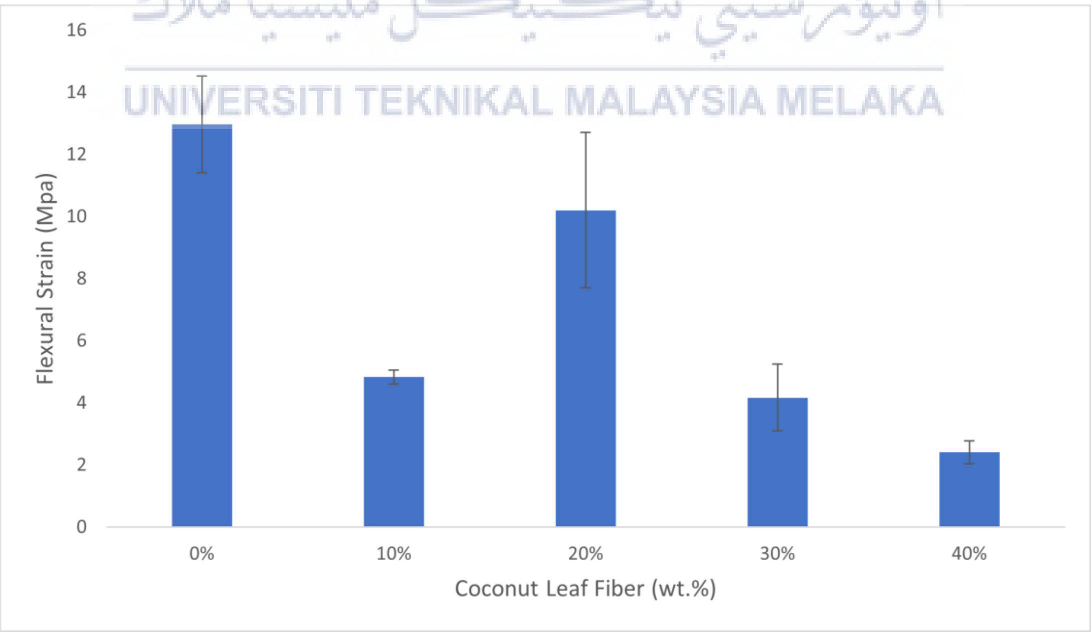


Figure 4.7 : The flexural strain (MPa) versus CLF loading (wt.%).

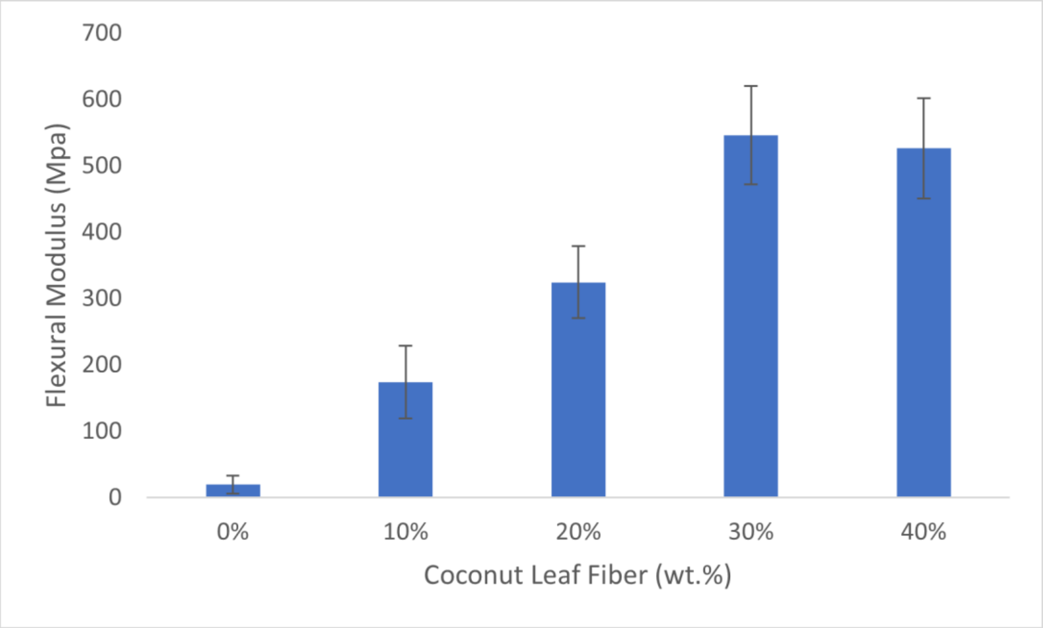


Figure 4.8 : The flexural modulus (MPa) versus CLF loading (wt.%).

Table 4.2 : Summary of the analysis of variance (ANOVA) of flexural properties

Variables	df	Flexural Strength	Flexural Strain	Flexural Modulus
Mixture	4	0.00*	0.00*	0.00*

4.3 Thermal Analysis

4.3.1 Thermogravimetric Analysis (TGA)

Thermogravimetric or thermal gravimetric analysis was performed to investigate the material's degradation and stability. This behavior can be identified as the weight of the material decreasing as the temperature rises. TGA is a useful approach for the quantitative assessment of the degradation activity and the composition of the fibre and the matrix in a composite. Information on the component and the reciprocal effect of the composite parts on the temperature scale also provides the magnitude and position of peaks found in the derivative thermogravimetric (DTG) curve.

According to Razali et al., (2015) state that, before using TGA in a polymer composite, it is important to recognise the degradation of the natural fibre at a high temperature. During exposure to elevated temperatures during the production process with polymer/resin, the fibres are also affected. The analysis was carried out in an aluminium crucible pan under a dynamic nitrogen atmosphere with a heating rate of 10°C min^{-1} and temperatures ranging from 25°C to 900°C. Figure 4.9 shown TGA thermograms of TPCS reinforced by CLF after treatment. Meanwhile Figure 4.10 shown DTG curve of TPCS reinforced by CLF at different composition after treatment.

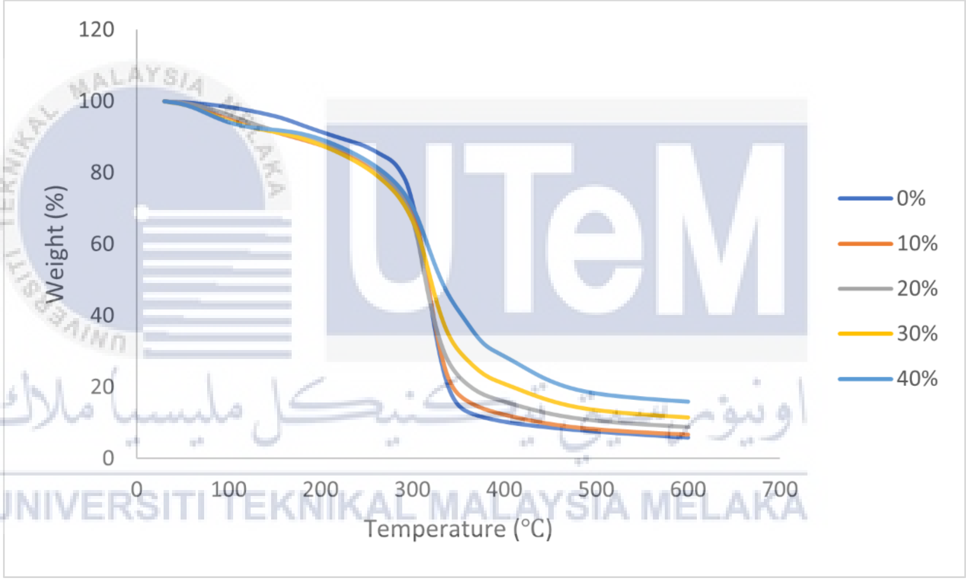


Figure 4.9 :Thermograms of TPCS reinforced by CLF after treatment.

All of the curves are shown the immediate onset decomposition reaction completed is between at temperature between between 350°C and 420 °C. Based on this graph, the highest weight loss occurred are from the lowest percentage of coconut leaf fiber on the composite. The thermal degradation at this temperature is due to the thermal decomposition of natural fibres from hemicellulose, lignin, pectin and glycosidic cellulose linkages (Asim et al., 2020). Hence, a similar finding was observed by Sahari et al., (2014) state that, the mass loss due to the decomposition of the three major constituents of natural fibers which are hemicellulose, cellulose, and lignin.

It was determined that as the temperature was increased, the sample's weight reduced due to degradation. At temperatures about 200 ° C, the first thermal event contributed to the initial weight loss. This might be attributed to the evaporation of moisture from the sample's water (Jumaidin et al., 2021). This was also supported by Ibrahim et al., (2019) which state that in the previous study, the weight loss mostly due to fructose fragment volatilization and water particles' evaporation. A similar was reported by Asim et al., (2018) in the previous study on kenaf/pineapple leaf fibres phenolic hybrid composites, which state that the first weight losses occurred due to the water molecules evaporating or dehydrating in untreated and treated PALF/KF hybrid composites.

The second thermal event is between 250℃ to 310℃. Due to the depolymerization and degradation of the carbon chain within the starch matrix, which is the main compound of the composite, the highest mass loss occurs (Ibrahim et al., 2019). According to Asim et al., (2018) which state that, the greatest weight loss occurred between 278 and 306^{o}C, owing to the heat decomposition of hemicellulose, lignin, pectin, and the glycosidic connections of cellulose in natural fibres. This was also supported by Nadlene et al., (2018) in the previous study which state that, the thermal degradation of the roselle fibre occurs due to the thermochemical change in the fiber's hemicellulose content produced by cellular breakdown as the temperature increases. Meanwhile, decomposition of lignin was shown at 300^{o}C at the third thermal. It might be attributed to the lignin is a particularly tough component that is responsible for the stiffness of plant materials (Edhirej et al., 2017). This finding was in agreement with a study by Sahari et al., (2013) which state that in the previous study on environmentally friendly composites derived from sugar palm tree, the third phase involved the breakdown of lignin. In comparison to hemicellulose and cellulose, it is the most hardest to decompose. This is due to lignin, an extremely resistant component that is also known as the ingredient that gives plant materials their rigidity.

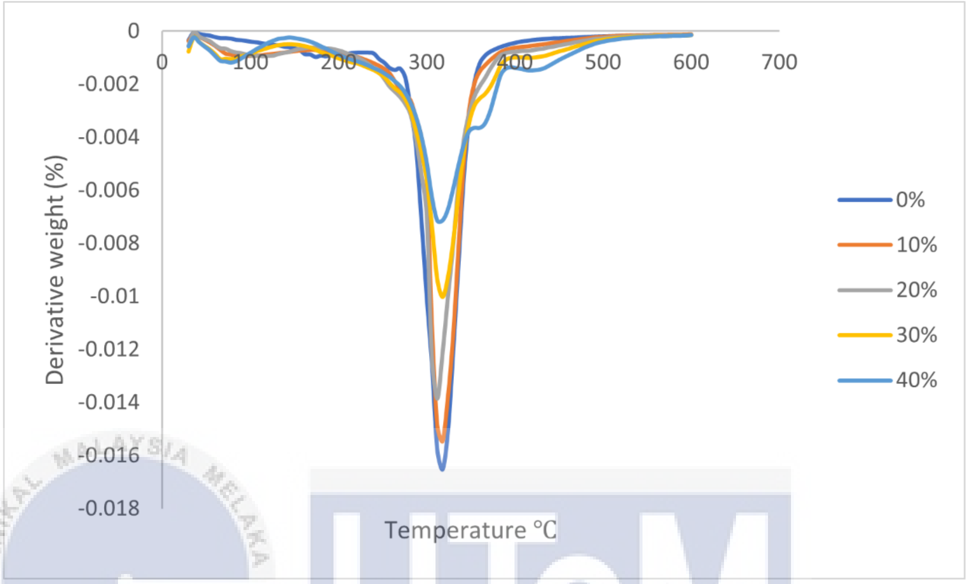


Figure 4.10 : DTG curve at the different composition of CLF after treatment

Meanwhile, Figure 4.10 shown DTG curves clearly depict the degrading features. The result shown that on the 0 wt.% loadings of fibre are shown the highest loss in derivative weight. According to Jumaidin et al., (2020) state that by adding fibre to starch matrix enhances heat stability due to the matrix's high adhesion to the fibre, which results in less weight loss in the specimens. This was also supported by Q. Zhou et al., (2009) in the previous study on Effect of fiber surface treatment on their properties which state that, the degradation rate showed the decomposition of fibre cellulose and hemicellulose or fibre loosening in composites.

4.4 Other Testing

4.4.1 Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR test was performed to determine the presence of functional groups in coconut leaf fibre. Aside from that, the purpose of this test is to investigate the functional group and chemical properties that exist in the material composite which in this case is between fiber and starch. The spectra of the material was obtained using an IR spectrometer (Nicolet 6700 AEM). Figure 4.11 shows that FTIR Spectroscopy Machine.

Figure 4.11 shows the FTIR spectrometer of TPCS/Beeswax with integration of coconut leaf fibre composite consisting of 0% to 40% fibre content. Generally, similar band patterns are exhibited for 0%, 10%, 20%, 30%, and 40% fibre content, respectively. This pattern indicates that the combining of materials such as cassava starch, glycerol, beeswax, and coconut leaf fibre has no effect on the chemical composition. This finding might be due to starch and fibres were primarily composed of cellulose structure (Prachayawarakorn, 2013). Similar finding reported by Edhirej et al., (2017) on previous study about Cassava/sugar palm fiber reinforced cassava starch hybrid composites which state that, due to the materials were generated from biological resources, the FT-IR spectra of all samples revealed the same peaks. According to Lomelí-Ramírez (2014) about bio-composites of cassava starch-green coconut fiber. Based on the previous finding, the spectra of all TPS composites revealed the same pattern of bands. This indicates that the starch is not chemically altered or modified by the presence of glycerol or the amount of fiber during the plasticizing process. Furthermore, their association may be directly attributed to molecular interactions.

A part from that, it was observed that the presence of hydroxyl groups, O-H, in the TPCS/coconut leaf fibre ranged from 0% to 40% fibre content, which was positioned between 3400 and 3200 cm-1. Cassava starch and coconut leaf fibre were the primary contributors to the O-H group's presence. According to Edhirej et al., (2017) state that, the intense peaks at 3200–3500 cm−1 indicated the presence of O H groups in starch and fiber, showing that starches are very sensitive to water molecules due to the presence of hydroxyl groups. This was also supported by Sahari et al., (2013) in the previous study on environmentally friendly composites derived from sugar palm tree which state that, The presence of O–H groups in starch and fibre shown that starches are extremely sensitive to water molecules due to their hydroxyl group content.

Based on the Figure 4.11, the wavenumber of O- H bands 30% fiber content is decreasing from 3291 cm^{-1} to 3272 cm^{-1}. It can be observed that the presence of O-H bands changes slightly as the fiber content increases. According to Ma et al., (2009) state that on previous study about thermoplastic pea starch composites, the differences in the bandwidth and frequency of the OH band between native starch and matrix and composites are seen in the region of 3299–3303 cm^{1}. This modification could have occurred because of the plasticizing process. This indicates that the presence of glycerol influences the intermolecular hydrogen bond network between starch molecules. A similar finding was reported by Jumaidin et al., (2017) which stated that on previous study, the spectra band peaks was affected by the interaction of intermolecular hydrogen bonding.

Additionally, the characteristic of C-H stretch was shown in the band between 2966 and 2918 cm^{-1}. This finding might be due to the presence of cellulose and hemicellulose in natural fiber contributes to the presence of the C-H band (Jumaidin et al., 2017). Similar finding was reported in the previous study on properties of roselle fiber-reinforced vinyl ester composites which state that the presence of the C-H band is due to the presence of the characteristic bands for the CAH stretching vibration from CH and CH^{2} in the cellulose and hemicellulose components of untreated roselle fibers (Nadlene et al., 2018).

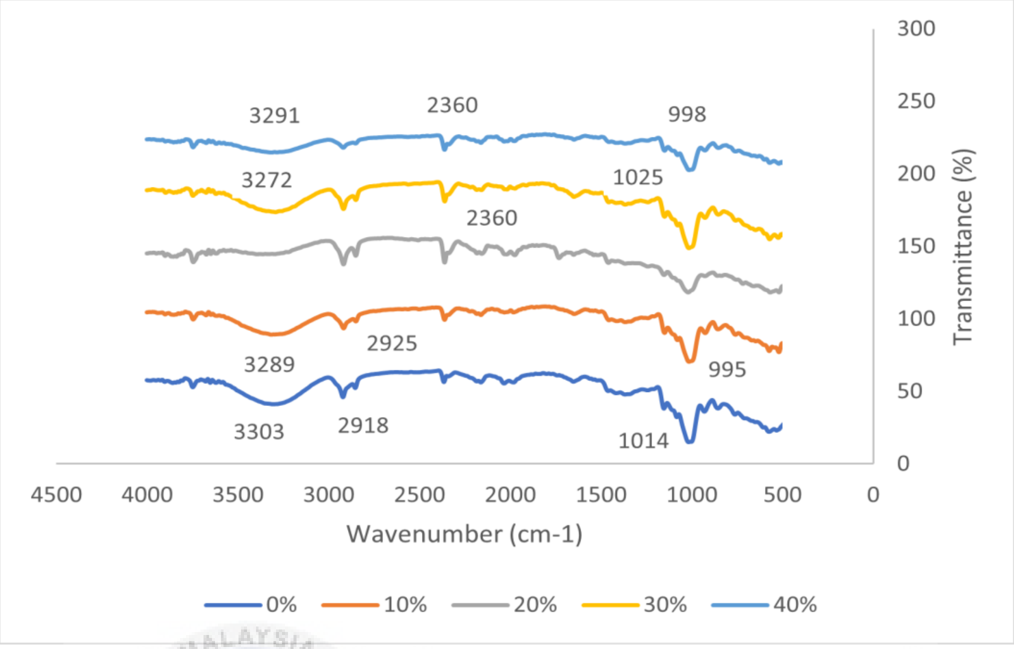


Figure 4.11 : FTIR Spectroscopy of TPCS/Coconut leaf fiber composite with different percentage of fiber loading

4.4.2 Scanning electron microscope (SEM) analysis

A scanning electron microscope is a kind of electron microscope that collects images of a sample by scanning the surface with a centred electron beam. The electrons interact with the atoms in the sample, creating different signals that provide details about the surface's topography and the sample composition. The purpose of this study's scanning electron microscope is to analyze the morphology and failure mechanism of TPCS/coconut leaf fiber composite. According to Edhirej et al., (2017) state that, the interface between the matrix and fiber of the composite material can be seen through SEM micrographs. Hence, the use of SEM also makes it possible to monitor the failure approach at the micro level (Kamal, 2012).

The sample is taken from a fractured tensile sample from different TPCS reinforced with coconut leaf fiber to analyze the morphology and test using model Zeiss

Evo 18 machine. Figure 4.12 shows the morphology of tensile fractured from a different percentage of TPCS reinforced with coconut leaf fiber composites a) 0%, b) 10%, c) 20%, d) 30% and 40% fiber content. Basically, it was observed that the TPCS matrix's surface was smoother than the fiber content. These findings indicate that previous mixing of starch and glycerol increased starch plasticization (Jumaidin et al., 2020). Similar finding were reported in the previous study on the effect of water and citric acid on sago starch bio-plastics which state that, by adding the glycerol, it can make the smooth structure (Zuraida et al., 2012). Hence, the results indicated that when different fiber contents were loaded, the microstructures of each specimen varied.

Figure 4.12 a) shows the TPCS reinforced with coconut leaf fiber composites (0% wt.). The Figure shows that, the surface of the sample can be seen in shiny structure which shows the appearance of beeswax that alters the starch structure. Hence, the structure of a surface with 0% wt. fiber content, has a homogeneous surface and no visible air pockets. This might due to the addition of glycerol has improved the starch plasticization, which is also attributable to the melting of the starch during the manufacturing process (Jumaidin et al., 2020). Similar finding were reported in the previous study on cassava/sugar palm fiber reinforced cassava starch hybrid composites state that, the pure cassava starch film has a compact structure and a homogeneous surface as well as good adherence of the SPF to the TPS matrix, all of which contribute to the improved performance of the material when observe under SEM micrograph (Edhirej et al., 2017).

The results indicated that when different fiber contents were loaded, the microstructures of each specimen varied. Fiber breakage was observed in all composites because of tensile fracture caused by the matrix's high stress transfer to the fibers, which reinforced the composites. Figure 4.12 b) shows the SEM micrographs of TPCS with 10% coconut leaf fiber while the figure 4.12 c) shows the SEM micrographs of TPCS with 20%

coconut leaf fiber. The figure was shown that fiber breakage and micro void is visible in the composite samples with 10% and 20% fiber content. Fiber breakage was observed due to the matrix's high stress transfer to the fibers, which reinforced the composites (Ridhwan Jumaidin et al., 2021). A similar finding was obtained in a study carried out by (Mo et al., 2010) on properties of TPCS reinforced with banana fiber. The findings indicated that TPCS was deposited on the surface of banana fiber and that fiber breakage was clearly visible due to the increasing the amount of fiber in a composite can influence the composition of the composite. Besides that, it also was attributed to the fact that TPS and banana fiber form strong intermolecular hydrogen bonds. This result was also connected with an increase in tensile strength, demonstrating that TPS was a good matrix for natural fibers.

Figure 4.12 d) shows the SEM micrographs of TPCS with 30% coconut leaf fiber while Figure 4.12 e) shows the SEM micrographs of TPCS with 40% coconut leaf fiber. Both Figure shows that the presence of more void and fiber breakage on fracture surface. High fiber content will cause the composition to be unstable where the matrix cannot cover the entire area and therefore cause void to occur. This statement is supported by (Mo et al., 2010) which state that on previous study the increasing the amount of fiber in a composite can influence the composition of the composite. Since the percentage of fiber content has increased, the state of the fiber has begun to deteriorate, resulting in the formation of voids on the surface of the samples composing the composite. Similar finding were reported in the previous study on processing and characterization of banana leaf fiber reinforced thermoplastic cassava starch composites which state that a higher fiber level resulted in more rough fractures than a lower fiber concentration (Jumaidin et al., 2021). Hence, the void also makes the composite strength decrease and make the fracture surfaces coarser and stiffer (Ibrahim et al., 2019). According to Krishnaiah et al.,

(2018) state that, these wide voids may be due to the fiber pull-out from the matrix process when tensile force was applied, indicating weak interfacial adhesion in the TPCS/CLF composites between the fiber and matrix interface. Similar finding was reported in the previous study on mechanical properties of pineapple leaves fiber. They noticed that because of voids between PLF and PP, poor adhesion and their mechanical properties have been affected (Kasim et al., 2015).

Thus, using SEM micrographs, it was proved that increasing the fiber loading enhanced the composites' flexural and tensile strength. Since the sample is taken from a fractured tensile sample from different TPCS reinforced with coconut leaf fiber to analyze the morphology.

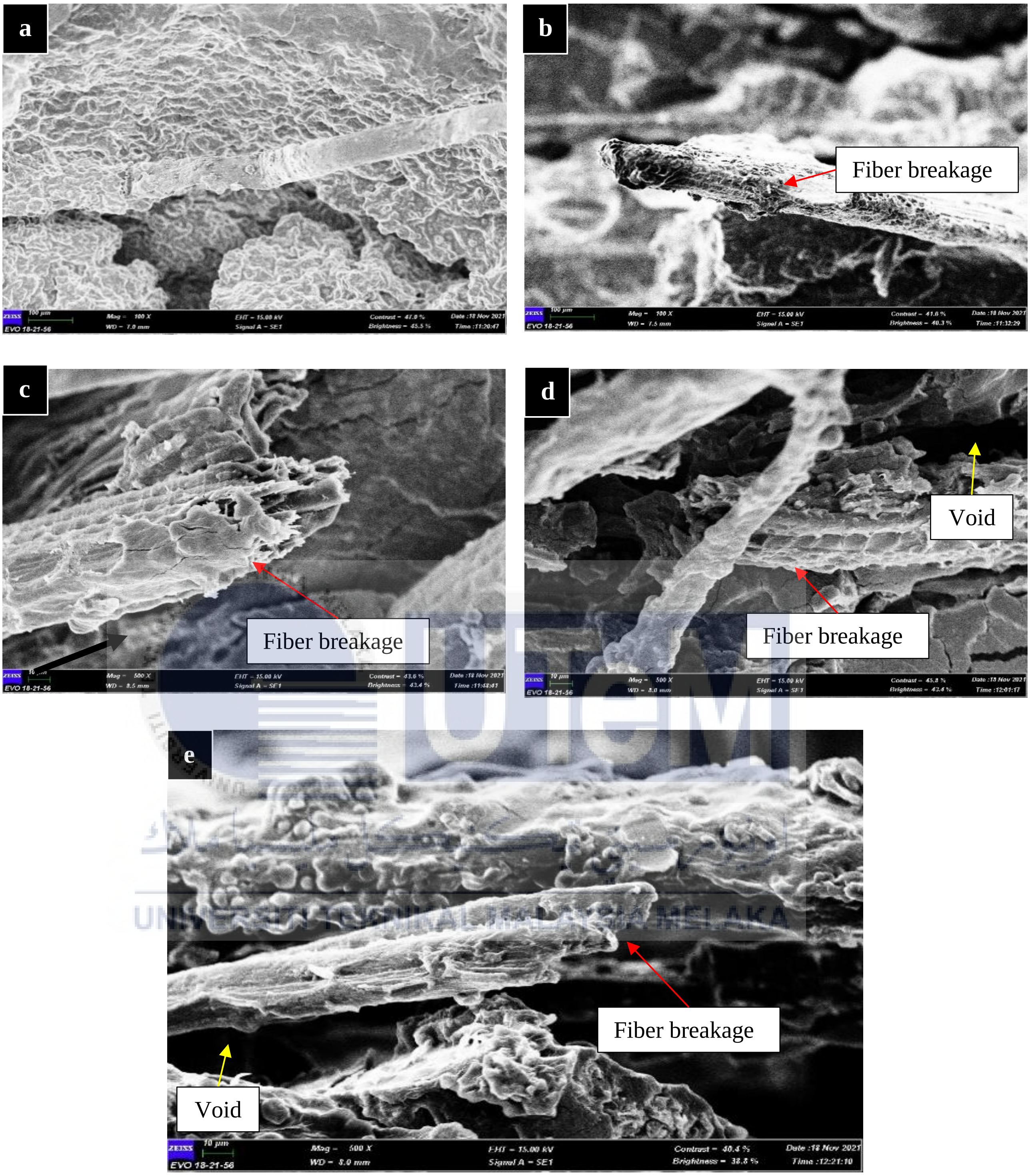


Figure 4.12 : SEM Micrograph of TPCS reinforced by coconut leaf fiber composites a) 0%wt. b) 10%wt. c) 20% wt. d) 30%wt. e) 40% wt.

4.5 Fabrication of Packaging Tray

The biodegradable packaging tray from the coconut leaf fiber composite was successfully manufactured using hot-pressing equipment 155°C for 60 minutes and cooling for 20 minutes. The fabrication of the packaging tray was comparable to the fabrication of material testing samples. The process started with the physical mixing of four basic ingredients: cassava starch, beeswax, glycerol, and coconut leaf fiber. Then, using the blender, continue blending until the liquid is uniform. In this case, a fiber mix of 20% was chosen throughout the fabrication process. The size of the packaging tray is 130 mm (L) x 80 mm (W) x 3 mm (T).

Figure 4.13 : TPCS with 20% coconut leaf fiber sample tray

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

Many researchers have conducted on the development of new ecologically friendly and long-lasting materials. The development of new biodegradable products is essential currently to preserve nature. The primary goal of this study is to document the advancement of a unique material derived from cassava starch. Three key objectives guide this research. The following are the study's aims and conclusion:

i. **To produce biodegradable thermoplastic cassava starch reinforced with coconut leaf fiber composite.**

The biodegradable thermoplastic composite composed from cassava starch and coconut leaf fiber was successfully manufactured using dry mixing and hot-pressing equipment. The mechanical properties of TPCS reinforced with coconut leaf fiber composite were determined at various fiber loading percentages.

ii. **To investigate the thermal testing and mechanical testing of biodegradable thermoplastic cassava starch reinforced with coconut leaf fiber composite.**

The tensile properties and flexural properties of TPCS reinforced with coconut leaf fiber composite were evaluated. In generally, a similar trend in the tensile and flexural characteristics of the TPCS/ coconut leaf fiber composite was observed. Due to the addition of fiber, the result shows that at 30% shows the maximum tensile and flexural strength, modulus. When various percentages of coconut leaf fiber were added, it was observed that the tensile strength, and modulus significantly higher as the coconut leaf fiber content was increased and then decreased at 40% wt. Hence, for the tensile strain, it was found that at 10% shows the maximum tensile strain and for the flexural shows that, at 20% shows the maximum result for flexural strain. Besides that, the characterization of TPCS reinforced with coconut leaf fiber was done by using SEM and FTIR. It was shown from SEM micrograph that different microstructure of the composite due to increasing of fiber content. In the FTIR spectroscopy, it was found that there the present of O-H, C-H and C-O bands in the samples. It can be seen a slight change of O-H bands when increasing of fiber content. Hence, in term of thermal, it improved thermal stability. The increase the residue content, this indicates the increase in fiber content.

iii. To produce biodegradable packaging from the coconut leaf fiber

The biodegradable packaging tray from the coconut leaf fiber composite was successfully manufactured using hot-pressing equipment 155°C for 60 min and cooling for 20 minutes. The fabrication of the future product was comparable to the fabrication of material testing samples. The process started with the physical mixing of four basic ingredients: cassava starch, beeswax, glycerol, and coconut leaf fiber. Then, using the blender, continue blending until the liquid is uniform. In this case, a fiber mix of 20% was chosen throughout the fabrication process. The size of the product is 130 mm (L) x 80 mm (W) x 3 mm (T). Hence, this product has a high chance of being commercialized in industry as a single-use tray if the production process is tweaked a bit. This material has a lot of potential as a synthetic plastic substitute. The survey has been conducted to obtain information on a product that can be purchased from a market store to determine that this product has industry-wide commercialization potential.

5.2 Recommendation

Recommendations for future work and potential for progress are described as follows to further and enhance the production of biodegradable plastic in natural fiber studies that reinforce matrix material:

i. To study a new fabrication process of material for a high-volume production such as injection molding.
ii. To study a proper method on extraction of coconut leaf fiber especially in high volume extraction.
iii. To study a new type of natural fiber that can be used to fabricate the composite material

Overall, it can be concluded in this research are, the TPCS reinforced by coconut leaf fiber was a material that can be studied further due to the strength of the composite.

5.3 Project Potential

The process of producing the possible product was comparable to that of developing material testing samples. The procedure began with physically mixing the four important ingredients, which were cassava starch, beeswax, glycerol, and coconut leaf fiber. Then, using the blender, continue blending until the liquid is completely homogeneous. The fiber percentage in this fabrication process was set at 20%. The liquid was then poured into the prepared mold, which had been coated with Mylar film to make removal easier. The mold was placed in a hot press machine set to 155°C for 1 hour then cooling for 20 minutes. Hence, this product has a high chance of being commercialized in industry as a single-use tray if the production process is tweaked a bit. This material has a lot of potential as a synthetic plastic substitute. A possible new product is shown in Figure 5.1.

Figure 5.1 shows another thermoplastic tray application. Cassava starch/beeswax supplemented with coconut leaf fiber to keep scents and skin care. Lipstick and make-up are some of the products available. Hence, this product's inexpensive price is another benefit. The quantity of raw material used is minimal. Table 5.1 below shows a rough cost estimate for manufacturing. Thermoplastic made of cassava starch and beeswax, reinforced with coconut leaf fiber The report claims that the cost is comparable to other non-biodegradable bioplastics, as shown in Table 5.1. The composite is only RM0.17. It was decided to conduct a survey of end users, such as owners. To obtain information on a product that can be purchased from a market store determined that this product has industry-wide commercialization potential.

Table 5.1 : Total Cost of Raw Material for One Tray

Material	Weight (g)	Price per kg (RM)	Price per gram (RM)	Price per tray (RM)
Cassava Starch	38.50	3.00	0.003	0.11
Glycerol	11.60	2.60	0.0026	0.03
Beeswax	5.82	2.60	0.0026	0.02
Coconut Leaf Fiber	11.64	1.00	0.001	0.01
Total cost				0.17

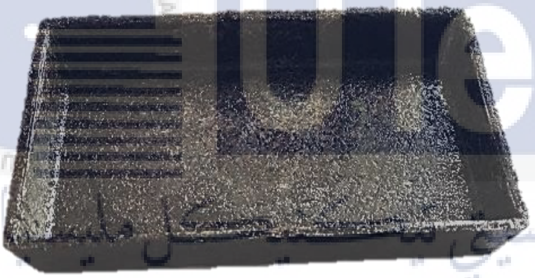
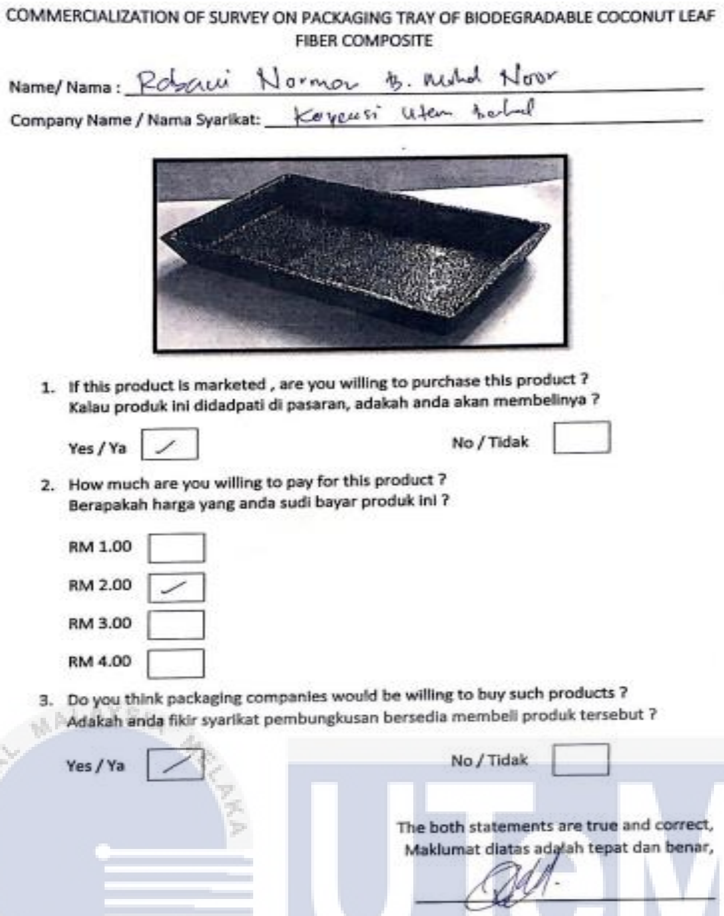


Figure 5.1 : TPCS with 20% coconut leaf fiber sample tray

Figure 5.2 : Application of TPCS with coconut leaf fiber as skin care and medicine



COMMERCIALIZATION OF SURVEY ON PACKAGING TRAY OF BIODEGRADABLE COCONUT LEAF FIBER COMPOSITE

Name/ Nama : Rosawi Normar B. Mohd Noor

Company Name / Nama Syarikat: Koperasi Utem berhad

1. If this product is marketed , are you willing to purchase this product ?
   Kalau produk ini didadpati di pasaran, adakah anda akan membelinya ?

   Yes / Ya ☑ No / Tidak ☐

2. How much are you willing to pay for this product ?
   Berapakah harga yang anda sudi bayar produk ini ?

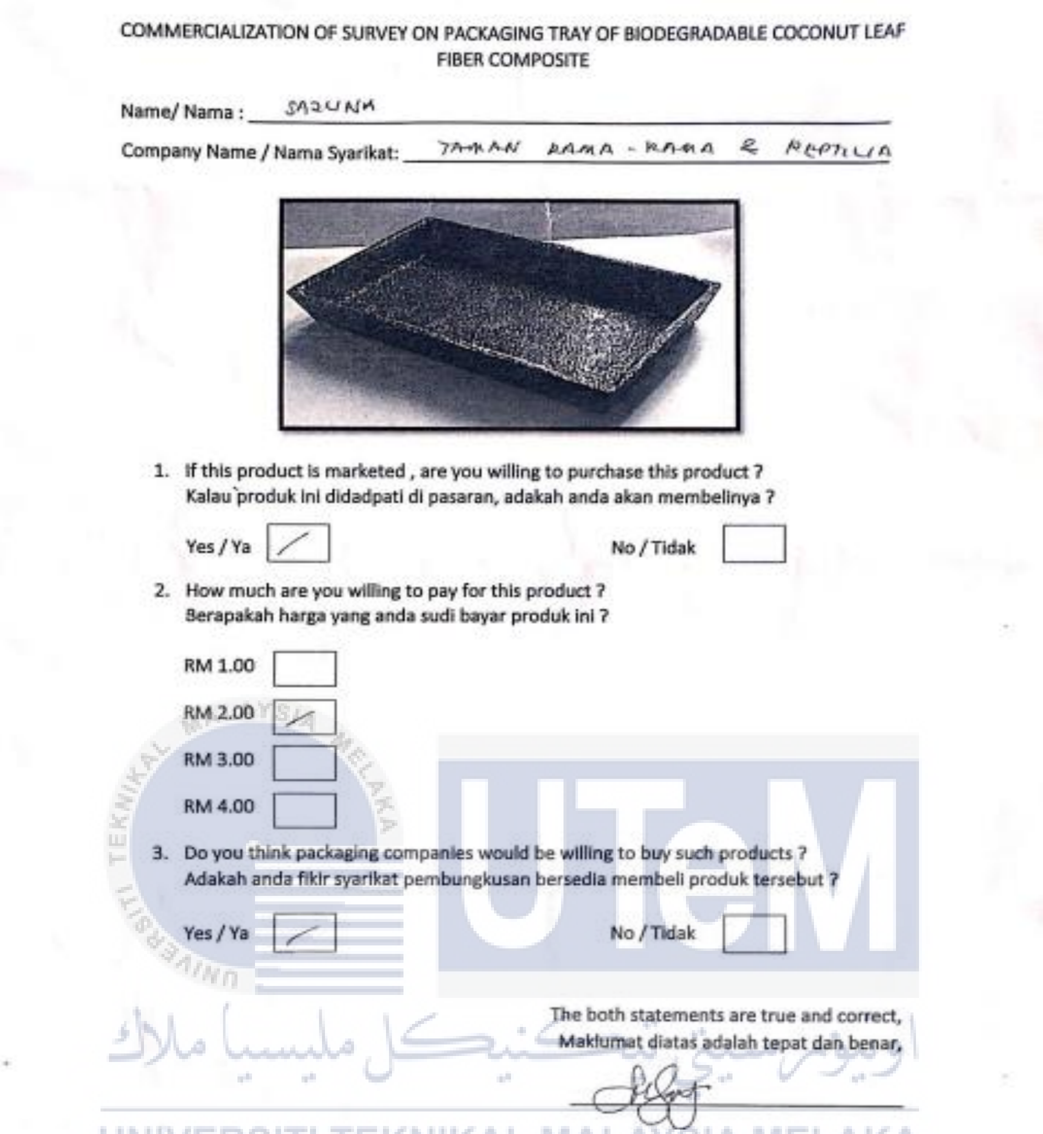
   RM 1.00 ☐
   RM 2.00 ☑
   RM 3.00 ☐
   RM 4.00 ☐

3. Do you think packaging companies would be willing to buy such products ?
   Adakah anda fikir syarikat pembungkusan bersedia membeli produk tersebut ?

   Yes / Ya ☑ No / Tidak ☐

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

Figure 5.3 : Survey Market



COMMERCIALIZATION OF SURVEY ON PACKAGING TRAY OF BIODEGRADABLE COCONUT LEAF FIBER COMPOSITE

Name/ Nama : SAZUNA

Company Name / Nama Syarikat: TAMAN RAMA-RAMA & REPTILIA

1. If this product is marketed , are you willing to purchase this product ?
   Kalau`produk ini didadpati di pasaran, adakah anda akan membelinya ?

   Yes / Ya ☑ No / Tidak ☐

2. How much are you willing to pay for this product ?
   Berapakah harga yang anda sudi bayar produk ini ?

   RM 1.00 ☐
   RM 2.00 ☑
   RM 3.00 ☐
   RM 4.00 ☐

3. Do you think packaging companies would be willing to buy such products ?
   Adakah anda fikir syarikat pembungkusan bersedia membeli produk tersebut ?

   Yes / Ya ☑ No / Tidak ☐

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

Figure 5.4 : Survey Market

5.4 Lifelong Learning

This two-semester study on Thermoplastic Cassava Starch/Beeswax Reinforced with Coconut Leaf Fiber Composite has taught me a lot of new things and supplied me with a lot of new information, from literature review through sample construction and testing. This study gave a new perspective on data analysis using variance statistical analysis (ANOVA), which was utilized to determine the significant changes in the tests. Aside from that, this assignment has helped me improve my writing skills to a good level. On occasion, when reporting the report to the supervisor, the writing ability was improved. Furthermore, effective communication is critical to the project's success. It entails both communication with the supervisor and communication among teammates. Any components of the project that the student does not understand must be communicated to the supervisor. Teams must work together to help one another to complete this project. A good time management system is also required when completing laboratory work and attending online classes. Hence, both soft skills and practical skills improved during the two semesters of PSM 1 and PSM 2. The soft skills of the participants improved during the preparation and presentation of PSM 1 and PSM 2. The students' practical skills improved greatly when completed laboratory tests such as Tensile testing, Flexural test, Thermogravimetric analysis (TGA), Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) increased.

REFERENCES

Adamcová, D., Radziemska, M., Fronczyk, J., Zloch, V., & Vaverková, M. D. (2017). Research of the biodegradability of degradable/biodegradable plastic material in various types of environments. Scientific Review Engineering and Environmental Sciences, 26(1), 3–14. Https://doi.org/10.22630/PNIKS.2017.26.1.01

Agarwal, A., Thombre, M., Chandrajeet, & Kashyap, S. (2010). Preparation and Characterization of Polymer Matrix Composite Using Natural Fiber Lantana-Camara Polymer Matrix Composite Using. Journal of Mechanical and Civil Engineering, 008, 60–65. Http://ethesis.nitrkl.ac.in/2793/1/PREPARATION_AND_CHARACTERIZTION+23-09-10(REVISED).pdf

Alcázar-Alay, S. C., & Meireles, M. A. A. (2015). Physicochemical properties, modifications and applications of starches from different botanical sources. Food Science and Technology, 35(2), 215–236. Https://doi.org/10.1590/1678-457X.6749

Asim, M., Paridah, M. T., Saba, N., Jawaid, M., Alothman, O. Y., Nasir, M., & Almutairi, Z. (2018). Thermal, physical properties and flammability of silane treated kenaf/pineapple leaf fibres phenolic hybrid composites. Composite Structures, 202, 1330–1338. Https://doi.org/10.1016/j.compstruct.2018.06.068

Asim, Mohammad, Paridah, M. T., Chandrasekar, M., Shahroze, R. M., Jawaid, M., Nasir, M., & Siakeng, R. (2020). Thermal stability of natural fibers and their polymer composites. Iranian Polymer Journal (English Edition), 29(7), 625–648. Https://doi.org/10.1007/s13726-020-00824-6

Asim, Mohammad, Thariq, M., Sultan, H., & Com-, H. P. (2017). Synthetic Fiber Processing of hybrid polymer compos- ites — a review Natural lightweight hybrid composites for aircraft structural applications Bioprocessing of synthetic fibres.

Asperger, A., Engewald, W., & Fabian, G. (1999). Analytical characterization of natural waxes employing pyrolysis-gas chromatography-mass spectrometry. Journal of Analytical and Applied Pyrolysis, 50(2), 103–115. Https://doi.org/10.1016/S0165-2370(99)00031-5

Asuquo, I. (2018). Plastic Waste in the Aquatic Environment: Impacts and Management. Environment, 2(1), 1. Https://doi.org/10.31058/j.envi.2018.21001

Aviara, N. A., Igbeka, J. C., & Nwokocha, L. M. (2010). Effect of drying temperature on physicochemical properties of cassava starch. International Agrophysics, 24(3), 219–225.

Awuchi, C. G. (2017). Sugar Alcohols : Chemistry , Production , Health Concerns and Nutritional Importance. International Journal of Advanced Academic Research | Sciences, Technology & Engineering, 3(April), 31–66.

Bharath, K. N., Sanjay, M. R., Jawaid, M., Harisha, Basavarajappa, S., & Siengchin, S. (2019). Effect of stacking sequence on properties of coconut leaf sheath/jute/E-glass reinforced phenol formaldehyde hybrid composites. Journal of Industrial Textiles, 49(1), 3–32. Https://doi.org/10.1177/1528083718769926

Bolcu, D., & Stănescu, M. M. (2020). A study of the mechanical properties of composite materials with a dammar-based hybrid matrix and two types of flax fabric reinforcement. Polymers, 12(8), 1–20. Https://doi.org/10.3390/POLYM12081649

Bongarde, U. S., & Shinde, V. . . (2014). Review on natural fiber reinforcement polymer composites. International Journal of Engineering Science and Innovative Technology (IJESIT), 3(2), 431–436.

Brinson, H. F., & Brinson, L. C. (2015). Polymer engineering science and viscoelasticity: An introduction, Second edition. In Polymer Engineering Science and Viscoelasticity: An Introduction. Https://doi.org/10.1007/978-1-4899-7485-3

Canyon Hydro, Summary, E., Of, F., Potential, T. H. E., Ferreres, X. R., Font, A. R., Ibrahim, A., Maximilien, N., Lumbroso, D., Hurford, A., Winpenny, J., Wade, S., Sataloff, R. T., Johns, M. M., Kost, K. M., State-of-the-art, T., Motivation, T., Norsuzila Ya'acob1, Mardina Abdullah1, 2 and Mahamod Ismail1, 2, Medina, M., … Masuelli, M. (2013). We are intechopen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %. Intech, 32(July), 137–144. Http://www.intechopen.com/books/trends-in-telecommunications-technologies/gps-total-electron-content-tec- prediction-at-ionosphere-layer-over-the-equatorial-region%0aintec%0Ahttp://www.asociatiamhc.ro/wp-content/uploads/2013/11/Guide-to-Hydropower.pdf

Carvalho, A. J. F. (2008). Starch: Major sources, properties and applications as thermoplastic materials. Monomers, Polymers and Composites from Renewable Resources, 321–342. Https://doi.org/10.1016/B978-0-08-045316-3.00015-6

Cassagnau, P., Bounor-Legaré, V., & Fenouillot, F. (2007). Reactive processing of thermoplastic polymers: A review of the fundamental aspects. International Polymer Processing, 22(3), 218–258. Https://doi.org/10.3139/217.2032

Castillo, L. A., López, O. V., García, M. A., Barbosa, S. E., & Villar, M. A. (2019). Crystalline morphology of thermoplastic starch/talc nanocomposites induced by thermal processing. Heliyon, 5(6). Https://doi.org/10.1016/j.heliyon.2019.e01877

Chauhan, S., & Kumar Bhushan, R. (2017). Study of Polymer Matrix Composite with Natural Particulate/Fiber in PMC: A Review. International Journal of Advance Research, 3, 1168–1179. Www.IJARIIT.com

Chen, Z., & Liu, D. (2016). Toward glycerol biorefinery: metabolic engineering for the production of biofuels and chemicals from glycerol. Biotechnology for Biofuels, 9(1), 1–15. Https://doi.org/10.1186/s13068-016-0625-8

Cheng, W. (2019). Preparation and properties of lignocellulosic fiber/caco 3 /thermoplastic starch composites. Carbohydrate Polymers, 211(November 2018), 204–208. Https://doi.org/10.1016/j.carbpol.2019.01.062

Ching, Y. C., Chuah, C. H., Ching, K. Y., Abdullah, L. C., & Rahman, A. (2017). Applications of thermoplastic-based blends. In Recent Developments in Polymer Macro, Micro and Nano Blends: Preparation and Characterisation (Issue November). Elsevier Ltd. Https://doi.org/10.1016/B978-0-08-100408-1.00005-4

Coronado, C. R., Carvalho, J. A., Quispe, C. A., & Sotomonte, C. R. (2014). Ecological efficiency in glycerol combustion. Applied Thermal Engineering, 63(1), 97–104. Https://doi.org/10.1016/j.applthermaleng.2013.11.004

Cuevas-Carballo, Z. B., Duarte-Aranda, S., & Canché-Escamilla, G. (2017). Properties and Biodegradability of Thermoplastic Starch Obtained from Granular Starches Grafted with Polycaprolactone. International Journal of Polymer Science, 2017. Https://doi.org/10.1155/2017/3975692

Cuevas-Carballo, Z. B., Duarte-Aranda, S., & Canché-Escamilla, G. (2019). Properties and Biodegradation of Thermoplastic Starch Obtained from Grafted Starches with Poly(lactic acid). Journal of Polymers and the Environment, 27(11), 2607–2617. Https://doi.org/10.1007/s10924-019-01540-w

Curvelo, A. A. S., De Carvalho, A. J. F., & Agnelli, J. A. M. (2001). Thermoplastic starch-cellulosic fibers composites: Preliminary results. Carbohydrate Polymers, 45(2), 183–188. Https://doi.org/10.1016/S0144-8617(00)00314-3

Das, A. K., & Biswas, S. K. (2014). Effective use of mid-rib of coconut (Cocos nucifera) leaves for pulp and paper industry evaluating pulp quality. March.

Davis, J. R. (2004). Introduction to Tensile Testing. Tensile Testing, 1–13.

Deepak, K. B., & Jnanesh, N. A. (2016). Analysis of Various Characteristics of Coconut Leaves as a Biomass Briquette. National Conference on Advances in Mechanical Engineering Science (NCAMES-2016), ISSN, 2231–5381.

Dinker, A., Agarwal, M., & Agarwal, G. D. (2017). Experimental Study on Thermal Performance of Beeswax as Thermal Storage Material. Materials Today: Proceedings, 4(9), 10529–10533. Https://doi.org/10.1016/j.matpr.2017.06.414

Duru, R. U., Airuehia, G. I., & Otaigbe, J. O. (2019). Natural & synthetic wax emulsifications. September 2013.

Dynisco. (2019). Understanding Plastics and Polymers - The Different Types of Plastic. Azom, 1–11. Https://www.azom.com/article.aspx?Articleid=17477.

Edhirej, A., Sapuan, S. M., Jawaid, M., & Zahari, N. I. (2017). Cassava/sugar palm fiber reinforced cassava starch hybrid composites: Physical, thermal and structural properties. International Journal of Biological Macromolecules, 101, 75–83. Https://doi.org/10.1016/j.ijbiomac.2017.03.045

El-Shekeil, Y. A., Sapuan, S. M., Abdan, K., & Zainudin, E. S. (2012). Influence of fiber content on the mechanical and thermal properties of Kenaf fiber reinforced thermoplastic polyurethane composites. Materials and Design, 40, 299–303. Https://doi.org/10.1016/j.matdes.2012.04.003

Elanchezhian, C., Ramnath, B. V., Ramakrishnan, G., Rajendrakumar, M., Naveenkumar, V., & Saravanakumar, M. K. (2018). Review on mechanical properties of natural fiber composites. Materials Today: Proceedings, 5(1), 1785–1790. Https://doi.org/10.1016/j.matpr.2017.11.276

Fekete, E., Kun, D., & Móczó, J. (2018). Thermoplastic starch/wood composites: Effect of processing technology, interfacial interactions and particle characteristics. Periodica Polytechnica Chemical Engineering, 62(2), 129–136. Https://doi.org/10.3311/ppch.11228

Fernandes de Oliveira, H., Dos Santos Mota, O., Rocha Pinto, F., Barbosa de Alencar, D., Santos Fontineles, F. H., Dos Santos Santarém, S., & Samuel Dias Maia, D. (2019). Descriptive Analysis of Advantages and Disadvantages of Expanded Polystyrene Monolytic Panels - EPS. International Journal for Innovation Education and Research, 7(11), 159–168. Https://doi.org/10.31686/ijier.vol7.iss11.1867

Fiore, V., Scalici, T., & Valenza, A. (2014). Characterization of a new natural fiber from Arundo donax L. As potential reinforcement of polymer composites. Carbohydrate Polymers, 106(1), 77–83. Https://doi.org/10.1016/j.carbpol.2014.02.016

Folino, A., Karageorgiou, A., Calabrò, P. S., & Komilis, D. (2020). Biodegradation of wasted bioplastics in natural and industrial environments: A review. Sustainability (Switzerland), 12(15), 1–37. Https://doi.org/10.3390/su12156030

Fratini, F., Cilia, G., Turchi, B., & Felicioli, A. (2016). Beeswax: A minireview of its antimicrobial activity and its application in medicine. Asian Pacific Journal of Tropical Medicine, 9(9), 839–843. Https://doi.org/10.1016/j.apjtm.2016.07.003

Frost, K. (2010). Thermoplastic Starch Composites and Blends of Doctor of Philosophy.

Ganiron, T. U., Ucol-Ganiron, N., & Ganiron Iii, T. U. (2017). Recycling of Waste Coconut Shells as Substitute for Aggregates in Mix Proportioning of Concrete Hollow Blocks. Wsn, 77(2), 107–123. Www.worldscientificnews.com

Garriga, M. R. (2019). Evaluation of natural wax for green packaging applications. 1–96.

Gopal, M., Bhute, S. S., Gupta, A., Prabhu, S. R., Thomas, G. V., Whitman, W. B., & Jangid, K. (2017). Changes in structure and function of bacterial communities during coconut leaf vermicomposting. Antonie van Leeuwenhoek, International Journal of General and Molecular Microbiology, 110(10), 1339–1355. Https://doi.org/10.1007/s10482-017-0894-7

Gunorubon, J., & Kekpugile, K. (2012). Modification of Cassava Starch for Industrial Uses. International Journal of Engineering and Technology, 2(6), 913–919.

Gupta, G., Kumar, A., Tyagi, R., & Kumar, S. (2016). Application and Future of Composite Materials : A Review. International Journal of Innovative Research in Science,Engineering and Technology, 5(5), 6907–6911. Https://doi.org/10.15680/IJIRSET.2016.0505041

Gupta, N., & Doddamani, M. (2018). Polymer Matrix Composites. Jom, 70(7), 1282–1283. Https://doi.org/10.1007/s11837-018-2917-x

Hasmadi, M., Harlina, L., Jau-Shya, L., Mansoor, A. H., Jahurul, M. H. A., & Zainol, M. K. (2020). Physicochemical and functional properties of cassava flour grown in different locations in sabah, malaysia. Food Research, 4(4), 991–999. Https://doi.org/10.26656/fr.2017.4(4).405

Hastenreiter, L. L. G., Ramamoorthy, S. K., Srivastava, R. K., Yadav, A., Zamani, A., & Åkesson, D. (2020). Synthesis of lactic acid-based thermosetting resins and their ageing and biodegradability. Polymers, 12(12), 1–17. Https://doi.org/10.3390/polym12122849

Hemashree, K., & Bhat, J. I. (2017). Synthesis, characterization and adsorption behavior of coconut leaf carbon. Research on Chemical Intermediates, 43(8), 4369–4386. Https://doi.org/10.1007/s11164-017-2883-x

Hisham A. Maddah. (2016). Polypropylene as a Promising Plastic: A Review. American Journal of Polymer Science, 6(1), 1–11. Https://doi.org/10.5923/j.ajps.20160601.01

Ho, M. P., Wang, H., Lee, J. H., Ho, C. K., Lau, K. T., Leng, J., & Hui, D. (2012). Critical factors on manufacturing processes of natural fibre composites. Composites Part B: Engineering, 43(8), 3549–3562. Https://doi.org/10.1016/j.compositesb.2011.10.001

Ho Thanh, B., Roberts, T. K., & Lucas, S. (2018). An overview on biodegradation of polystyrene and modified polystyrene: the microbial approach. Critical Reviews in Biotechnology, 38(2), 308–320. Https://doi.org/10.1080/07388551.2017.1355293

However, C. (2001). 1. Types of Plasticizers. Encyclopedia of Polymer Science and Technology Vol 3, 3(1), 498–525.

Hussain, S. A., & Rangadu, V. P. (2015). Mechanical Properties of Green Coconut Fiber Reinforced Hdpe Polymer. November 2011.

Ibrahim, I. D., Jamiru, T., Sadiku, R. E., Kupolati, W. K., Agwuncha, S. C., & Ekundayo, G. (2015). The use of polypropylene in bamboo fibre composites and their mechanical properties - A review. Journal of Reinforced Plastics and Composites, 34(16), 1347–1356. Https://doi.org/10.1177/0731684415591302

Ibrahim, M. I. J., Sapuan, S. M., Zainudin, E. S., & Zuhri, M. Y. M. (2019). Potential of using multiscale corn husk fiber as reinforcing filler in cornstarch-based biocomposites. International Journal of Biological Macromolecules, 139, 596–604. Https://doi.org/10.1016/j.ijbiomac.2019.08.015

Ibrahim, O. O. (2016). Sugar alcohols: Chemical structures, manufacturing, properties and applications. Journal of Nutrition & Food Sciences, 06(05). Https://doi.org/10.4172/2155-9600.c1.026

Janjarasskul, T., & Krochta, J. M. (2010). Edible packaging materials. Annual Review of Food Science and Technology, 1(1), 415–448. Https://doi.org/10.1146/annurev.food.080708.100836

Jishnu, V. P., Sankar, N., & Chandrakaran, S. (2019). Strength behaviour of cohesionless soil reinforced with coconut leaf let as a natural material. Materials Today: Proceedings, 31(xxxx), S340–S347. Https://doi.org/10.1016/j.matpr.2020.04.637

Jumaidin, R, Sapuan, S. M., & Ilyas, R. A. (2019). Physio-mechanical properties of thermoplastic starch composites : A review. Prosiding Seminar Enau Kebangsaan 2019, April, 104–108.

Jumaidin, Ridhwan, Diah, N. A., Ilyas, R. A., Alamjuri, R. H., & Yusof, F. A. M. (2021). Processing and characterisation of banana leaf fibre reinforced thermoplastic cassava starch composites. Polymers, 13(9). Https://doi.org/10.3390/polym13091420

Jumaidin, Ridhwan, Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2017). Thermal, mechanical, and physical properties of seaweed/sugar palm fibre reinforced thermoplastic sugar palm Starch/Agar hybrid composites. International Journal of Biological Macromolecules, 97, 606–615. Https://doi.org/10.1016/j.ijbiomac.2017.01.079

Jumaidin, Ridhwan, Zainel, S. N. M., Adam, N. W., Hussin, M. S. F., Ghani, A. F. A., Taha, M. M., Mansor, M. R., Yaakob, M. Y., Ahmad, M. N., Maidin, N. A., Wahid, M. K., Yatim, N. A. M., Rahman, M. H. A., & Osman, M. H. (2020). Thermal Degradation and Mechanical Characteristics of Sugarcane Bagasse Reinforced Biodegradable Potato Starch Composites. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 78(1), 157–166. Https://doi.org/10.37934/ARFMTS.78.1.157166

Kale, G., Kijchavengkul, T., Auras, R., Rubino, M., Selke, S. E., & Singh, S. P. (2007). Compostability of bioplastic packaging materials: An overview. Macromolecular Bioscience, 7(3), 255–277. Https://doi.org/10.1002/mabi.200600168

Kamal, M. (2012). Scanning Electron Microscopy Study of Fiber Reinforced Polymeric Nanocomposites. Scanning Electron Microscopy, October. Https://doi.org/10.5772/35494

Karuppiah, A., & Engineering, G. (2016). Predicting the Influence of Weave Architecture on the Stress Relaxation Behavior of Woven Composite Using Finite Element. December 2016, 4–5. Https://doi.org/10.13140/RG.2.2.17881.16482

Kasim, A. N., Selamat, M. Z., Aznan, N., Sahadan, S. N., Daud, M. A. M., Jumaidin, R., & Salleh, S. (2015). Effect of pineapple leaf fiber loading on the mechanical properties of pineapple leaf fiber – Polypropylene composite. Jurnal Teknologi, 77(21), 117–123. Https://doi.org/10.11113/jt.v77.6617

Kaur, K., Ahluwalia, P., & Singh, H. (2016). Cassava: Extraction of starch and utilization of flour in bakery products. International Journal of Food and Fermentation Technology, 6(2), 351. Https://doi.org/10.5958/2277-9396.2016.00059.3

Krishnaiah, P., Thevy Ratnam, C., & Manickam, S. (2018). Morphology Water Absorption and Biodegradable Properties of Polylactide Biocomposites Reinforced with Sisal Fibers. Materials Today: Proceedings, 5(10), 22506–22516. Https://doi.org/10.1016/j.matpr.2018.06.622

Lima, E. B. C., Sousa, C. N. S., Meneses, L. N., Ximenes, N. C., Santos Júnior, M. A., Vasconcelos, G. S., Lima, N. B. C., Patrocínio, M. C. A., Macedo, D., & Vasconcelos, S. M. M. (2015). Cocos nucifera (L.) (arecaceae): A phytochemical and pharmacological review. Brazilian Journal of Medical and Biological Research, 48(11), 953–964. Https://doi.org/10.1590/1414-431X20154773

Liu, H., Xie, F., Yu, L., Chen, L., & Li, L. (2009). Thermal processing of starch-based polymers. Progress in Polymer Science (Oxford), 34(12), 1348–1368. Https://doi.org/10.1016/j.progpolymsci.2009.07.001

Lomelí-Ramírez, M. G., Kestur, S. G., Manríquez-González, R., Iwakiri, S., De Muniz, G. B., & Flores-Sahagun, T. S. (2014). Bio-composites of cassava starch-green coconut fiber: Part II - Structure and properties. Carbohydrate Polymers, 102(1), 576–583. Https://doi.org/10.1016/j.carbpol.2013.11.020

Luan, L., Wu, W., Wagner, M. H., & Mueller, M. (2010). Seaweed as Novel Biofiller in Polypropylene Composites Lixing. Journal of Applied Polymer Science, 116(5), 2658–2667. Https://doi.org/10.1002/app

M. Nayeem Ahmed, P. Vijaya Kumar, H. K. S., & Muzammil, S. B. (2013). Ijmet © I a E M E a Study on Flexural Strength of Hybrid Polymer. August, 274–286.

Ma, X., Chang, P. R., Yu, J., & Stumborg, M. (2009). Properties of biodegradable citric acid-modified granular starch/thermoplastic pea starch composites. Carbohydrate Polymers, 75(1), 1–8. Https://doi.org/10.1016/j.carbpol.2008.05.020

Ma, X., & Yu, J. (2004). The plastcizers containing amide groups for thermoplastic starch. Carbohydrate Polymers, 57(2), 197–203. Https://doi.org/10.1016/j.carbpol.2004.04.012

Macgregor, E. A. (2013). Biopolymers Development of Vapor / Gas Sensors From Biopolymer Composites.

Macosko, C. W. (1993). Plastic Behavior. Rheology: Principles, Measurements, and Applications, 92.

Maha S. H. (2017). Composites Classification and Manufacturing Operations: A Review. International Journal of Advance Research, Ideas and Innovations in Technology, 3(3), 1708–1713.

Material, B., & Gad, S. E. (2020). S.E. Gad, in Encyclopedia of Toxicology (Third Edition), 2014.

Mendagri. (2008). Waste management system in Malaysia. Waste Management System in Malaysia, 49, 69–73.

Ming-Ju Chen, Kreuter, J. Y.-T. K. (1996). Nanoparticles and microparticles for drug and vaccine delivery. Journal of Anatomy, 189 (Pt 3(Ii), 503–505. Https://doi.org/10.1002/bit

Mitrus, M., & Mościcki, L. (2009). Physical properties of thermoplastic starches. International Agrophysics, 23(3), 305–308.

Mitrus, Marcin, & Mościcki, L. (2011). Thermoplastic Starch. Extrusion-Cooking Techniques: Applications, Theory and Sustainability, 177–189. Https://doi.org/10.1002/9783527634088.ch14

Mo, X., Zhong, Y., Liang, C., & Yu, S. (2010). Studies on the properties of banana fibers-reinforced thermoplastic cassava starch composites: Preliminary results. Advanced Materials Research, 87–88, 439–444. Https://doi.org/10.4028/www.scientific.net/AMR.87-88.439

Mohamad Yazid, N. S., Abdullah, N., Muhammad, N., & Matias-Peralta, H. M. (2018). Application of Starch and Starch-Based Products in Food Industry. Journal of Science and Technology, 10(2), 144–174. Https://doi.org/10.30880/jst.2018.10.02.023

Morgan, P. W. (1981). Brief History of Fibers from Synthetic Polymers. Journal of Macromolecular Science: Part A - Chemistry, 15(6), 1113–1131. Https://doi.org/10.1080/00222338108066456

Morrison, L. R. (2000). Glycerol. Kirk-Othmer Encyclopedia of Chemical Technology. Https://doi.org/10.1002/0471238961.0712250313151818.a01

Müller, C. M. O., Laurindo, J. B., & Yamashita, F. (2012). Composites of thermoplastic starch and nanoclays produced by extrusion and thermopressing. Carbohydrate Polymers, 89(2), 504–510. Https://doi.org/10.1016/j.carbpol.2012.03.035

Muller, J., González-Martínez, C., & Chiralt, A. (2017). Combination Of Poly(lactic) acid and starch for biodegradable food packaging. Materials, 10(8), 1–22. Https://doi.org/10.3390/ma10080952

Nadlene, R., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Yusriah, L. (2018). The effects of chemical treatment on the structural and thermal, physical, and mechanical and morphological properties of roselle fiber-reinforced vinyl ester composites. Polymer Composites, 39(1), 274–287. Https://doi.org/10.1002/pc.23927

Nafchi, A. M., Moradpour, M., Saeidi, M., & Alias, A. K. (2013). Thermoplastic starches: Properties, challenges, and prospects. Starch/Staerke, 65(1–2), 61–72. Https://doi.org/10.1002/star.201200201

Nagavally, R. R. (2017). Composite Materials - History, Types, Fabrication Techniques, Advantages, and Applications. International Journal of Mechanical And Production Engineering, 5(9), 82–87.

Nathanael, W. R. N. (1961). CHEMICAL AND TECHNOLOGICAL INVESTIGA - TIONS ON COCONUT PRODUCTS.

Ncube, L. K., Ude, A. U., Ogunmuyiwa, E. N., Zulkifli, R., & Beas, I. N. (2020). Environmental impact of food packaging materials: A review of contemporary development from conventional plastics to polylactic acid based materials. Materials, 13(21), 1–24. Https://doi.org/10.3390/ma13214994

Oecd, S. (2002). Glycerol Cas N ° : 56-81-5. 56–81.

Omidi, M., Fatehinya, A., Farahani, M., Akbari, Z., Shahmoradi, S., Yazdian, F., Tahriri, M., Moharamzadeh, K., Tayebi, L., & Vashaee, D. (2017). Characterization of biomaterials. In Biomaterials for Oral and Dental Tissue Engineering (Issue August). Elsevier Ltd. Https://doi.org/10.1016/B978-0-08-100961-1.00007-4

Paiva, D., Pereira, A. M., Pires, A. L., Martins, J., Carvalho, L. H., & Magalhães, F. D. (2018). Reinforcement of thermoplastic corn starch with crosslinked starch/chitosan microparticles. Polymers, 10(9), 1–14. Https://doi.org/10.3390/polym10090985

Pattanashetti, N. A., Heggannavar, G. B., & Kariduraganavar, M. Y. (2017). Smart Biopolymers and their Biomedical Applications. Procedia Manufacturing, 12(December 2016), 263–279. Https://doi.org/10.1016/j.promfg.2017.08.030

Peleikis, K. (2011). Properties , Compositions.

Pestaño, L. D. B., & Jose, W. I. (2016). Production of Solid Fuel by Torrefaction Using Coconut Leaves As Renewable Biomass. International Journal of Renewable Energy Development, 5(3), 187–197. Https://doi.org/10.14710/ijred.5.3.187-197

Prachayawarakorn, J., Sangnitidej, P., & Boonpasith, P. (2010). Properties of thermoplastic rice starch composites reinforced by cotton fiber or low-density polyethylene. Carbohydrate Polymers, 81(2), 425–433. Https://doi.org/10.1016/j.carbpol.2010.02.041

Prachayawarakorn, Jutarat. (2013). Effect of jute and kapok fibers on properties of thermoplastic cassava starch composites. Materials and Design, 47, 309–315. Https://doi.org/10.1016/j.matdes.2012.12.012

Quispe, C. A. G., Coronado, C. J. R., & Carvalho, J. A. (2018). Glycerol : Production , consumption , prices , characterization and new trends in combustion Glycerol : Production , consumption , prices , characterization and new trends in combustion. Renewable and Sustainable Energy Reviews, 27(October), 475–493. Https://doi.org/10.1016/j.rser.2013.06.017

Radzi, A. M., Sapuan, S. M., Jawaid, M., & Mansor, M. R. (2019). Mechanical performance of Roselle/Sugar palm fiber hybrid reinforced polyurethane composites. Bioresources, 13(3), 6238–6249. Https://doi.org/10.15376/biores.13.3.6238-6249

Rajak, D. K., Pagar, D. D., Kumar, R., & Pruncu, C. I. (2019). Recent progress of reinforcement materials: A comprehensive overview of composite materials. Journal of Materials Research and Technology, 8(6), 6354–6374. Https://doi.org/10.1016/j.jmrt.2019.09.068

Rajak, D. K., Pagar, D. D., Menezes, P. L., & Linul, E. (2019). Fiber-reinforced polymer composites: Manufacturing, properties, and applications. Polymers, 11(10). Https://doi.org/10.3390/polym11101667

Rajendra, G. A., & Bhatu, P. D. (2020). General Introduction and Scope of Polymers. American Journal of pharmtech Research, 8(2), 12–33. Https://doi.org/10.46624/ajphr.2020.v8.i2.002

Rajendra, I. M., Winaya, I. N. S., Ghurri, A., & Wirawan, I. K. G. (2019). Pyrolysis study of coconut leaf’s biomass using thermogravimetric analysis. IOP Conference Series: Materials Science and Engineering, 539(1). Https://doi.org/10.1088/1757-899X/539/1/012017

Ramesh, M., Sri Ananda Atreya, T., Aswin, U. S., Eashwar, H., & Deepa, C. (2014). Processing and mechanical property evaluation of banana fiber reinforced polymer composites. Procedia Engineering, 97, 563–572. Https://doi.org/10.1016/j.proeng.2014.12.284

Rana, M., Das, A., & Ashaduzzaman, M. (2015). Physical and mechanical properties of coconut palm (Cocos nucifera) stem. Bangladesh Journal of Scientific and Industrial Research, 50(1), 39–46. Https://doi.org/10.3329/bjsir.v50i1.23808

Ratna Prasad, A. V., & Mohana Rao, K. (2011). Mechanical properties of natural fibre reinforced polyester composites: Jowar, sisal and bamboo. Materials and Design, 32(8–9), 4658–4663. Https://doi.org/10.1016/j.matdes.2011.03.015

Razali, N., Salit, M. S., Jawaid, M., Ishak, M. R., & Lazim, Y. (2015). A study on chemical composition, physical, tensile, morphological, and thermal properties of roselle fibre: Effect of fibre maturity. Bioresources, 10(1), 1803–1823. Https://doi.org/10.15376/biores.10.1.1803-1824

Rianti, A., Novenia, A. E., Christopher, A., Lestari, D., & Parassih, E. K. (2018). Ketupat as traditional food of Indonesian culture. Journal of Ethnic Foods, 5(1), 4–9. Https://doi.org/10.1016/j.jef.2018.01.001

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013). Mechanical and thermal properties of environmentally friendly composites derived from sugar palm tree. Materials and Design, 49, 285–289. Https://doi.org/10.1016/j.matdes.2013.01.048

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2014). Biodegradability and mechanical behaviour of sugar palm starch based biopolymer. American Journal of Applied Sciences, 11(10), 1836–1840. Https://doi.org/10.3844/ajassp.2014.1836.1840

Sangroniz, A., Zhu, J. B., Tang, X., Etxeberria, A., Chen, E. Y. X., & Sardon, H. (2019). Packaging materials with desired mechanical and barrier properties and full chemical recyclability. Nature Communications, 10(1), 1–7. Https://doi.org/10.1038/s41467-019-11525-x

Sanjay, M. R., Arpitha, G. R., Naik, L. L., Gopalakrishna, K., & Yogesha, B. (2016). Applications of Natural Fibers and Its Composites: An Overview. Natural Resources, 07(03), 108–114. Https://doi.org/10.4236/nr.2016.73011

Saravanan, A. M., & Sulaiman, K. A. (2014). A Study on the Process Plant Design for the Production of Polypropylene Plant. International Journal of Emerging Technology and Anvanced Engineering, 4(8), 631–635.

Senthilkumar, K., Saba, N., Chandrasekar, M., Jawaid, M., Rajini, N., Alothman, O. Y., & Siengchin, S. (2019). Evaluation of mechanical and free vibration properties of the pineapple leaf fibre reinforced polyester composites. Construction and Building Materials, 195, 423–431. Https://doi.org/10.1016/j.conbuildmat.2018.11.081

Serra Bonvehi, J., & Orantes Bermejo, F. J. (2012). Detection of adulterated commercial Spanish beeswax. Food Chemistry, 132(1), 642–648. Https://doi.org/10.1016/j.foodchem.2011.10.104

Sharma, M., & Sharma, M. (2021). Classification of Polymers. Biodegradable Polymers, 29–49. Https://doi.org/10.1201/9781003171591-2

Shogren, r. L. (1998). Starch: properties and materials applications. Biopolymers from renewable resources, 30–46. Https://doi.org/10.1007/978-3-662-03680-8_2

Shrivastava, a. (2018). Introduction to plastics engineering. Introduction to plastics engineering, i, 1–16. Https://doi.org/10.1016/b978-0-323-39500-7.00001-0

Siakeng, r., jawaid, m., ariffin, h., sapuan, s. M., asim, m., & saba, n. (2019). Natural fiber reinforced polylactic acid composites: a review. Polymer composites, 40(2), 446–463. Https://doi.org/10.1002/pc.24747

Silva, p. M., martins, a. J., fasolin, l. H., & vicente, a. A. (2021). Modulation and characterization of wax-based olive oil organogels in view of their application in the food industry. Gels, 7(1), 1–18. Https://doi.org/10.3390/gels7010012

Song, j. H., murphy, r. J., narayan, r., & davies, g. B. H. (2009). Biodegradable and compostable alternatives to conventional plastics. Philosophical transactions of the royal society b: biological sciences, 364(1526), 2127–2139. Https://doi.org/10.1098/rstb.2008.0289

Suderman, n., isa, m. I. N., & sarbon, n. M. (2018). The effect of plasticizers on the functional properties of biodegradable gelatin-based film: a review. Food bioscience, 24(june), 111–119. Https://doi.org/10.1016/j.fbio.2018.06.006

Sulaiman, k. S., mat, a., & arof, a. K. (2016). Activated carbon from coconut leaves for electrical double-layer capacitor. Ionics, 22(6), 911–918. Https://doi.org/10.1007/s11581-015-1594-9

Sýkora, d., & švec, f. (2001). Synthetic polymer. Chemical and engineering news, 79(31), 16. Https://doi.org/10.1016/b978-0-12-801889-7.00028-5

Thomas, s. P., thomas, s., abraham, r., & bandyopadhyay, s. (2008). Polystyrene/calcium phosphate nanocomposites: contact angle studies based on water and methylene iodide. Express polymer letters, 2(7), 528–538. Https://doi.org/10.3144/expresspolymlett.2008.63

Tinto, w. F., elufioye, t. O., & roach, j. (2017). Waxes. In pharmacognosy: fundamentals, applications and strategy. Elsevier inc. Https://doi.org/10.1016/b978-0-12-802104-0.00022-6

Tonukari, n. J. (2004). Cassava and the future of starch. Electronic journal of biotechnology, 7(1), 12–15. Https://doi.org/10.2225/vol7-issue1-fulltext-9

Uygunoglu, t., gunes, i., & brostow, w. (2015). Physical and mechanical properties of polymer composites with high content of wastes including boron. Materials Research, 18(6), 1188–1196. Https://doi.org/10.1590/1516-1439.009815

Velásquez Herrera, J. D., Lucas Aguirre, J. C., & Quintero Castaño, V. D. (2017). Physical-chemical characteristics determination of potato (Solanum phureja Juz. & Bukasov) starch. Acta Agronomica, 66(3), 323–330. Https://doi.org/10.15446/acag.v66n3.52419

Version, I., Kumar, P. K. H., & Kanimozhi, B. (2014). Design Analysis And Application Of Nylon66 In Rotary Spars. Engineering Research and Applications, 4(4), 331–334. Www.ijera.com

Vlachopoulos, J., & Strutt, D. (2003). Polymer processing. Materials Science and Technology, 19(9), 1161–1169. Https://doi.org/10.1179/026708303225004738

Wang, M.-L., Chang, R.-Y., & Hsu, C.-H. (David). (2018). Material Properties of Plastics. Molding Simulation: Theory and Practice, 19–54. Https://doi.org/10.3139/9781569906200.002

Weber, D. N., Shaw, C. F., & Petering, D. H. (1987). Euglena gracilis cadmium-binding protein-II contains sulfide ion. Journal of Biological Chemistry, 262(15), 6962–6964. Https://doi.org/10.1016/s0021-9258(18)48186-0

Wheatley, C. C., Chuzel, G., & Zakhia, N. (2003). CASSAVA | The Nature of the Tuber. Encyclopedia of Food Sciences and Nutrition, 964–969. Https://doi.org/10.1016/b0-12-227055-x/00181-4

Xia, X., Liu, W., Zhou, L., Hua, Z., Liu, H., & He, S. (2016). Modification of flax fiber surface and its compatibilization in polylactic acid/flax composites. Iranian Polymer Journal (English Edition), 25(1), 25–35. Https://doi.org/10.1007/s13726-015-0395-3

Yashas Gowda, T. G., Sanjay, M. R., Subrahmanya Bhat, K., Madhu, P., Senthamaraikannan, P., & Yogesha, B. (2018). Polymer matrix-natural fiber composites: An overview. Cogent Engineering, 5(1). Https://doi.org/10.1080/23311916.2018.1446667

Yin, P., Zhou, W., Zhang, X., Guo, B., & Li, P. (2020). Bio-based thermoplastic starch composites reinforced by dialdehyde lignocellulose. Molecules, 25(14). Https://doi.org/10.3390/molecules25143236

Yoo, S. (2001). Structures, properties, and biogenesis of starch and cyanobacterial glycogen..pdf.

Zai, P. (1988). Applications of Polymers. Applications of Polymers, 1–12. Https://doi.org/10.1007/978-1-4684-5448-2

Zaremba, L. S., & Smoleński, W. H. (2000). Optimal portfolio choice under a liability constraint. Annals of Operations Research, 97(1–4), 131–141. Https://doi.org/10.1023/A

Zhang, Z., Tian, J., Fang, H., Zhang, H., Kong, X., Wu, D., Zheng, J., Liu, D., Ye, X., & Chen, S. (2020). Physicochemical and digestion properties of potato starchwere modified by complexing with grape seed proanthocyanidins. Molecules, 25(5), 1–12. Https://doi.org/10.3390/molecules25051123

Zheng, K., Liang, D., & Zhang, X. (2013). Analysis of comprehensive utilization of coconut waste. Analysis of Comprehensive Utilization of Coconut Waste, 05(10), 84–87.

Zhou, K. J. H., Ho, J. C. M., & Su, R. K. L. (2011). Flexural strength and deformability design of reinforced concrete beams. Procedia Engineering, 14, 1399–1407. Https://doi.org/10.1016/j.proeng.2011.07.176

Zhou, Q., Cho, D., Song, B. K., & Kim, H. J. (2009). Novel jute/polycardanol biocomposites: Effect of fiber surface treatment on their properties. Composite Interfaces, 16(7–9), 781–795. Https://doi.org/10.1163/092764409X12477449494437

Zhu, F. (2015). Composition, structure, physicochemical properties, and modifications of cassava starch. Carbohydrate Polymers, 122, 456–480. Https://doi.org/10.1016/j.carbpol.2014.10.063

Zuraida, A., Yusliza, Y., Anuar, H., & Mohd Khairul Muhaimin, R. (2012). The effect of water and citric acid on sago starch bio-plastics. International Food Research Journal, 19(2), 715–719.

APPENDICES A

GANTT CHART : PSM 1

TASK/PLANNING	WEEKS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PSM 1: PROJECT BRIEFING	🟥								MID SEM BREAK						
CHAPTER 1 : INTRODUCTION															
Understanding the paper objective													🟥		
Report Writings													🟥●		
CHAPTER 2: LITERATURE REVIEW															
Research Finding			🟥	🟥	🟥	🟥	🟥	🟥							
Report Writings			🟥	🟥	🟥	🟥	🟥	🟥●							
CHAPTER 3 : METHODOLOGY															
Preparation Of Fiber Material (Coconut Leaf)											🟥				
Report Writings											🟥●				
CHAPTER 4 : PRELIMANARY RESULT															
Previous Study Finding											🟥	🟥			
Report Writings												🟥	🟥	🟥●	
OTHERS PREPARATION															
Gantt Chart													🟥		
Format Thesis													🟥	🟥	
Slide Presentation Preparation														🟥	
Video Presentation														🟥	
Submit Final Psm 1 Report														🟥●	

APPENDINCES B

GANTT CHART : PSM 2

TASK/PLANNING	WEEKS (2021 - 2022)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revise Previous Project	🟥								MID SEM BREAK						
Supervisor meeting Discussion	🟥	🟥													
Preparation Material Fiber		🟥	🟥												
Laboratory Experiment															
Thermal Analysis			🟥	🟥											
Thermogravimetric Analysis (TGA)				🟥	🟥 ●										
Other Testing				🟥	🟥										
Fourier Transform Infrared Spectroscopy				🟥	🟥										
Scanning electron microscope (SEM)				🟥	🟥 ●										
Mechanical Analysis															
Tensile Test						🟥	🟥								
Flexural Test							🟥	🟥							
TESTING PRODUCT															
Working Product										🟥	🟥 ●				
OTHERS PREPARATION															
Format Thesis											🟥	🟥			
Slide Presentation Preparation													🟥		
Video Presentation														🟥	
Submit Final Psm 2 Report														🟥 ●	

Milestone for Gantt Chart PSM 1:

Description	Point 1	WEEK
Completion of introduction	M1	13
Completion of literature review	M2	8
Completion of Methodology	M3	11
Completion of preliminary finding	M4	14
Submittion of Final Draft	M5	14

Milestone for Gantt Chart PSM 2:

Description	Point 1	WEEK
Completion of Thermal Analysis	M1	5
Completion of Other Testing	M2	5
Completion of Mechanical Testing	M3	10
Completion of Product Testing	M4	11
Submittion of Final Draft	M5	14

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **BIODEGRADABLE PACKAGING DERIVED FROM COCONUT LEAF FIBER: MECHANICAL PROPERTIES**

SESI PENGAJIAN: **2021/2022 Semester 1**

Saya **CHE AMIMI YASMIN BINTI CHE ASUDIN**

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 (✓)

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

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

☑ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:
No 12, Taman Pasir Puteh Indah,
Kampung Gong Kua, 16800 Pasir
Puteh, Kelantan.

Cop Rasmi:
DR. RIDHWAN BIN JUMAIDIN
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 18/1/2022

** 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.