DEVELOP CORN AND TAPIOCA STARCH BASED AS BIO PLASTIC MATERIALS FOR PACKAGING MATERIALS.

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**This report is submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering with Honours**

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this project report entitled "Develop Corn and Tapioca Starch Based as Bio Plastic Materials For Packaging Materials" is the result of my own study except as cited in the reference.

Signature :....................................
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Date :....................................

SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report and in my opinion this report is acceptable in term of scope and quality of the award of the degree of Bachelor of Mechanical Engineering.

Signature :...................................

Name of Supervisor :...................................

Date :...................................

DEDICATION

I would like to dedicate this to my beloved parents. Next to my, Supervisor, Professor Madya TS Dr. Mohd Zulkefli Bin Selamat. Laboratory technician Mr. Rizal, my friends and all people that had guided me throughout completion of this project. To the person that encourages me to pursue mechanical engineering field. To the person who give me an inspiration for not giving up studying mechanical engineering

ABSTRACT

Previous studies show that synthetic plastic has more disadvantages than bioplastic such as high cost and higher environmental risk. Recent studies tend to concern towards the environmental issues. The use of starch based TPS films act as an alternative synthetic plastic competitor. The aim of this project is to study the suitable composition of corn and tapioca starch as bio plastic materials and the properties of corn and tapioca starch based TPS as bio plastic materials. Corn and Tapioca starch is usually mix with glycerol and the composition that being selected is 70TPS/30GLY. Another than that, the fabrication process that used in this project is by using casting method, but the result of this method is not satisfying to do mechanical test so the effort that can made in this project going smoothly and efficiently is by fabricate bioplastic film in corn and tapioca starch-based TPS using hot press method to ensure the objectives of this project will be achieved. Three testing that have been done are Tensile Test by referring (ASTM D 3039), Hardness Test (ASTMD 2240 D) and Density Test. From all these three tests, found that the composition of 50% corn 50% tapioca starch has the highest tensile value which is 0.15(Mpa). The hardness test value of this composition is slightly lower than pure tapioca with the value 39 compared to 100% tapioca which is 48. While the density value of composition 50% corn and 50% tapioca is the highest of the overall sample composition which the value is 1.42. These findings present this hybrid TPS 50% corn and 50% tapioca starch composition as a best TPS properties for the development of biodegradable packaging materials.

ABSTRAK

Kajian terdahulu menunjukkan bahawa plastik sintetik mempunyai lebih banyak keburukan berbanding bioplastik seperti kos yang tinggi dan risiko alam sekitar yang lebih tinggi. Kajian terkini cenderung mengambil berat terhadap isu alam sekitar. Penggunaan filem TPS berasaskan kanji bertindak sebagai pesaing plastik sintetik alternatif. Matlamat projek ini adalah untuk mengkaji komposisi jagung dan kanji ubi kayu yang sesuai sebagai bahan bio plastik dan sifat-sifat TPS berasaskan kanji jagung dan ubi kayu sebagai bahan bio plastik. Kanji jagung dan Tapioka biasanya dicampur dengan gliserol dan komposisi yang dipilih ialah 70TPS/30GLY. Selain itu, proses fabrikasi yang digunakan dalam projek ini adalah dengan menggunakan kaedah tuangan, tetapi hasil kaedah ini tidak memuaskan untuk melakukan ujian mekanikal maka usaha yang boleh dilakukan dalam projek ini berjalan dengan lancar dan cekap adalah dengan membuat filem bioplastik dalam TPS berasaskan kanji jagung dan ubi kayu menggunakan kaedah hot press bagi memastikan objektif projek ini tercapai. Daripada ketiga-tiga ujian ini, didapati komposisi 50% jagung 50% kanji ubi kayu mempunyai nilai tegangan yang paling tinggi iaitu 0.15 (Mpa). Nilai ujian kekerasan komposisi ini adalah lebih rendah sedikit daripada ubi kayu tulen dengan nilai 39 berbanding ubi kayu 100% iaitu 48. Manakala nilai ketumpatan komposisi 50% jagung dan 50% ubi kayu adalah yang tertinggi daripada keseluruhan komposisi sampel yang nilainya iaitu 1.42. Penemuan ini mengemukakan TPS hibrid 50% jagung dan 50% komposisi kanji ubi kayu ini sebagai TPS terbaik untuk pembangunan bahan pembungkusan biodegradasi.

ACKNOWLEDGEMENT

First of all, Alhamdulillah and gratefulness to Allah the Almighty for the good health and wellbeing that were necessary to complete this final year project with ease and on time. On this opportunity, I would like to express my special gratitude to my supervisor Prof Madya Dr. Zulkefli Bin Selamat who offer me and gave me the opportunity to do this research as my final year project. His guide me and gave me a lot a of advice and thank you for him to sharing his expertise in completing my project from PSM I until PSM II.

Secondly, I also acknowledge with grateful heart and thanks to University Technical Malaysia Melaka (UTeM) for giving me such a great opportunity, chance of working on this project and help me with their facilities to undergo final year report. Next, I would like to express my appreciation to technician laboratory En. Rizal, Laboratory technician, for their kindness and advice during final year project. Thus, not forgetting thankfully to my course mates, who had helped, support the good idea and give opinion to solve the problem during final year project and studies.

Lastly, would like to thank my parents, siblings and all my friends who have been a great supporter and advised me throughout my final year in order to complete my final year project. Hence to give me such as support for me to finish this project successful. I am extremely thankful.

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LIST OF ABBREVIATIONS

MMC	Metal Matric Composite
SW Corp	Solid Garbage Management and Public Cleansing Corporation
CMC	Ceramic Matric Composite
PMC	Polymer Matric Composite
PLA	Polylactic Acid
PVA	Polyvinyl Alcohol
TPS	Thermo Plastic Starch
ASTM	American Society for Testing and Material
NFRP	Natural Fibre Reinforced Polymer
PVC	Polyvinyl Chloride
PE	Polyethylene
PS	Polystyrene
PP	Polypropylene
ESEM	Environmental Scanning Electronic Microscopy
SEM	Scanning Electron Microscope

LIST OF SYMBOLS

cm	=	Centimeters
$°C$	=	Celsius
%	=	Percentage
rpm	=	Rate per Minute
min	=	Minute

CHAPTER 1

INTRODUCTION

1.1 Background

Recently, numerous studies on the development of biodegradable film packaging especially made from biopolymers have been done. Generally, there is a huge interest in biodegradable film packaging due to the excessive use of conventional petroleum based as food packaging material which is non-biodegradable and contributed to land disposal problems. The new study on global analysis of plastics made from petroleum reported that out of 6.3 billion metric tons of plastics have become a wastage and on top of that, only 9% has been recycled (Geyer et al., 2017). Based to the Solid Garbage Management and Public Cleansing Corporation (SWCorp), Malaysia generated roughly 1.17 kg of solid waste per inhabitant per day in 2014, making this a serious issue in our country. Plastic garbage, which accounted for 13.2% of total garbage in 2012, is one of the solid wastes that is now being addressed. Plastic garbage, behind food and organic trash (44.5 percent), diapers (12.1 percent), and paper, was the fourth most common type of garbage in Malaysia, according to the National Solid Waste Management Department (2012). (8.5 percent). However, according to the most recent statistics from 2019, the mix of waste is changing, with plastic accounting for almost 20% of all waste. Due to population and tourism expansion, the amount of garbage generated is predicted to increase (Jayashree, 2012).

The current research focuses on bioplastics made from corn and tapioca starch for packaging. Plastics such as polyethylene, polyvinyl chloride, and polystyrene are now made from petrochemicals. More fossil fuels are used to make plastics, resulting in increased greenhouse gas emissions that deplete the ozone layer (Morales-Méndez & Silva-Rodrguez, 2018). Because these polymers remain persistent in the atmosphere. From previously said, plastic is one of the most commonly generated wastes on a global scale. If this hazardous plastic garbage is poorly disposed of and causes contamination in the environment, it will be damaging to living things. When plastics are discarded in landfills, they combine with water and generate dangerous compounds, causing harm to the environment and human health. Due to the characteristics of plastic, which include high molecular weight and closely bound molecules, total degradation of a single plastic waste takes around 100 years. In 2017, Nehra Kiran published a book titled "Nehra Kiran" (Nehra Kiran 2017)

More material with specified properties, such as high tensile strength, lightweight, safe, and less expensive material, is in demand in today's age of modernization (Matthew and Rawling 2003). As a result, natural resources are becoming insufficient to meet rising demands on material capacities. As a result, experts in this field are constantly looking for ways to improve traditional materials. Composites are not a new concept; they have been around for a long time, and composites were employed in ancient Egypt, according to historical records.

Reinforcement-matrix bonding is vital in composites because the load applied on the matrix must be transferred to the reinforcement (Matthew and Rawling, 2003). Reinforcing materials such as Glass, Carbon, and Aramid are available in a variety of strengths and densities. Metal Matric Composite (MMC) (aluminum, magnesium, copper, and lead), Ceramic Matric Composite CMC (silicon carbide, silicon nitride, aluminum oxide), and Polymer Matric Composite (PMC) (silicon carbide, silicon nitride, aluminum oxide) are examples of ductile or tough matrix materials (thermoset and thermoplastic).

The materials commonly used in biodegradable composites, which are the focus of this project, are a mix of two or more natural resource components made up of

Fibers/Reinforced and Matrix/Binder. The researcher or engineer will benefit from this combination because it will provide a desired quality.

This study will focus on Polymer Matric Composites in greater depth (PMC). Polymer Matric Composite (PMC) is a biodegradable composite that can be classified as partially or entirely biodegradable in the future (Ghanbarzadeh, et al., 2013). When exposed to microorganisms in aerobic and anaerobic processes, such as polysaccharide and polypropylene, biodegradable polymers lose their chemical and physical properties and fully breakdown. A polymer that is partially biodegradable is one that has both biodegradable and non-biodegradable components.

Many natural materials, such as bones, wood, and grasses, are formed of composites, according to Matthew and Rawling (2003). Natural fiber-based composites are becoming increasingly popular because to their long-term sustainability, low cost, low density, and greater specific characteristics (Matthew and Rawling, 2003). The ability to deliver natural based fiber on a continual basis is driving the move. Plant fibers, animal fibers, and mineral fibers are the three forms of natural-based composites that are currently being investigated (Mathivanan et al. 2015). Although natural based fiber has acceptable physical and mechanical properties, the type of natural resources employed affects the physical and mechanical qualities.

Agricultural plantations abound in Malaysia. There have been numerous researches conducted on various elements of plant-based fiber. This is demonstrated by the numerous journals that have been published on green composites or bio composites. One of the natural resources that can be used as a composite is the plant. Plants are becoming increasingly popular in the production of new materials. One of the reasons for this is that it has a high tensile strength. Furthermore, not only may the fiber be of natural origin, but the matrix can be made from a variety of natural resources, including starch, sago starch, soy starch, potato, corn, and wheat (Pickering et al. 2016).

The goal of this study is to create a new biodegradable film formulation based on starch and tapioca starch that can be used as a bioplastic material for packaging and to evaluate its qualities. Corn, often known as maize (Zea mays), is one of the most widely consumed cereal grains on the planet. It is the seed of a grass plant that's native to Central America but available in a wide range of variants around the world. PLA (polyactic acid) is commonly manufactured from corn starch, cassava, or sugarcane sugars. It is edible, biodegradable, and carbon neutral. Corn kernels are immersed in sulfur dioxide and hot water to convert them to plastic, where their components break down into carbohydrates, protein, and fiber. The maize oil is extracted from the starch after the kernels have been pulverized. Like the carbon chains in plastic made from fossil fuels, starch is made up of long chains of carbon molecules. Some citric acids are added to create a long-chain polymer (a big molecule made up of smaller units that repeat) that is used to make plastic. PLA can resemble polyethylene (used in plastic films, packaging, and bottles), polystyrene (Styrofoam, and plastic cutlery), or polypropylene (used in plastic cutlery) in appearance and behavior (packaging, auto parts, textiles). Nature Works, based in Minnesota, is one of the most well-known manufacturers of PLA under the Ingeo brand (Renee Cho,2017). Due to the low water resistance of starch-based edible films, they can have an impact on the physical and mechanical properties of the edible film. Other biopolymers, such as hydrophobic and antibacterial compounds, require having starch added to them (Susilawati et.al,2019).

This project will contribute to the waste to wealth objective by focusing on natural fiber-based composites that are appropriate for the title chosen for this project, which is to produce corn and tapioca starch-based bioplastic materials.

1.2 Problem Statement

Every day, there is a greater demand for plastic. This condition adds to the major difficulty of dealing with non-biodegradable plastic garbage, which is not easily biodegradable and has been put in landfills for a long period. As a result, non-biodegradable plastic garbage will pollute the ecosystem, resulting in economic and environmental harm (Drzyzga & Prieto, 2019). A lot of research has been study to replace non-biodegradable garbage with biodegradable garbage. Biodegradable plastic is frequently viewed as a possible waste management solution to the trash accumulation caused by traditional plastic (Mostafa et al., 2018). This is since biodegradable plastics can be degraded by microorganisms after being discarded in the environment, releasing carbon dioxide and water as a byproduct of the decomposition (Nik Abdullah et.al, 2014).

As our awareness of the environmental situation grows, so does our understanding of how important it is to preserve the environment. The area of material science has progressed rapidly in this green effort throughout the years. To stay up with the ever-changing technological environment, many innovative technologies have been developed. The trend away from synthetic plastic composites and toward natural based fiber composites is one evident technological achievement (Santosha, et al. 2017).

According to Santosha et al. (2017), natural fibers have been demonstrated to be a viable alternative to synthetic fibers in recent years. Synthetic polymers are well-known and in high demand for a variety of reasons, including their mechanical and physical qualities. There is always a disadvantage to a synthetic-based composite, no matter how wonderful it is. Composites made of synthetic materials are harmful to the environment and pollute the soil (Norshahida et al. 2012). This issue will be addressed with environmentally friendly materials. As the world becomes more conscious of sustainability, our reliance on petroleum-based materials is dwindling.

Plastics made from petroleum have been widely used all over the world. The disposal of waste plastics has become a big issue as the number of uses has expanded. As a result, the creation of novel polymers that can be destroyed by microbes in soil and ocean has received a lot of interest recently (Park, Chough, Yun, & 4 Yoon, 2005). In the realm of biomaterials, starch has been used as a plentiful and inexpensive raw material. Packing films, on the other hand, are made completely of starch and lack the strength and stiffness needed to survive the forces that many packaging materials are subjected to (Parvin, Rahman, & Islam, 2010).

Thermoplastic starch appears to be an ideal approach for obtaining commercial packaging materials made entirely of pure starch while avoiding the use of synthetic polymers in the formulation. Thermal and mechanical processing, on the other hand, should rupture semi-crystalline starch granules in order to obtain thermoplastic starch. Because the melting point of pure starch is significantly greater than its decomposition temperature, plasticizers such as glycerol are required. Temperature and shear stresses cause the normal crystalline structure of starch granules to be disrupted, and polysaccharides form a continuous polymer phase (Mitrus & Moscicki, 2013).

Biopolymers are the material that has been studied the most. They typically have poor mechanical qualities in terms of processability and end-use functioning due to thermoforming's fragility, which limits their application potential. Plasticizers are used to provide biopolymers the workability they need to overcome this challenge (Vieira et. al. 2011). Blending is another way to improve starch's mechanical properties, and current research has focused on pure starch-based products as well as starch/degradable polymer blend products including starch/cellulose and starch/PVA (Park et. al. 2005).

1.3 Objective

The objectives of this project are as follows:

1.Determine the suitable composition of corn and tapioca starch’s as bio plastic materials.

2.Determine the properties of corn and tapioca starch’s based as bio plastic materials.

1.4 Scope of Study

The scopes of the project are as follows:

Preparation of Bioplastics Film in tapioca and corn starch- based TPS, glycerol is used as plasticizer, due to its better mechanical properties and good water solubility, ranging from 18 to 25% through it can increase up to 36%. It was shown that glycerol concentration would not affect the glass transition temperatures. TPS film was prepared according to the following procedure: The starch, glycerol were added to 100 mL distilled water in various ratios. The mixture was stirred at a rate of 180 rpm for 10 min. then the mixture was heated on a plate at 100 °C, and manual stirred was done for 70 min, continuously. It was then poured onto a silk/cloth strain on frame and spread uniformly. It took 3-4 days for the mixture to dry out and cast film was removed. The properties corn and tapioca starch based as bio plastic materials composite, the tests such as tensile, density, hardness test, moisture content tests and microstructure analysis will be performed.

CHAPTER 2

LITERATURE REVIEW

2.1 Composites

According to Matthew and Rawling (2003), composites are made up of two elements, one of which is called the reinforcing phase and the other is called the matrix phase. At low densities, reinforcing materials are generally strong, but the matrix is usually a ductile or hard material (Matthew and Rawling, 2003). If the composite is designed and made correctly, it can combine reinforcement strength with matrix resilience to produce a unique combination of desirable qualities not found in any other material. There are a few different sorts of composites that can be classified (Matthew and Rawling, 2003). The composite's matrix material might be made of ceramic, metal, or polymeric material. Fabrication techniques differ depending on the physical and chemical qualities of the matrix and reinforcing fibres (Matthew and Rawling, 2003).

Fiber-reinforced polymer (FRP) is a biodegradable composite material made up of a polymer matrix reinforced with fibre. Nature fibre can be used in a variety of ways. Many sectors are interested in using natural fibre composites in the development of their products. Bamboo, coconut, rice husk, wood, and pineapple leaf are just a few of the natural fibre composite materials employed. A biodegradable composite material, often known as a bio composite, is a composite material with a grid and common fibre support. The behaviour of biomaterial in diverse circumstances is linked to biocompatibility. The ability of a substance to behave in a precise place with a suitable host response.

A polymer is a macromolecule made up of many different components linked together. Epoxy and polyester thermosetting plastics are the most often used thermosetting plastics. In the automotive, aerospace, marine, and construction industries, biodegradable fibre-reinforced polymer (FRP) is frequently utilised. For reinforced composite materials, there are two types of fibre that are used.

(i) Fibres made of synthetic materials

(ii) Natural fibres

Synthetic fibre is commonly used to reinforce plastic because of its excellent mechanical qualities and low cost of production, yet it is well worth it. Synthetic fibre, on the other hand, has a number of drawbacks, including high energy consumption, exposure to damage from hot washing, non-renewability, and high density. Furthermore, on the other hand, fibre reinforced polymer composite has attracted global attention due to its high specific strength and modulus. Furthermore, material composites with high strength fibres, such as glass and graphite, are extensively employed in aircraft and automotive components.

Natural fibre composites have earned a reputation for replacing synthetic fibres such as glass fibre reinforced composites, which are well-known for being harmful to the natural environment. Natural fibres can be found in a variety of places, including pineapple leaves. Bamboo, banana leaf, and kenaf are all examples of natural materials. Fiber-reinforced polymer (FRP) is a biodegradable composite material made up of a polymer matrix reinforced with fibre. Nature fibre has a wide range of applications. Many sectors are interested in using natural fibre composites in the development of their products.

Bamboo, coconut, rice husk, wood, and pineapple leaf are just a few of the natural fibre composite materials employed. Biodegradable composite material, also known as Bio composite, is a composite material with a grid and common fibre support. The behaviour of biomaterial in diverse circumstances is linked to biocompatibility. The ability of a material to act in a precise position with a suitable host response (black, J.2005).

2.2 Types of Matrices

This matrix or binder is crucial to consider during the early stages of composite material synthesis. This is owing to the matrix's durability in varying rheological behaviour, heat stability, moisture sensitivity, density, and ease of handling, among other qualities (Matthew and Rawling, 2003). Aside from that, the matrix used will have an impact on the fabrication procedure as well as the matrix's effect on the reinforcement qualities (Matthew and Rawling, 2003). There are several sorts of composites, each of which is determined by the matrix type. Their natural behaviour and traits are used to identify them. Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC), and Polymer Matrix Composites are among them (PMC).

2.2.1 Metal Matrix Composite (MMC)

Metal matrix composites are made up of fibres or particles that are encased in a metal matrix. The utilisation of a metal matrix allows for the creation of a composite with extremely high stiffness, strength, and temperature resistance. The temperature resistance outperforms not only polymer matrix composites, but also pure metal. Metal matrix composites have other advantages over polymer matrix composites, such as better abrasion resistance, creep resistance, fluid resistance, dimensional stability, and non-flammability, but their application is limited due to their much higher weight and production cost (http://www.hsctut.materials.unsw.edu).

Metal matrix composites are widely employed in the manufacture of chamber nozzles for aeroplanes, tubes, cables, heat exchangers, the space shuttle, the automotive industry, and structural elements. This is owing to the metal matrices' qualities of increased strength, fracture toughness, and stiffness. In addition, compared to polymer composites, metal could tolerate high temperatures in corrosive environments (George, J. et al. 1997).

2.2.2 Ceramic Matrix Composite (CMC)

The primary goals in producing the ceramic matrix composite are to increase strength or toughness of a materials. Normally it is found that there is a good outcome in the improvement in strength and stiffness of a material by using ceramic matrix composites (George et al. 1997).

2.2.3 Polymer Matrix Composite (PMC)

As our contemporary civilization progresses, more research into the health of our environment is being conducted. A growing interest in employing bio-based polymers has piqued the curiosity of manufacturers. Bio-based polymer matrices are manufactured from renewable resources, demonstrating that they are more sustainable than other matrices. Biodegradable and non-biodegradable polymers exist. Polylactide (PLA), thermoplastic starch, and cellulose are examples of natural-based polymers (Verma, et al., 2016). The matrixes for this project are corn starch and tapioca starch. Glycerol will be used to analyze corn and tapioca starch.

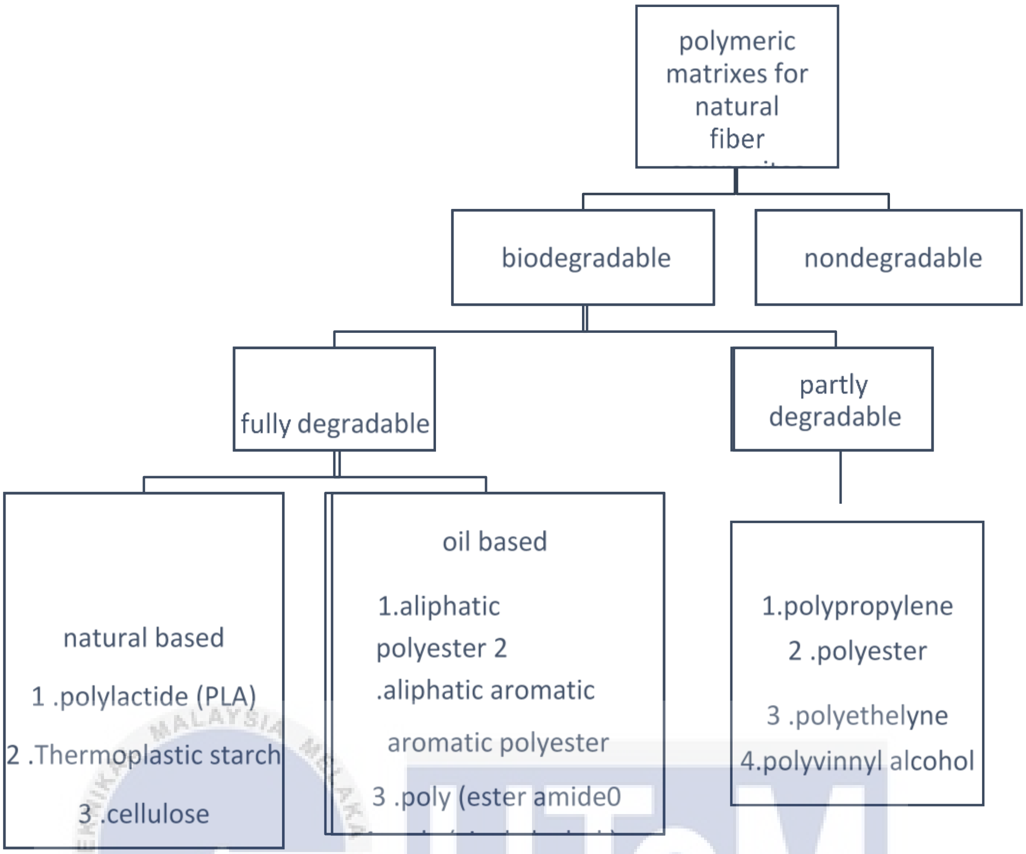


Figure 2.1: Classification of polymer matrixes (adapted from Ghanbarzadeh, et al.2013).

2.3 Natural Fiber

Natural fiber-reinforced polymer composites have gained a strong reputation among engineers and material scientists in recent years due to their ability to produce excellent mechanical and dielectric properties while also providing many environmental benefits such as renewability and biodegradability. Furthermore, by utilizing these natural fibers, numerous environmental issues can be addressed. In the construction business, these composites can also be utilized as a wood substitute. Furthermore, natural fibers have gained popularity due to the numerous drawbacks of standard petroleum-based plastic, glass, or carbon fiber, such as the fact that they are not environmentally friendly, are very expensive, and need the use of advanced technology. Pineapple leaf, bamboo, jute, banana, and coir are among the natural fibers utilized as reinforcement in polymer composites (Dhal, et al 2012).

Natural fibers come in a variety of forms, one of which is lignocellulosic fiber. Binder substances named "lignin" and "hemicellulose" hold the fibers together in the fiber cell. The fiber can also be found on the fiber bundles' and leaves' outer layers. The fiber cells are divided into layers, which are typically formed by groups of Nano-scale cellulose chains stretching helically down the fiber cell axis and joined by amorphous lignin and hemicellulose regions (Rowell, et al. 1997).

Vegetable fibers, on the other hand, are thought to be more complicated due to the large diversity of organic compounds included in the fiber, such as lignin, hemicellulose, fatty acids, lipids, waxes, and others (Rowell, et al, 2000).

Furthermore, natural fiber is widely used in a variety of industries, including the construction industry. This is due to the properties of natural fiber, which make it a good heat insulator. The natural fiber 1S was chosen because it is environmentally friendly, energy efficient, and provides a long-term financial benefit due to its low cost, lack of skilled labor, and lack of toxicity to human health when compared to commercial thermal building insulators made primarily of minerals wools, glass foam, and rock wools (Liang, et al, 2007).

2.4 Hybrid Polymer Composites

Composites are made up of two or more chemically and physically diverse constituents that, when mixed, provide a new value-added class of materials with qualities that differ from their constituents. The primary ingredient is known as a matrix, which dominates the majority of the time. As a result, hybrid polymer composites require some polymeric content, either in the matrix (in most situations) or in the reinforcements (which may be either fibre or powder in form). Nonetheless, fibre Reinforced composites have always proven to be superior to powder reinforced composites. equivalents in terms of mechanical qualities (Rodriguez and Rodrigue,2016).

This article focuses on hybrid vehicles in particular. polymer composites made up of polymeric matrix (mainly synthetic) and natural components reinforcements. Thermoplastics have found their way into hybrid polymer composites, with the customary reinforcements being primarily of natural origin. Recent research has focused on developing biopolymers such as PLA (polylactic acid) to manufacture such materials. In nature, composites are fully biodegradable. In most cases, the manufacturing procedures Compression moulding, roto moulding, injection moulding, and other thermoplastic processes others.

The fundamental reason for adding natural fibres into these hybrid fabrics is their durability. ability to improve the mechanical properties of the matrix However, this is not the case. In the case of lignocellulose being a large component of the fibre, for interface adhesion Because of mismatched hydrophilicity and polarity, the interaction between the fibre and matrix is hampered. As a result, the mechanical properties of the resultant composites are compromised (Rodriguez and Rodrigue, D.,2016).

2.5 Biodegradable Plastic

Plastic biodegradability is determined by the chemical structure of the forming substance. Natural or synthetic resins can be used to make bioplastics. Natural bioplastics are made from renewable resources, such as starch. Synthetic bioplastics are made from non-renewable resources, such as petroleum. Bioplastics are plant-based plastics, such as those created from flax oil, soybean oil, or corn oil. Starch Bioplastics have easily decomposable characteristics. CO2 can degrade bioplastics. Where the fundamental mechanism is the action of methane, water, inorganic chemicals, or biomass, microorganism-produced enzymes (Juari,2006). Biodegradable plastic has the potential to reduce landfill waste while also increasing material recycling. It can be made from renewable resources, microbially manufactured, or chemically synthesised (Flieger, M., Kantorová, M., Prell, A., and others, 2003). Natural biodegradable plastics, for starters, are made from renewable materials. Biodegradable plastic components have derived from agricultural or animal. Plastic made from petroleum is held together by repeating molecular chains.

2.6 Classification of Plastics

Plastics are categorized based on a variety of factors such as thermal properties, degradability properties, and chemical properties.

2.6.1 Thermal Properties

Thermoplastic and thermosetting plastics are subdivided based on their heat characteristics. Thermoplastics are a form of plastic that does not change chemical composition when heated and may be manufactured repeatedly. Thermoplastics include polypropylene (PP), polyvinyl chloride (PVC) polyethylene (PE), and polystyrene (PS). (Fernando Pacheco-Torgal, Jamal Khatib, Francesco Colangelo, 2018). Besides, Thermosetting plastic, could not be recycled because the change of chemical is permanent since it has a pass-linked structure rather than a linear structure like thermoplastic (Grigore, 2017). Phenol-formaldehyde and polyurethanes are examples of thermosetting plastics. The molecular structure of thermoplastic and thermosetting plastics differs as seen in Figure 2.3.

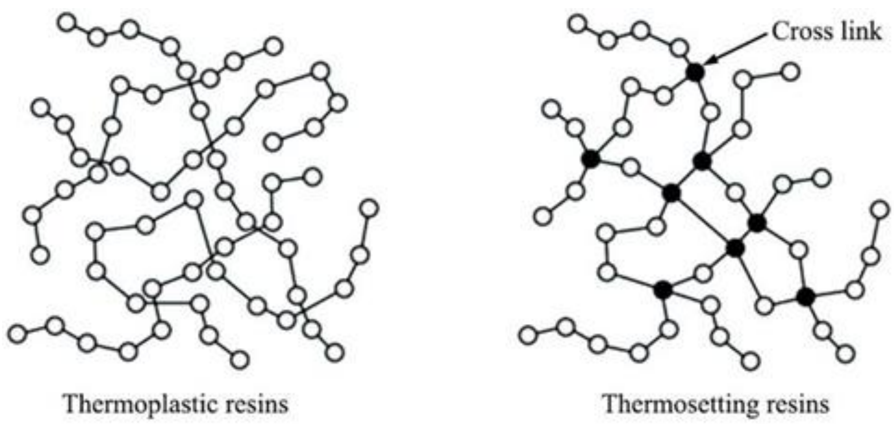


Figure 2.2: Thermoplastic and thermosetting plastic Molecular structure

2.6.2 Degradability Properties

Non-degradable and biodegradable plastics are the two types of plastic. Petrochemicals are used to create non-biodegradable polymers, which have a high molecular weight due to the high repetition of monomers (small units that make up a polymer). In contrast, degradable plastic is derived from renewable elements and can also be generated by microbes. UV light, gentle pH fluctuations, water, and enzymes all help to break down the biodegradable plastic.

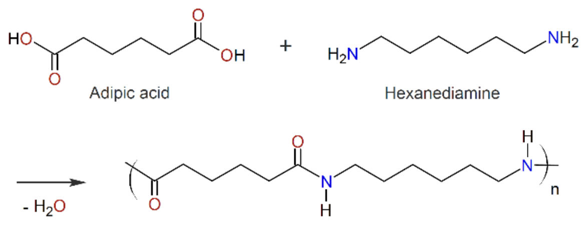
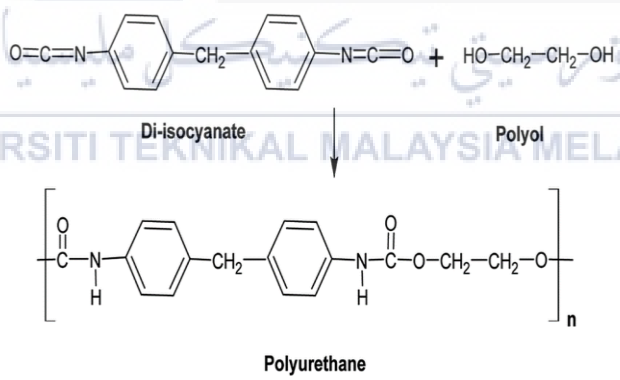
In a compost site, biodegradable bioplastics breakdown organically. Microorganisms degrade it at the same rate as other organic materials, leaving no harmful trace evident (Toketemu, 2018). After that, photodegradable bioplastics degrade when exposed to ultraviolet (UV) radiation over an extended period (Yousif, E., & Haddad, R., 2013). It is happening because photodegradable bioplastics have light-sensitive groups connected to the polymer's backbone, making them light-sensitive (Yousif, E., & Haddad, R., 2013). Bio-based bioplastics, also known as bioplastics, are made from biomass. Some bio-based bioplastics are degradable, whereas others are not (BioCannDo, 2017). Plant and fossil fuel bioplastics are both biodegradable and can be destroyed spontaneously by microorganisms.

2.6.3 Chemical Properties

Chemical processes can also be used to make plastic. The reactions that generate plastic, according to (Kaltenbach, 2012), are addition polymerization, polycondensation, and polyaddition. Table 2.1 depicts the several processes that lead to the creation of plastic.

Table 2.1 : Different types of reactions that occur during the production of plastic

Types of reaction	Explanation	References
Addition polymerization	Polymerization also involves the joining of multiple tiny molecules known as monomers into a chain to generate a larger molecule known as a polymer. In addition polymerization, styrene monomers come together to make polystyrene (PS). 	Kaltenbach (2012), Speight (2017)
Polycondensation	Different monomers consist of two or more reactive groups joined together to generate polymers by eliminating tiny molecules such as water or methanol in the polycondensation reaction. Water is removed from nylon 6,6 through a reaction between the monomers adipic acid and hexanediamine.	Kaltenbach (2012)

		
Polyaddition	Polyaddition is a reaction that occurs when two monomers with at least two functional groups combine to produce a polymer. As the two monomers unite by covalent connection, hydrogen atoms transfer from one monomer to the other monomer in this reaction. Polyurethane is formed when multifunctional isocyanate groups react with multifunctional alcohol groups, for example. 	Sapuan et al. (2017)

2.7 Thermoplastic Starch

Thermoplastic starch (TPS) normally made from native starch exhibits tensile strength (TS) of less than 5 MPa, elongation-at-break of less than 50%, and water vapor permeability (WVP) of higher than 31.2 g mm m^{-2} h^{-1} kPa^{-1}, indicating TPS has low mechanical strength and high WVP. This chapter summarizes the methods used to improve the properties of TPS. These methods include addition of other materials, choosing different plasticizers, blending starch with other polymers, and using a starch source containing high amylose, etc. Experimental results show that addition of nanoclays, polymers, plasticizers, fibers, addition of fatty acids and organic acids, and other methods, such as chemical modification of starch, enhance TPS mechanical strength and flexibility and lower WVP. Further efforts are still need to improve the TPS properties and satisfy the industry needs.

2.8 Starch

Potato peel, cassava starch, banana peel, and maize husk are examples of agricultural waste items from which starch can be recovered. Amylose and amylopectin are the two fractions of starch that can be isolated. The structure of amylose and amylopectin is the fundamental distinction between them. As demonstrated in Figure 2.2, amylose is a linear chain polymer.

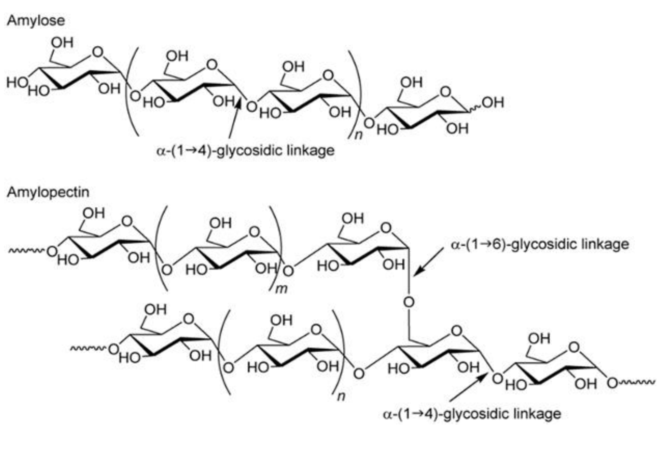


Figure 2.3: Differences between the branches of amylose and amylopectin

Amylose is made up of -D-glucose units joined by a 1,4-glycosidic bond on the same side as the ring oxygen, whereas amylopectin has both a 1,6-glycosidic bond and a 1,4-glycosidic bond. Biofilm formation necessitates the presence of both amylose and amylopectin. The amylose content contributes to the film's strength, while amylopectin provides the film's mechanical qualities. Due to the abundance of naturally occurring starch and its low cost, it has emerged as a potentially valuable source to produce biodegradable polymers. Starch-based polymers are in high demand today, with applications in packaging.

2.8.1 Corn Starch

Corn starch is often used to make PLA (polylactic acid). It is carbon-neutral, edible, and biodegradable. To turn corn kernels to plastic, they are soaked in sulfur dioxide and hot water, where their components break down into carbs, protein, and fiber. After the kernels have been pulverized, the maize oil is separated from the starch. PLA (polylactic acid) starch is commonly manufactured from the sugars found in maize starch, cassava, or sugarcane. It is edible, biodegradable, and carbon neutral. Corn kernels are immersed in sulfur dioxide and hot water to convert them to plastic, where their components break down into carbohydrates, protein, and fiber. The maize oil is extracted from the starch after the kernels are pulverized. Long chains of carbon molecules make up starch, just as the carbon chains in plastic made from fossil fuels. Some citric acids are added to create a long-chain polymer (a big molecule made up of smaller units that repeat) that is used to make plastic. PLA can resemble polyethylene (used in plastic films, packaging, and bottles), polystyrene (used in Styrofoam and plastic cutlery), or polypropylene (used in plastic cutlery) (packaging, auto parts, textiles). Nature Works, based in Minnesota, is one of the main producers of PLA under the Ingeo brand.

2.8.2 Tapioca Starch

Tapioca starch (Manihot esculenta C.) was chosen to be used in this study because it can be easily found in tropical climate country such as Brazil, Thailand, Indonesia, and also in Malaysia. Films made from polysaccharides mainly starches are able to form a continuous polymer matrix even without the addition of plasticizer (Cerqueira et al., 2011).Tapioca is a starch made from the cassava root, a South American tuber. The cassava root is reasonably easy to grow and is a staple food in various African, Asian, and South American cultures. Tapioca is almost entirely made up of starch, with very little nutritional value. However, because it is naturally gluten-free, it can be used as a wheat substitute in cooking and baking for gluten-free persons. Tapioca is almost entirely made up of carbohydrates because it is practically pure starch. Protein, fat, and fibre are all in trace amounts.

It also includes just trace levels of nutrients. In one serving, the majority of them contain less than 0.1 percent of the daily recommended dose (1Trusted Source, 3). 100 calories per ounce (28 grammes) of dry tapioca pearls (3). Tapioca is nutritionally inferior to most grains and flours due to its lack of protein and minerals (1Trusted Source). Tapioca, in fact, can be thought of as "empty" calories. It gives you energy while depriving you of practically all critical nutrients (Kolapo, et al. 2009).

2.9 Analysis

The analysis of bioplastics film in tapioca and corn starch- based TPS analysed by the tests such as tensile, density, moisture content tests and microstructure analysis will be performed to study the biodegradable material produce.

2.9.1 Tensile Test

The tensile test is a method for determining tensile characteristics of polymer matrix composite materials. The ASTM D3039 standard test is used to perform the tensile test. The test specimen will have a predetermined size based on the orientation of the materials and is typically rectangular in shape. The ultimate tensile strength, ultimate tensile strain, transition strain [ASTM D3039], tensile chord modulus of elasticity, and Poison's ratio are all determined using this testing procedure. The load in tension on the specimen will gradually increase until it reaches its limit. The ultimate strength can be evaluated by measuring the highest load carried before it breaks, and the value of strain can be calculated by using a strain gauge in the specimen.

Figure 2.4: The Instron Universal Testing Machines

2.9.2 Density Test

In this part, a Digital Electronic Densimeter (MD- 300S) is used to measure the density and specific gravity of the bioplastic film, as illustrated in Figure 2.6. The density and specific gravity of the bioplastic film will be based on the [AST D792] standard. Furthermore, this standard [AST D792] can be used to test solid plastics in water and solid plastics in liquids other than water.

Figure 2.5: Digital Electronic Densimeter (MD- 300S)

2.9.3 Macrostructure Analysis

The macrostructure investigation is carried out using Environmental scanning electronic microscopy (ESEM) based on a prior work (Liu W, et al. 2005). However, in this work, macrostructure analysis was carried out utilising a scanning electron microscope (SEM) to investigate the macrostructure composite.

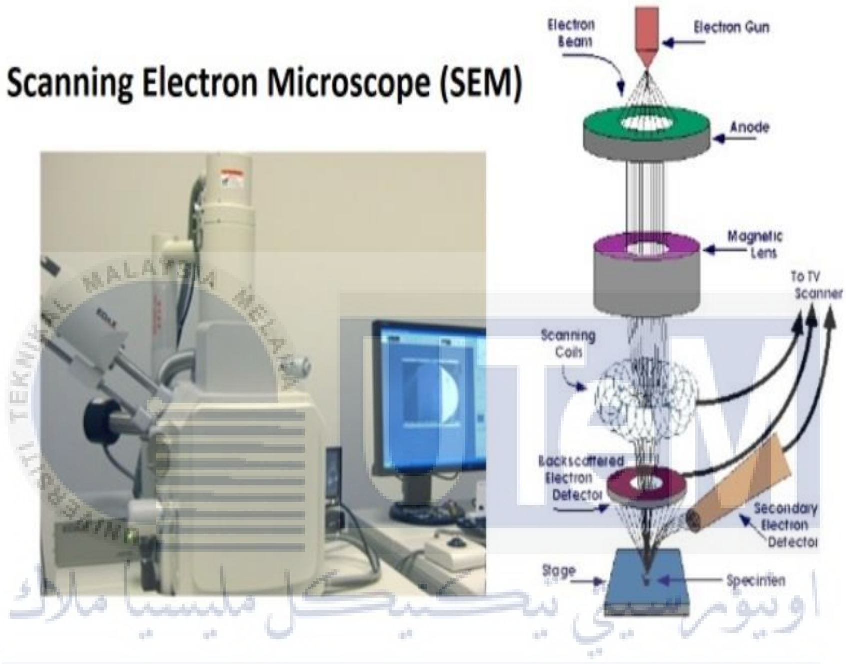


Figure 2.6: The Scanning Electron Microscope (SEM)

2.9.4 Moisture Content Test

In most manufacturing and laboratory facilities, moisture content testing is a vital component of material quality and fundamentally a function of quality control. Moisture content control affects the physical qualities and product quality of practically all substances and materials at all phases of processing and final product existence, from biological research organizations to pharmaceutical makers to food producers and packers.

Moisture content determination accuracy will be as exact as the representative sample quality for substance samples indicating a greater bulk volume. The area of sample selection is critical when selecting material samples from a batch. A test sample must be fully representative of the entire homogeneous batch being tested in order to get repeatable test findings. Before obtaining a representative sample from a bulk powder mixing procedure, for example, it must be completely blended. A common occurrence in the bulk mixing process is a higher concentration of moisture away from the surface and edges of the material. A test sample taken from the top of the batch will not be representative of the entire batch.

Figure 2.7: Moisture content test

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will provide an outline on how the research or study will be carried out. A description about the preliminary data, testing method and equipment needed for the study will be provided in this section. In this research will applied previous study method done by another researcher. The process flow of production of biodegradable film from corn and tapioca is shown in Figure 3.1.

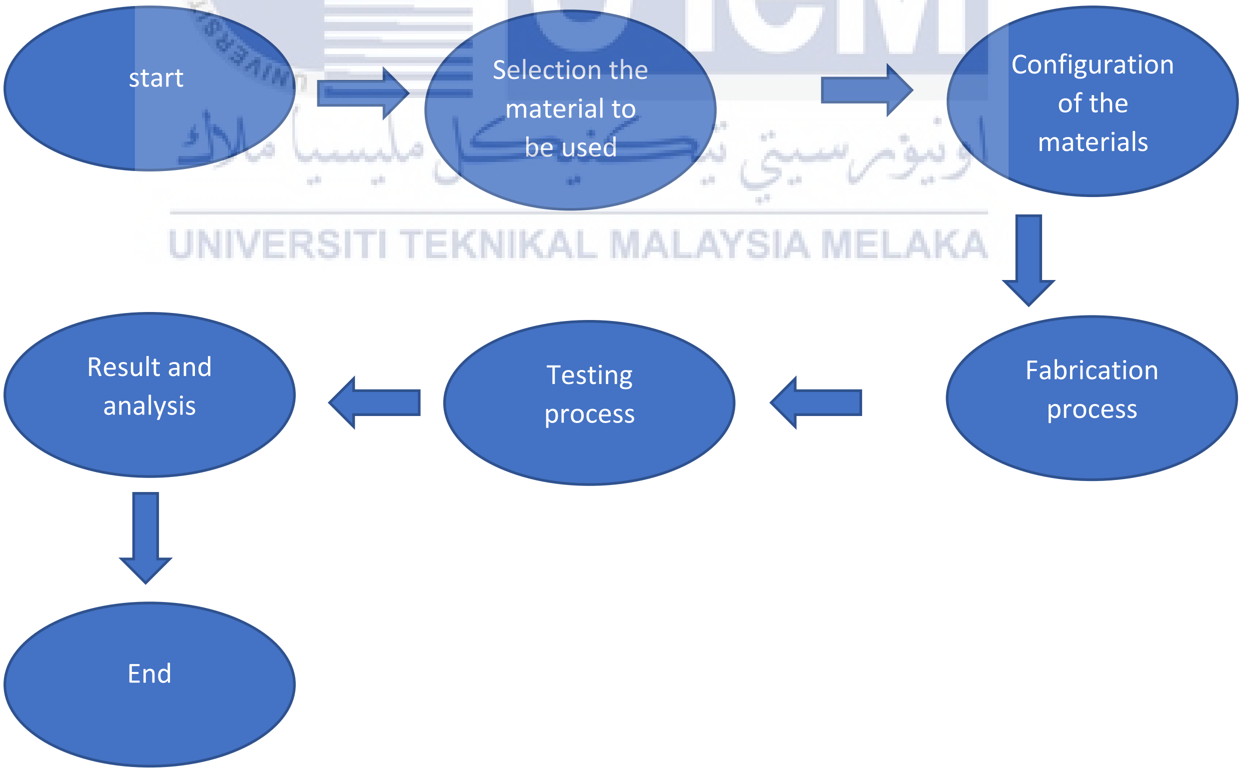


Figure 3.1: The process flow of production of biodegradable film

3.2 Experimental Overview

The target in this chapter is making and accomplish the objectives that going to achieved. A several procedures must be taken to reach all the objectives stated and make the project run smoothly and successful. Based on the flow chart above, the first step that must be consider is to determine what types of materials that must be used or in other words the selection of materials that want to be used. In this project, two major components are selected which is corn starch and tapioca starch. Second steps are preparation of all materials. Next, the process continues to mix both starch and glycerol. From this aspect, to determine the composition distribution of the materials. After several suitable compositions are found, the process will proceed to the fabrication process and a few samples will be made before the process is done. Then, testing will be done to the several samples before collecting the data. The detail on this study will be overview in this chapter.

3.3 Raw Materials

To figure out the concept in selecting the materials that will be used is very important in this experiment since the material selection is a very significant process in any engineering application. This is because all the specification that want to be achieved are based on materials selection and the type of materials that want to be tested. For instead, since in this project we used the composite of the material selection, the method that can be done for an example are on the composition of the selected materials to form them into a composite material. Besides, on these project composite materials are using combination of raw materials which is the starch composite. Hence the selection of those two parts is very significantly to conduct in this project. In this project, will be focusing on the suitable composition of corn and tapioca starch as bio plastic materials and the properties of corn and tapioca starch based as bio plastic materials. The project will approach to the mechanical properties of starch composite and will determined used tensile test, density measurement, hardness test, moisture content test and microstructure analysis. Materials and chemicals with their purpose of use are shown in Table 3.1.

Table 3.1: List of material and chemical with their purpose of use.

Material/Chemical	**Suplier/Source**	**Purpose of use**
Corn starch	Laboratory Brand:Tepung jagung anak pintar	To act as main source of thermoplastic starch for production of biodegradable film
Tapioca starch	Laboratory Brand:Tepung ubi kayu anak pintar	To act as main source of thermoplastic starch for production of biodegradable film.
Glycerol	Laboratory Brand:QReC	To act as main source of Plasticizer for production of biodegradable film.

3.4 Preparation of Materials

Preparation of Bioplastics Film in tapioca and corn starch- based TPS, glycerol is used as plasticizer, due to its better mechanical properties and good water solubility, ranging from 18 to 25% through it can increase up to 36%. It was shown that glycerol concentration would not affect the glass transition temperatures. TPS film was prepared according to the following procedure: The starch, glycerol were added to 100 mL distilled water in various ratios.

3.5 Composition of Prepared Bioplastics

Table 3.2: The composition of prepared bioplastics

Sample	Corn starch (in grams)	Tapioca starch (in grams)	Glycerol (in grams)	Water (in grams)
1	60	20	20	100
2	55	25	20	100
3	50	30	20	100
4	45	35	20	100
5	40	40	20	100
6	35	45	20	100
7	30	50	20	100
8	25	55	20	100
9	20	60	20	100

3.6 Fabrication Process by using casting method

Below shows the procedure fabrication process of casting method that will use in this project to make bioplastic film from corn and tapioca starch based TPS.

3.6.1 Fabrication of Silk Frame

Silk frames are used for casting the sample. After done the samples of corn and tapioca starch with glycerol, this samples will pour onto a silk strain on frame and spread uniformly. So, before started this experiment this silk frame should be done. Below shows the picture of the silk frame which the frame is made up by using wooden plate which the measurement of the frame is 150mmx100mm.

Figure 3.2: silk frame

3.6.2 Fabrication of Sample

Firstly, we should prepare all the apparatus such as beakers, magnetic stirrer, scales, stirrer and so on to move forward to this experiment. Then we measure the amount of corn starch and tapioca starch by using the scale.

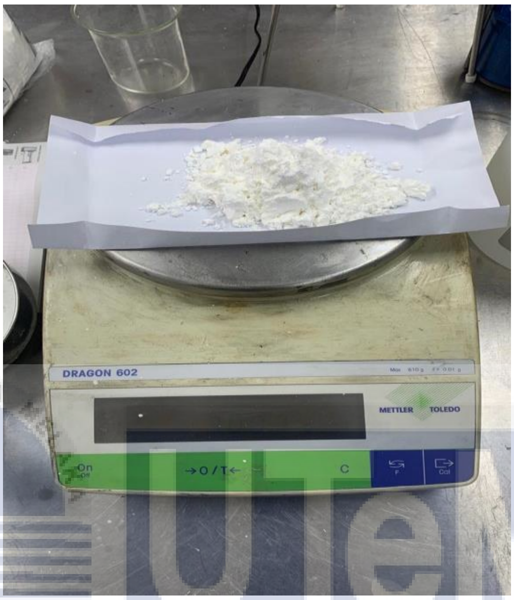


Figure 3.3: measuring corn starch by using scale

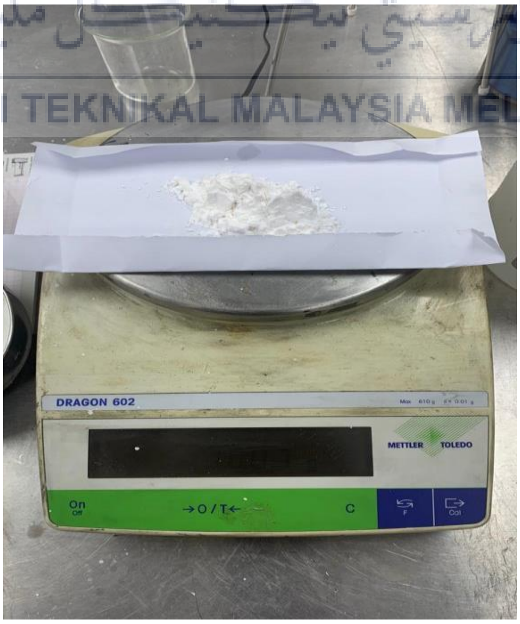


Figure 3.4: measuring tapioca starch by using scale

After that we put distilled water into a beaker as shown in figure 3.5 and lastly, poured glycerol into a beaker and measured it as shown in figure 3.6.

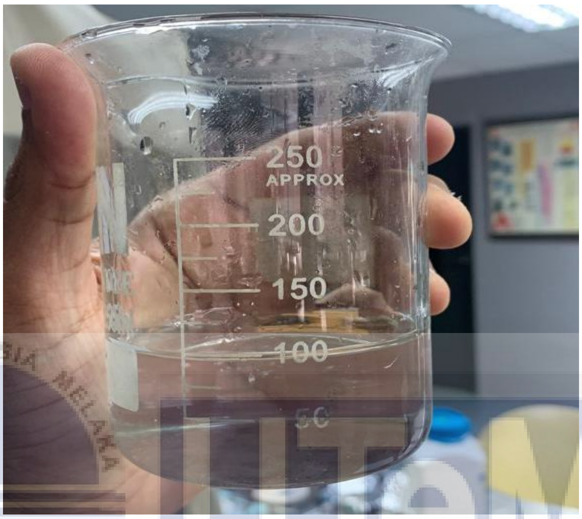


Figure 3.5: measuring distilled water

Figure 3.6: measuring glycerol by using scale

After all composition already be measure, start poured all of this material into a large beaker to mix all of this composition and stirred it. Then can go for heating this composition by using magnetic stirrer in this magnetic stirrer. Should know the setting of the heat and the stirred which we can put the heat at the 100 ℃ temperature and stirred at 189 rpm for 10 minutes as shown in figure 3.7 and then stirred it manually until the mixture become sticky and poured onto silk strain on frame and spread uniformly as shown in figure 3.8. It took 3-4 days for the mixture to dry out and cast film was removed as shown in figure 3.9.

Figure 3.7: setup magnetic stirrer

Figure 3.8: sample already poured onto silk strain on frame.

Figure 3.9: the sample after dry out

3.7 Analysis of Film

The properties corn and tapioca starch based as bio plastic materials composite, the tests such as tensile, density, moisture content tests and microstructure analysis will be performed.

3.7.1 Tensile Test (ASTM D 3039).

In this study, the tensile strength, young's modulus and strain of bio plastic materials composite will be determined. To do that, Instron Universal Testing Machine (Model 8872) controlled with Bluehill 2 software will be use and refer to standard test method for tensile properties ASTM D 3039.

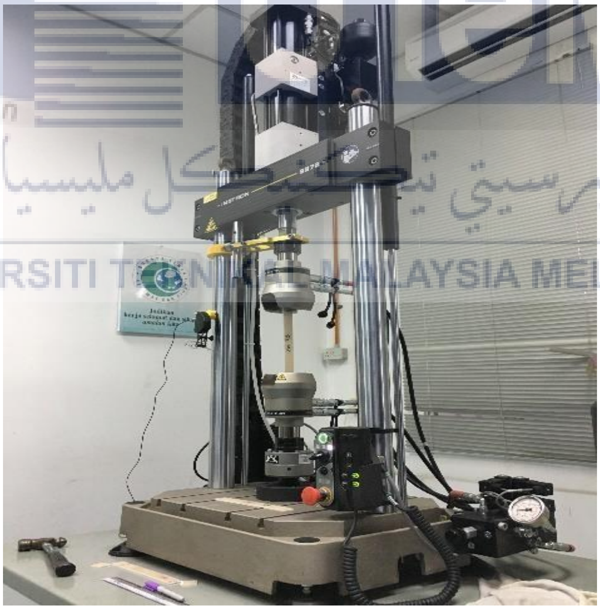


Figure 3.10: Instron Universal Testing Machine (Model 8872)

3.7.2. Density Test (ASTM D792)

In this study, the specific gravity of bioplastics Film in tapioca and corn starch- based TPS will be determined. To do that, Electronic Densimeter MD-300S being use. In this section, the density was performed by using Electronic Densimeter (as shown in figure 3.10). The objective in this study is to measure the specific gravity or density of the materials which is bioplastics Film in tapioca and corn starch- based TPS. The testers were put inside the container and the mass of the specimen is measured. Then. The specimen was put inside water. Furthermore, the specific gravity and volume of the specimen are automatically being measured. All the steps were repeated for each sample and the data being collected.

Figure 3.11: Electronic Densimeter MD-300S

3.7.3 Macrostructure Analysis (ASTM D7136 / D7136M – 15)

In this study, the macrostructure of Bioplastics Film in tapioca and corn starch- based will be analyzed. DinoLite Digital Microscope was use in SEM Analysis. Scanning Electron Micrographs (SEM) were obtained by JEOL JSM 6360 LV high-resolution scanning electron microscope. The purpose of microstructure analysis is to investigate the behavior of the microstructure of the composite. The qualified wool to macrostructure analysis is boon used which is the Scanning Electron Microscopy (SEM), Figure 3.11 shows the specialized tool of the macrostructure analysis.

Figure 3.12: DinoLite Digital Microscope

3.7.4 Moisture Content Test

In this chapter, the Bioplastics Film in tapioca and corn starch- based TPS that have made is analyzed by using Moisture content test. This moisture content test is a critical component of material quality and essentially a function of quality control in most production and laboratory facilities. By measuring the weight loss of films, the moisture content was estimated. The Bioplastics Film in tapioca and corn starch- based TPS samples were cut into square pieces of 2.0 cm2. The samples were weighed accurately. The dry film mass was recorded upon drying in an oven at 110 ◦C until a fixed dry weight was acquired. Each film treatment was used with five replications, and the moisture content was measured:

$$\text{Moisture Content in (\%)} = [(W_i \; i \; W_f)/W_i] \times 100,$$

Figure 3.5: Moisture content test

CHAPTER 4

RESULT & DISCUSSION

4.1 Introduction

The use of biodegradable films depends on several features including, availability, function, mechanical properties, optical quality and more.

4.2 Fabrication Process by Using Casting Method

Below are the attempts samples of composition of Corn Starch and Tapioca Starch with Glycerol at a varied composition. This gives a rough outlook on the composition to start making the actual samples following the standard procedure samples sizes. The outcome from the different composition is amazingly different. The method to get the best composition for each fabrication here is only by try an error method.

4.2.1 Fabrication 1

This fabrication is processed using the same temperature and the same material but different composition ratio. Table 4.1 shown the main parameters has been used. According to the optical quality can be appraised as the characteristic of the samples has been observed.

Table 4.1: The parameters used for this fabrication 1

Parameters	Value
Temperature	100 ℃
Magnetic stirrer speed	186 rpm
Stirred using magnetic stirrer	10 minutes
Manual stirred	60 minutes
Composition TPS/Glycerol	40:10
Composition Corn/Tapioca	20:20 10:30 30:10 15:25 25:15

Figure 4.1: Fabrication 1 20:20 composition ratio of corn starch and tapioca starch

Figure 4.2: Fabrication 1 10:30 composition ratio of corn starch and tapioca starch

Figure 4.3: Fabrication 1 30:10 composition ratio of corn starch and tapioca starch

Figure 4.4: Fabrication 1 15:25 composition ratio of corn starch and tapioca starch

Figure 4.5: Fabrication 1 25:15 composition ratio of corn starch and tapioca starch

4.2.2 Fabrication 1 discussion

From the result in the Table 4.1, for the composition ratio of 20:20 the texture or the material behavior is brittle. It can be observed that the material is very brittle and fall apart at the slightest touch. It also can be seen that there a lot of cracks forming on the sample. For the composition ratio of 10:30 the condition is also brittle and crack forming almost gone. For the composition ratio of 30:10 condition is brittle, and the crack forming is gone. Composition ratio of 15:25 the sample condition is brittle and the crack forming coming back. This marked the starting point of discovering the almost suitable blend of composition ratio of material. For the composition ratio of 25:15 the sample condition is brittle with the appearance of water patches at the center of film.

By far there are not even one of the samples are suitable form to fabricate a composite material. This is because of its feature that are too brittle and easily fall apart at the slightest touch. The other thing to do to get a better sample which is increase the amount of glycerol because in this experiment glycerol act as plasticizer so it will be able to give a strong sample of this experiment.

In conclusion, the composition ratio 30:10 shows a good optical quality. The samples are fabricated be with different suitable and improved the amount of glycerol.

4.2.3 Fabrication 2

This fabrication is processed using the same temperature and the same material but increase the amount of glycerol. By increasing the amount of glycerol, the sample will be stronger than fabrication 1. Table 4.2 shown the main parameters has been used. According to the optical quality can be appraised as the characteristic of the samples has been observed.

Table 4.2: The parameters used for this fabrication 2

Parameters	**Value**
Temperature	100 °C
Magnetic stirrer speed	186 rpm
Stirred using magnetic stirrer	10 minutes
Manual stirred	60 minutes
Composition TPS/Glycerol	35:15
Composition Corn/Tapioca	20:15 17.5:17.5

Figure 4.6: Fabrication 2 20:15 composition ratio of corn starch and tapioca starch

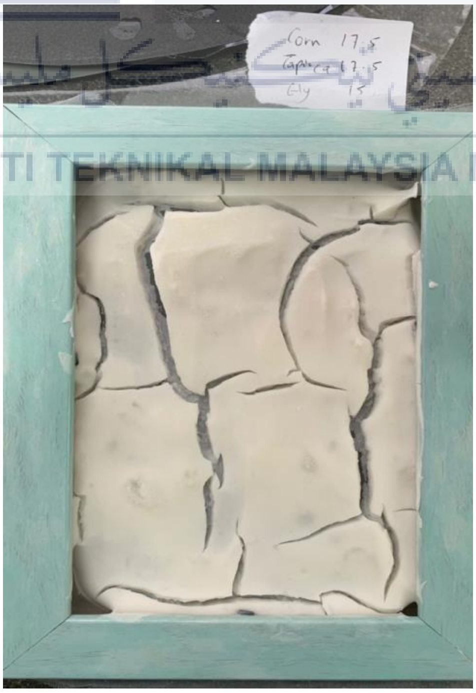


Figure 4.7: Fabrication 2 17.5:17.5 composition ratio of corn and tapioca starch

4.2.4 Discussion Fabrication 2

From the Figure 4.6, the observation has provided the finding above it can be seen that the composition ratio 20:15 are better than fabrication 1 which is the material are not brittle. The sample are not fall apart at the slightest touch, but it is too soft. For the composition ratio 17.5:17.5 shows there a lot of cracks forming on the sample. By far Fabrication 2 are not suitable form to fabricate a composite material. This is because of its feature that are too soft which it could not be testing for mechanical test such as tensile test.

In conclusion, the composition ratio 20:50 shows a good optical quality. The samples are fabricated be with different suitable and improved the amount of glycerol. Similar finding was reported by (Liu et al,2011), which stated that the addition of glycerol could lead to the homogeneity of thermoplastic starch film. This is because glycerol can easily penetrate between the starch networks and disrupt the starch molecules interactions. Hence, the higher glycerol content will increase the swelling capability of the starch network accordingly, and thereby increase the homogeneity of the film.

4.2.5 Fabrication 3

This fabrication is processed using the same temperature and the same material but still increasing the amount of glycerol to identify the best composition of biodegradable plastic. Table 4.3 shown the main parameters has been used. According to the optical quality can be appraised as the characteristic of the samples has been observed.

Table 4.3: The parameters used for this fabrication 3

Parameters	**Value**
Temperature	100 ℃
Magnetic stirrer speed	186 rpm
Stirred using magnetic stirrer	10 minutes
Manual stirred	60 minutes
Composition TPS/Glycerol	32:18
Composition Corn/Tapioca	16:16

Figure 4.8: Fabrication 3 16:16 composition ratio of corn starch and tapioca starch

4.2.6 Discussion Fabrication 3

Fabrication 3 shows the most astounding results. After two previous fabrications the suitable parameter are chosen. Using the parameter stated in the table previously. It can be noted that fabrication 3 give quite a good result. This is because the impression of the optical quality this result manages to present. 16:16 composition ratio result is too flexible and has an almost elastic feature to it by touch only. However, due to the condition of the sample are too soft mechanical properties measurements cannot be attempted.

In conclusion, the fabrication process by using casting method does not give solid results for mechanical testing to determine the properties of corn and tapioca starch based as bio plastic materials. The varying amount of glycerol content significantly affected the properties of starch film by reducing the brittleness and tensile strength. However, increased glycerol content would lead to the improvement in flexibility, elongation at break and physical properties of the films. The other fabrication process that can do to achieve the objective which is determine the suitable composition of corn and tapioca starch as bio plastic materials and determine the properties of corn and tapioca starch based as bio plastic materials is by using hot press.

4.3 Fabrication Process By Using Hot Press

In this project, the fabrication process by using casting method on the suitable composition of corn and tapioca starch as bio plastic materials and the properties of corn and tapioca starch based as bio plastic materials are fail which the observation of the samples is too soft to be testing by mechanical testing such as tensile test. So, the fabrication process by using hot press will be takeover to ensure the suitable composition of corn and tapioca starch as bio plastic materials and the properties of corn and tapioca starch based as bio plastic materials will be determine. The hot press machine that uses is Motorise Hydraulic Moulding Test Press. The mold that be used for this hot press is rectangular shape with dimension 140mm X 250mm.

4.3.1 Processing Method

In this part, the first method will be start mixing method, the TPS which is corn starch and tapioca starch will be mixing with glycerol and pour into the mold. Then the mold can go for the compressing molding in the hot press machine and lastly testing process which is classify or analyze the properties of corn and tapioca starch based as bio plastic materials.

4.3.2 Appropriate Parameter

The next step has been taken to give appropriate parameter of hot compression molding process for mixing of TPS which is corn starch and tapioca starch with glycerol. In order to obtain good sample, the first step must know the melting point of the corn starch and tapioca starch and then followed by the pressure of compression molding. By using 250mm X 140mm mold, the composition of corn starch and tapioca starch which mixing with glycerol are put into the mold then being heated by using the hot press machine. Firstly, the sample have been on hot compressed with the temperature of 140 °C with pressure 200 psi for compression about 50 minutes and pre- heating time of 30 minutes. Secondly, the next trial is by increasing the range temperature is about is 150 °C with is the pressure constant. The third trial also same with the second, by increase the temperature with different value which is 160 °C and constant pressure which is 142 psi. Three same compositions with different parameter will be test on this experiment. The best parameter will be used for the other composition which to determine the suitable composition of Corn and Tapioca starch as bio plastic materials. Several trials have been conducted for an example the sample of this parameter will be discuss more further on discussion. The parameters that have been used to find the best sample by using 70/30 composition of TPS/GLY.

4.3.3 Fabrication Experimental

Below are the attempts samples of composition of Corn Starch and Tapioca Starch with Glycerol at a varied temperature. This gives a rough outlook on the parameter to start making the actual samples following the standard procedure samples sizes. The outcome from the different temperature is amazingly different. The method to get the optimal parameter condition for each fabrication here is only by try an error method.

4.3.4 Fabrication 1

This fabrication is processed using the same temperature and the same material but different composition ratio. Table 4.4 shown the main parameters has been used. According to the optical quality can be appraised as the characteristic of the samples has been observed.

Table 4.4: The parameters used for this fabrication 1

Parameters	**Value**
Temperature	140°c
Pressure	10kg/cm^2@ 142psi
Pre-Heat	30 minutes
Hot pressed	50 minutes
Composition TPS/Glycerol	70:30
Composition Corn/Tapioca	50:50

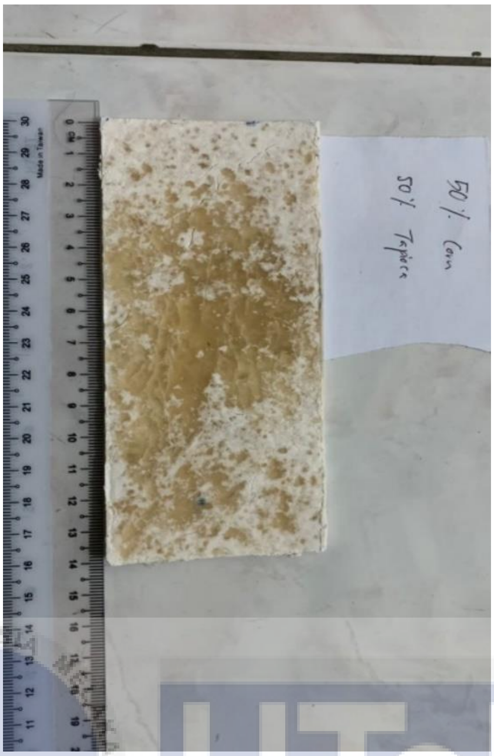


Figure 4.9: Fabrication 1 50:50 composition ratio of corn starch and tapioca starch

4.3.5 Discussion fabrication 1

From the Figure 4.5, the observation has provided the finding above it can be seen that the 50:50 composition ratio of corn starch and tapioca starch with the parameter temperature is 140℃ not give the desirable optical and good quality of the sample. It can only be partly glossy while the white parts are very brittle.

The difference that can made for better quality sample which is change for higher temperature because can see the powder of starch on the sample which can conclude that the sample not cook very well.

4.3.6 Fabrication 2

For this fabrication, the parameter of temperature will be increased to make sure the sample give the desirable optical and good quality of the sample.

Table 4.5: The parameters used for this fabrication 2

Parameters	**Value**
Temperature	150°c
Pressure	10kg/cm^2@ 142psi
Pre-Heat	30 minutes
Hot pressed	50 minutes
Composition TPS/Glycerol	70/30
Composition Corn/Tapioca	50:50

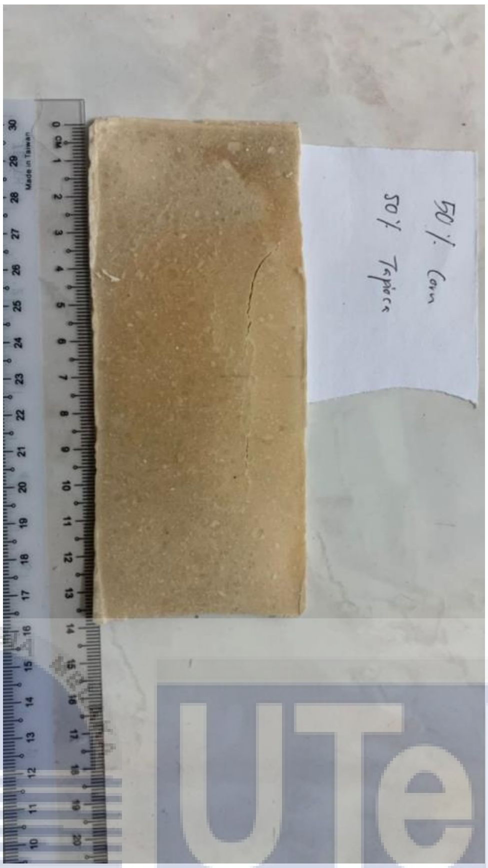


Figure 4.10: Fabrication 2 50:50 composition ratio of corn starch and tapioca starch

4.3.7 Discussion fabrication 2

Based on observation of the samples has been fabricated, figure 4.10 shown the Composition of this sample is 50:50 corn starch and tapioca starch which the temperature is 150℃. The condition of this sample is rigid and the transparent part are forming almost fully. This marked the starting point of discovering the almost suitable blend of composition ratio of material. For the parameter temperature 150℃, the sample came out as rigid along with the appearance of white patches at the center of film.

4.3.8 Fabrication 3

Based on Fabrication 2, the new set of main parameters of fabrication process has been selected as shown in Table 4.6. This new set of parameters has used which is increase the temperature for the best result of composition of corn starch and tapioca starch.

Table 4.6: The parameters used for this fabrication 3

Parameters	**Value**
Temperature	160°c
Pressure	10kg/cm^2@ 142psi
Pre-Heat	30 minutes
Hot pressed	50 minutes
Composition TPS/Glycerol	70:30
Composition Corn/Tapioca	75:25 50:50 60:40 25:75 0:100

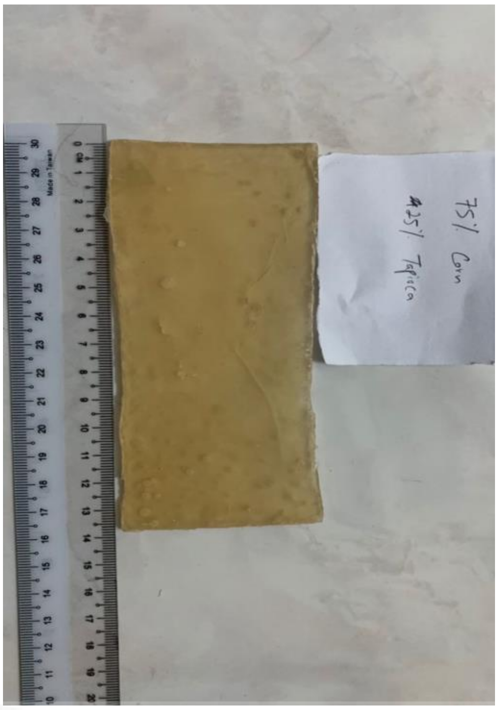


Figure 4.11: Fabrication 3 75:25 composition ratio of corn starch and tapioca starch

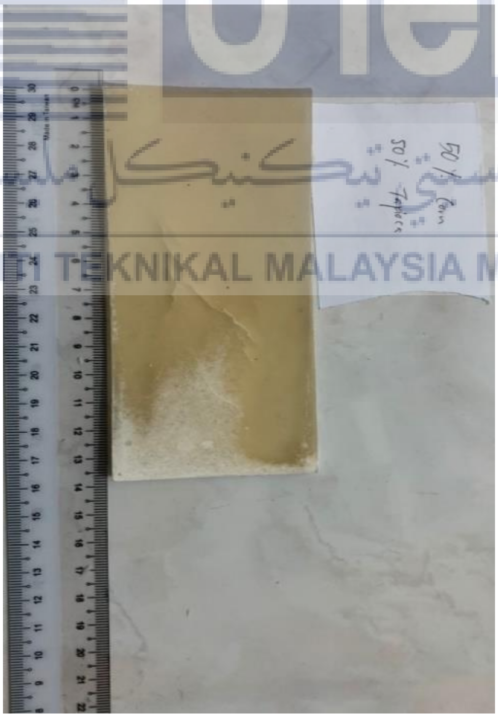


Figure 4.12: Fabrication 3 50:50 composition ratio of corn starch and tapioca starch

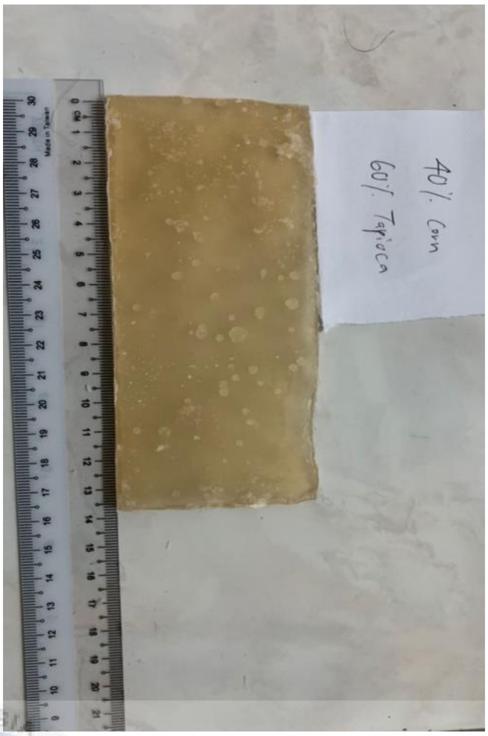


Figure 4.13: Fabrication 3 40:60 composition ratio of corn starch and tapioca starch

Figure 4.14: Fabrication 3 25:75 composition ratio of corn starch and tapioca starch

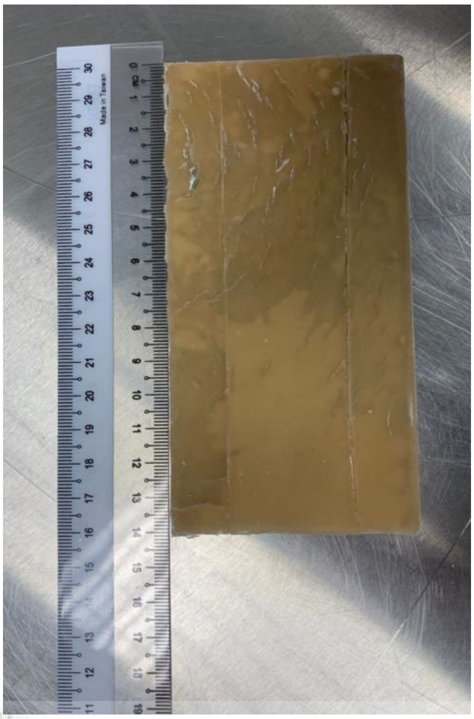


Figure 4.15: Fabrication 3 0:100 composition ratio of corn starch and tapioca starch

4.3.9 Discussion Fabrication 3

Fabrication 3 shows the most astounding results. After two previous fabrications the suitable parameter are chosen. Using the parameter temperature 160°C, It can be noted that fabrication 3 give quite a good result. This is because the impression of the optical quality this result manages to present. 50:50 composition ratio result is flexible and has an almost elastic feature to it by touch only.75:25 composition ratio result is a good result because this film by organoleptic properties feels similar to polypropylene sample. It is rigid and at certain pressure it will break. Obtained from the observation that the samples with 60:40 composition ratio result is flexible.

For composition of 25:75 and 0:100, the sample look great. The result flexible and has an almost elastic feature. This composition by far is the most suitable form to fabricate bioplastic. This is because of its feature that can hold it form almost identical to polypropylene film sample.

Fabrication 3 prepared about 5 various samples by using 160℃ based on differ composition which it shows a good result for further analysis to determine the properties of corn and tapioca starch based as bio plastic materials.

4.4 Test Result and Discussion

In this subtopic, shows all the experimental data and result for all testing that have done. All three testing that have been done are Tensile Test by referring (ASTM D 3039), Hardness Test (ASTMD 2240 D) and Density Test. Each sample has been done 3 test point to get the average values.

4.4.1 Tensile Test Result

Instron 8872 machine was used to complete this tensile test. The Standard test method for tensile Properties of Polymer Matrix of Composite Materials (ASTM D 3039/ D3039 M-0) has been related. The test was run, and the crosshead speed rate of the tensile test was 0.2mm/ sec constant speed. In this study all the result of the samples was taken, and the data were collected. Below shows data of tensile test.

Table 4.7: Tensile Test Data

Sample	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord – Cursor)[Mpa]
75:25 A	61.87	0.10	0.15497	2.08599
75:25 B	53.41	0.09	0.10415	1.87008
75:25 C	63.55	0.11	0.13423	1.56912
50:50 A	79.02	0.13	0.04756	3.59208
50:50 B	95.11	0.16	0.07437	4.78047
50:50 C	97.20	0.16	0.04419	6.04371
40:60 A	68.94	0.11	0.22741	1.79431
40:60 B	58.63	0.10	0.14208	1.27414
40:60 C	66.45	0.11	0.22652	1.59381
25:75 A	51.95	0.09	0.11249	1.67656
25:75 B	51.53	0.09	0.11734	1.64156
25:75 C	59.85	0.10	0.09171	2.36043
0:100 A	63.55	0.11	0.13423	1.56912
0:100 B	58.63	0.10	0.14208	1.79431
0:100 C	60.47	0.10	0.13423	1.87008

4.4.2 Tensile Test Discussion

From the data collected from tensile test, the highest value of tensile stress at maximum load is 0.16 (Mpa) which at composition 50:50 of corn and tapioca starch while the lowest value of tensile stress at maximum load is 0.09 (Mpa). Based on the data collected, graph Tensile Stress at maximum load (Mpa) against sample composition of corn starch and tapioca starch sample has been conduct as shown below. From the graph, the average data composition 50:50 of corn starch and tapioca starch sample shows the best result which the tensile stress at maximum load is 0.15 (Mpa). It is such an amazing result which the hybrid composition of corn and tapioca starch sample get higher tensile stress result compared to pure sample which average data composition of 100% tapioca is 0.103 (Mpa).

Based on the trend graph below, it is found that the tensile stress at maximum load value increased from sample composition 75:25 to 50:50. Then the tensile value decreased in composition 40:60 and 25:75 samples and finally it increased in 100% tapioca samples. On this situation shows that on the sample composition 50:50 have more tensile stress at maximum load value compared to other composition which more tensile stress at maximum value than pure tapioca sample. These findings present this composition as a best TPS for the development of biodegradable materials.

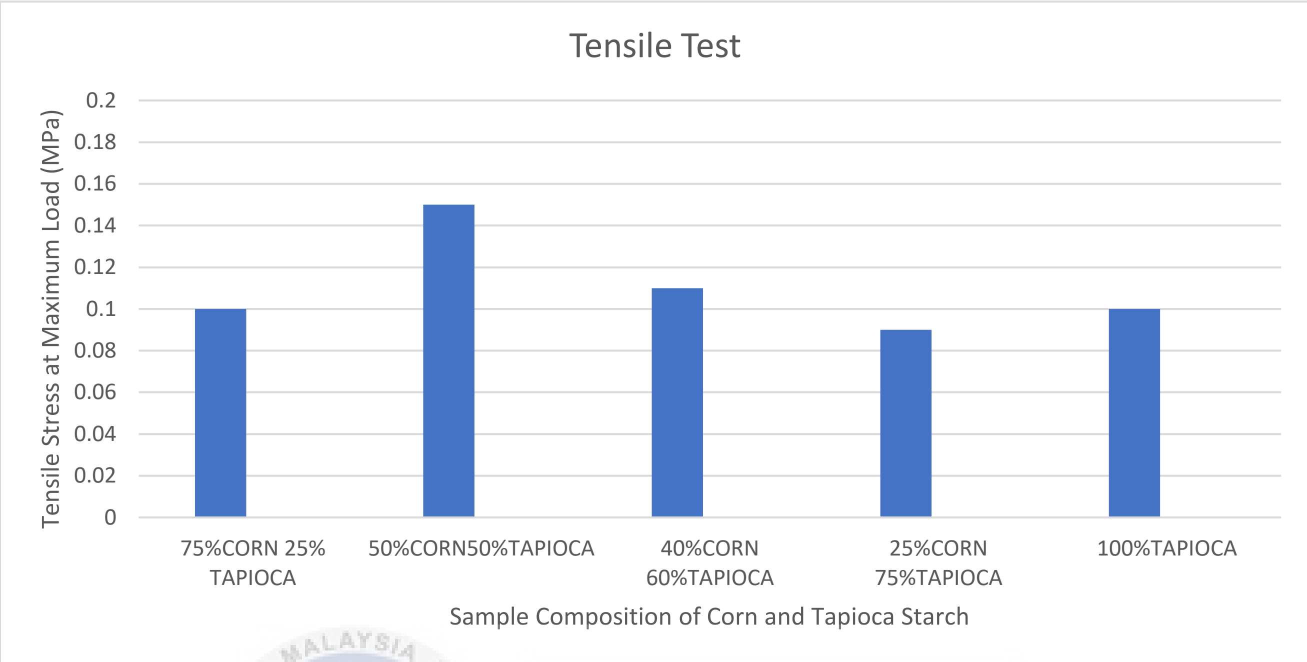


Figure 4.16: Graph Tensile Test

4.4.3 Hardness Test Result

In this section, the hardness test will be running for the samples of corn starch and tapioca starch which is all the samples have different ratio of corn starch and tapioca starch. In this study, The Shore hardness device 1S type D that be used to test the hardness of each sample, by referring standard of ASTM D2240.

Table 4.8: Hardness Data

Composition sample	Hardness Data
75%corn 25%tapioca	Sample A=30 Sample B=32 Sample C=32 Average=31
50%corn 50%tapioca	Sample A=39 Sample B=38 Sample C=40 Average=39
40%corn 60%tapioca	Sample A=25 Sample B=28 Sample C=28 Average=27
25%corn 75%tapioca	Sample A=25 Sample B=21 Sample C=22 Average=23
0%corn 100%tapioca	Sample A=49 Sample B=48 Sample C=46 Average=48

4.4.4 Hardness Test Discussion

From the table 4.8 data of the hardness test on the five test samples. Each sample has been done 3 test point to get the average values. Based on table 4.8, the hardness test result from five different composition of corn and tapioca starch being collected. It shows that the increment and decrement value of the hardness data.

The increasing and decreasing value pattern of the data shown in graph (figure 4.17) below. The highest value of hardness test is 48 which the sample of 100% tapioca starch. While the lowest values of hardness test are 23 at composition 25% corn and 75% tapioca. Based on the trend graph below, it is found that the hardness value increased from sample composition 75:25 to 50:50. Then the hardness value decreased in composition 40:60 and 25:75 samples and finally it increased in 100% tapioca samples. On this situation shows that on the sample composition 50:50 have more hardness value compared to other hybrid composition. These findings present this composition as a best TPS for the development of biodegradable materials.

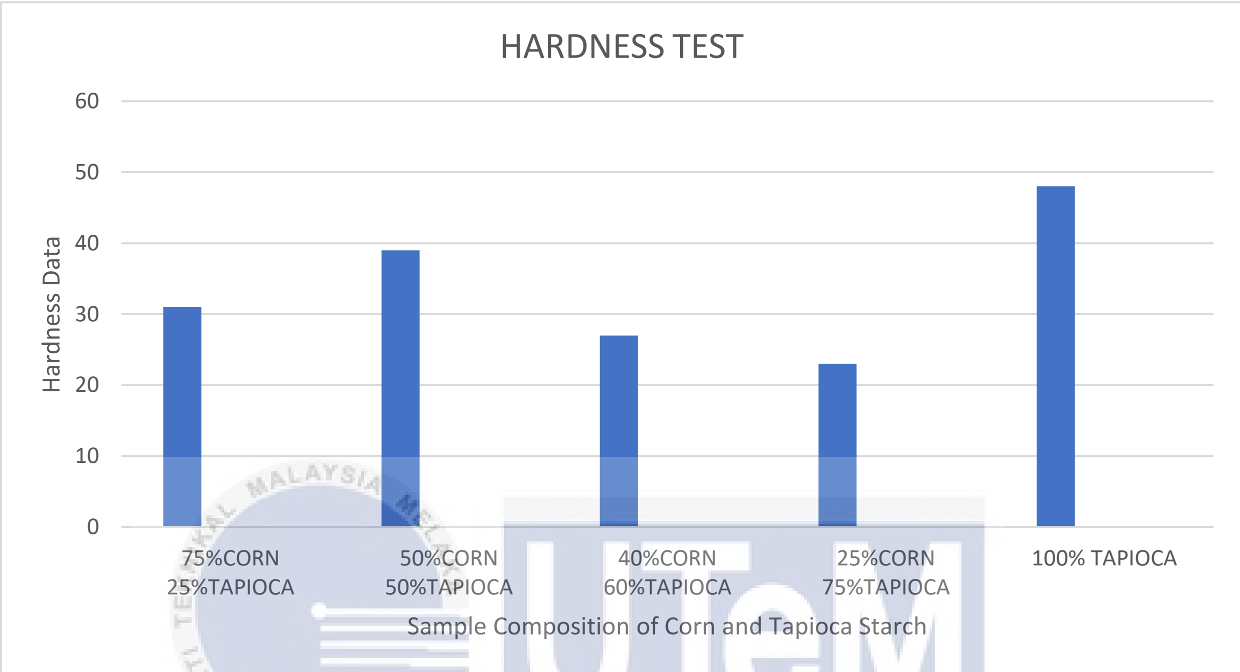


Figure 4.17: Graph Hardness Test

4.4.5 Density Test Result

The density of composites was measured by Electronic Densimeter, and distilled water was used as the immersing liquid with three repetitions. The sample was weighed before putting into Electronic Densimeter that contains liquid. After that, the sample in the Electronic Densimeter was weighed (m) and the density (ρ) was calculated by the equation: $\rho = m\,V$.

Table 4.9: Density Test Data

Composition sample	**Density, ρ**
75%corn 25%tapioca	Sample A=1.385 Sample B=1.391 Sample C=1.396 ρ total=1.39
50%corn 50%tapioca	Sample A=1.418 Sample B=1.420 Sample C=1.418 ρ total=1.42
40%corn 60%tapioca	Sample A=1.394 Sample B=1.359 Sample C=1.324 ρ total=1.36
25%corn 75%tapioca	Sample A=1.398 Sample B=1.409 Sample C=1.420 ρ total=1.41
100% tapioca	Sample A=1.385 Sample B=1.397 Sample C=1.381 ρ total=1.38

4.4.6 Density Test Discussion

From the table 4.9 data of the density test on the five test samples. Each sample has been done 3 test point to get the average values. Based on table 4.9, the density test result from five different composition of corn and tapioca starch being collected. It shows that the increment and decrement value of the hardness data.

The increasing and decreasing value pattern of the data shown in graph (figure 4.18) below. The highest value of density test is 1.42 which the sample of 50:50 composition corn and tapioca starch. While the lowest values of density test are 1.36 which the sample of 25:75 composition corn and tapioca starch. Based on the trend graph below, it is found that the density value increased from sample composition 75:25 to 50:50. Then the hardness value decreased in composition 40:60 samples and its increasing at sample 27:75. Finally it is decreasing at composition 100% tapioca samples. On this situation shows that on the sample composition 50:50 have more density value compared to other composition which more than density value from pure tapioca sample. These findings present this composition as a best TPS for the development of biodegradable materials.

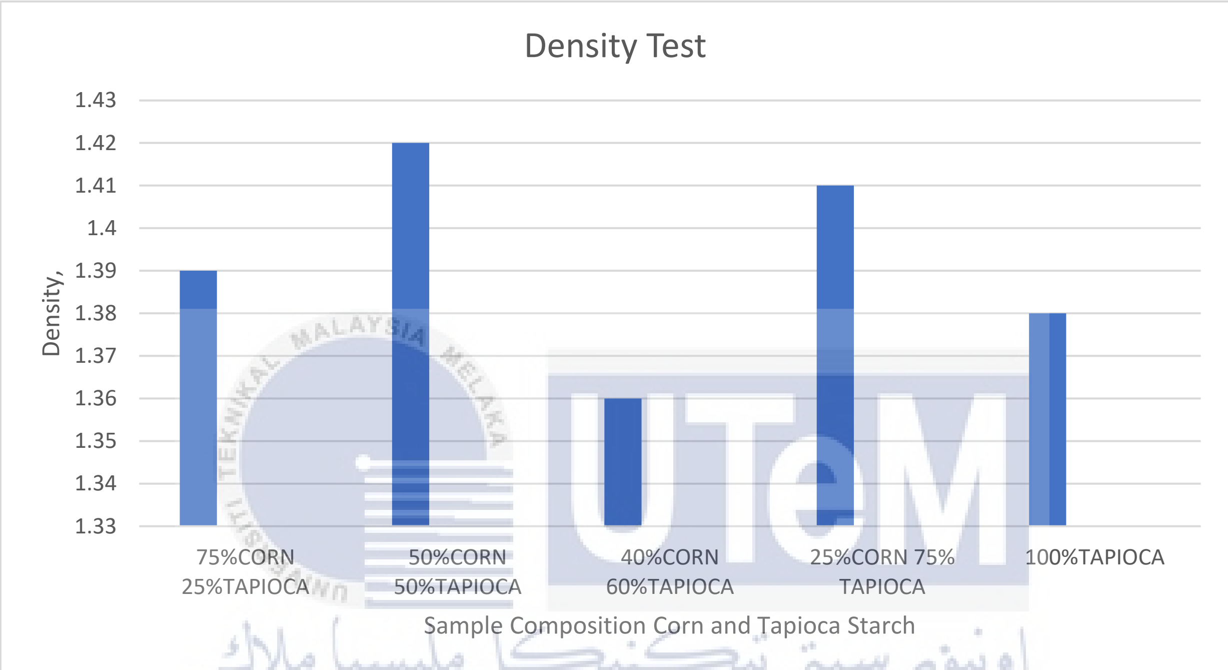


Figure 4.18: Density Test Graph

4.5 Summary Finding

From all these four tests, found that the composition of 50% 50% has the highest tensile value which is 0.15(Mpa). The hardness test value of this composition is slightly lower than pure tapioca with the value 39 compare to 100% tapioca which is 48. While the density value of composition 50% corn and 50% tapioca is the highest of the overall sample composition which the value is 1.42. With the result of this test proved that the composition of 50% corn and 50% tapioca has good bioplastic properties to be used as packaging materials.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

TPS sources had been studied by researcher on investigation the influences of TPS properties. Therefore, the focus of the study was to determine the suitable composition of corn and tapioca starch as bio plastic materials and determine the properties of corn and tapioca starch based as bio plastic materials that can give good optical quality, tensile stress, hardness, and density for its potential to become a items and biodegradability of GLY/TPS blend composite. Preparation of Bioplastics Film in corn and tapioca starch- based TPS, glycerol is used as plasticizer, due to its better mechanical properties.

The method that used to fabricate bioplastic film in corn and tapioca starch based TPS is by using casting method which TPS film was prepared according to the following procedure: The starch, glycerol added to 100 mL distilled water in various ratios. The mixture was stirred at a rate of 180 rpm for 10 min. then the mixture was heated on a plate at 100 °C, and manual stirred was done for 70 min, continuously. It was then poured onto a silk/cloth strain on frame and spread uniformly. It took 3-4 days for the mixture to dry out and cast film was removed but the result of this method are not satisfying to do mechanical test so the effort that can made in this project going smoothly and efficiently is by fabricate bioplastic film in corn and tapioca starch-based TPS using hot press to ensure the objective of this project will be achieve.

The hot press machine that uses is Motorise Hydraulic Moulding Test Press. The mold that be used for this hot press is rectangular shape with dimension 140mm X 250mm. The method to get the optimal parameter condition for each fabrication here is only by try an error method. The result of this method shows improvement which is flexible and has an almost elastic feature by far are the most suitable form to fabricate bioplastic. This is because of its feature that are able to hold its form almost identical to polypropylene film sample.

The test also shows that the sample composition 50% corn and 50% tapioca have higher tensile stress at maximum load, hardness test and density test compared to all composition that have made. These findings present this 50% corn and 50% tapioca starch composition as a best TPS for the development of biodegradable materials.

5.2 Recommendation

For further research in this study, there are a few recommendations important that should be highlighted to be improve that result of mechanical properties of bioplastic film in corn and tapioca starch based TPS. The following recommendation need to consider in this study:

I. Composition of The Bioplastic Materials

Bioplastic film in corn and tapioca starch based TPS composition is 70TPS/30GLY. For the further study, try to change the composition of TPS conversely. This can be giving a different result that can be investigate. Besides, try to change the percentage of TPS and GLY. Gelatin, and citric acid also can include in this bioplastic film in corn and tapioca starch based TPS composition.

II. Testing Method

Mechanical testing had been done to determine the suitable composition of corn and tapioca starch as bio plastic materials and determine the properties of corn and tapioca starch based as bio plastic materials. In addition, to improve this research, result adding more testing such as microstructure analysis, water absorption test, impact tested and degradation analysis in future study. For this purpose, other effect mechanical properties testing can be study to improve the research of bio plastic materials.

REFERENCES

1. Jayashree Srinivasan, Marthadan Govindan, Malarvizhi Chinnasami and Indrakaran Kadiresu, (2012). "Solid Waste Management in Malaysia – A Move Towards Sustainability".

2.Matthew, F.L., and Rawling, R.D., (2003). "Composite Materials: Engineering and Science, Woodhead Publishing Limited".

3.Ghanbarzadeh, B., & Almasi, H. (2013). "Biodegradable polymers. Biodegradation-life of science".

4.Mathivanan, D., Norfazilah, H., Siregar, J. P., Rejab, M. R. M., Bachtiar, D., & Cionita,T. (2016). "The study of mechanical properties of pineapple leaf fibre reinforced tapioca-based bioplastic resin composite". In MATEC Web of Conferences (Vol. 74).

5.Park, Chough, Yun, & Yoon, (2005). "Properties of Starch/PVA Blend Films Containing Citric Acid as Additive"

6.Ahmed, J., Tiwari, B. J., Imam, S. H., & Rao, M. A. (2012). "Starch-Based Polymeric Materials and Nanocomposites".

7.Azhari, N. A., Othman, N., & Ismail, H. (2011). "Biodegradation Studies of Polyvinyl Alcohol/Corn Starch Blend Films in Solid and Solution Media".

8.Noorul Hidayah Yusoff, Kaushik Pal, Thinakaran Narayanana, Fernando Gomes de Souzac,(2021). "Recent trends on bioplastics synthesis and characterizations: Polylactic acid (PLA) incorporated with tapioca starch for packaging applications".

9.Amanda B. Dias, Carmen M.O. Mu¨ller, Fa´bio D.S. Larotonda, Joa˜o B. Laurindo, (2010). “Biodegradable films based on rice starch and rice flour”.

10.M. K. Marichelvam,Mohammad Jawaid, and Mohammad Asim,(2019). “Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials”.

11.William D. Callister, Jr., and David G. Rethwisch,(2005). “Materials Science and Engineering: An Introduction, 10th Edition” chapter 16: composite.

12.Oliver Drzyzga & Auxiliadora Prieto (2019). “Plastic waste management, a matter for the ‘community’”.

13.Mitrus & Moscicki, (2013). “Advances in Agrophysical Research” (pp.319-346) Chapter: Extrusion-cooking of starch.

14. Black, J. (2005). Biological performance of materials: fundamentals of hocompatibility. Cr Press.

15. George, J. Bhagawan, S.S. and Thomas, S. (1997). "Effects of environment on the properties of low-density polyethylene composites reinforced with pineapple-leaf fiber". Composites Science and Technology, 58(9):1471-1485.

16. Dhal, J., & Mishra, S. (2012). "Processing and Properties of Natural Fiber- Reinforced Polymer Composite". Journal of Materials, 1-6.

17. Rowell, R. M., Young, R.A., Rowell, J. K., (1997). “Paper and Composites from Agro based Resources", Lewis Publishers, New York.

18. Liang HH, Ho MC (2007). "Toxicity characteristics of commercially manufactured insulation materials for building applications in Taiwan", Constr. Build. Mater, 21: 1254-1261.

19.Liu W. Misra M, Askeland P. Drzal L. T. Mohanty A. K, (2005). 'Green' Composites from Soy Based Plastic and Pineapple Leaf Fiber: Fabrication and Properties Evaluation.

20. Fernando Pacheco-Torgal, Jamal Khatib, Francesco Colangelo, Rabin Tuladhar, (2018). “Use of Recycled Plastics in Eco-efficient Concrete”, 1st Edition.

21. M. Grigore, (2017). “Methods of Recycling, Properties and Applications of Recycled Thermoplastic Polymers”,

22. Toketemu, (2018). ”What’s the difference: Biodegradable and Compostable”

23. Emad Yousif & Raghad Haddad, (2013). “Photodegradation and photostabilization of polymers, especially polystyrene”.

24. Kaltenbach & Hans-Michael, (2012). “A Concise Guide to Statistics”.

25. B. A. Ahmed Ali, M. Sapuan, Mohammad Jawaid, Muhammed Lamin Sanyang, (2017). “Expert Material Selection for Manufacturing of Green Bio Composites”.

26. M. Flieger, M. Kantorová, A. Prell, T. Řezanka & J. Votruba, Folia Microbiologica, (2003). “Biodegradable plastics from renewable sources”.

27. Sonar, T., Patil, S., Deshmukh, V., & Acharya, R. (2015). “Natural Fiber Reinforced Polymer Composite Material”-A Review. IOSR Journal of Mechanical and Civil Engineering, 2278-1684.

28. Verma, Deepak Jain, Siddharth Zhang, Xiaolei Gope, Prakash Chandra. (2016). “Green Approaches to Biocomposite Materials Science and Engineering”. IGI Global.

29. Keya, K. N., Kona, N. A., Koly, F. A., Maraz, K. M., Islam, M. N., & Khan, R. A. (2019). “Natural fiber reinforced polymer composites: history, types, advantages and applications”. Materials Engineering Research, 1(2), 69-85.

30. Ghanbarzadeh, B., & Almasi, H. (2013). “Biodegradable polymers. Biodegradation-life of science”. InTech Publications, Croatia, 141-186.

31. Bledzki,A.K and Gasan J, (1999). “Effect of coupling agents on the moisture absorption of natural fiber reinforced plastics”.

32. M. K. Marichelvam, Mohammad Jawaid, and Mohammad Asim, (2019).” Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials”.

33. School of Materials Science and Engineering. (n.d.). Retrieved from http://www.materials.unsw.edu.au/tutorials/online-tutorials/7-metal-matrix-composites.

34. Rodriguez-Castellanos, W. and Rodrigue, D. (2016). Production and Characterization of Hybrid Polymer Composites Based on Natural Fibers. Composites from Renewable and Sustainable Materials.

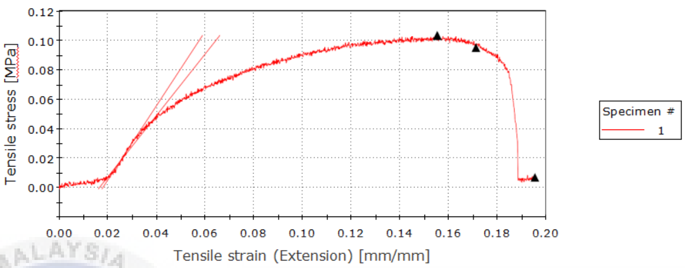
35. J. Y. Zhanjun Liu, Lei Zhao, Minnan Chen, Carbohydr. Polym. 83, 447–451 (2011).

36. Juari, (2006). Preparation and characterization of bioplastics from poly-3-hydroxyalkanoate (APA) produced by ralstoia eutropha on sago starch hydrolyzate with addition of dimethyl phthalate (DMF) (Agricultural Technology Faculty Institut Teknologi Pertanian Bogor)

APPENDICES

BIOPLASTIC

BIOPLASTIK 75/25 A1

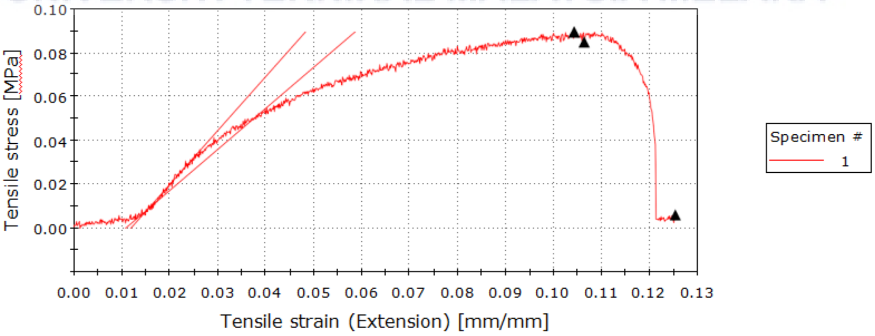


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	61.87	0.10	0.15497	2.08599

	Modulus (Automatic Young's) [MPa]
1	2.51790

BIOPLASTIC

BIOPLASTIK 75/25 A2



	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	53.41	0.09	0.10415	1.87008

	Modulus (Automatic Young's) [MPa]
1	2.45797

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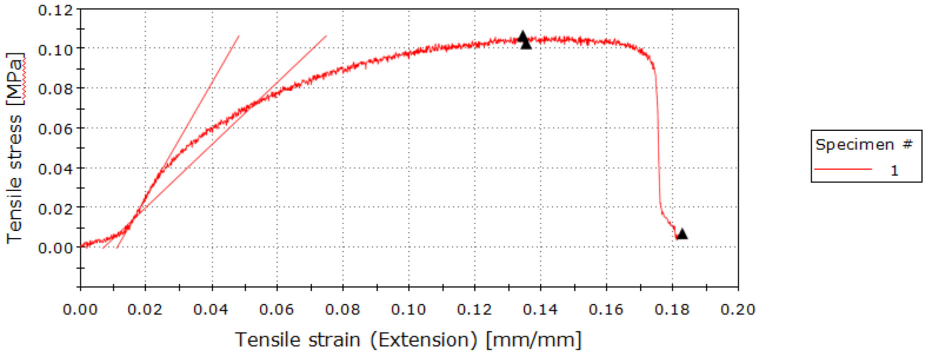
BIOPLASTIK 75/25 A3

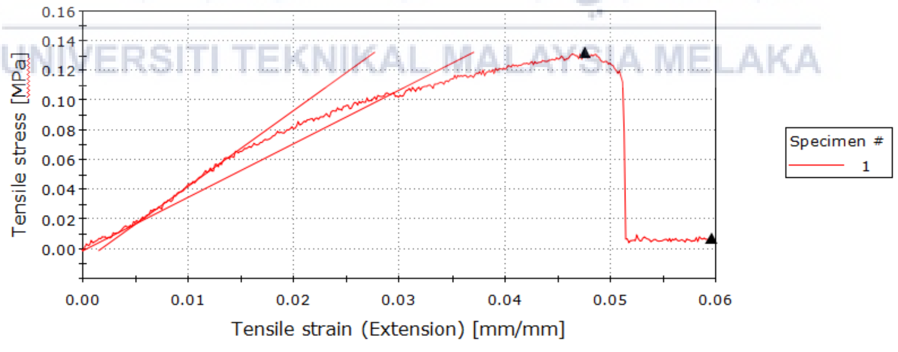


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	63.55	0.11	0.13423	1.56912

	Modulus (Automatic Young's) [MPa]
1	2.85996

BIOPLASTIC

BIOPLASTIK 50/50 A1

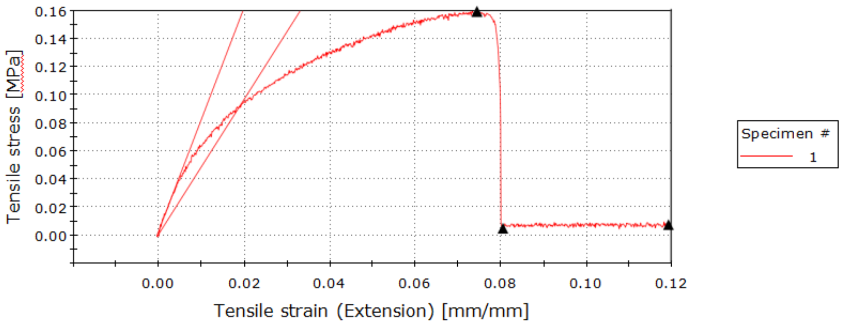


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	79.02	0.13	0.04756	3.59208

	Modulus (Automatic Young's) [MPa]
1	5.07918

BIOPLASTIC

BIOPLASTIK 50/50 A2

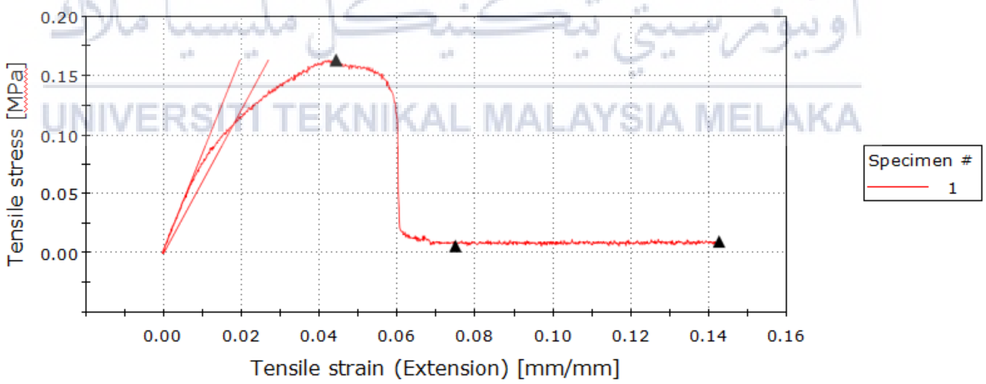


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	95.11	0.16	0.07437	4.78047

	Modulus (Automatic Young's) [MPa]
1	7.91007

BIOPLASTIC

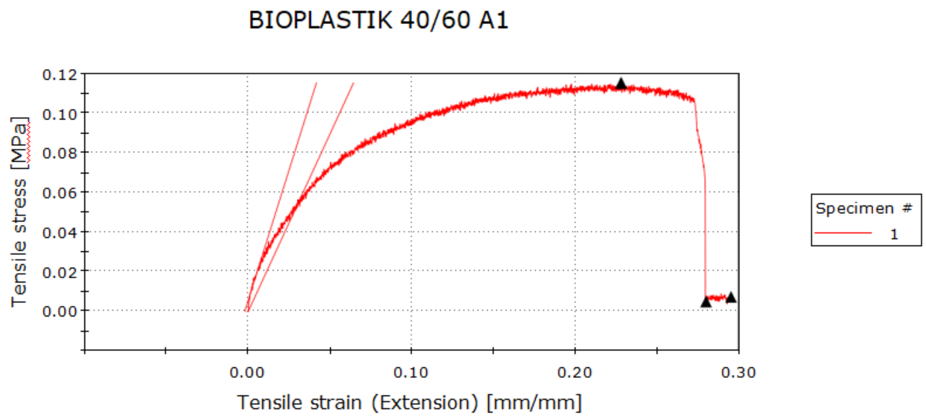
BIOPLASTIK 50/50 A3



	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	97.20	0.16	0.04419	6.04371

	Modulus (Automatic Young's) [MPa]
1	8.15472

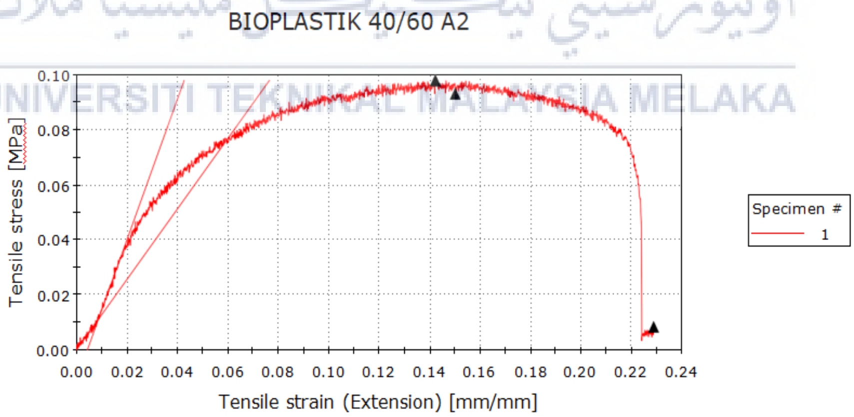
BIOPLASTIC



	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	68.94	0.11	0.22741	1.79431

	Modulus (Automatic Young's) [MPa]
1	2.63984

BIOPLASTIC

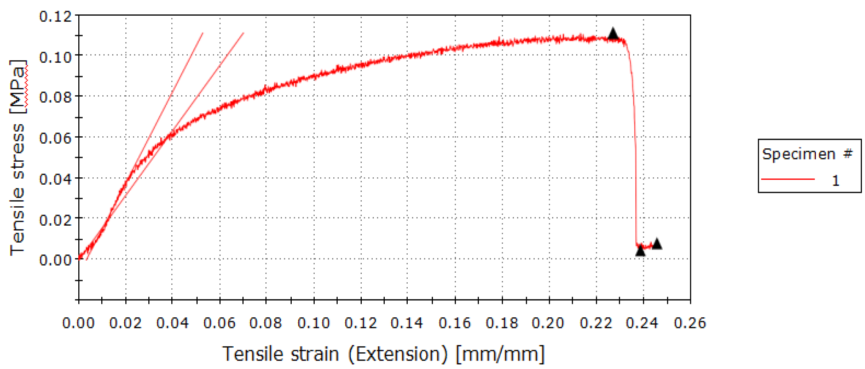


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	58.63	0.10	0.14208	1.27414

	Modulus (Automatic Young's) [MPa]
1	2.53844

BIOPLASTIC

BIOPLASTIK 40/605 A3

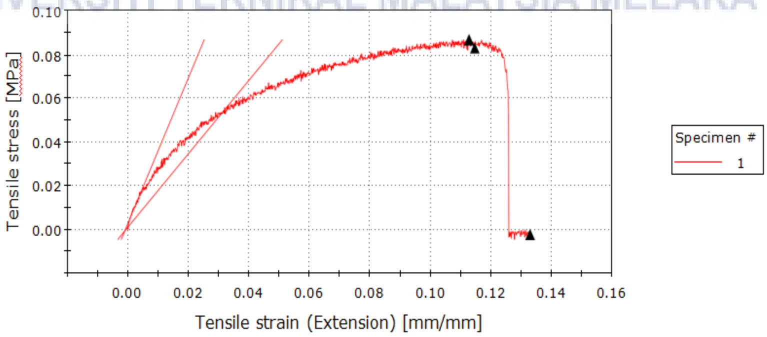


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	66.45	0.11	0.22652	1.59381

	Modulus (Automatic Young's) [MPa]
1	2.24969

BIOPLASTIC

BIOPLASTIK 25/75 A1

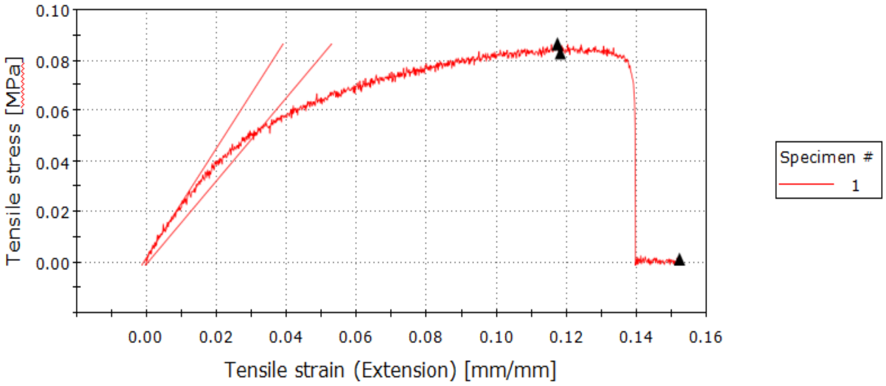


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	51.95	0.09	0.11249	1.67656

	Modulus (Automatic Young's) [MPa]
1	3.32328

BIOPLASTIC

BIOPLASTIK 25/75 A2

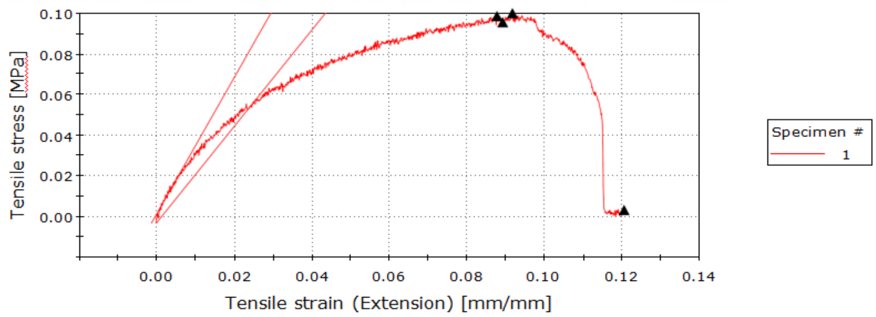


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	51.53	0.09	0.11734	1.64156

	Modulus (Automatic Young's) [MPa]
1	2.15919

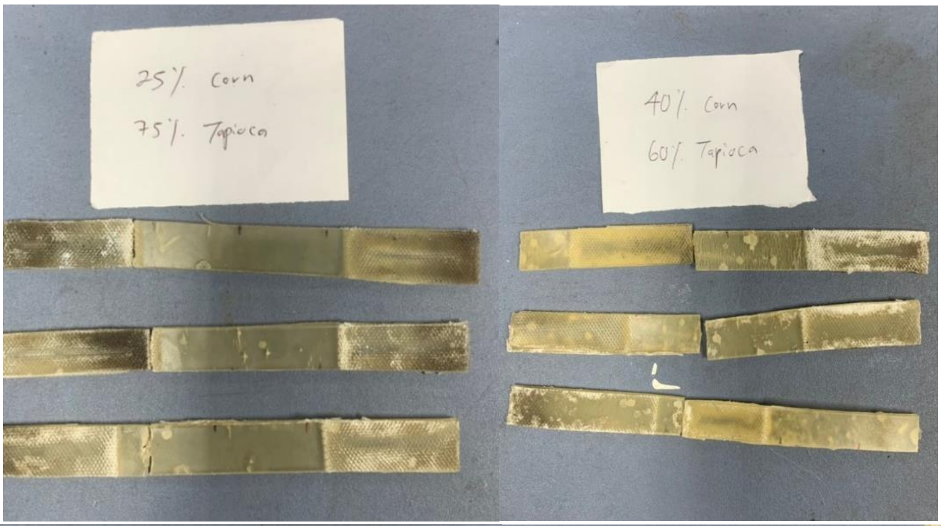
BIOPLASTIC

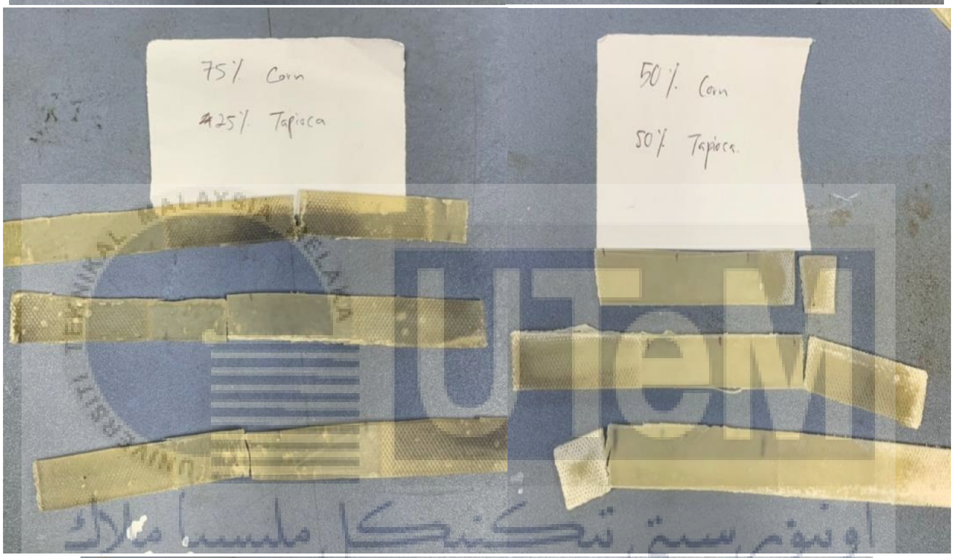
BIOPLASTIK 25/75 A3



	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Tensile strain (Extension) at Maximum Load [mm/mm]	Modulus (Chord - Cursor) [MPa]
1	59.85	0.10	0.09171	2.36043

	Modulus (Automatic Young's) [MPa]
1	3.33721


25% Corn
75% Tapioca
40% Corn
60% Tapioca


75% Corn
25% Tapioca
50% Corn
50% Tapioca.