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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE STUDY OF PHYSICAL & ENVIRONMENTAL CHARACTERIZATION ON SAGO STARCH

NURUL AFIQAH BINTI ZULKEFLAY

BACHELOR OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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NURUL AFIQAH BINTI ZULKEFLAY

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

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled “The Study of Physical and Environmental Characterization on Sago Starch” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Nurul Afiqah binti Zulkeflay

Date : 15 January 2022

APPROVAL

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

Signature : ....

Supervisor Name : Ts. Dr. Nazri Huzaimi bin Zakaria

Date : 21 January 2022

DEDICATION

This thesis is dedicated to my parents Zulkeflay bin Jamahari and Nor A’ini binti Hussin.

Thanks for your unyielding support and love.

ABSTRACT

The usage of composites is very common in industry. However, there are some drawback issues regarding of the composite materials to the environment. Researchers have discover of using natural resources to counter this issue. One of the natural resources that have been used is sago starch. Sago starch has been widely used for multiple purposes from food industry to manufacturing industry. The properties of sago starch are the crucial criteria for material selection to be used as biodegradable material. In this thesis, the physical and environmental characterization of sago starch are being studied to determined the suitable matrix parameters in different percentage of plasticizers. The sample is fabricated by mixing the sago starch (60 wt.%, 65 wt.%, 70 wt.%, 75 wt.% and 80 wt.%) with glycerol. The mixing is homogenously done by using a blender in the UTeM laboratory. Then, it is poured into the 160mm × 60mm and 140mm × 60mm size of mould and being fabricate by hot compression moulding at 165°C up to 185°C for 8 to 20 minutes at 25 kg/cm2. The thermoplastics sago starch fundamental properties is tested to evaluate their characterization. For physical testing, the sample is tested on density measurement, water absorption and moisture content. Meanwhile, for the environmental testing, the sample undergo soil burial and water solubility testing. Water absorption is done by following ASTM 570, the soil burial testing is following the Municipal Solid Waste (MSW) aerobic compost test according to ASTM D6003-96. The other testing are conducted by referring to previous studies by other researchers and according to its honorable procedures. The high moisture content result was contributed by lower thermoplastics sago starch content (60 wt.%) around 11.11% and the low moisture content result was revealed at higher thermoplastics sago starch content (75 wt.%). For density measurement, 60 wt.%. thermoplastics sago starch has the lowest value of density with only 0.08 kg/cm3 difference in reduction with the highest value. The water absorption decreases as the thermoplastics sago starch (%) increases. Only 3.36% water absorption rate at 75 wt.% sago starch content at 0.5 hours. In water solubility testing, it shows that water solubility slightly decreases from 41.43% to 40.64% with the addition 5% of sago starch from 60 wt.%. Meanwhile, all of the samples able to degrade over 50% of initial weight except for 75 wt.% sample where it degrades 48% for soil burial testing. In conclusion, this study provided preliminary information to assist further material research and assess any possible application fields of thermoplastics sago starch. Hence, this material can become an alternative for non-biodegradable bioplastic in the future and optimized the usage of natural resources.

ABSTRAK

Penggunaan bahan komposit adalah sangat biasa dalam industri. Walau bagaimanapun, bahan komposit mempunyai beberapa kelemahan untuk alam sekitar. Penyelidik telah menemui cara untuk menyelesaikan masalah ini menggunakan sumber semula jadi. Salah satu sumber alam yang telah digunakan ialah kanji sagu. Kanji sagu telah digunakan secara meluas untuk pelbagai tujuan daripada industri makanan sehinggalah kepada pembuatan. Sifat-sifat kanji sagu adalah kriteria utama untuk memilih bahan yang boleh digunakan sebagai bahan terbiodegradasi. Kajian ini melaksanakan penyelidikan sifat fizikal dan persekitaran kanji sagu untuk menentukan parameter matriks yang sesuai dalam nisbah pemplastis yang berbeza. Sampel disediakan dengan mencampurkan kanji sagu (60 wt.%, 65 wt.%, 70 wt.%, 75 wt.% dan 80 wt.%) dengan gliserol. Sampel digaul dengan menggunakan pengisar di makmal UTeM. Kemudian, ia dituangkan ke dalam acuan bersaiz 140mm×60mm dan 160mm×60mm, dan dibuat dengan mesin penekan panas pada tekanan 25kg/cm^2 *pada suhu 165°C hingga 185°C selama 8 hingga 20 minit. Sifat asas kanji sagu termoplastik telah diuji untuk menilai sifatnya. Untuk ujian fizikal, sampel tertakluk kepada pengukuran ketumpatan, penyerapan air dan ujian kandungan lembapan. Sementara itu, untuk ujian alam sekitar, sampel telah menjalani ujian pengebumian tanah dan keterlarutan air. Ujian penyerapan air adalah berdasarkan ASTM 570 dan ujian pengebumian tanah setiap Ujian Pengkomposan Aerobik Sisa Pepejal Perbandaran (MSW) ASTM D6003-96. Ujian-ujian lain telah dijalankan dengan merujuk kepada kajian-kajian penyelidik yang lepas dan mengikut prosedur mereka. Hasil kandungan lembapan yang lebih tinggi disebabkan oleh kandungan kanji sagu termoplastik yang lebih rendah (60 wt.%), iaitu kira-kira 11.11%, manakala kandungan lembapan yang lebih rendah (wt.%) menurun. Untuk ukuran ketumpatan, 60 wt.%. kanji sagu termoplastik mempunyai nilai ketumpatan yang paling rendah, dengan pengurangan hanya 0.08 kg/cm3 daripada nilai tertinggi. Penyerapan air berkurangan dengan peningkatan kanji sagu termoplastik (%). Pada 75 wt.% kandungan kanji sagu, penyerapan air pada 0.5 jam hanya 3.36%. Dalam ujian keterlarutan air, ditunjukkan bahawa selepas menambah 5% kanji sagu pada 60 wt.%, keterlarutan air menurun sedikit daripada 41.43% kepada 40.64%. Sementara itu, semua sampel menghasilkan penurunan lebih daripada 50% berat awalnya kecuali sampel 75 wt.%, yang merosot 48% dalam ujian pengebumian tanah. Kesimpulannya, kajian ini menyediakan maklumat awal untuk membantu penyelidikan bahan lanjutan dan menilai mana-mana kawasan aplikasi yang mungkin boleh ditambah baik untuk kanji sagu termoplastik. Justeru, bahan ini pada masa hadapan boleh menjadi alternatif kepada bioplastik tidak terbiodegradasi dan mengoptimumkan penggunaan sumber semula jadi.*

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

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

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LIST OF SYMBOLS AND ABBREVIATIONS

m - Mass
ρ - Density
PLA - Polylactic Acid
Tg - Glass transition temperature
Tm - Crystalline melting temperature
TPS - Thermoplastics starch
TPSS - Thermoplastic sago starch
V - Volume
W_f - Final weight
W_i - Original/Initial weight
wt.% - Percentage by weight
w/w% - Weight concentration of a solution

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CHAPTER 1

INTRODUCTION

1.1 Background

Petroleum-based polymer products have provided numerous benefits to humanity. People waste the planet's limited amount of land by disposing of non-biodegradable materials (Lee, 2018). Derivatives that do not decompose naturally may end up in landfills, taking up much more space than biodegradable materials. When people litter, some non-biodegradable trash may not even make it into landfills (Lee, 2018). Instead, it could end up in forests, parks, fields, or the sea. Styrofoam, also known as foamed polystyrene, is a non-biodegradable material that can pollute the environment when it becomes litter. Styrene, a neurotoxin, for example, can release toxic out of polystyrene materials at high doses when temperatures rise (Lee, 2018). Nowadays, researchers are looking for an alternative to using bio-degradable material to reduce the environmental problem and to save the ecosystem due to the properties of the petroleum-based material that are non-renewable and non-biodegradable. However, thorough research must be conducted to study the characterization of the material, whether it is environmentally friendly as bio-degradable material or not.

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 polysaccharides and polypropylene, biodegradable polymers lose their chemical and physical properties and fully break down. A partially biodegradable polymer has both biodegradable and non-biodegradable components. A polymer matrix reinforced with natural fibres has higher resistance, and the interfacial bonding between them helps to preserve their chemical and mechanical identities. In general, the fibres are the primary charge carriers, while the matrix keeps them in place and at the desired orientation, serves as a means of transferring charge between them, and protects them from environmental damage (Yashas Gowda et al., 2018). Biodegradable plastics are made from renewable natural resources and have emerged as a viable option for reducing pollution. Biodegradable plastics are polymers that decompose through microbial processes such as bacteria, algae, and fungi. Materials made from starch, chitosan, and lignocellulosic base are examples of naturally derived biodegradable plastics (Ab Wahab et al., 2021).

The sago palm (Metroxylon sagu) is a crop par excellence for sustainable agriculture. The word 'sago' is originally Javanese, meaning starch-containing palm pith. The scientific name is derived from 'metra', meaning core or parenchyma and 'xylon', meaning xylem (Singhal et al., 2008). The extraction and purification process isolate sago starch from the sago palm. Malaysia, the world's largest sago exporter, exports 44,000 tonnes of sago products per year to Japan, Europe, America, and Singapore. Commercial sago palm production occurs in Sarawak, where the crop is primarily grown on peat soils. Metroxylon sagu is the most widely cultivated sago species because it produces higher quality products (Tuan Mohamood et al., 2018). Starch is perceived as one of the most promising obtainable natural polymers for the development of biodegradable materials due to its appealing combination of characteristics such as low cost, abundant availability, thermoplastic behaviour, and biodegradability (Ismail et al., 2013). Starch is one of the renewable resources that can be converted into biodegradable thermoplastic or bioplastic (Z. Ahmad et al., 2011). In recent years, sago starch has been increasing in diverse food and non-food applications (Ahmad et al., 2011). There is a growing interest in developing fiction and underutilized starchy crops for various applications. Among these innovative and underutilized starches, sago starch has gained popularity, attributed to the crop's sustainability (A. N. Ahmad et al., 2020).

Sondari et al., (2019) mentioned that glycerol as a plasticizer gives the pliability and flexibility to improved handling of starch-based films and coatings and is the most widely used plasticizer to enhance biofilms' mechanical properties and transparency (Sondari et al., 2019). The hydroxyl groups present in glycerol handle inter and intramolecular interactions (hydrogen bonds) in polymeric chains, providing films with a more flexible structure providing films with a more flexible structure (Sondari et al., 2019). Adding a plasticizer such as glycerol combined with heating and high shear can further improve the ductility of gelatinized starch, and the obtained plasticized starch is known as thermoplastic starch (TPS). Unfortunately, thermoplastic starch is a very hydrophilic material with limited performance (Huneault & Favis, 2009).

Thus, this study focuses on the various percentage of sago starch (wt.%) added with glycerol. Thus, the physical and environmental effect of thermoplastic sago starch (TPSS) is characterized and recorded throughout this study that may provide preliminary information to assist further material research and assess any possible application fields of thermoplastics sago starch. Hence, this material can become an alternative for non-biodegradable bioplastic in the future and optimize the usage of natural resources.

1.2 Problem Statement

Sago starch had some disadvantages such as inconsistent viscosity, varied pasta texture, mouldy odour, and slightly reddish colour.It also had some limitations in usage because of its resistance to shear and low temperatures, high retrogradation and syneresis, low heat resistance and solubility also its instability in an acidic environment. There are some modifications of sago starch need to be done to improve its physical and mechanical properties to tackle those limitations and disadvantages. (Sondari et al., 2019). It is also mentioned by Sondari et al., (2019) that sago starch is a naturally highly hydrophilic material. Thus, it is challenging to improve the water sensitivity of a starch-based system while maintaining the composite's biodegradability. The properties of sago starch are the crucial criteria for material selection as biodegradable material. Most thermoplastic starch (TPS) is produced using an extruding machine and the hot-press method using water as the plasticizer. However, the mixture results in the samples becoming brittle and having a lower strength.

In this thesis, the physical and environmental characterization of the sago starch matrix is being studied to determine the suitable parameters in different percentages of sago starch and plasticizer. By conducting this experimental approach, this study could distinguish the properties of the sago starch matrix from characterization from the environmental and physical aspects.

1.3 Research Objective

The main aim of this research is to study the physical and environmental characterization on sago starch. Specifically, the objectives are as follows:

a) To fabricate the sago starch sample by adding various glycerol loading.

b) To investigate the physical behavior of sago starch influenced by different glycerol loads.

c) To analyze the environmental behavior of sago starch influenced by different glycerol loads.

1.4 Scope of Research

In order to achieve the objectives, several scopes have been determined:

- Prepare the sample by using close mould and hot press machine.
- Apply 20 to 40 wt.% of glycerol into sago starch.
- Use the density, moisture content, and water absorption to test find physical behaviour.
- Conduct the water solubility and soil burial test for environment testing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This new paradigm change presents itself well to composite materials, particularly “green composites.” Simply described, bio-based materials are durable materials made from renewable agricultural and forestry feedstocks such as wood, agricultural waste, grasses, and natural plant fibers composed of carbohydrates like sugars and starch, lignin, vegetable oils, proteins, and cellulose (Mohanty et al., 2005).

2.2 Biodegradable Plastic

Nowadays, plastics have become an essential material for manufacturing products. They are famously known as one of the petroleum-based advanced materials. It gives a long list of utilization for humankind. It has adverse side effects, especially for the environment, due to the materials’ properties that cannot break down by themselves or are non-biodegradable. The event has caused substantial environmental issues such as oxygen depletion, soil fertility issues, marine-life effects, and landfills issues. Therefore, researchers recently came out with many ways to reduce this environmental problem by producing bio-degradable composites consisting of plastics and natural resources. By 2050, the estimated cumulative growth of primary plastic trash created will exceed 25 billion metric tons due to a seismic shift in economic objectives prompted by mounting and irrefutable data from industry (Meereboer et al., 2020).

From 2020 to 2030, the production of bio-based/non-biodegradable and biodegradable plastics estimated to expand at a rate of 13% per year. It is linked with the trend toward sustainability of using non-petroleum-based plastics. By 2025, leading plastic packaging manufacturers hope to use 100 percent recycled, biodegradable, or reusable plastics in their goods (Meereboer et al., 2020). In addition, biodegradable is characterized as “capable of being broken down especially into harmless products by the action of living creatures (such as microorganisms)” (Webster, 2021). Biodegradable materials knowns as degradable materials, where the degradable also refer to substances that can break down on themselves without the bacterium. This material is needed to reduce the environmental issues that have been widely affecting the earth.

Thermoplastic starch (TPS), PLA, and polybutylene adipate terephthalate (PBAT) are the most common biodegradable polymers, accounting for 83% of all biodegradable plastic made in 2018. Polybutylene succinate (PBS) is also biodegradable plastic increasing in production as it has a cheaper production cost than others. Cradle- to- cradle implementation method has figured the output in an exact time frame to offer a better sustainable, biodegradable materials option. Figure 2.1 shows the cradle-to-cradle and cradle-to-approaches of the biodegradable and non-biodegradable plastics cycle (Meereboer et al., 2020).

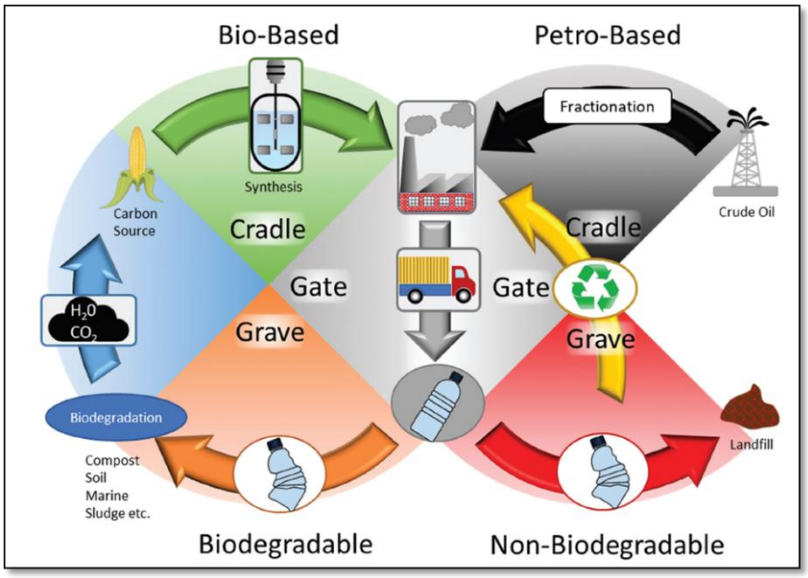


Figure 2.1 Cradle-to-cradle and cradle-to-grave approach of biodegradable and non-biodegradable plastics (Meereboer et al., 2020)

Plastic is generally a different polymer with molecular weights and can be degraded by various processes. The terms' bio-plastic has got many misconceptions. The research by (Tokiwa et al., 2009) stated that bio-plastics comprise bio-degradable plastics and bio-based plastics. The inter-relation between bio-degradable plastics and bio-based plastics is shown in Figure 2.2.

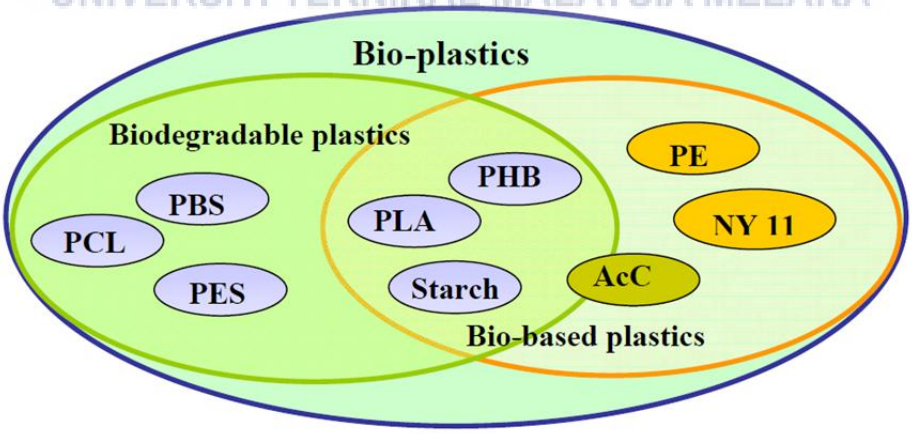


Figure 2.2 Inter-relation between bio-degradable plastics and bio-based plastics (Tokiwa et al., 2009)

For instance, Polycaprolactone (PCL) and poly (butylene succinate) (PBS) are petroleum-based, but microorganisms can degrade them. On the other hand, poly(hydroxybutyrate) (PHB), poly(lactide) (PLA), and starch blends are produced from biomass or renewable resources and are thus biodegradable. Although manufacturers can make polyethylene (PE) and Nylon 11 (NY11) from biomass or renewable resources, they are non-biodegradable (Tokiwa et al., 2009).

The biodegradability of plastics depends on the material characteristics and properties themselves. Plastic properties have features that may affect their biodegradation mechanism. Their surface properties, including the surface area, hydrophilic, and hydrophobic properties, their chemical structure, molecular weight, and molecular weight distribution, and high-order structures including the glass transition temperature, melting temperature, modulus of elasticity, crystallinity, and crystal structure may affect the biodegradation mechanism and process. Biodegradable plastics are an excellent solution for the environmental issues that the non-biodegradable plastics landfills and waste have significantly caused. The environmental-friendly properties of biodegradable plastics are seen as alternatives to reduce the impact. In addition, starch has been studied and recognized as the top resource for innovative biopolymer development due to the material structure of starch advantages where they are renewable, biodegradable, low cost, and quickly found or available in many places (Tokiwa et al., 2009).

2.3 Matrix

Composites are materials created by combining two or more materials with different physical and chemical properties to make a new material, either physically or chemically. Matrix is the continuous structure component in a composite, and meanwhile, the fillers in the matrix are the discontinuous or the discrete structure component. The single substance of composite comes from both the matrix and the stuffing. The crucial part is the filler in the composites, whereas the matrix, which is the reinforcing element, binds the fillers together. Composites come in a variety of shapes and sizes. There are three examples of standard composites (Sharma et al., 2020). Ceramic matrix composites (CMC), polymer matrix composites (PMC), and metal matrix composites (MMC) as in Figure 2.3.

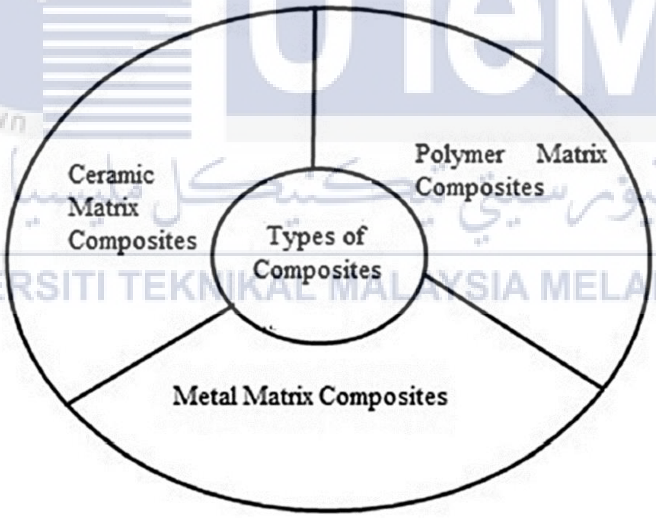


Figure 2.3 Types of Composites (Sharma et al., 2020)

Composite materials are categorized as particle composites, fiber-reinforced composites, or structural composites, depending on the type of reinforcement used (Ibrahim et al., 2015). Figure 2.4 below shows the classification of the composite materials.

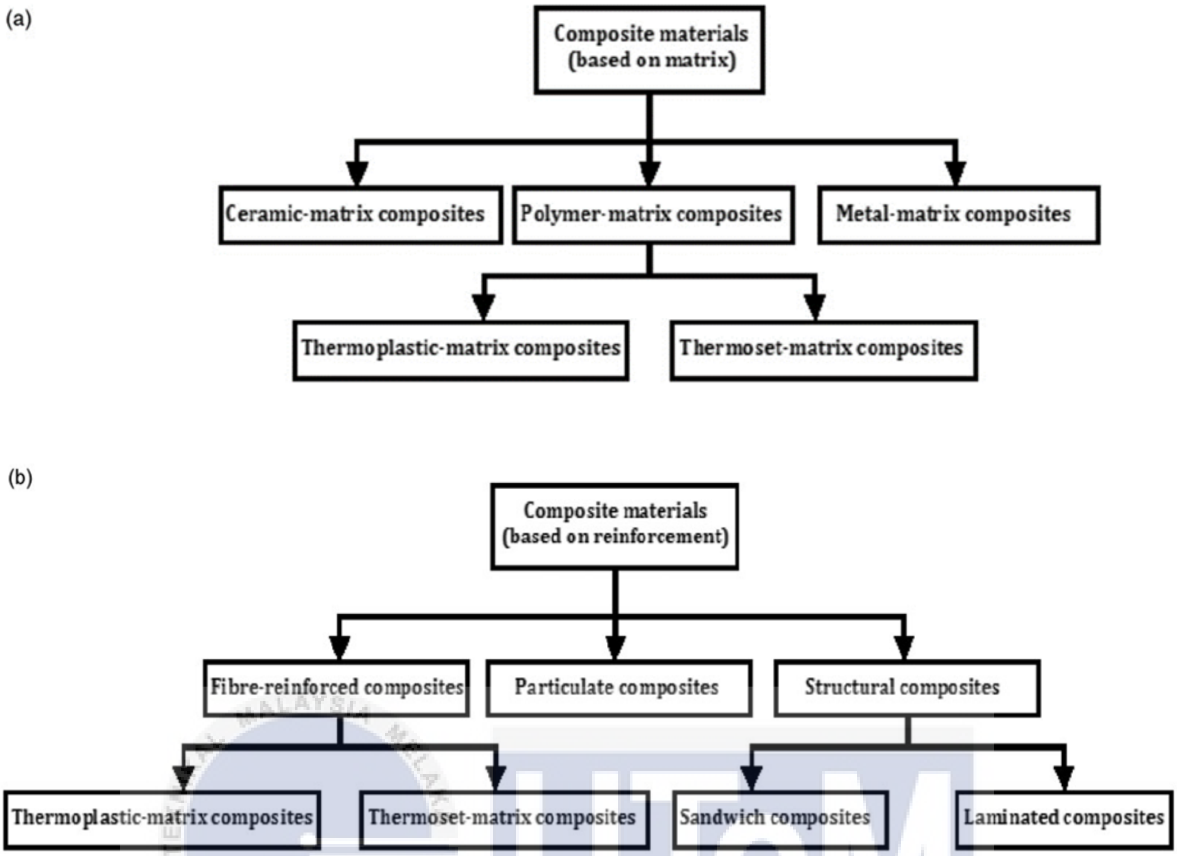


Figure 2.4 Classification of composite materials. (a) Based on matrix materials and (b) based on reinforcement materials (Ibrahim et al., 2015)

2.3.1 Polymer Matrix Composites

Polymer matrix composites (PMC) are widely applied in various technical applications. Due to their relatively higher mechanical qualities, low cost, environmental friendliness, and biodegradability, natural materials have emerged as substitutes for synthetic fibers as reinforcing materials composites (Mahesh et al., 2021). There are two main kinds of polymers: thermoplastic and thermoset, as shown in Figure 2.5, with their different structural linkage (Kashyap, 2019). The matrix, reinforcement, process parameters, microstructure, composition, and interphase all influence the features of PMCs. PMCs are well-known for their low cost and simple manufacturing process. Because ceramic fibers have a higher strength than the matrix material, they are widely utilized to reinforce the matrix in PMCs (Sharma et al., 2020). There has been a sharp increase in consumer awareness of new renewable-energy products in recent years. Green marketing, new recycling directives, societal influence, and a shift in cognitive values have influenced consumers to seek out environmentally friendly items (Peças et al., 2018).

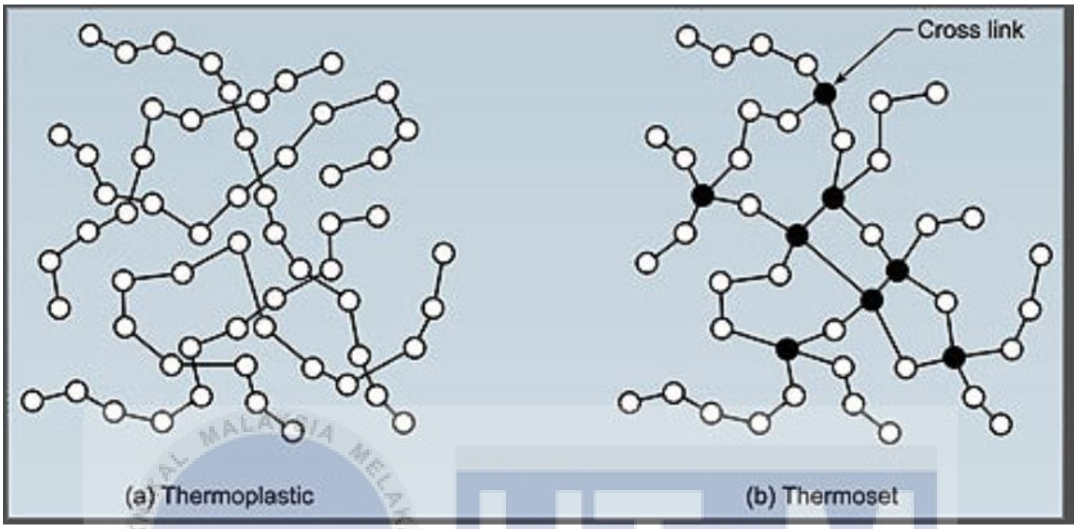
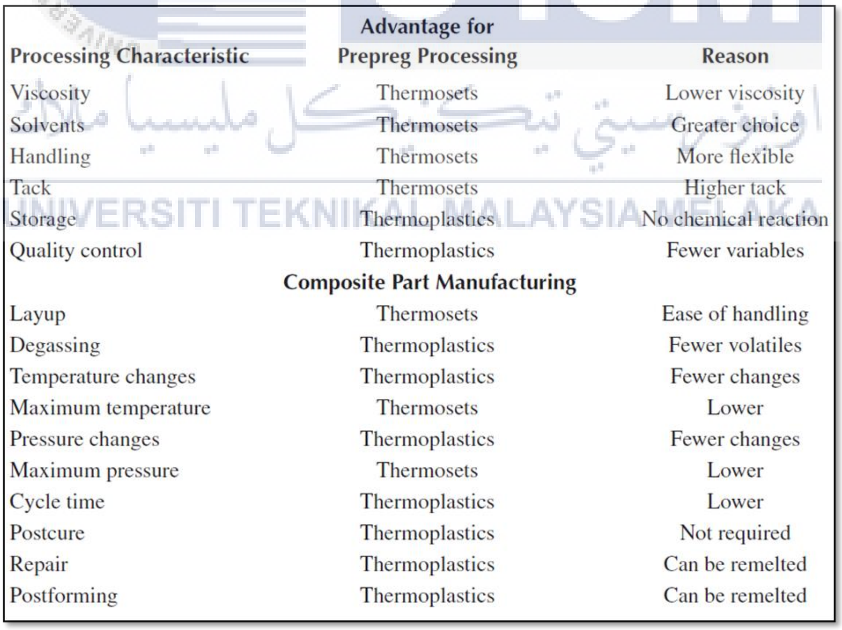


Figure 2.5 Polymers linkage (a) Thermoplastic (b) Thermoset (Kashyap, 2019)

The matrix in a PMC keeps the fibers in place, transfers load between them, and protects them from moisture, chemicals, and other environmental factors. The matrix qualities greatly influence the composite's compressive and shear properties, and any changes in the matrix properties owing to increased temperature or moisture absorption are reflected in these matrix-controlled composite properties (Mallick, 2018). Plus, each manufacturing process contains factors that enable the type of product produced. The manufacturer can provide the most acceptable alternative for the consumer from this information. Polymer matrix composites comprise a matrix comprising thermoplastic or thermosetting plastic and one or more reinforcements such as carbon, glass, steel, or natural fibers (Sharma et al., 2020).

Thermoplastic is one of the polymer composite family matrices. It has the simplest molecular structure and independent macromolecules chemically. Thus, heating can also change structure when softened or melted; after that, they can be shaped, formed, welded, and solidified when curing and cooled. They can be processed by heating or cooling multiple times and damage the materials. Thus, these properties allow reprocessing and recycling. The blends of the starch in TPS provide a non-miscible reinforcement to the matrices and increase their mechanical strength (Biron, 2007). As matrix material in PMCs, thermoplastic polymers are used in much larger volumes than thermosetting polymers. A key difference is that, unlike thermoset matrix prepregs, thermoplastic matrix prepregs can be stored indefinitely without the need for any special storage facilities, such as refrigerators. Another difference is that the thermoplastic matrix prepreg is not very sticky, so it can be crimped or stacked without any gasket or backing material between them (Mallick, 2018). However, the lack of tack has a disadvantage: the prepreg layers cannot adhere to each other well when stacked, as shown in Figure 2.6.



Processing Characteristic	Advantage for Prepreg Processing	Reason
Viscosity	Thermosets	Lower viscosity
Solvents	Thermosets	Greater choice
Handling	Thermosets	More flexible
Tack	Thermosets	Higher tack
Storage	Thermoplastics	No chemical reaction
Quality control	Thermoplastics	Fewer variables
	Composite Part Manufacturing	
Layup	Thermosets	Ease of handling
Degassing	Thermoplastics	Fewer volatiles
Temperature changes	Thermoplastics	Fewer changes
Maximum temperature	Thermosets	Lower
Pressure changes	Thermoplastics	Fewer changes
Maximum pressure	Thermosets	Lower
Cycle time	Thermoplastics	Lower
Postcure	Thermoplastics	Not required
Repair	Thermoplastics	Can be remelted
Postforming	Thermoplastics	Can be remelted

Figure 2.6 The differences in the processing of thermoset and thermoplastic matrix composite prepregs (Mallick, 2018)

There are plenty of results reported on the addition of natural resources into the TPS matrix widely known, including the sugar palm, jute, the kapok, kenaf, cotton, and coir. According to Zhang et al., (2013), water resistance is enhanced by incorporating natural fiber into TPS material. These studies focused on improving the TPS mechanical and thermal properties (Zhang et al., 2013).

The blends of a biodegradable polymer such as polycaprolactone and granular starch have disclosed a high degree of biodegradation (Tokiwa et al., (2009). Natural fibers provide several advantages over standard commonly used plastics, including cheaper cost, sustainability, fewer emissions, less abrasive damage, low density, and higher specific strength and stiffness (Pickering et al., 2016).

2.3.2 Ceramic Matrix Composites

Ceramic Matrix Composites (CMM) are a mixture of these components. They are the ceramic particulates, fibers, and whiskers in a matrix of another ceramic also can be defined as solid materials with robust bonding that is usually ionic but can be covalent in a few cases. Ceramics, metals, glasses, and polymers can be used to reinforce the ceramic matrix. Ceramic-based matrix materials provide excellent corrosion resistance, high melting points, improved compressive strength, and temperature stability. It is evident that the reinforcement, combined with particulates and continuous fibers, has increased toughness. Still, the increase is even more significant for the second CMCs, either oxide-based or non-oxide-based, as demonstrated in Figure 2.7 by comparing modulus of elasticity of a few ceramics (Sharma et al., 2020).

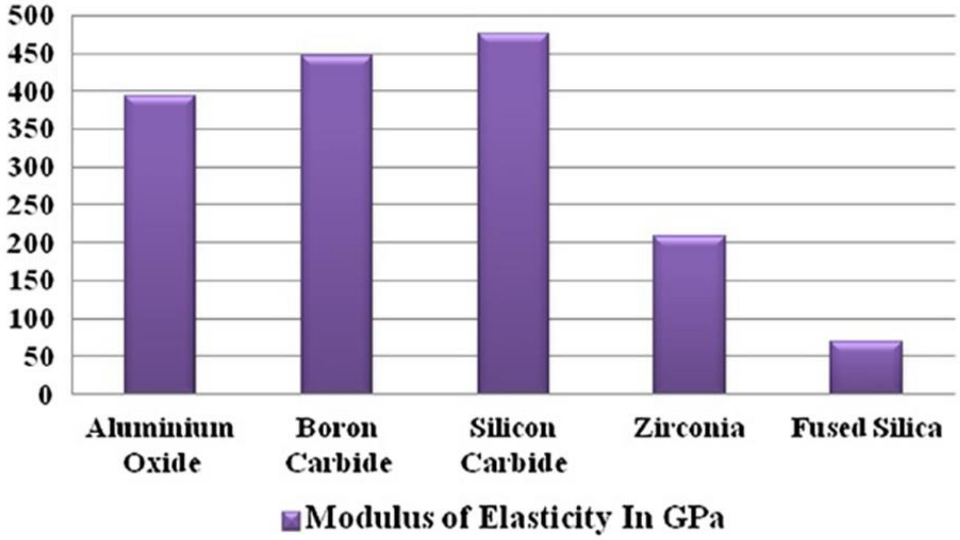


Figure 2.7 Modulus of elasticity of ceramics materials (Sharma et al., 2020)

It has been recorded that adding reinforcements materials to increase the ceramics strength is ineffective since they mostly have low tensile strain and high modulus elasticity. The typical matrix elongation where the rupture of ceramics at the stress level is affected by composite reinforcement to transfer the load's adequate quantum (Kashyap, 2019).

2.3.3 Metal Matrix Composites

Metal Matrix Composites (MMC) are pretty known as a material that is well off advanced. MMCs outperform standardly conventional used materials in properties such as mechanical and thermal qualities, including excellent wear resistance and thermal conductivity. Figure 2.8, Figure 2.9 and Figure 2.10 depict some metals' mechanical properties that are commonly used as a matrix (Sharma et al., 2020). Metal matrices provide superior strength, fracture toughness, and stiffness when compared to polymer counterparts. Obviously, a metal matrix is more resistant to high temperatures and can survive better in corrosive ambience than typical polymer composites.

The majority of metals and alloys are familiar as matrices. Thus, as a result, reinforcement structures materials that are both temperature stable and non-reactive are required (Kashyap, 2019).

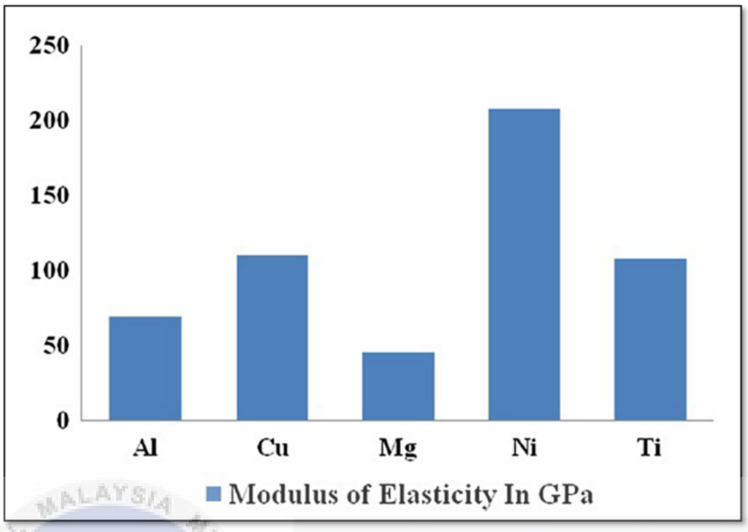


Figure 2.8 Modulus of elasticity for different metals normally used as matrix material (Sharma et al., 2020)

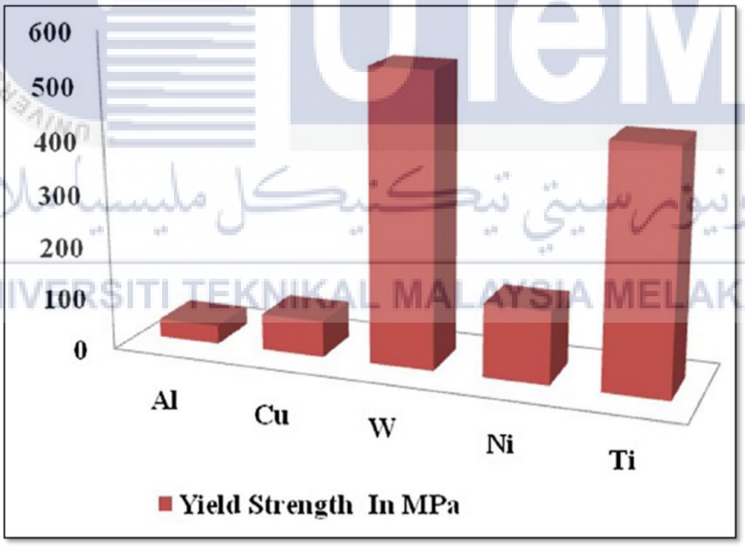


Figure 2.9 Yield Strength of metals generally used as matrix material (Sharma et al., 2020)

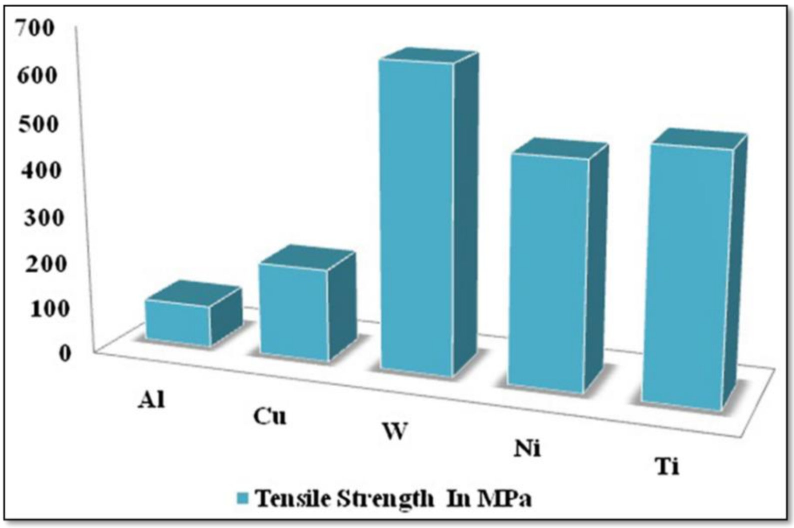


Figure 2.10 Comparison of Tensile Strength of metals commonly used as matrix materials (Sharma et al., 2020)

Metal Matrix Composites have inspired a wave of interest in these recent years for their potential industrial uses. MMCs have a broader spectrum of benefits in a variety of manufacturing industries. Recent research in the interest of MMCs has explored the importance of producing composites with exceptional mechanical properties. Apparently, the most common matrix metals are Aluminium, Copper, Iron, Magnesium, Nickel and Titanium (Sharma et al., 2020).

2.4 Starch

Starches often are derived from common cereal seeds. For instance, corn, wheat, rice, tubers such as potatoes, and roots for industrial usage such as tapioca. Although starches from various sources usually are the same chemically, their granules differ in size, molecule structures and shape. The contents of the polysaccharides amylose and amylopectin proportion are perhaps the essential factor (Chiou et al., 2005). Starch has the chemical formula $(C6H10O5)n$ and is a homopolymer of the Glucopyranose units. Amylose and amylopectin are two forms of polymer chains found in starch. Amylose obviously possesses a linear structure with α1–4 glycosidic linkage, and meanwhile, amylopectin includes the branched system with α1–4 as well as α1–6 glycosidic connections (Nawaz et al., 2020). According to Ilyas et al., (2018), along with its complete biodegradability, availability, renewability, and cheaper cost of manufacturing, starch is recognized one of the most promising biopolymers. Some starch polymers form helical structures due to the existence of a linkages, which contribute to its extraordinary properties and enzyme digestibility. Figure 2.11 shows the chemical structures of amylose and amylopectin. G is an anhydroglucose unit (Srikaeo et al.,2016).

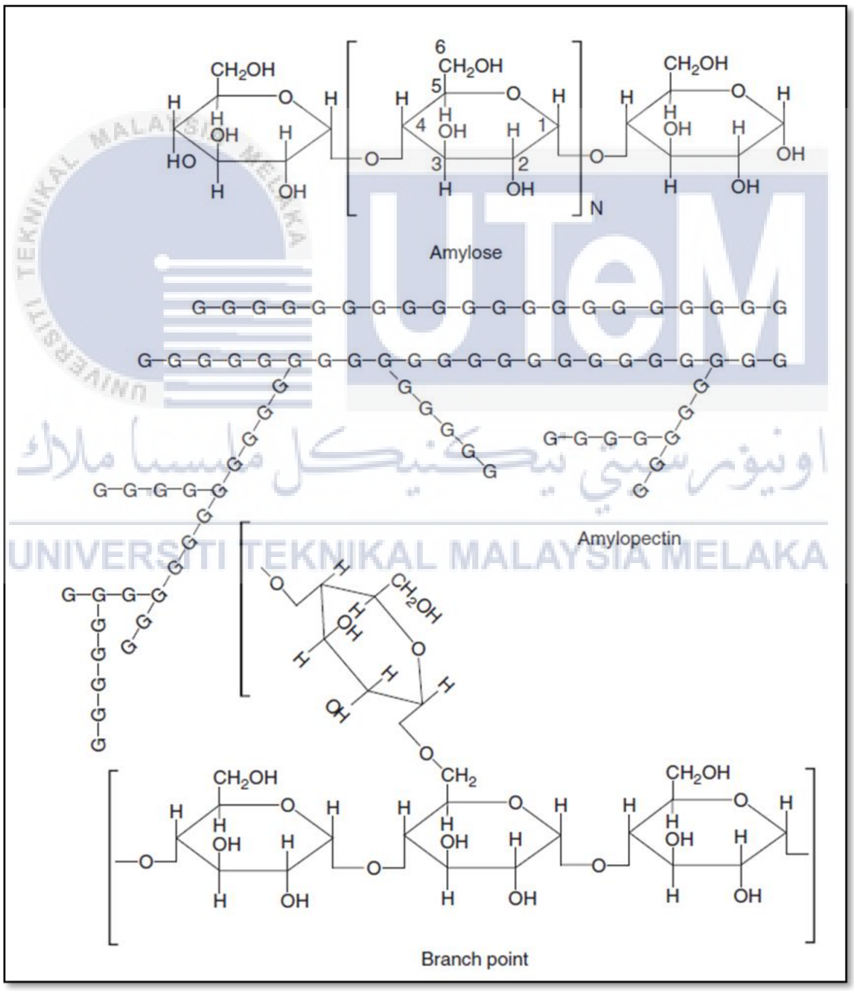
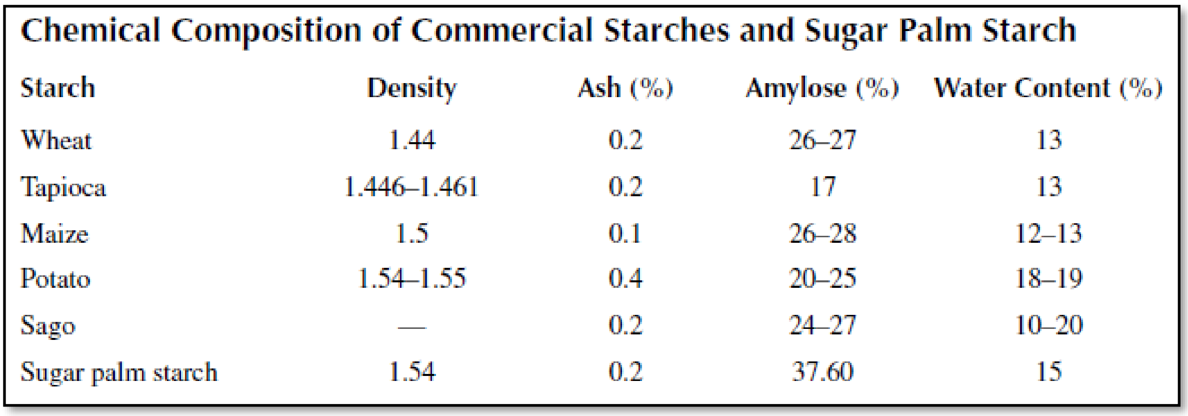


Figure 2.11 Chemical structures of amylose and amylopectin with G, an anhydroglucose unit (Chiou et al., 2005).

In addition, thermoplastic starch (TPS) is created as the starch molecular structure disrupted, where heating of starch granules caused swelling and a non-irreversible transition of amorphous regions in the presence of a plasticizer under a specific condition (Tokiwa et al., 2009). TPS was discovered to have similar synthetic thermoplastic properties, which enables the material to undergo various fabrication manufacturing processes. The machines that can be used for TPS-based products are extrusion, compression moulding, injection moulding, etc. However, according to Jumaidin et al., (2016), pure TPS also possesses several disadvantages, such as poor mechanical strength and water resistance, which limits its potential application. Therefore, modification of TPS is often necessary in order to prepare this material for the actual application. The blending of TPS with other natural polymer appears to be a good approaching order to preserve the biodegradable aspect of this biopolymer. A recent study of the tensile and tear properties of the produced starch films carried out by using a universal testing machine has been reported (Jumaidin et al., 2016).

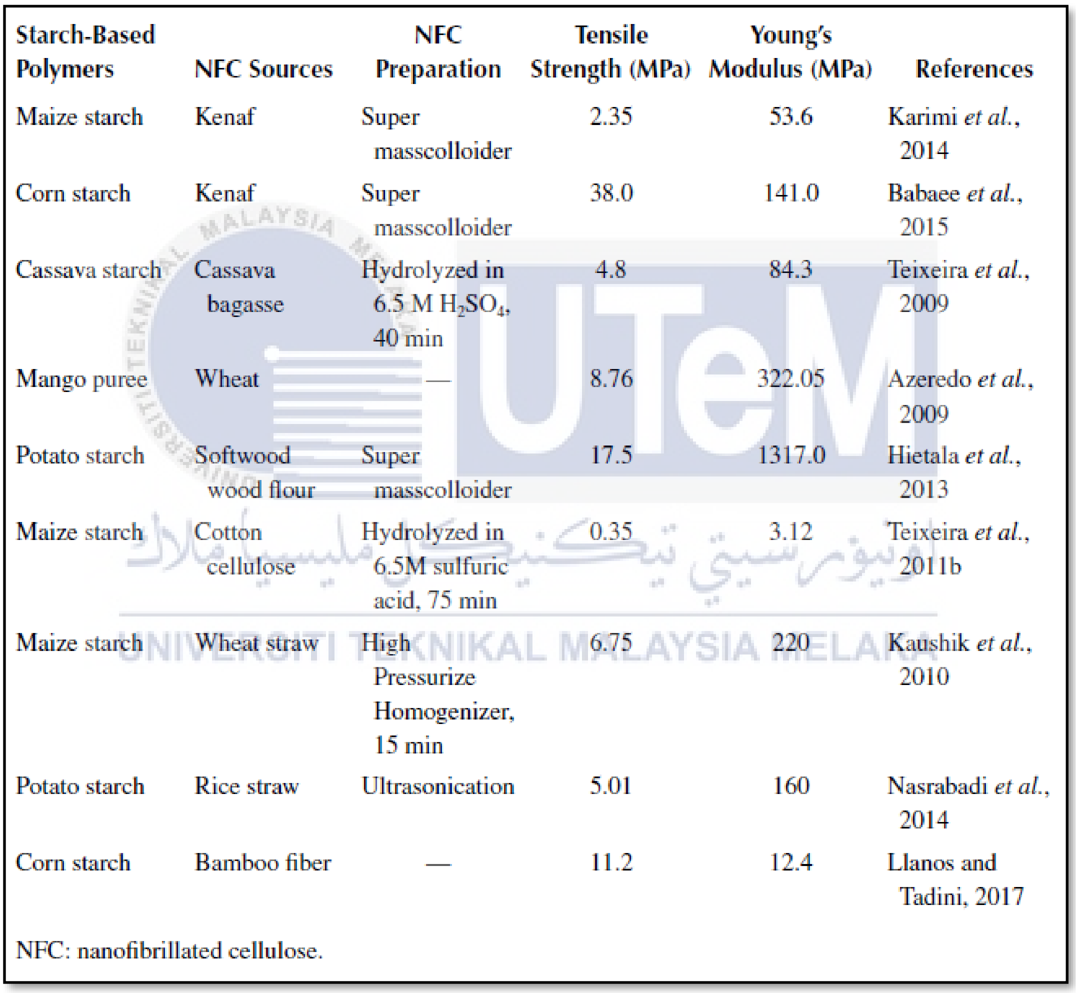
Though they are stable in oils and fats, they can be unstable in hot or cold water, depending on the type. Traditional plastics processing processes can be used to process them. The starch particles operate as weak connections in the plastic matrix and as sites for a biological attack at lower starch levels (less than 60%). Plus, the polymer matrix can dissolve into minute fragments as a result, but the polymer structure as a whole does not biodegrade. Specific TPS grades are totally water-soluble, in addition to biodegradation of the polymers by sugar molecules (Wojtowicz, 2010). Figure 2.12 shows the chemical composition of starch (Sanyang et al., 2016). Meanwhile, Figure 2.13 shows starch-based polymers and their mechanical properties (Ilyas et al., 2018).



Chemical Composition of Commercial Starches and Sugar Palm Starch

Starch	Density	Ash (%)	Amylose (%)	Water Content (%)
Wheat	1.44	0.2	26–27	13
Tapioca	1.446–1.461	0.2	17	13
Maize	1.5	0.1	26–28	12–13
Potato	1.54–1.55	0.4	20–25	18–19
Sago	—	0.2	24–27	10–20
Sugar palm starch	1.54	0.2	37.60	15

Figure 2.12 Chemical composition of starch (Sanyang et al., 2016)



Starch-Based Polymers	NFC Sources	NFC Preparation	Tensile Strength (MPa)	Young's Modulus (MPa)	References
Maize starch	Kenaf	Super masscolloider	2.35	53.6	Karimi *et al.*, 2014
Corn starch	Kenaf	Super masscolloider	38.0	141.0	Babaee *et al.*, 2015
Cassava starch	Cassava bagasse	Hydrolyzed in 6.5 M H_2SO_4, 40 min	4.8	84.3	Teixeira *et al.*, 2009
Mango puree	Wheat	—	8.76	322.05	Azeredo *et al.*, 2009
Potato starch	Softwood wood flour	Super masscolloider	17.5	1317.0	Hietala *et al.*, 2013
Maize starch	Cotton cellulose	Hydrolyzed in 6.5M sulfuric acid, 75 min	0.35	3.12	Teixeira *et al.*, 2011b
Maize starch	Wheat straw	High Pressurize Homogenizer, 15 min	6.75	220	Kaushik *et al.*, 2010
Potato starch	Rice straw	Ultrasonication	5.01	160	Nasrabadi *et al.*, 2014
Corn starch	Bamboo fiber	—	11.2	12.4	Llanos and Tadini, 2017

NFC: nanofibrillated cellulose.

Figure 2.13 Starch-based polymers and their mechanical properties (Ilyas et al., 2018)

2.4.1 Sago Palm Tree

Sago trees can be found up to 700 metres above sea level between longitudes 90° to 180° E and latitudes 10° N to 10° S. The tree is one of the few tropical plants that can grow in moist environments like peat swamps. Sago is one of the most outstanding yielding crops globally in terms of energy value per hectare. In addition, sago has a potential yield of 37 tons per hectare, making it highly competitive in terms of productivity compared to other starch crops. Consequently, with a planting density of 102 palms per hectare, sago produces roughly 17 tonnes of starch each year. In Malaysia, 45.3 thousand tonnes of sago starch are exported each year, generating a total income of 40.4 million Malaysian Ringgit (RM). Sarawak comprises 1.5 million hectares of sago palm plantations, amounting to 13% of the state's total land area (Halimatul et al., 2019).

Figure 2.14 shows the image of the sago palm tree (Lim et al., 2019). The trunk of the sago palm contains an immense amount of starch, and its productivity was nearly four times that of paddy rice (Karim et al., 2008). True sago palms store starch in their trunks until they flower. The sago palm has a high starch production. It takes an average of 8–12 years for the palm to grow into stage of maturity to the point where it can be harvested for its starch. The bark of mature palms is gray, rough, and fissured in long plates or corky ridges. The stem is frequently surrounded by deteriorating, partially attached leaf-sheaths. The lower internodes frequently have suckers and/or sharp to blunted adventitious roots. On younger trees the bark is smoother and paler gray to brownish in color. The inner bark is light colored and bitter (Elevitch, 2007).

Figure 2.14 The sago palm tree (Lim et al., 2019)

Figure 2.15 shows the growth stages of the sago palm are classified as follows in Sarawak. After eight to twelve years, the palm reaches full maturity and begins to flower, followed by the fruiting process. The event of the mature fruit dropping off foreshadows the palm demise (Lim et al., 2019).

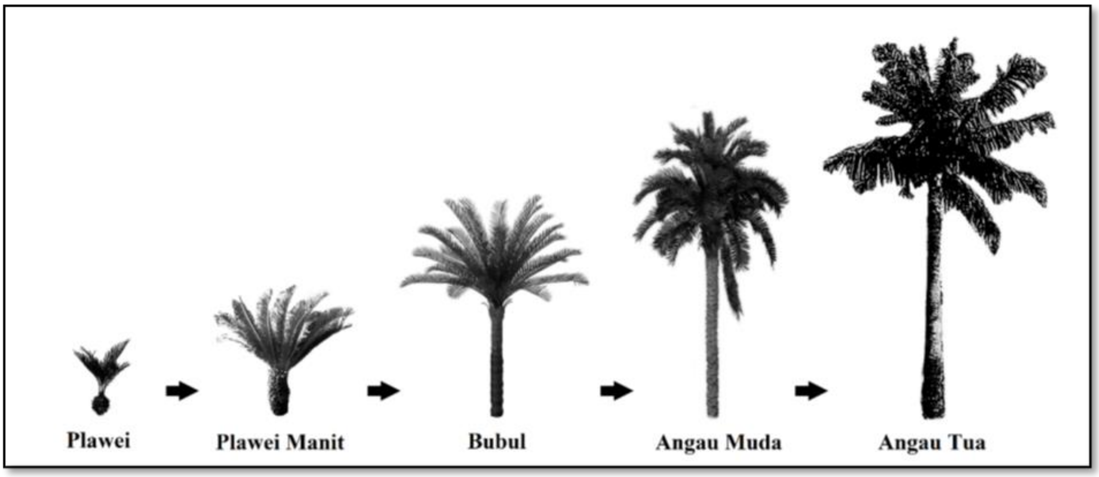


Figure 2.15 The five developmental stages of sago palm, namely: Plawei, Plawei Manit, Bubul, Angau Muda (Lim et al., 2019)

2.4.2 Sago Starch

Sago starch, derived from sago trunks, can be used as a bioplastic's raw material. There is a lot of interest in this field because starch is abundant, has no colour, taste, or smell, and does not affect humans or the environment (Halimatul et al., 2019). Moreover, for its low cost, availability as a renewable resource, biodegradability, and harmless degradation products, sago starch is the essential raw material. Temperature and shearing action would be used to convert sago starch into thermoplastic starch. Because of the low decomposition temperature of granular starch, the plasticizer is required during processing as Zuraida et al., (2011) work on the study to look into the possibility of sago starch as a natural source for biodegradable thermoplastics. The Scanning Electron Microscope (SEM) shows the native starch of thermoplastics sago starch as in Figure 2.16.

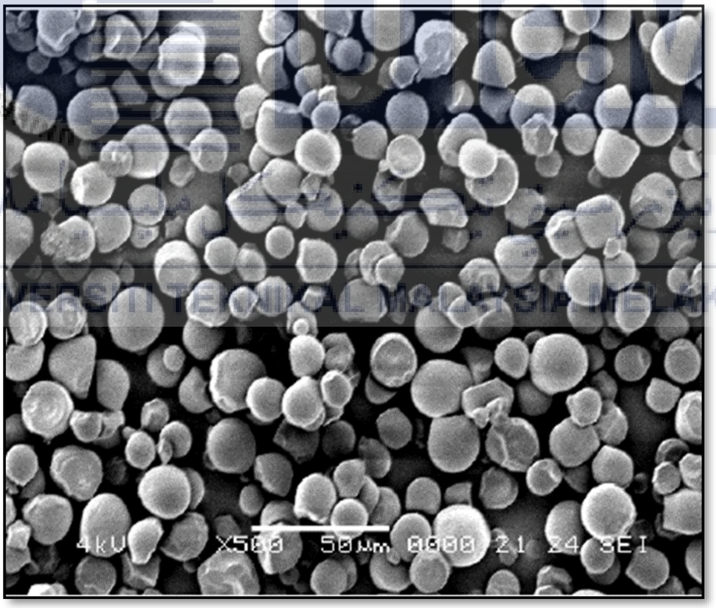


Figure 2.16 SEM of native sago starch (Zuraida et al., 2012)

2.4.3 Advantages and Disadvantages of Sago Starch

Sago starch, extracted from sago trunks, can be used as a bio-plastics raw material. Furthermore, bioplastics made from starch have a limited shelf life and decompose quickly, making them a renewable resource that meets the requirements for environmentally beneficial products. There is a sign of interest in this field as starch is abundant, has no colour, taste, or smell, and does not affect humans or the environment (Halimatul et al., 2019). In addition, according to Halimatul et al., (2019), bioplastics manufactured from starch have a short lifespan and decompose quickly. Still, they are a renewable resource that meets the criteria for environmentally acceptable products.

According to Tuan Mohamood et al., (2018), the physicochemical properties of sago starch allows the forms to be altered through various chemical or physical treatment. In comparison to other starch sources, sago starch has a low production cost and a high yield. Among the starchy crops, the sago palm has one of the highest starch yields. Furthermore, sago produces substantially more starch than other vital crops such as maize, rice, and cassava (Ahmad et al., 2020).

Because of the solid and cohesive interactions between the polymer molecules, sago starch, like other forms of starch, has several disadvantages, such as natural brittleness. Plasticizers must make starch appropriate for engineering applications due to its characteristics such as inadequate melting, high water solubility, processing difficulty, and brittleness. In addition, limited research efforts have been focused on sago starch as a potential bioplastics' raw material (Halimatul et al., 2019).

2.4.4 Previous Study of Sago Starch

A review by Singh et al., (2007) stated that sago starch must be modified to increase its industrial qualities. These alterations have been shown to increase swelling, solubility, and light transmission. On the other hand, it is reported that with a ratio of sago starch and water of 1: 5, variations in the tensile strength of plastic films with the addition of plasticizers of 7%, 8%, and 9% as shown in Figure 2.17 below. Consequently, it is recorded that the addition of sorbitol at a concentration of 7% resulted in the maximum tensile strength value of 0.363 kgf /cm2. However, because the mixture of starch and water in the comparison is still quite viscous, the addition of 7% glycerol and 9% sorbitol cannot be tested for tensile strength (Amni et al., 2019).

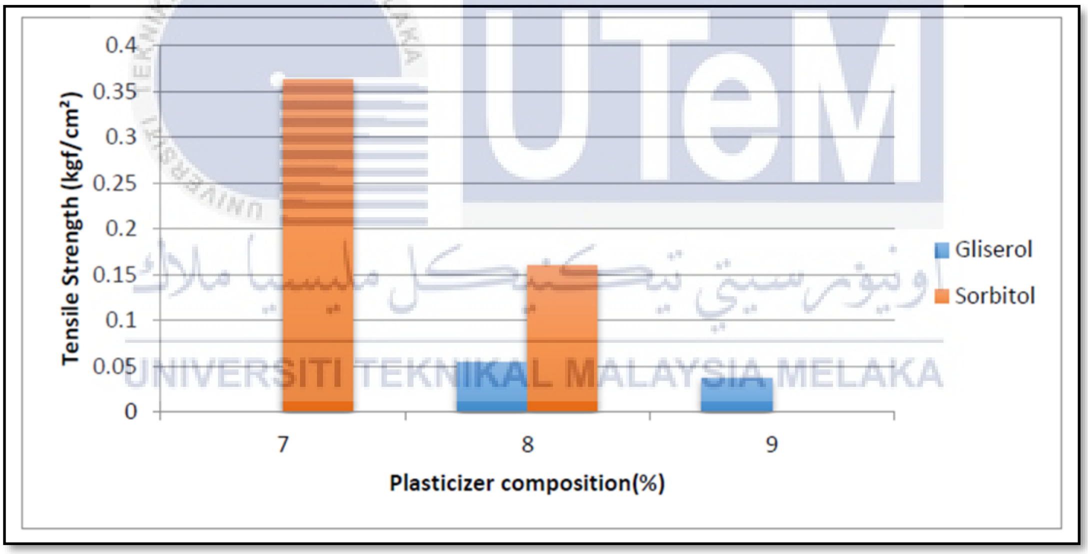


Figure 2.17 Effect of Plasticizer Composition on Tensile Strength by Comparison of Weight of Sago Starch and Water 1: 5 (Amni et al., 2019)

In a recent study by Tuan Mohamood et al., (2018), the physicochemical properties of sago starch have been altered where a carboxymethyl group was introduced into a starch molecule using carboxymethylation. The CMSS–acid hydrogel swelled in both alkaline and salt solutions but shrank and de-swelled in acidic or low pH solutions, according to the findings. The creation of hydrogel as a smart material has a wide range of opportunities. On the other hand, Figure 2.18 shows that Zuraida et al., (2011) have done a study where starch was added with 15-30 wt.% of glycerol to prepare workable bioplastics. The result shows that the bioplastic's tensile strength increases when the amount of glycerol is increased until it reaches the optimal level of 30 wt.%

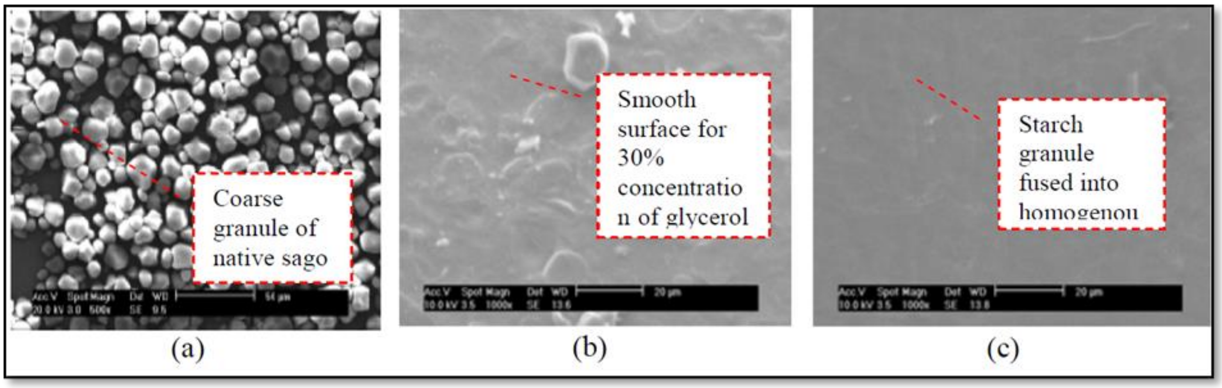


Figure 2.18 (a) SEM micrograph of sago starch (b) SEM micrograph of 20w/w% Glycerol (c) SEM micrograph of 30w/w% Glycerol (Zuraida et al., 2011)

Figure 2.19 shows that with the addition of citric acid, a similar pattern emerges. The drop in strength after the optimum point is visible in the specimens with citric acid added, which are around 50% less than the specimens without citric acid. The residual weight of composition 20% increased with a citric acid content, according to TGA analysis. This showed that the presence of citric acid affects the binding of plasticizers to starch in a significant way. To put it simply, the link between citric acid and starch is stronger than the bond between glycerol and starch (Zuraida et al., 2011).

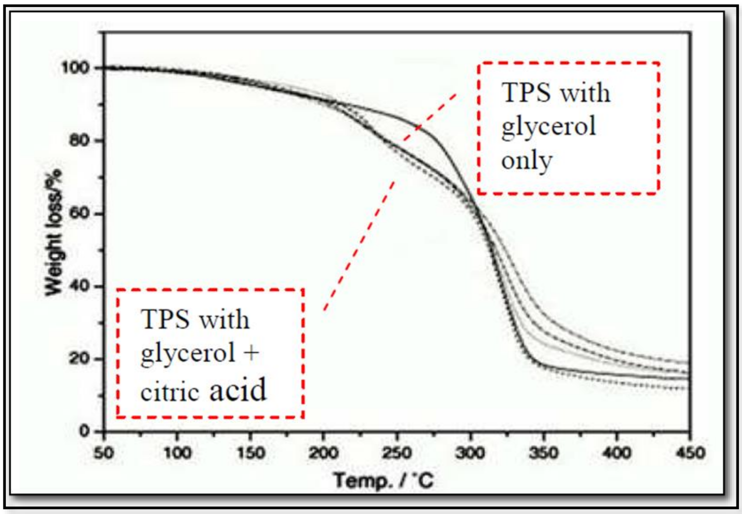


Figure 2.19 TGA for TPSS with glycerol and TPSS with glycerol and citric acid (Zuraida et al., 2011)

2.5 Plasticizer

2.5.1 Introduction

Plasticizers are needed to make starch appropriate for engineering applications due to its characteristics such as inadequate melting, high water solubility, processing difficulty, and brittleness (Ilyas et al., 2019). It is also mentioned that since the glass transition temperature (Tg) and melting temperature (Tm) of pure, dry starch are both higher than the breakdown temperature, the gelatinization process requires the addition of a plasticizer. Heating starch granules in an aqueous solution cause them to gelatinize. Moreover, as amylose leaches from the granules and amylopectin becomes fully hydrated, gelatinization occurs, resulting in starch solubilization and starch solubilization. This process causes molecular order to break down and native starch crystals to melt. From a processing aspect, the gelatinization starts temperature is crucial and varies greatly depending on the starch type (Chiou et al., 2005).

2.5.2 Type of Plasticizer

For the record, water has typically been the most often used plasticizer in starch processing, but its exclusive usage in starch plastics has significant limitations. Water can quickly escape from the product, leading it too brittle over time. As a result, various plasticizers such glycols, sugars, and amides can be added to the sample to lower the glass transition, Tg and produce a more rubber-like starch. Plasticizers with a low molar mass, a high boiling point, and low viscosities and temperature coefficients of viscosity are often efficient. The plasticizer must be homogenously blended in the polymer. Starch can be used to make a transparent film without any additives after gelatinization. However, such films have poor physical qualities and are vulnerable to water. Starch must be changed or combined with other materials to improve its physical attributes and reduce its water sensitivity to produce economically acceptable products (Chiou et al., 2005).

Acetic acid and plasticizers like water, glycerol, and sorbitol are added to starch to increase flexibility and extensibility by reducing intermolecular interactions between adjoining polymer chains (Halimatul et al., 2019). Glycerol, sorbitol, and citric acid were investigated as plasticizers for film casting (Zou et al., 2007). They found that the film containing citric acid was better than that with glycerol or sorbitol. Hydrogen bonding between the hydroxyl and carboxyl groups in citric acid improved inter/intramolecular interactions between starch polyvinyl alcohol and plasticizers. It is also reported by Zuraida et al., (2011) on an alternate biodegradable material developed by combining locally accessible sago starch with biodegradable glycerol as a plasticizer and a set of compositions containing citric acid as a co-plasticizer. To make viable bioplastics, starch is mixed with 15-30 wt.% of glycerol, resulting in an improved as Figure 2.20 shows the starch in powder form and TPS of 60/40 natural starch/glycerol (Ocelić Bulatović et al., 2019).

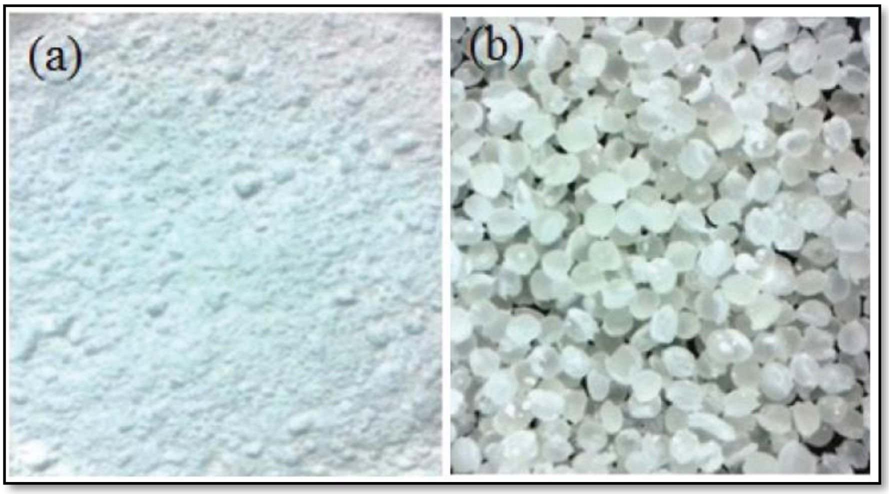


Figure 2.20 (a) Native wheat starch in powder form, and (b) TPS (60/40 natural starch/glycerol) (Ocelić Bulatović et al., 2019)

Several plasticizers, such as glycerol, have been utilized in the plasticization process to transform starch into TPS for use in polymer blends (Kaseem et al.,2012). In addition, it is also mentioned that although water is a better plasticizer than glycerol, glycerol is the most commonly utilized plasticizer in TPS manufacture due to its high boiling point, availability, and inexpensive cost. Figure 2.21 shows the commonly used plasticizer, and the highest percentage is glycerol (Kaseem et al., 2012).

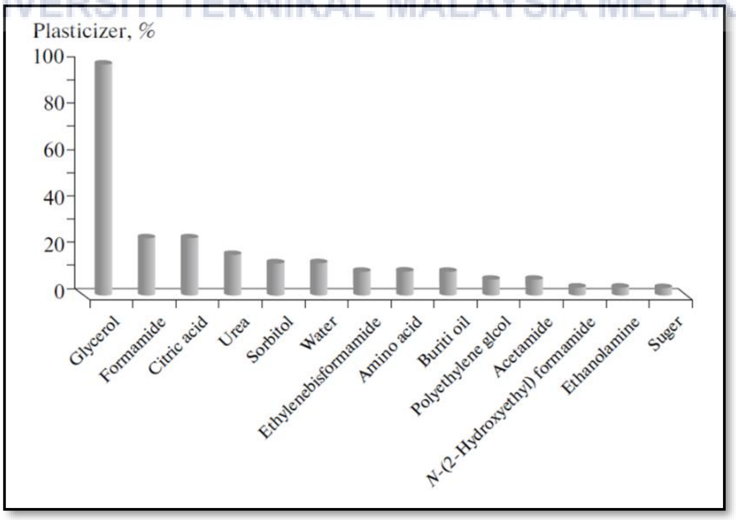
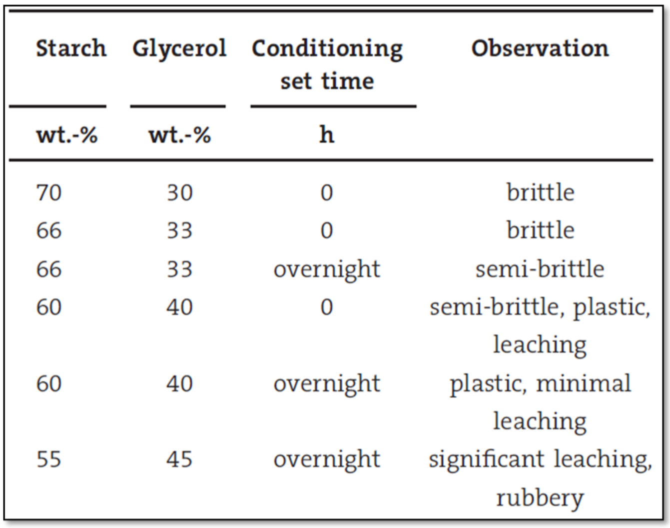


Figure 2.21 The commonly used plasticizer and the highest percentage is glycerol (Kaseem et al., 2012)

Glycerol is one of the most regularly used plasticizers for starch. Alternative uses of glycerol, a by-product of biodiesel synthesis, are currently being promoted widely in the emerging biodiesel industry. As the price of petroleum-based fuels rises, so does the demand for biodiesel, and as biodiesel production increases, so does glycerol production (Parulekar & Mohanty, 2007). Furthermore, Shaari & Kamarudin, (2019) mentioned that glycerol is an example of a polyol, and it is compatible with most hydrocolloid films. Glycerol can be used in a variety of ways, including as a plasticizer. Glycerol is a very hygroscopic substance commonly added to the polymer solution during the film formulation process to keep the film fragile. Glycerol also commonly used as plasticizer in biofilms to improve mechanical properties and transparency. The hydroxyl groups in glycerol are responsible for inter and intramolecular interactions (hydrogen bonds) in polymeric chains, resulting in more flexible films (Souza et al., 2012). Plus, Shaari & Kamarudin, (2019) mentioned that Su et al., (2010) recorded when small glycerol particles fill the space between the polymer chains, the contact between them weakens, resulting in improved film flexibility and extensibility. It is also pointed out in Sothornvit & Krochta, (2005) that as the small glycerol particles fill the space between the polymer chains, the contact between them weakens, resulting in improved film flexibility and extensibility.

Starch and glycerol were mixed using a sigma-blade mixer and allowed to sit overnight to import glycerol into the starch. On the other hand, for the processing, Parulekar & Mohanty, (2007) has carried out the plasticization in a Werner-Pfleidderer ZSK 30 Twin Screw Extruder with co-rotating screws having 30mm diameter and 30:1 L/D ratio outfitted with three vent ports. The processing was carried out at a temperature of 150 8°C (zone temperatures range from 110 8°C at the inlet to 150 8°C at the die) and a speed of 125rpm at 60% torque. The pelletized samples were taken from the extruded samples. The starch plasticization experiments and observation are recorded in Figure 2.22.



Starch	Glycerol	Conditioning set time	Observation
wt.-%	wt.-%	h	
70	30	0	brittle
66	33	0	brittle
66	33	overnight	semi-brittle
60	40	0	semi-brittle, plastic, leaching
60	40	overnight	plastic, minimal leaching
55	45	overnight	significant leaching, rubbery

Figure 2.22 Starch Plasticization experiments and obeservations (Parulekar & Mohanty, 2007)

Accordingly, TPS appears to be an alternate because it can be processed using conventional synthetic plastics manufacturing technology (extrusion, injection moulding). At room temperature, TPS made from starch plasticized simply with water becomes exceedingly brittle. Other plasticizers, such as glycerol, propylene glycol, glucose, sorbitol, and others, are utilized to improve material flexibility and processing. Other additives can be used to improve the mechanical characteristics of TPS-based materials. Emulsifiers, cellulose, plant fibres, bark, kaolin, pectin, and other elements are among them. Thermal and mechanical processing should fragment semi-crystalline starch granules to produce thermoplastic starch. As the melting point of pure starch is significantly greater than its breakdown temperature, plasticizers such as water are required (Mitrus, 2009). Figure 2.23 shows thermoplastic starch with different glycerol contents where a) 15% glycerol, and b) 25% glycerol (Mitrus, 2009).

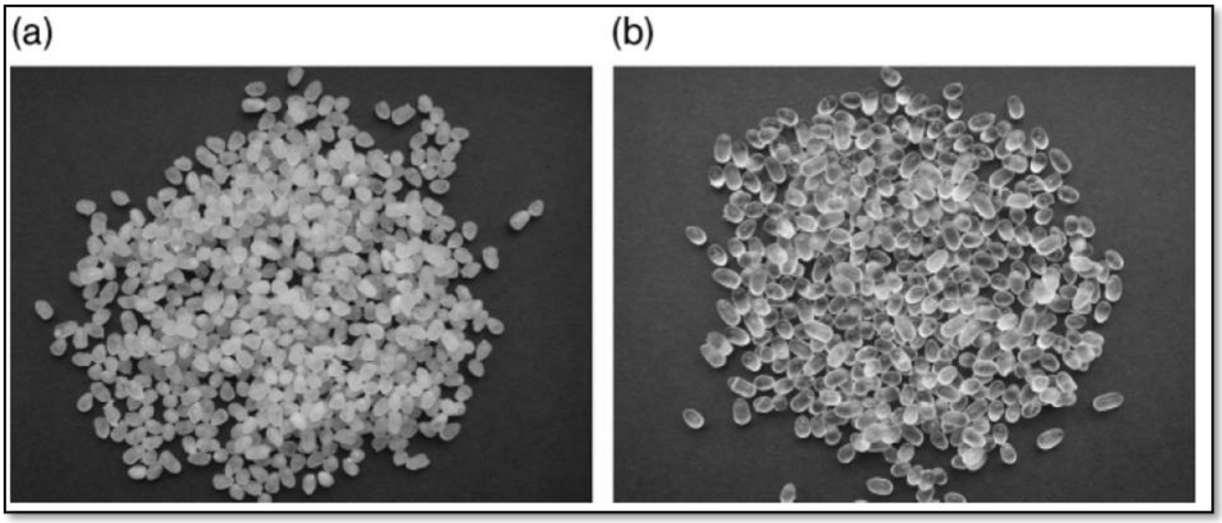


Figure 2.23 Thermoplastic starch with different glycerol contents: a) 15% glycerol, and b) 25% glycerol (Mitrus, 2009)

Plus, Sanyang et al., (2015) mentioned that the thickness of films is greatly influenced by the type of plasticizer used. The result of glycerol and sorbitol effect on the thickness of plasticized SPS films is shown in Figure 2.24 shown below. By using glycerol, its molecules will occupy the voids in the matrix and react with the starch that will form a film polymer (Sanyang et al., 2015). Moreover, it is reported that the plasticizer added to the manufacture of the edible film can bind with starch to form a starch-plasticizer polymer so that the starch-starch bond is replaced by the starch-glycerol-starch bond, which led to improvement of the film thickness (Bourtoom, 2008).

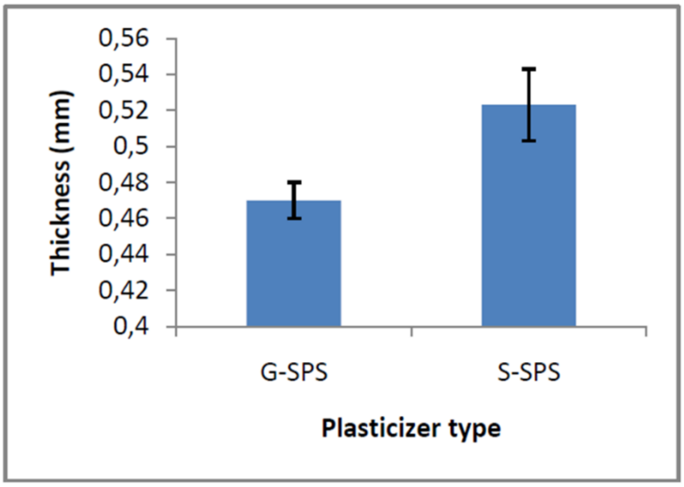


Figure 2.24 Effect of glycerol and sorbitol on the thickness of plasticized SPS films (Sanyang et al., 2015)

The starch type applied has a significant impact on the structure of a TPS granulate surface. With increasing glycerol concentration, a gradual smoothing of the granulate surface has been found in potato starch application. A granulate texture containing 30% of this plasticizer developed flaws due to granule stickiness, owing to the high viscosity generated by glycerol migration. The gelatinized, inflated starch clusters in the material made from potato starch had a reasonably smooth structure with prominent wrinkles of varying size and widened outlines (Mitrus, 2009).

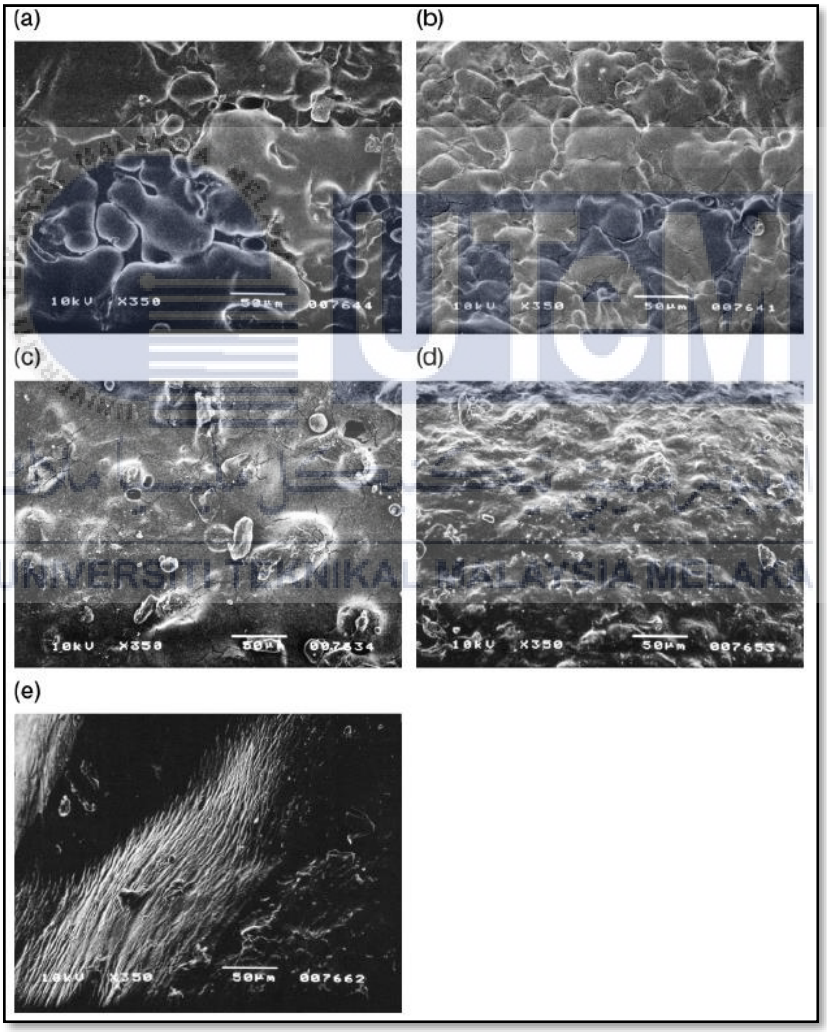


Figure 2.25 Surfaces of TPS granulates produced with different contents of glycerol, enlargement ×350 (Mitrus, 2009)

Figure 2.25 shows a) potato starch with 20% glycerol, b) potato starch with 25% glycerol, c) potato starch with 30% glycerol, d) corn starch with 20% glycerol, and e) wheat starch with 20% glycerol. Based on the figure, the further flowing of starchy structures is observed with a 25% increase in glycerol concentration, resulting in smoothing and homogeneity of the entire bulk. Also noticeable are the irregular forms of gelatinized starch grains. Thus, a 30% increase in plasticizer resulted in forming a dense, gelatinized inner structure of the granulates, with only a few solitary starch granules visible (Mitrus, 2009).

2.6 Testing for Biodegradable Thermoplastics Sago Starch

Table 2.1 below shows few previous studies that have conducted various testing for biodegradable thermoplastic sago starch.

Table 2.1 Testing for Biodegradable Thermoplastics Sago Starch

No.	Testing	Author	Year Published	Journal
1.	Tensile Strength Fourier Transform Infrared Spectroscopy (FTIR) analysis Scanning Electron Microscopy (SEM) Thermo Gravimetric (TGA) analysis	Zuraida Ahmad Hazleen Anuar Yusliza Yusof	2011	The Study of Biodegradable Thermoplastics Sago Starch
2.	Repeated soaking and drying method to test: Tensile Tearing properties	M.J. Halimatul S.M. M. Jawaid M.R. Ishak R.A. Ilyas	2019	Effect of sago starch and plasticizer content on the properties of thermoplastic films: mechanical testing and cyclic soaking-drying
3.	Swelling test by modifying starch structure using Carboxymethylation method: Determine functional group by Fourier transform-infrared spectroscopy (FT-IR) X-ray diffraction (XRD) Surface morphology study using Scanning electron microscopy (SEM)	Nur Fattima' Al-Zahara' Tuan Mohamood Norhazlin Zainuddin Mansor Ahmad@Ayob Sheau Wei Tan	2018	Preparation, optimization and swelling study of carboxymethyl sago starch (CMSS)– acid hydrogel

4.	Mechanical Properties Thermal Properties Morphological Properties	Norshahida Sarifuddin Hanafi Ismail Zuraida Ahmad	2012	Effect of Fiber Loading on Properties of Thermoplastics Sago Starch/ Kenaf Core Fiber Biocomposites
5.	Physicochemical properties improvement to prolong the shelf life of sago starch-chitosan nanofillers by testing method: Tensile strength Thermogravimetric Analysis Fourier transform-infrared spectroscopy (FT-IR)	Basirah Fauzi Mohd Ghazali Mohd Nawawi Roslinda Fauzi Siti Norliyana Mamauod	2019	Physicochemical Characteristics of Sago Starch- Chitosan Nanofillers Film

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the methodology for this experiment carried out is explained. It includes the raw materials, equipment, and testing procedure. This experiment is carried out by referring to the latest existing journals and methods. The influence of fiber-matrix natural resources upon the mechanical, thermal, and morphological properties study has been made. Furthermore, Hamid et al., (2009) mentioned various approaches could be used to generate natural fiber-reinforced biopolymer composites, such as altering the fiber loadings, fiber ratio, fiber type (short, long), fiber orientation (random, unidirectional, woven), number of plies, and ply stacking sequence.

Moreover, Yahaya et al., (2015) have investigated the effect of ply on the mechanical properties of hybrid natural fiber composite laminates of woven Kenaf. Meanwhile, Jawaid et al. (2011) have further studied layering jute reinforced epoxy composites. Plus, Zakaria et al., (2020) mentioned that the ply stacking sequence between the combined fibers and matrix interaction affects the final hybrid composite product quality. Therefore, the technique of layering the matrix of the thread and thermoplastics is a vital concern in every study as it can affect the results onwards (Zakaria et al., 2020).

3.2 Flow Chart

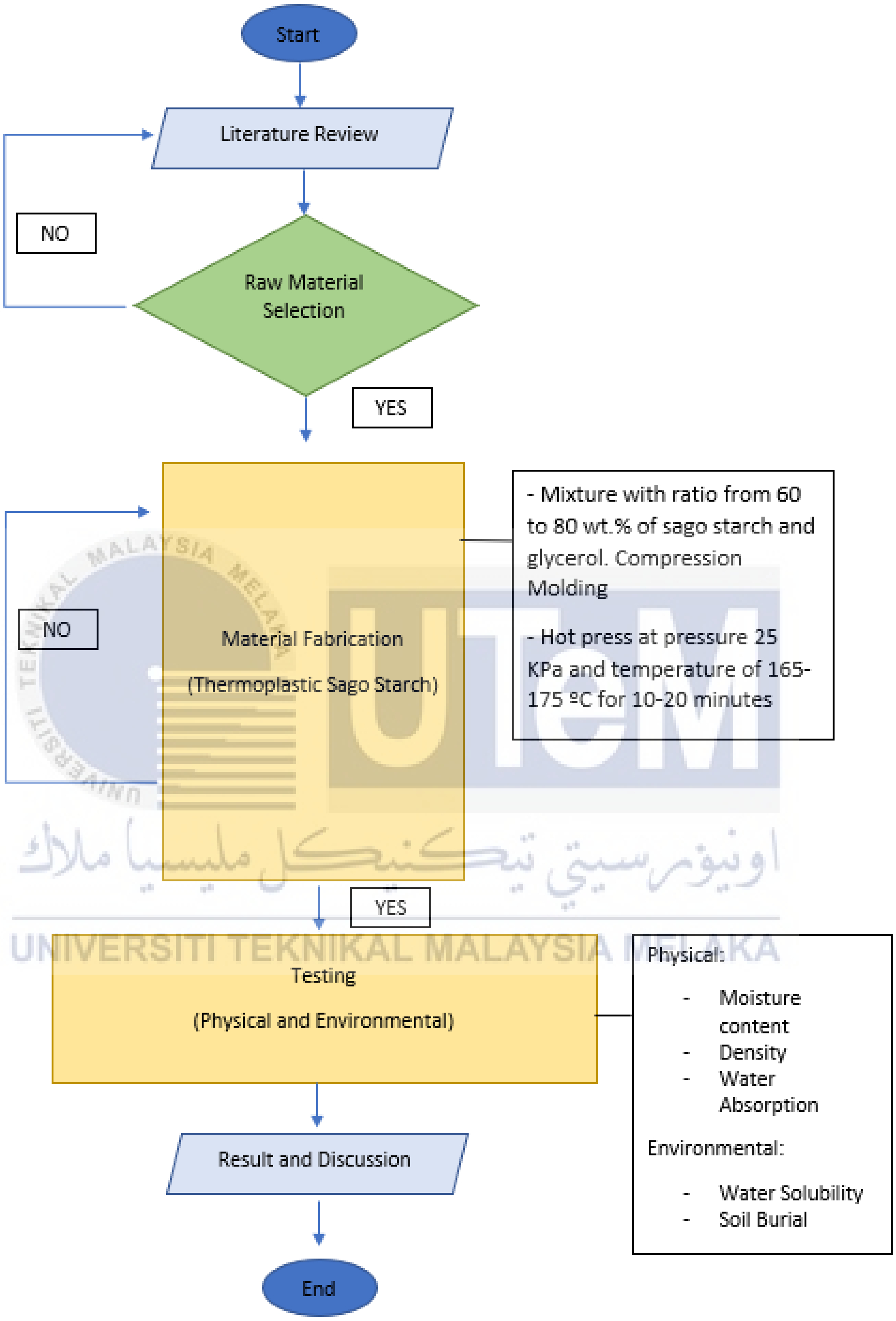


Figure 3.1 Flow chart of the study of sago starch characterization

3.3 Proposed Methodology

i. Prepare the sample by using close mold and hot press machine.

ii. Apply glycerol into 60 wt.% to 80 wt.% sago starch.

iii. Use the density, moisture absorption, and water absorption to test find physical behaviour.

iv. Conduct the water solubility and soil burial test for environment testing

3.4 Experimental Setup

The experiment is done by referring to ASTM standard and referring to the previous experimental method that has been made by the other researchers. The material, equipment and method are done by using the suitable and approved standard and formulae.

3.4.1 Raw Material

The raw materials for this study are sago starch and 99.5% glycerol, as shown in Figure 3.2. Glycerol is a valuable by-product produced in a variety of methods and by a variety of industries. Both raw materials are purchased from Polyscientific Enterprise Sdn. Bhd. The sago starch comes in a powder form which is mainly used for various application such as food industries and manufacturing industrial application. Meanwhile, the 99.5% glycerol is a G4018-1-2500 type from Qrec brand.

Figure 3.2 (a) Sago starch (b) 99.5% Glycerol

Glycerol, also called glycerine or propane-1,2,3-triol, is a chemical with a wide range of applications in the pharmaceutical, cosmetics, and food industries. Glycerol is some kind of organic substance with the formula $C_3H_8O_3$. The glycerol content ingredients is on the Table 3.1 below.

Table 3.1 Glycerol contents

Ingredients	Contents
Assay (acidimetric)	Min 99.5%
Insoluble in water	Passes test
Acidity/ alkalinity	Passes test
Halogen compunds (as Cl)	Max 0.003%
Chloride (Cl)	Max 0.001%
Sulphates (SO_4)	Max 0.001%
Ammonium (NH_4)	Max 0.0015%
Arsenic (As)	Max 0.0001%
Copper (Cu)	Max 0.001%
Heavy metals (as Pb)	Max 0.0005%
Iron (Fe)	Max 0.005%
Lead (Pb)	Max 0.001%

Nickel (Ni)	Max 0.0005%
Zinc (Zn)	Max 0.001%
Aldehydyes (HCHO)	Max 0.0005%
1,2,4-butantriol (G.C)	Max 0.2%
Suphated Ash	Max 0.01%
Water	Max .2%

3.4.2 Equipment

The equipment used in this study is the mould for the sample fabrication, cutting machine, hot press machine, de-mould machine, oven and dessicator for water absorption and soil burial test is shown in Figure 3.3, Figure 3.4, Figure 3.5, Figure 3.6, Figure 3.7 and Figure 3.8 below.

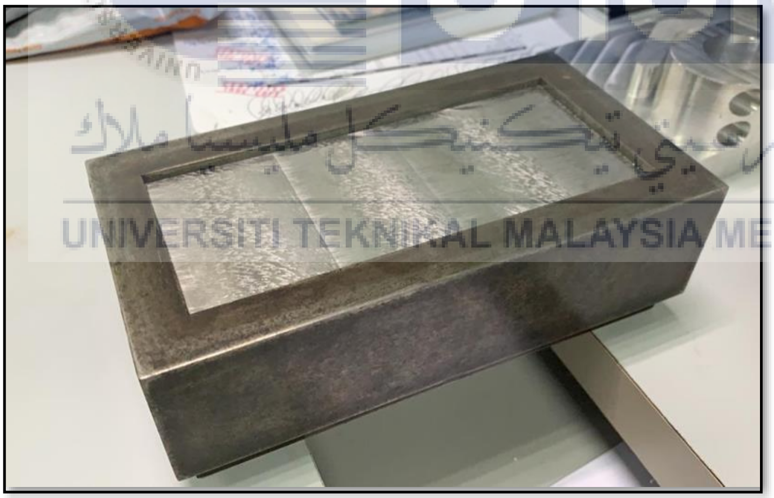


Figure 3.3 Mild Steel Mould

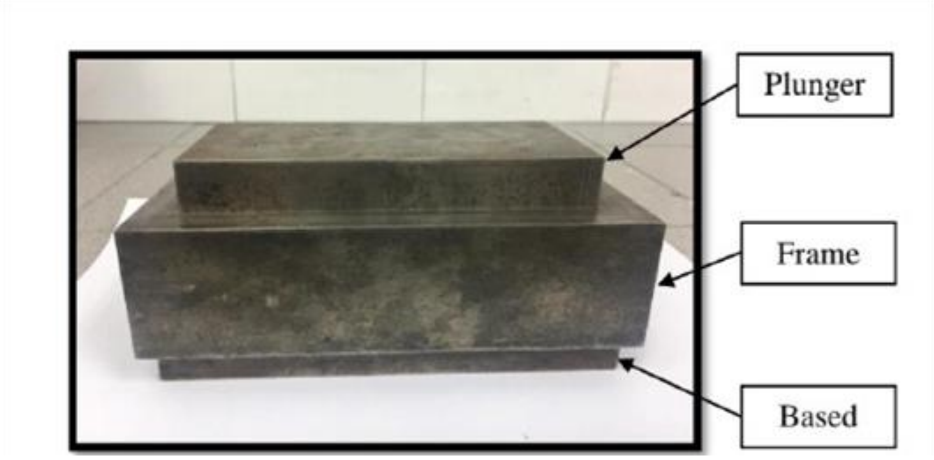


Figure 3.4 Mould description

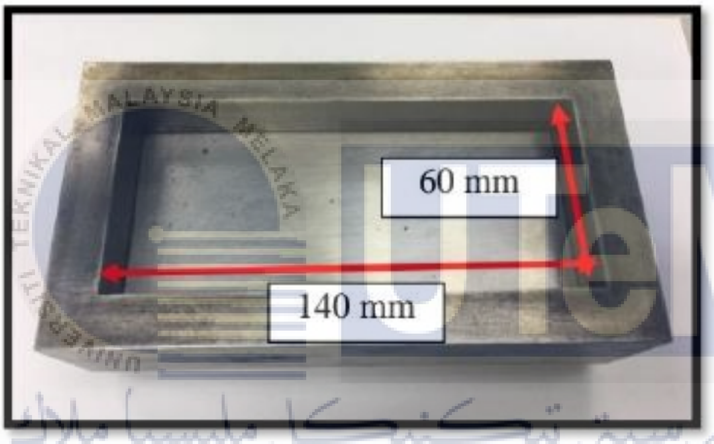


Figure 3.5 Mould dimension

Figure 3.6 (a) Hot-compression machine (b) De-mould machine

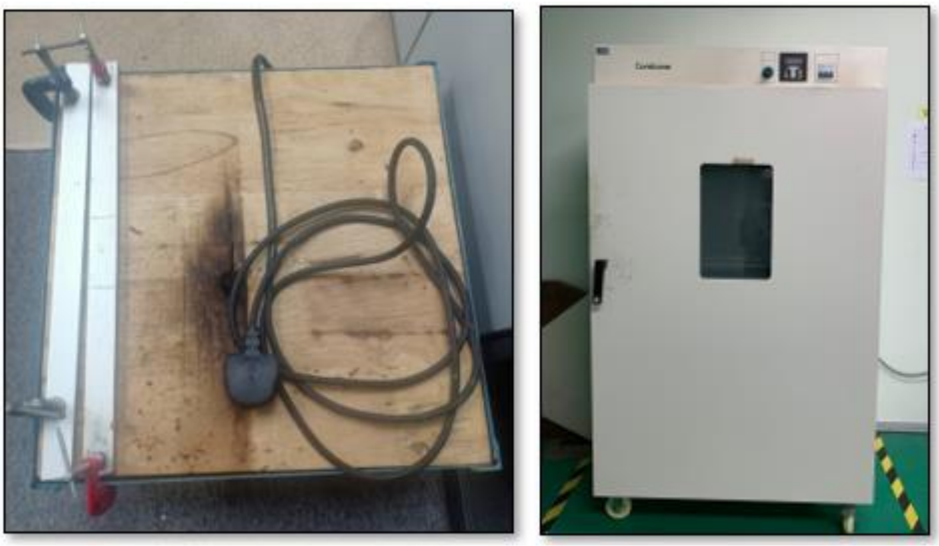


Figure 3.7 (a) Cutting machine (b) Oven

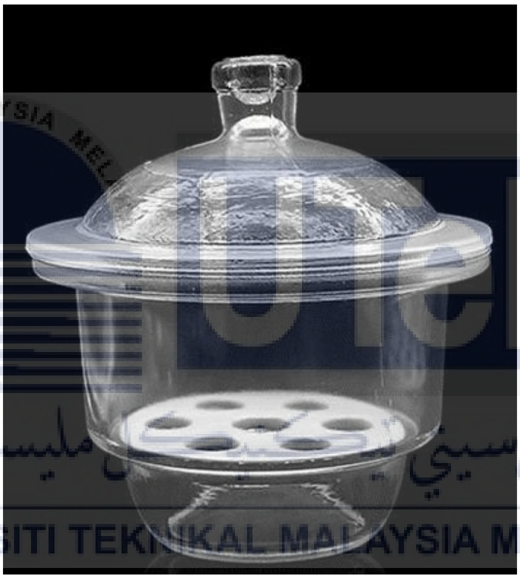


Figure 3.8 Dessicator

3.4.3 Sample Fabrication

The sample fabrication is referred to by the previous study by Zuraida et al., (2012), where the sago starch powder is dried in a vacuum oven at 80˚C for 24 hrs. The sample is fabricated into five (5) different weight percent of sago starch (wt.%) and glycerol. As the sample is fabricated, the sample is stored in a dessicator to maintain and preserve the moisture and sample properties before the testing can be done. Then, five samples of dimensions 10 x 10 x 3 mm from each TPSS composition is cut from the sheet-shaped hot press samples by using the cutting machine, to proceed for their physical and environmental characterization. The flow of thermoplastics sago starch fabrication process is shown in Figure 3.9 below.

3.4.4 Composition of Sago Starch and Glycerol

The composition of sago starch and glycerol blends is shown in the Table 3.2 below.

Table 3.2 Composition of Sago Starch and Glycerol (wt.%)

Sample Sago Starch/Glycerol	Starch (wt.%)	Glycerol (wt.%)	Mixture Weight/mould (gram)
60/40	60	40	75
65/35	65	35	
70/30	70	30	
75/25	75	25	

Measuring process for sago starch using digital scale.

Put the weighted starch into container

Measuring process for glycerol using digital scale.

Put the weighted glycerol into the container

Manually mix the sago starch and glycerol using hand.

Dry mixing the material for 3-5 minute using high speed blender.

Put the blended material into mould that have been prepared.

Closed the mould.

The mould will be hot press for about 10-20 min following with curing of 20 min using Hot Compression Moulding Machine.

After curing, demould process will be done with press machine.

Cured sago starch with mixture of glycerol.

Cutting process of the sample according to testing standard.

Figure 3.9 The flow of thermoplastic sago starch fabrication process

3.5 Physical Testing

These testing methods involve the measurement of physical characteristics of a material. Plus, it is useful for emulating how a product will behave when it is being used by the end user. The physical characterization is found by conduct physical testing on the sample. It is done by using the ASTM standard procedure and by referring to experimental testing method by other researcher’s previous studies.

3.5.1 Density Measurement

To determine the specific gravity of the thermoplastic sample, a density test is carried out by using the Electronic Densimeter (Zakaria et al., 2020). The procedure includes proper smaller cut pieces into 10 mm x 10 mm x 3 mm. After that, the mass of the smaller pieces is calculated on the Densimeter machine. In order to get the density, the sample is placed into the densimeter, and this process is repeated for each sample. The average values of the density can be obtained by this procedure, according to Ilyas et al., (2019). The density is calculated by using Equation 3.1, where, m = mass (g), V = volume (cm3):

$$\boldsymbol{\rho = \frac{m}{V}}$$

Equation 3.1

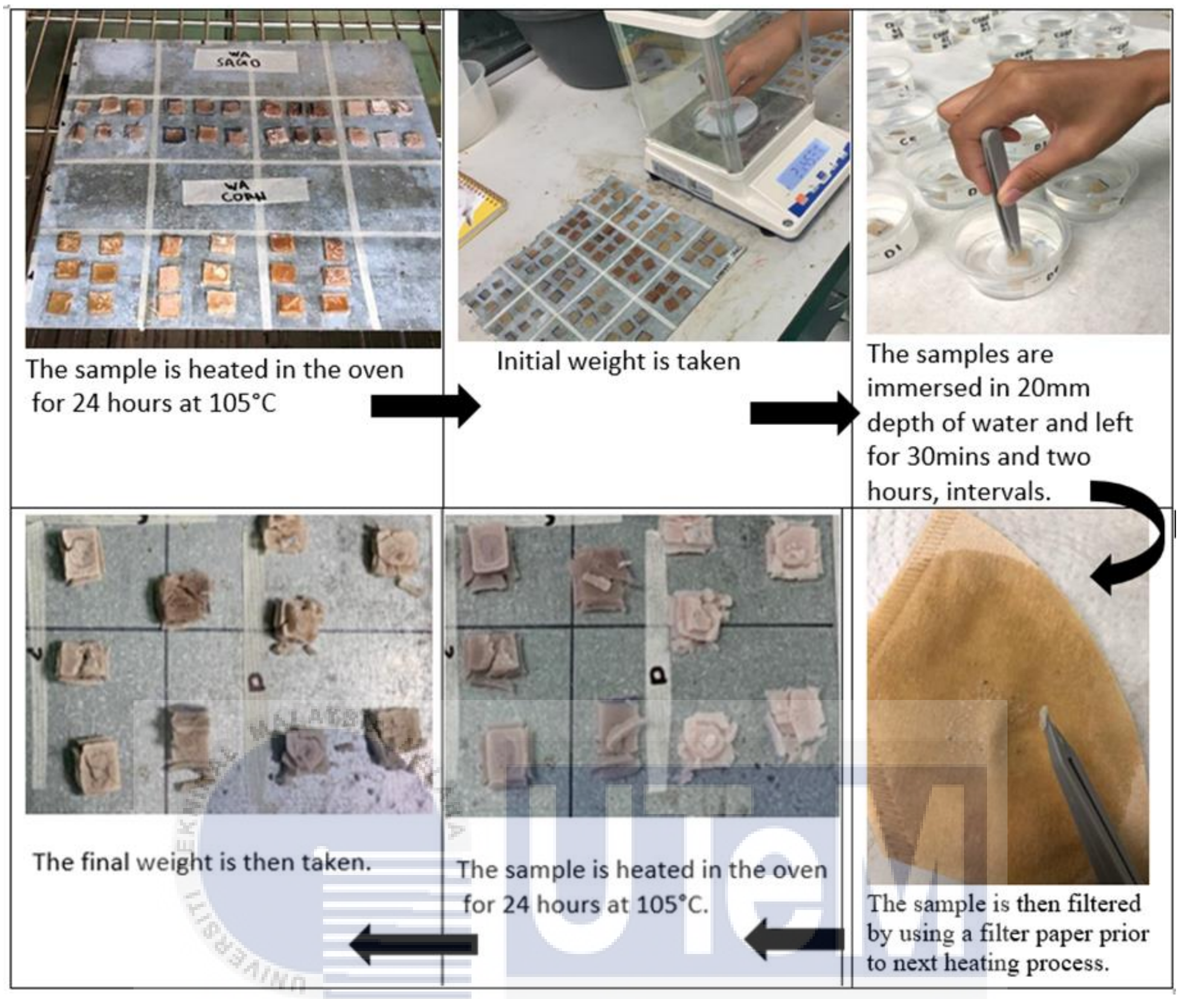
Figure 3.10 Density testing using Densimeter

3.5.2 Water Absorption

Figure 3.11 shows the flow of the water absorption testing that have been conducted. The water absorption capacity was expressed as grams of water bound per gram of the specimen on a dry basis. The data were collected in triplicate to obtain a mean value. For the composites, five specimen size (10 mm × 10 mm × 3 mm) was dried in an air circulating oven at 105º C ± 2 for 24 hours in order to remove the existing moisture. Then the specimen is immersed in water at a room temperature (23 ± 1º C) for 0.5 hours and 2 hours (Zakaria et al., 2020). The formula use for the water absorption testing is as shown in Equation 3.2:

$$\textbf{Increase in weight}, \% = \frac{\textbf{wet weight} - \textbf{conditioned weight}}{\textbf{conditioned weight}} \times \mathbf{100}$$

Equation 3.2



The sample is heated in the oven for 24 hours at 105°C

Initial weight is taken

The samples are immersed in 20mm depth of water and left for 30mins and two hours, intervals.

The sample is then filtered by using a filter paper prior to next heating process.

The sample is heated in the oven for 24 hours at 105°C.

The final weight is then taken.

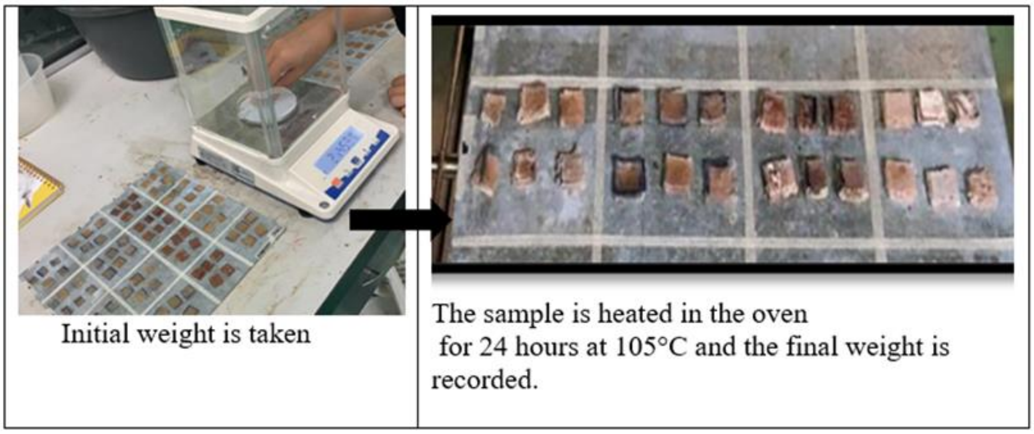
Figure 3.11 Water absorption testing

3.5.3 Moisture Content

Figure 3.12 shows the moisture content testing being conducted. Five samples from each composition are heated at 105 °C for 24 hours. Prior to the heating, the weight, Wi, of the specimen is recorded. The weight of the heated samples also recorded, Wf. This method is carried out by referring to Zakaria et al., (2020). The moisture content is calculated by using the Equation 3.3 below where where, Wi = original weight, Wf = final weight:

$$\textbf{Moisture Content (\%)} = [(W_f - W_i) / W_i] \times 100$$

Equation 3.3



Initial weight is taken

The sample is heated in the oven for 24 hours at 105°C and the final weight is recorded.

Figure 3.12 Moisture content testing

3.6 Environmental Testing

This type of testing enables the researchers to understands the materials operational limitations within its end-use in the environment ambiance. The physical characterization is found by conduct physical testing on the sample. It is done by using the ASTM standard procedure and by referring to experimental testing method by other researcher's previous studies.

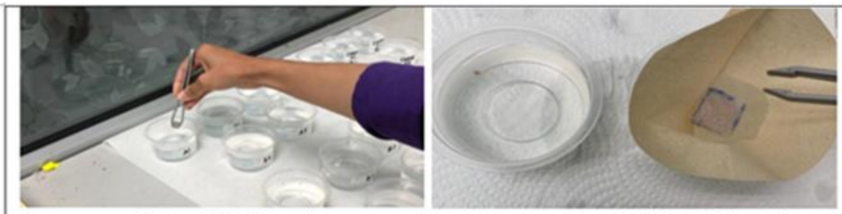
3.6.1 Water Solubility

Figure 3.13 shows water solubility testing is conducted. For this testing, the sample for each composition with dimension 10 mm x 10 mm x 3 mm is dried at 105 °C for a length of 24 hours. Then, the initial weight, W_i, is recorded before it is immersed into 30 ml of distilled water and gently stirred. The sample is left immersed for 24 hours.

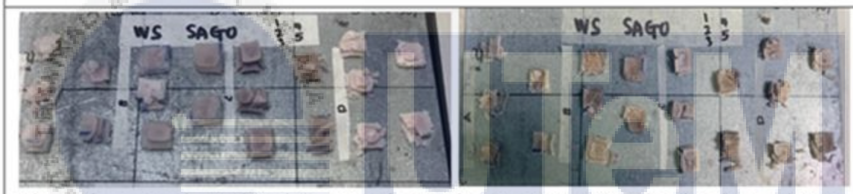
After this process, use the filter paper to removes the excess water on the surface of the samples. Then, it must be dried again in a hot oven to get the final weight, W_f. This method is referring to Kanmani & Rhim, (2014). The water solubility of the samples is calculated by using Equation 3.4, where, W_i = original weight, W_f = final weight:

$$\textbf{Water solubility (\%)} = [(W_i - W_f) / W_i] \times 100$$

Equation 3.4



The sample is dried in the oven for 24 hours at 105°C. After that, the initial weight is recorded before it is and gently stirred then immersed for 24 hours at 20mm depth of water. The sample is then filter by using filter paper to removes excess water.



Then the sample is dried in oven for 24 hours at 105°C. The final weight is recorded.

Figure 3.13 Water solubility testing

3.6.2 Soil Burial

On the other hand, the soil burial testing is run by using natural compost soil. There are many studies concerning the use of bio-fibre and bio- flour as reinforcing in biodegradable polymer bio-composite systems.

Figure 3.14 shows soil burial testing is conducted by referring to Zakaria et al., (2020), the original weight, Wi, is determined by drying the specimens at 105 °C for 24 hours then weighing them. Thus, testing periods were conducted for two weeks. They were then dried for another 24 hours at 105 °C and weighed to get the final weight, W_f. Moreover, a total of five samples with the dimension 10 mm x 10 mm x 3 mm is buried in the compost soil in 10 cm depth. The final weight loss of this soil burial method is determined by the Equation 3.5, where, Wi = original weight, W_f = final weight:

$$\textbf{Weight loss (\%)} = [(W_i - W_f) / W_i] \times 100$$

Equation 3.5

The initial weight of sample is taken and the dried in the oven for 24 hours at 105°C. The sample is then taken out and buried in the compost soil in 10 cm depth with 2cm from the base.

The sample is taken out after two weeks. After cleaning out the dirt, the sample is dried in the oven for 24 hours at 105°C.

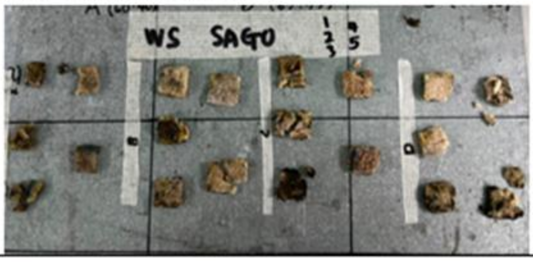


Figure 3.14 Soil burial testing

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results based on the previous study and research. It is also gained based on the methodology and procedure that is demonstrated in the literature review. Sondari et al., (2019) reported that moisture content from native sago starch is higher than the modified one. Thus, it is expected that the quality of the thermoplastic sago starch is increased along the increasing of the glycerol added. On the other hand, Kaseem, (2012) reported that the thermoplastic starch blends with glycerol have significantly prevents flaws such as surface cracks where it shows a good compatibility combination. According to Zuraida, (2011), thermoplastic sago starch that have been plasticized with 30 wt.% glycerol result in fined granule compared to native starch had a clear and smooth surface. The density of the thermoplastics sago starch film matrix is lessened as it is mix with the glycerol. This is due to the structural changes of the starch linkages represents by the starch and glycerol ratio. Lowering the ratio resulted in closer spacing between the starch particles, resulting in fewer voids causing the matrix to become denser (Zuraida et al., 2012). For the soil burial tests, a previous report from Wojtowicz, (2010) found that a wheat starch-aliphatic polyester blend has good biodegradability. These mixes' exceptional qualities make them suited for use as commodity biodegradable polymers. Polyvinyl alcohol (PVOH) is combined with starch to create biodegradable polymers. It is expected that the usage of glycerol also would enhance the biodegradability of the thermoplastic sago starch within in the range weeks. The fabricated blends of thermoplastic sago starch mix with the glycerol for every ratio is as shown in Figure 4.1.

Figure 4.1 The blends of sago starch mix with glycerol (wt.%)

4.1.1 Qualitative Analysis based on the Parameter Setting

Various parameter setting is applied for each of the sample fabrication by using the hot-compression moulding machine. Until the outcome of the sample is obtained smooth and have minimum defects by using a particular parameter setting, the sample fabrication process is then proceeded with a constant parameter setting. Table 4.1, Table 4.2, Table 4.3 and Table 4.5 below shows the various parameter setting that have been used to fabricate the samples for each of ratio (wt.%).

Table 4.1 Parameter Setting Sample 60 wt.%

Parameter	**1**	**2**	**3**
Pre-heat duration (min)	10	10	15
Compressed duration (min)	10	10	10
Upper mold temperature (°C)	160	165	175
Lower mold temperature(°C)	160	165	170
Cooling duration (min)	15	15	20
Fabricated Sample	Bubble 	Brittle 	OK 

Table 4.2 Parameter Setting Sample 65 wt.%

Parameter	1	2	3
Pre-heat duration (min)	10	15	20
Compressed duration (min)	10	8	8
Upper mold temperature (°C)	180	180	180
Lower mold temperature(°C)	175	175	175
Cooling duration (min)	20	20	20
Fabricated Sample	Bubble 	Bubble 	OK 

Table 4.3 Parameter Setting Sample 70 wt.%

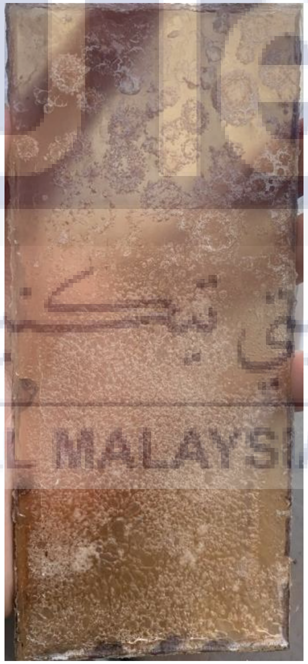
Parameter	1	2	3
Pre-heat duration (min)	20	20	20
Compressed duration (min)	15	10	15
Upper mold temperature (°C)	165	170	170
Lower mold temperature(°C)	165	165	165
Cooling duration (min)	20	20	20
Fabricated Sample	Bubble Inside 	Bubble 	OK 

Table 4.4 Parameter Setting Sample 75 wt.%

Parameter	1	2	3
Pre-heat duration (min)	15	20	30
Compressed duration (min)	15	15	15
Upper mold temperature (°C)	180	180	180
Lower mold temperature(°C)	180	180	180
Cooling duration (min)	20	20	20
Fabricated Sample	Brittle 	Brittle 	OK 

Table 4.5 Parameter Setting Sample 80 wt.%

Parameter	**1**	**2**
Pre-heat duration (min)	15	15
Compressed duration (min)	15	25
Upper mold temperature (°C)	180	180
Lower mold temperature(°C)	175	175
Cooling duration (min)	20	20
Fabricated Sample	Very Brittle 	Burnt, very brittle (cookies-like) 

Hence, 80% fabrication of thermoplastics sago starch resulting in a very brittle sample. Thus, the testing procedure cannot be done on this ratio. This may cause by the rate of the glycerol mix is too low causing the material cannot be plasticized properly.

4.2 Physical Testing Results

4.2.1 Density Measurement

Jumaidin et al., (2017) mentioned that the weight of the material is an important consideration in the material selection process because it can affect the performance of the end products. Density is the main element that directly affect the process and materials (Zakaria et al., 2020). The density of the thermoplastics sago starch for various ratios are shown in Figure 4.2.

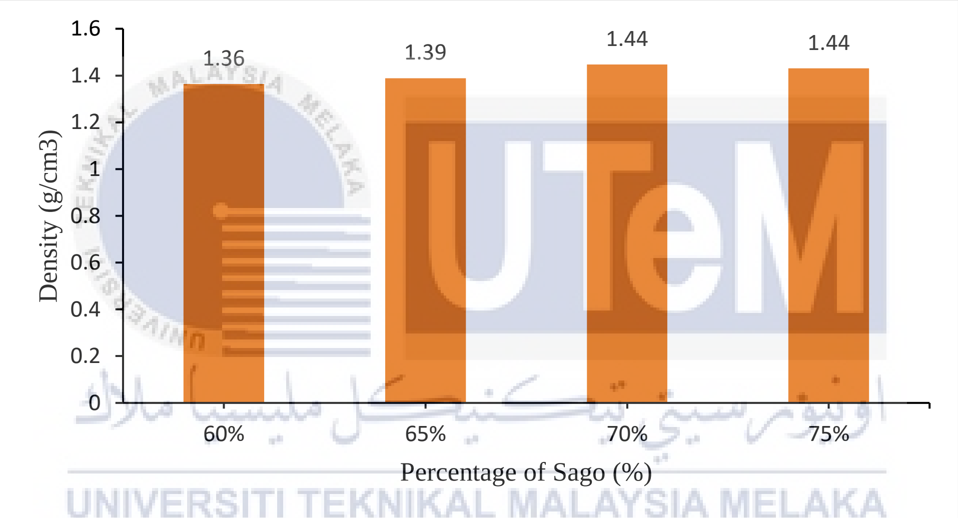


Figure 4.2 Density measurement

From this figure, the highest density occurs at 70 wt.% and 75 wt.% of thermoplastics sago starch which is about 1.44 g/cm3, respectively. Meanwhile the lowest value of density is 1.36 g/cm3 at 60 wt.% of thermoplastics sago starch. Thus, from the result above, the difference in reduction of the density results between higher and lower is around 0.08%. This is consistent with previous research on thermoplastics corn starch composite reinforced short pineapple leaf fibre that stated the voids in the composites affected the decrement of the density (Zakaria et al., 2020). Ratio with lower glycerol percent produced closer voids between the starch particles and thus, resulting in denser material (Zuraida et al., 2012). The study also mentioned that the incorporation of a higher amount of glycerol with the starch increased the thermoplastic sago starch water absorption because glycerol is hygroscopic in nature, while the hydrophilicity of the starch enhanced the water absorption even further. The amylose content in starch formed a network of stiff strands in which the pores entrapped more water.

4.2.2 Water Absorption

A study by Jumaidin et al., (2017) reported that the bio-based material is known to be more sensitive to the water. As such, it is important to consider the water absorption behaviour of the fully bio-based material in this study. Figure 4.3 belows shows the water absorption results in two different periods, 0.5 hours and 2 hours. As expected, 0.5 hours period resulting in lower water absorption rate compared with 2 hours period of time. After 0.5 hours, it shows decreasing pattern of water absorption percent. Only 8% water absorption rate at 75 wt.%. While the highest water absorption rate is 29.67% at 65 wt.%. There is a slight increment where the water absorption is 27.98% at 60 wt.%, only 1.69% difference. It might be due to small variation in the sample. However, this small difference is not significant to be taken into account as the effects of mixture (Jumaidin et al., 2019). The water absorption decreases as the thermoplastics sago starch (%) increases. This correlates to Halimatul et al., (2019) where the study mentioned the higher the thermoplastic sago starch loading (wt.%), the water uptake is lower.

Plus, since the sample is in amorphous form, water molecules can more easily penetrate and dissolve the polymer. This result also shows the same pattern with Ab Wahab et al., (2021) where the percentage of water absorption decreases as the thermoplastic (wt.%) increases. This is because the water could easily saturate the surfaces of the sample, and penetrates into the voids of the sample. Hence, the longer time of immersion (2 hours) had the lowest water uptake because saturation of water absorption in the blend constrained the penetrating of water absorption in the blends (Ab Wahab et al., 2021). After 2 hours, the result shows higher water absorption percent. This due to the longer diffusion process after 2 hours and the hydrophilic properties (Jumaidin et al., 2019). The highest percent recorded is 63.72% and it gradually decreases to 58.20%, 37.02% and fluactuate to 41.00%, respectively. According to Jumaidin et al., (2019), the fluctuation in the water absorption behaviour of the composites could be attributed to the composites' non-homogeneous structure, which resulted in inconsistent water absorption behaviour.

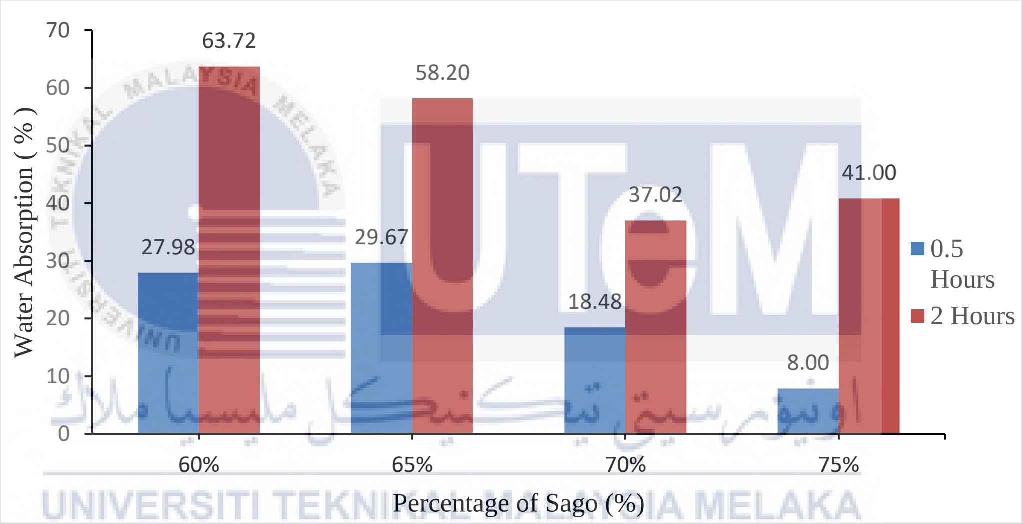


Figure 4.3 Water absorption result

The rate of water absorption is might be due to the hydrophilic behaviour of the thermoplastics sago starch. This meets with the previous study of water absorption behaviour of thermoplastics corn starch composite reinforced with short pineapple leaf fibre by Zakaria et al., (2020). Since sago starch is a naturally highly hydrophilic material, incorporating additional plasticizer into the matrix is a promising attempt to improve the water sensitivity of starch-based systems while preserving the composite's biodegradability (Halimatul et al., 2019).

4.2.3 Moisture Content

Moisture content is an essential aspect to consider before choosing a new potential natural material for polymer bio-composites. High moisture content may adversely impact the bio-strength, composite's dimensions, and porosity formation (Zakaria et al., 2020). Therefore, the low moisture content value in composite is desirable for further investigation. The results of moisture content of the thermoplastics sago starch (wt.%) are shown in Figure 4.4.

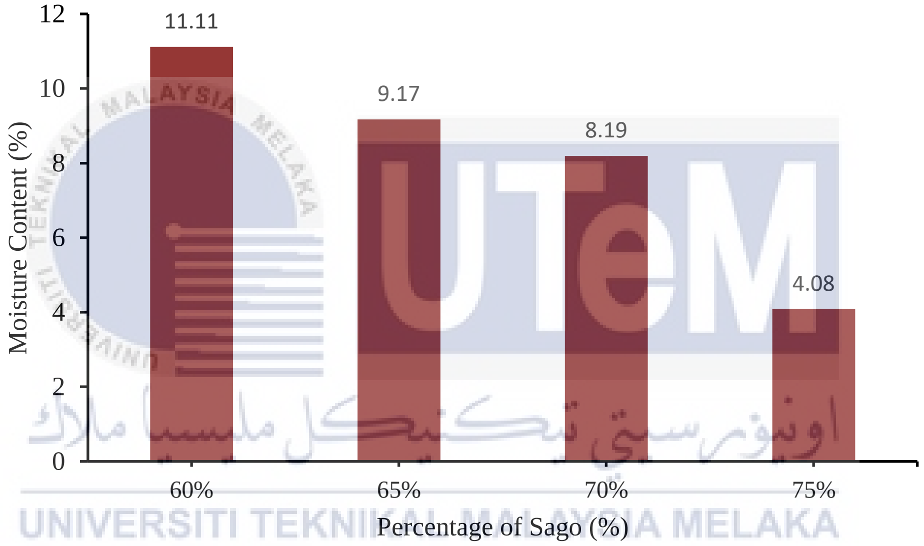


Figure 4.4 Moisture content result

In general, the result shows a decrement pattern in moisture content from 60 wt.% to 75 wt.%. The highest moisture content result is contributed at lower sago starch content (60 wt.%) around 11.11%. Plus, the lowest moisture content result was revealed at higher thermoplastics sago starch content (75 wt.%) almost 4.08%. The total reduction of moisture content result was about 7.03%. This result correlates with Zakaria et al., (2020) findings on thermoplastics corn starch composite reinforced short pineapple leaf fibre that the addition of glycerol to starch produced a mixture with high hydrophilic behaviour. A remarkable drop in moisture content of sugar palm starch bio-composites by Sahari et al., (2013).

4.3 Environmental Testing Results

4.3.1 Water Solubility

Recently, the main problem to the ecosystem is due to non-biodegradable materials cannot be disposed in the water. Therefore, bio-based materials are solution because of their readiness to decompose when disposed in the water (Zakaria et al., 2020). This result represents the water resistance of the composites when immersed and continuously stirred in water. On the other hand, water solubility also shows the degradation behaviour of composite when disposed in water. The results of water solubility of the thermoplastics sago starch for various ratios are shown in Figure 4.5.

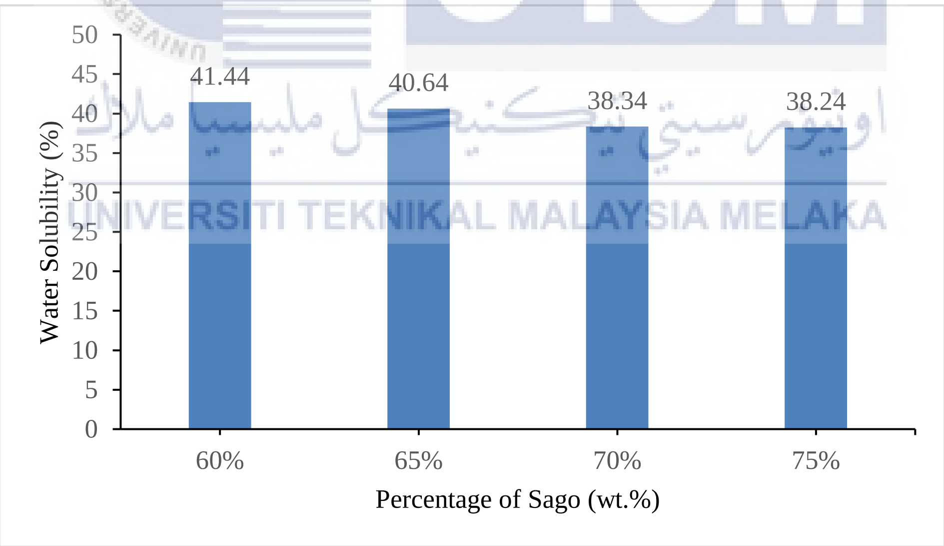


Figure 4.5 Water solubility result

From the result, it generally shows that water solubility steadily decreases from 41.44% to 40.64% with the addition 5 wt.% of sago starch from 60 wt.%. It then decreased to 38.34% as the thermoplastic sago starch ratio is at 70 wt.% up to 38.24 at 75 wt.%.

Therefore, it can be seen that the trend of water solubility decreasing as the thermoplastic sago starch increase (wt.%). The higher level of glycerol blends together makes the bind of thermoplastics more hydrophilic and immersible in water. In addition, this finding corresponds to the findings of R. Jumaidin et al., (2019), who discovered that increasing fibre content on thermoplastic corn starch with incorporation of cogon grass fibre reduces water solubility.

However, higher water solubility indicates a weak resistance to water in bio-composites (Zakaria et al., 2020). According to (Zuraida et al., 2011), as thermoplastic starch was developed in an attempt to tackle the concerns on environmental issues. Thermoplastic starch (TPS) is a thermoplastic product created from native starch that is homogeneous. Thermoplastic starch can change from semi-crystalline to amorphous polymeric material after going through several processes. Plus, it should be emphasized that thermoplastic starch is practical to use because it contains more than 70% starch, and materials with excellent qualities and biodegradability may be manufactured using appropriate plasticizing solvents. Thus, the results shown very slight differences amongst the ratios where it suggests that the degradability of thermoplastics sago starch with glycerol in water is good for sustainable waste disposal.

4.3.2 Soil Burial Results

According to Bootklad and Kaewtatip, 2013, the weight loss of material can be taken as the main indicator for the biodegradation process by moisture and microorganism during soil burial period. Many factors associated with soil influence the degradation of the polymer composites. Some of these important factors are the texture and soil structure, temperature, soil composition (mineral and organic), water activity, pH, and the oxygen and carbon dioxide content. Since the primary goal of developing a new material is for it to degrade easily in the natural environment. The degradation process is influenced by a number of factors, including the pH of the soil, temperature, the presence of microorganisms in the soil, humidity, and the character of the composite material itself. (Vasile et al., 2018). Plus, the biodegradation in the composites occurred due to the microorganism attack such as bacteria and fungi (Zakaria et al., 2020). Figure 4.6 represents the weight loss of thermoplastics sago starch after soil burial process in two (2) weeks of time.

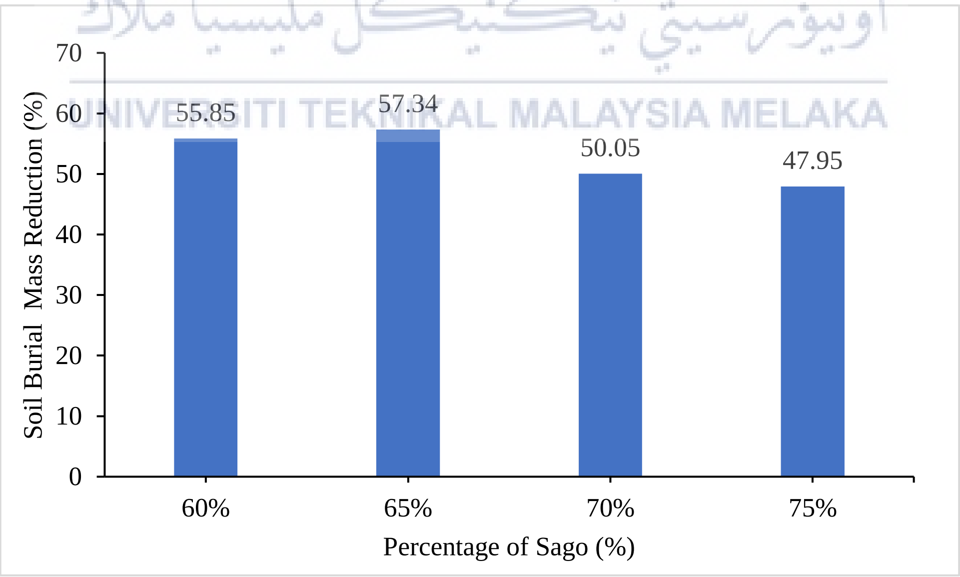


Figure 4.6 Percentage of mass reduction for soil burial testing

Increasing sago starch from 60 wt.% to 75 wt.% has decreased the weight loss of bio-composites from 55.85% to 57.34% to 50.05% and 47.95% after soil burial for two (2) weeks. This result is in agreement with (Zakaria et al., 2020), where lower mixture percent (wt.%) was associated with greater reduction in the weight. Therefore, it was concluded that the extent of degradation was inversely proportional to the mixture content implying that the composites were could be degradable. This result shows that the sample degrades almost and over 50% of its weight percent in just 2 weeks. Hence, this can be justifying by the study of Kaseem et al., (2012) that mentioned glycerol–urea complex forms are more stable and strong hydrogen bonds with water and starch–polyvinyl alcohol molecules than a single plasticizer such as glycerol. The higher level of glycerol blends together makes the bind of thermoplastics more hydrophilic and immersible in water. This finding is consistent with the findings of Maran et al., (2014) regarding the degradation of cassava (tapioca) starch-based composite film in indoor soil burial.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Countless researchers have conducted research on the development of new environmentally friendly and sustainable materials. Sago starch has been widely used for multiple purposes from food industry to manufacturing industry. The properties of sago starch are the crucial criteria for material selection to be used as biodegradable material. As sago starch has some drawbacks, the physical and environmental characterization of sago starch are being studied to determine the suitable matrix parameters in different percentage of glycerol as plasticizers. In conclusion, this study provided preliminary information to assist further material research and assess any possible application fields of thermoplastics sago starch. Hence, this material can become an alternative for non-biodegradable bioplastic in the future and optimized the usage of natural resources. This research has three primary goals. The study's objectives and conclusion are as follows:

i. Fabricate the sago starch (wt.%) by adding various glycerol loading

Various parameter setting is applied for each of the sample fabrication by using the hot-compression moulding machine. Until the outcome of the sample is obtained smooth and have minimum defects by using a particular parameter setting, the sample fabrication process is then proceeded with a constant parameter setting. Thermoplastic sago starch for sample 60 wt.%, 65 wt.%, 70 wt.%, 75 wt.% was obtained. However, thermoplastic sago starch for sample 80 wt.%, cannot be done. Several parameter setting on the hot-compression moulding machine have been use to fabricate the sample, but it results in very brittle as the rate of the glycerol mix is very low to plasticized the concentrated 80 wt.% sago starch. Thus, further study on this sample cannot be done.

ii. Investigate the physical behaviour of sago starch influenced by different glycerol loads

The moisture content shows a decrement pattern in moisture content from 60 wt.% to 75 wt.%. The highest moisture content result is contributed at lower sago starch content (60 wt.%) around 11.11%. Plus, the lowest moisture content result was revealed at higher thermoplastics sago starch content (75 wt.%) almost 4.08%. Meanwhile, for the water absorption it can be characterized that the water absorption decreases as the thermoplastic sago starch (%) increases. Since sago starch is a naturally highly hydrophilic material, incorporating additional plasticizer into the matrix is a promising attempt to improve the water sensitivity of starch-based systems while preserving the composite's biodegradability. The density shows an increment pattern as the thermoplastic sago starch (wt.%) increases. The highest density occurs at 70 wt.% and 75 wt.% of thermoplastics sago starch which is about 1.44 g/cm3, respectively. Meanwhile the lowest value of density is 1.36 g/cm3 at 60 wt.% of thermoplastics sago starch.

iii. Analyse the environmental behaviour of sago starch influenced by different glycerol loads.

As the water solubility testing is conducted, it can be seen that the trend of water solubility decreasing as the thermoplastic sago starch increase (wt.%). The higher level of glycerol blends together makes the bind of thermoplastics more hydrophilic and immersible in water. As the thermoplastic sago starch (wt.%) increases, the water solubility decreases. Nevertheless, the results shown very slight differences amongst the ratios of thermoplastic sago starch (wt.%) where it suggests that the degradability of thermoplastics sago starch with glycerol in water is good for sustainable waste disposal. On the other hand, soil burial result shows incorporation of thermoplastics sago starch from 60 wt.% to 75 wt.% has decreased the weight loss of bio-composites. It shows that the sample degrades almost and over 50% of its weight percent in just 2 weeks. Thus, the extent of degradation was inversely proportional to the mixture content implying that the composites were could be degradable completely over 2 weeks. Thus, the environmental characterization for thermoplastic sago starch is successfully evaluated.

5.2 Recommendations for Future Research

i) To study a new composition to be added in the thermoplastic sago starch matrix with various plasticizer such as sorbitol, glycerin and natural resources fibers.

ii) To study a coating material or method on preserving the properties of materials after being fabricated.

iii) To improve the fabrication process of material by using equipment that can produce high volume sample at one time to save cost and time.

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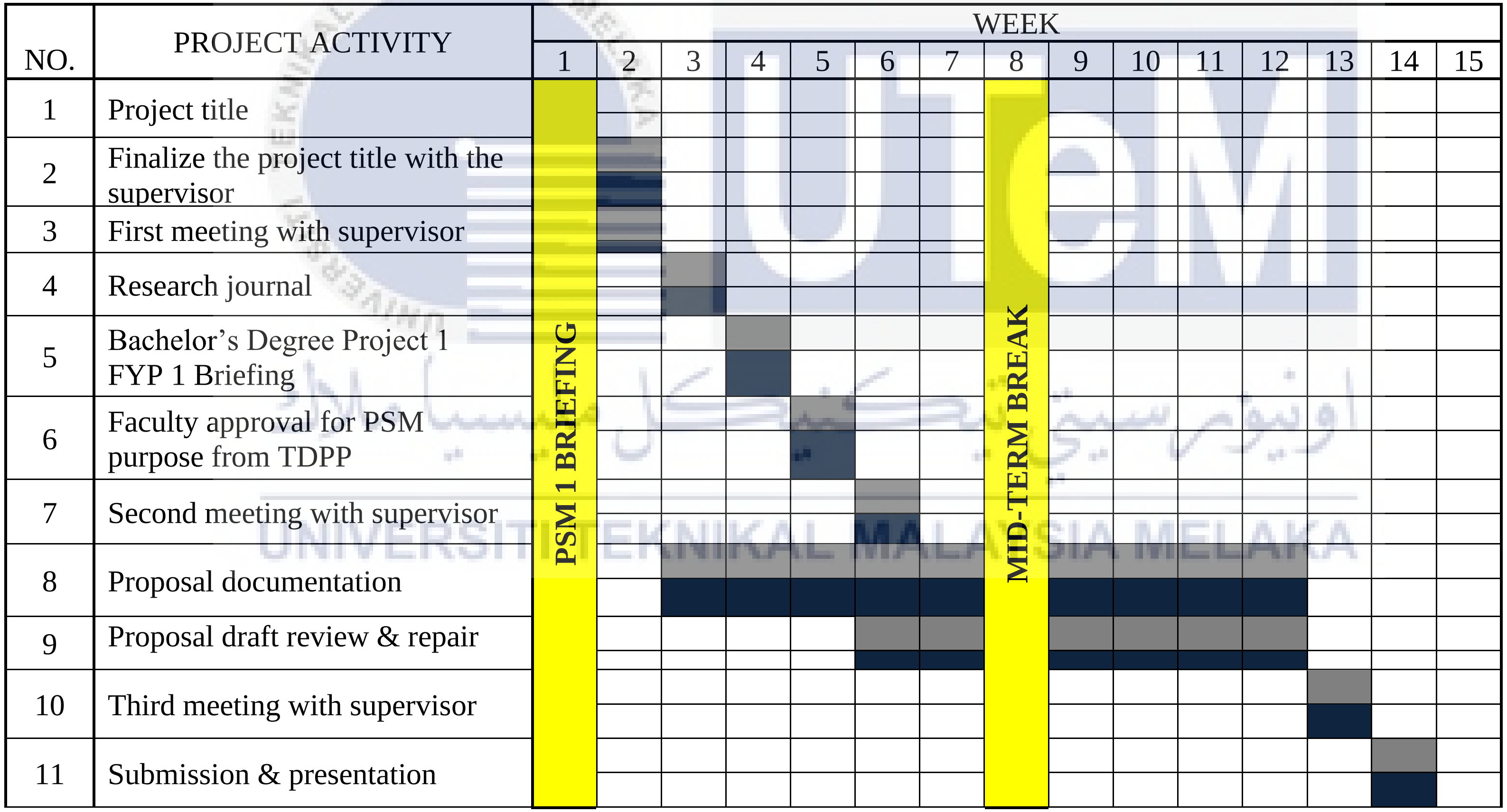
APPENDICES

APPENDIX A

Gantt Chart PSM 1



NO.	PROJECT ACTIVITY	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project title	PSM 1 BRIEFING							MID-TERM BREAK							
2	Finalize the project title with the supervisor		▨													
			■													
3	First meeting with supervisor		▨													
			■													
4	Research journal			▨												
				■												
5	Bachelor’s Degree Project 1 FYP 1 Briefing				▨											
					■											
6	Faculty approval for PSM purpose from TDPP					▨										
						■										
7	Second meeting with supervisor						▨									
							■									
8	Proposal documentation			▨	▨	▨	▨	▨		▨	▨	▨	▨			
				■	■	■	■	■		■	■	■	■			
9	Proposal draft review & repair						▨	▨		▨	▨	▨	▨			
							■	■		■	■	■	■			
10	Third meeting with supervisor													▨		
														■		
11	Submission & presentation														▨	
															■	

Expected: ▨
Actual: ■

APPENDIX B

Gantt Chart PSM 2

NO.	PROJECT ACTIVITY	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Research and journal study	PSM 1 BRIEFING							MID-TERM BREAK							
2	Thesis writing		▨	▨	▨	▨	▨	▨		▨	▨	▨				
			■	■	■	■	■	■		■	■	■				
3	First meeting with supervisor		▨													
			■													
4	Physical meeting and booking lab			▨												
				■												
5	Sample preparation 60 wt.%				▨	▨										
					■	■										
6	Sample preparation 65 and 70 wt.%					▨	▨	▨								
						■	■	■								
7	Sample preparation 75 and 80 wt.%						▨	▨		▨						
							■	■		■						
8	Physical testing										▨					
											■					
9	Environmental testing											▨	▨			
												■	■			
10	Third meeting with supervisor													▨		
														■		
11	Submission & presentation														▨	
															■	

Expected: ▨
Actual: ■

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **THE STUDY OF PHYSICAL AND ENVIRONMENTAL CHARACTERIZATION ON SAGO STARCH**

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

Saya **NURUL AFIQAH BINTI ZULKEFLAY**

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Tajuk Tesis: THE STUDY OF PHYSICAL AND ENVIRONMENTAL CHARACTERIZATION ON SAGO STARCH

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Sekian, terima kasih.

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