UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE STUDY OF PHYSICAL AND ENVIRONMENTAL CHARACTERIZATION OF SAGO STARCH MIXTURE WITH GLYCEROL

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

2023

Faculty of Mechanical and Manufacturing Engineering Technology

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

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I Muhammad Nizamuddin Bin Ja’afar Husni formally declare that this thesis' whole labor is mine. Entitled “The Study of Physical and Environmental Characterization on Sago Starch mixture with glycerol” unless as mentioned in the references, is the result of my own research. This thesis has not been accepted for any degree and is not being addressed at the same time.

Signature :

Name : MUHAMMAD NIZAMUDDIN BIN JA’AFAR HUSNI

Date : 11/1/2023

APPROVAL

I officially declare that I have reviewed this thesis and that, in my opinion, it is appropriate in scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Process and Technology) with Honours.

Signature :
Supervisor Name : TS . DR. NAZRI HUZAIMI BIN ZAKARIA
Date : 12/1/2023

DEDICATION

I would like to express my appreciation to my lovely families, especially my beloved wife Nur Nazilah Nazeri, my mother Norhuda Zaidan, and my father Ja'afar Husni Nuruddin for their devotion to educating and supporting me to pursue my education to the degree level. The sacrifices they made for me have made me proud to be a part of them. Further, I want to dedicate this essay to all of my siblings and friends, who have supported me tremendously in encouragement, motivation, and timely counsel in all aspects. Lastly, I want to thank my lecturer, and my supervisor for my PSM (*Projek Sarjana Muda)* Ts. Dr. Nazri Huzaimi bin Zakaria, and my classmate. Throughout my study, they have given me unlimited support and guidance. This study would be impossible to achieve in such a short amount of time without their blessing and encouragement.

ABSTRACT

Plastics are materials that are particularly flexible and have found use in a wide variety of applications, from easy packing to detailed engineering. The production of plastics has overtaken that of steel globally and still expanding. The manufacture of plastic products usually uses petroleum-based polymers and some of petroleum-based plastics are non-biodegradable. Consequently, the environment will be affected because the waste of non-biodegradable does not decompose. Sago starch has been broadly uses from food industry to manufacturing industry. However, there are some disadvantages of sago starch. Hence, this research presents the study of physical and environmental characterization of sago starch mixture with glycerol. The mixtures of sago starch with different weight percentages (wt.%) of glycerol as thermoplastics sago starch (TPSS) bio-composite. The mixtures of sago starch/glycerol contents were at 60/40 wt.%, 65/35 wt.%, 70/30 wt.%, 75/25 wt.%. The mixtures of sago starch / glycerol were made by using hot compression moulding machine to produces TPSS samples. The physical and environmental characteristic were done: Density testing, moisture content testing, water absoprtion testing, water solubility testing and soil burial testing. The physical test graph result show increment pattern on density testing. However, the graph result for moisture content testing, water absoprtion testing and water solubility testing shown decrement pattern. Last but not least, the environment test on soil burial graph result also shown decrement pattern.

ABSTRAK

Plastik ialah bahan yang sangat fleksibel dan telah didapati digunakan dalam pelbagai jenis aplikasi, daripada pembungkusan mudah kepada kejuruteraan terperinci. Pengeluaran plastik telah mengatasi pengeluaran keluli secara global dan masih berkembang. Pembuatan produk plastik biasanya menggunakan polimer berasaskan petroleum dan sesetengah plastik berasaskan petroleum tidak boleh biodegradasi. Akibatnya, alam sekitar akan terjejas kerana bahan buangan yang tidak terbiodegradasi tidak terurai. Pati sagu telah digunakan secara meluas daripada industri makanan kepada industri pembuatan. Walau bagaimanapun, terdapat beberapa kelemahan pati sagu. Justeru, kajian ini membentangkan kajian pencirian fizikal dan persekitaran campuran pati sagu dengan gliserol. Campuran kanji sagu dengan peratusan berat yang berbeza (berat%) gliserol sebagai matriks kanji sagu termoplastik (TPSS). Campuran kandungan pati sagu/gliserol adalah pada 60/40 wt.%, 65/35 wt.%, 70/30 wt.%, 75/25 wt.%. Campuran kanji sagu/gliserol dibuat dengan menggunakan mesin pengacuan mampatan panas untuk menghasilkan sampel TPSS. Ciri fizikal dan persekitaran telah dilakukan: Ujian ketumpatan, ujian kandungan lembapan, ujian penyerapan air, ujian keterlarutan air dan ujian pengebumian tanah. Keputusan graf ujian fizikal menunjukkan corak kenaikan pada ujian ketumpatan. Walau bagaimanapun, keputusan graf untuk ujian kandungan lembapan, ujian penyerapan air dan ujian keterlarutan air menunjukkan corak penyusutan. Akhir sekali, ujian alam sekitar pada hasil graf pengebumian tanah juga menunjukkan corak penyusutan.

ACKNOWLEDGEMENTS

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

First of all, I want to express my gratitude and praise to Allah the Almighty, my Creator and Sustainer, for all that I have received since the beginning of my life. I'd like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research environment. Thank you also for the financial support from the Malaysian Ministry of Higher Education (MOHE).

My deepest gratitude goes to my primary supervisor, Ts. Dr. Nazri Huzaimi bin Zakaria, lecturer at the Faculty of Mechanical and Manufacturing Technology Engineering Universiti Teknikal Malaysia Melaka (UTeM) for patiently guiding and assisting me during this semester of 2022 session. His knowledge, expertise, conscientiousness, suggestions, valuable comments, and helpful feedback that help me in completing this research project.

Lastly, I would like to thank to everyone who support me. Thank you for the spent time helping me related to this research. Without their support, I could not complete my research project successfully. Once again, I am grateful and honestly thankful to all.

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D,d - Diameter

% - Percentage

g/cm^3 - Gram per centimeter cubed

$^{\circ}$C - Degree Celcius

Wt. % - Written abbreviation for weight

V/W - Volume of a substance per unit of weight (mass)

ASTM - American Society for Testing and Materials

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Plastics are usually produced from synthetic polymers by adding various chemical additives. Synthetic polymers are often created by polymerizing monomers sourced from oil or gas (Halden, 2010) . Plastics are very flexible materials that are also cheap, light, strong, corrosion-resistant, durable, and have excellent thermal and electrical insulation qualities. Due to the variety of polymers and the adaptability of their qualities, a wide range of plastic items may be produced, which benefits society in a number of ways, including technical advancement, energy savings, and several other advantages (Nan et al., 2010). Plastic made from petroleum-based polymers are continually growing in engineering applications, including automotive industries, packaging industries and manufacturing industries. The waste disposal of petroleum-based polymer-based plastic will cause environmental damage in every aspect of life. The amount of plastic waste was increase due to production by plastic manufacture growing industry. Some part of the accumulated waste is recycled, other part is destructed and residue will continue to pollute the environment (Nagy & Kuti, 2016).

The "landfill problem", plastic consumption is a result of an environmental issue (Philp et al, 2013). Since dwindling disposal capacity, increased prices, and stricter environmental regulations, legislation, and in many places of the world, the growing amount of plastic waste has become a crisis. The "accumulation of plastics in oceans" is the second environmental issue. In addition, incineration of plastic releases hazardous pollutants like carbon dioxide and methane into the atmosphere. Moreover, Greenhouse gases (GHGs) play a role in global warming (Abrol & Adhya, 2017). Further, Plastic is not biodegradable, thus it will stay for hundreds of years in the ecosystem (Halden, 2010). Thus, "Competition for crude oil and energy security" is an economic issue.

Sago is a type of starch that is commonly extracted from the Metroxylon sago palm. It's mostly carbs and low in protein, fat, fiber, vitamins, and minerals. Starch is recognised as one of the most potential natural polymers currently accessible for the development of biodegradable products due to its enticing combination of qualities, including low cost, plentiful availability, thermoplastic behaviour, and biodegradability (Ali & Awale, 2016). Moreover, one of the renewable materials that can be used to create bioplastics or thermoplastics that degrade naturally is starch. The basic material for a bioplastic can be sago starch, which is obtained from sago trunks. In addition, starch is plentiful, has no colour, flavour, or smell, and has no negative effects on either people or the environment (Abd-Aziz, 2002).

A plasticizer is a substance that is applied to another material (typically a plastic or an elastomer) to soften or make it more malleable. Plasticization is the process of altering a polymer's structure to make it more bendable. Starch's drawbacks in terms of melting, high water solubility, processing difficulty, and brittleness require plasticizers to make it suitable for engineering applications. Additionally, little research has been done on sago starch as a viable raw material for bioplastics (Jabbar & Kale, 2015). Glycerol has many applications, one of which is as a plasticizer. To maintain the film delicate, glycerol, a very hygroscopic material, is frequently added to the polymer solution during the film formulation process. By using glycerol will cause its molecules to fill any gaps in the matrix and interact with the starch to create a film polymer. Hence, this research investigates the effects of using sago starch mixture with glycerol as a plasticizer on the physical, and environmental characteristic.

Bioplastic made from renewable resources with is sago starch as opposed to petroleum-based plastics (Yu & Chen, 2008). Bioplastic is energy efficient. Conventional plastic manufacturing requires less energy. On another side, plastic is created from approximately 4% of the oil consumed globally each year. Cause of the scarcity of oil, the creation of Plastics getting more and more fragile to economic fluctuations (Ezgi Bezirhan Arikan & Havva Duygu Ozsoy, 2015). Besides, bioplastic makes fewer greenhouse gases and contains no contaminants. According to Yu & Chen. (2008), bioplastics contribute significantly to the goal with only 0.49 kg CO2 emitted, and GHG emissions are being reduced for each kilogram of resin manufactured. It reduces when compared to petrochemicals, the potential for global warming is reduced by roughly 80%.

The primary goal of this research is to fabricate the composite matrix using biodegradable material which is sago starch mixed with glycerol or thermoplastic sago starch (TPSS) and investigated the physical and environmental characterization by different ratio percentage of TPSS. Therefore, five experimental methods which are density test, moisture content test, water absorption test, water solubility test and soil burial test have been used to investigated the properties of the TPSS.

1.2 Problem Statement

Non-degradable plastic can lead to waste disposal problems (Ismail et al., 2016). To counter this issue, biodegradable plastic development is needed. In this research, thermoplastic starch-based on sago starch mixture with glycerol. The polysaccharide groups of amylose and amylopectin in sago starch from the sago palm make it easy to gelatinize, extremely viscose, non-toxic, and biocompatible. However, due to their hydrophilic nature, starch-based materials have a low moisture barrier and others (Rudnik, 2007). Therefore, to increase interfacial adhesion with sago starch, glycerol was used as a plasticizer.

1.3 Research Objective

The research's general objective is to study the physical and environmental characterizations of sago starch mixture with glycerol. The specific objective is:

i. To fabricate sago starch mixture with glycerol.

ii. To investigate the properties of physical on sago starch mixture with glycerol.

iii. To find the properties of environmental on sago starch mixture with glycerol.

1.4 Scope Of Research

The focus of this research is to make a thermoplastic starch (TPSS) sample out of a sago starch and glycerol mixture with different concetration ratio (wt.%). Sago starch powder (25% amylose) and glycerol (95% purity) with a density of 1.261 g/cm3. The ratio of sago starch/glycerol (wt.%): 60/40, 65/35, 70/30, and 75/25. The sample will be poured into a mold with a dimension of 140 x 60 mm. The mold will be placed in a hot press machine by following parameter setting at a pressure of 25 kg/cm2, temperature of 165°C followed by heat time for 30 minutes and cooling for 15 minutes (Zuraida et al., 2012). The resulting samples will be cut into 4 sample testing sizes (10 x 10 x 3 mm) for each ratio of TPSS

The experiment method followed by the standard are:

i. Density testing (ASTM 792).

ii. Moisture content testing (ASTM G21).

iii. Water absorption testing (ASTM D570).

iv. Water solubility testing (ASTM D570).

v. Soil burial testing (ASTM G21).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Bioplastics, often known as biodegradable plastics, are plastics that had been using in the same way as ordinary plastics but can be simply thrown after use since they are dissolved by a microorganism (Nasution & Wulandari, 2021). According to Ezgi Bezirhan Arikan & Havva Duygu Ozsoy. (2015) Bioplastics are 21st-century new materials that will have a significant impact to the world of materials. Bioplastic manufacturing and usage will increase globally ahead. As a result, these materials must be carefully assessed for long-term viability and waste management.

The demand for materials with distinctive and unique qualities is still growing stronger. Materials with good qualities are still being required by industries for several different of applications in a wide range of industrial applications (Nagarajan et al., 2020). Composite are the only type of material that meets the demands of the industry. Composite materials are the only type of material that meets the needs of sector professionals. These materials are created by the desired qualities (Vigneshwaran et al., 2018). Metal, ceramic, and polymer composites are the three types of matrix materials used in composites. Polymer composite materials, among the different types of composite materials, play an important role in today's technology due to their superior physical and environmental features. Moreover, polymer-based Materials are used in a wide range of industries, including aerospace, vehicles, sports equipment, construction, and packaging. Nature fibers have recently been utilized materials used as reinforcement in the production of polymers matrix composite (PMCs). In bioplastic applications, polymer-based materials have been explored (Ravichandran et al., 2020).

Plastic that has been altered created from a combined with feedstock from agriculture, such as starch, provides a majestic solution to fulfil the qualifications and ensure at least partial breakdown of polymers to impart degradability (Mishra & Rai, 2006). Along with its appealing mix of properties like minimal rates, plentiful availability, and thermoplastic behavior. Starch is one of best potential natural polymers available for the manufacturing of things that are biodegradable (Sarifuddin et al., 2013). The linear amylose and highly branched amylopectin polysaccharide structures found in starch are the amylopectin (highly branched amylose) and amylose (linear amylose), respectively. Crystallinity in native starch is produced by intermolecular interactions and intramolecular hydrogen bonding between hydroxyl groups of starch molecules (Lin & Tung, 2009). In addition, it can respond like a thermoplastic material in the pre-plasticizer such as glycerol; at higher temperatures and lowest shear, it can quickly melt and flow, enables to be extruded or injected like most other synthetic thermoplastic polymers (Prachayawarakorn et al., 2010).

Bioplastics are created from renewable resources including tapioca, corn, potato, sago, etc. They're formed via a variety of microorganisms (Luengo et al., 2003). TPS (thermoplastic starch) is a biodegradable plastic with is relatively new biodegradable plastic. substance. Natural biopolymer starch is a low-cost option. Sago is one of the plants that has the ability to be used as a starch source (Metroxylon sp). Nevertheless, the structure of native starch needs to be properly changed before such material is produced. Because starch is a polymer with many hydroxyl groups, this is required. Because starch contains so many intermolecular and intramolecular hydrogen bonds, it is not regarded as a true thermoplastic. However, it rapidly melted and flowed in the distribution of plasticizers at higher temperatures and shear force (Nasution & Wulandari, 2021). Plasticizers are a sort of non-volatile, low-molecular-weight chemical which utilized as an implement in sectors of polymers. These compounds decrease a polymer's deformation tension, hardness, density, viscosity, and electrostatic charge while enhancing the polymer chain flexibility, fracture resistance, and dielectric constant. Resistance to biological deterioration is another property that is compromised (Vieira et al., 2011). Thus, the most widely used plasticizer is glycerol.

Lastly, comparable of bioplastic uses to conventional plastic but will be decomposed by microorganism activity upon environmental disposal, is one way to minimize the negative effect of plastic waste (Nissa et al., 2019). Therefore, the characteristic of the physical environment of sago starch mixture with glycerol will be examined because of how starch and glycerol work, which is it can be simply decomposed into eco-friendly compounds.

2.2 Composite

A composite is a substance created from two or more different materials which have significantly diverse characteristics, both physical and chemical. They are more powerful when used together than when used separately. Simply speaking, composites are made up of several different components. For instance, a material that compresses well may be combined with a material that stretches well to generate a compressible and stretchy composite. Before this, traditional materials included timber, mud, clay, wood, and straw. Traditional construction materials are those that have been used in a community or region for a long time to construct shelters and buildings. As a result, typical construction materials are heavy and expensive to transport and install, and the project takes longer to finish (Manalo et al., 2010). For this reason, composite is an alternative to replacing traditional materials. Since composite materials are constructed of synthetic materials with high strength-to-weight ratios, they are best categorised as high-performance systems.

Furthermore, composites are long-lasting because they have a better fracture toughness than the majority of polymers but a lower fracture toughness than metals. Because of the excellent dimensional stability, they can maintain their shape in hot or cold, damp or dry conditions (Prashanth et al., 2017).

Composite Properties

Composites typically have high strength, high modulus, and low density, as well as great wear resistance, corrosion, creep, and creep rupture. They also have a low coefficient of thermal expansion (CTE). According to Nan et al., (2010), when filler particles create a percolating network through the composite, particularly when there is a disparity in the constituent phases' characteristics is considerable, the physical properties of the composite occur. Electric conductivity and dielectric characteristics are used, near percolation, and physical properties are generally component independent. In theory, a similar increase as long as conductive fillers and an insulating matrix are utilised, electrical conductivity or dielectric constant can be seen.

Composite Process

In most composite production procedures, moulding is utilized to form the reinforcement and resin. A mould tool is required to shape the unformed resin and fibre mixture before and during the cure. Composite materials are transformed into a variety of goods and parts using moulding procedures. The more flexible resin, or matrix, gives the structure of the fiber, protects them, and distributes the load. The fibers provide strength and rigidity to the matrix, which helps it withstand cracks and fractures (Martin, 2019). In addition, fused deposition modelling (FDM) is the most significant additive manufacturing (AM) technology, it describes the process of building three-dimensional objects by adding consecutive layers of material in a computer-controlled environment. (Mohan et al., 2017).

Type of Composite

Polymer matrix composites (PMCs), metal matrix composites (MMCs), ceramic matrix composites (CMCs), and carbon matrix composites are the four basic forms of composites (CAMCs).

Polymer Matrix Composites (PMCs)

The continuous phase of PMCs is composed of a variety of organic polymers, and the dispersed phase is composed of reinforced fibres. As a matrix, the continuous phase holds the fibres together and enables effective load transfer between them. According to Mohan (2017), in PMCs, polymers are utilised as the basis matrix materials and metals, typically in the form of powder, are employed as reinforcement to create a material that combines the qualities of the two. The Properties including adhesiveness, flexibility, conductivity, process ability, toughness, and strength are influenced by the composition of the matrix and reinforcing elements. Apart from the electronic industry, polymers have the benefit of being easy to process, mechanically flexible, and inexpensive. Furthermore, the incorporation used of materials compatible with polymers used as electronic circuit support is required for integrating resistors and capacitors into the internal structure of printed wiring boards (PWB) or directly into integrated circuit packaging. Additionally, a variety of electromechanical devices use polymer materials to convert energy between electric and mechanical forms. (Dang et al., 2012). However, PMCs have low stiffness, handling abrasion sensitivity, and little fatigue resistance.

Metal Matrix Composite (MMCs)

Metals, alloys, or intermetallic compounds that have been reinforced with particles, whiskers, or continuous fibres are referred to as MMCs. Casting and powder metallurgy is used to create composite materials with a metal matrix. Casting techniques are used to create composite materials reinforced with platelets, dispersion particles, non-continuous (short), continuous (long), and hybrid reinforcement made up of particles. Composite materials reinforced by dispersion particles, platelets, non-continuous, and continuous are produced using powder metallurgy techniques (Kaczmar et al., 2000). Furthermore, MMCs have numerous because of their small weight, smooth surface, and mechanical qualities, they have applications in manufacturing. Its valuable applications in defence and space fields make it worthwhile to invest in potential low-cost and easy-to-use solutions. Functionally graded MMCs with both structural and non-structural engineering applications. The aeronautical industry could gain a lot from functionally grading MMCs because it would lead to affordable MMCs with the required functional properties at the required location of the product (S. Kumar et al., 2020).

Ceramic Matrix Composite (CMCs)

CMCs are a composite material and a ceramic material subgroup. They are constructed of fibres of ceramic material that are set into a ceramic matrix. Any ceramic material, including carbon and carbon fibres, can be used to create both the fibres and the matrix. A lot of people find ceramic materials intriguing because of their great strength and stiffness at very high temperatures, chemical inertness, low density, and other characteristics. This appealing package is marred by one fatal flaw: a complete lack of toughness. Therefore, is understandable that an overwhelming consideration in CMCs is to toughen the ceramics by putting fibres in them and therefore harness the desirable high-temperature strength and environmental resilience of ceramic materials without risking a catastrophic failure (Chawla, 2012).

Carbon Matrix Composite (CAMCs)

Carbon composites are a type of composite in which carbon fibers are embedded in a carbonaceous matrix. Carbon is a great high-temperature material when employed in an inert or non-oxidizing environment. CAMCs have the potential to be used in heat exchangers and heat sinks for a wide range of thermal management applications in HVAC&R systems, particularly in high-temperature and corrosive environments. Moreover, CAMCs provide new possibilities for heat exchanger design. Some of these new materials have greater in-plane thermal conductivity than all metals and alloys combined (Wang et al., 2012).

Composite application

Composites are versatile and used for both structural applications and components. According to Kaczmar (2000), in electrical sub-assemblies, laser devices, and computer sub-assemblies, composite materials should have strong heat conductivity, wear resistance, and the ability to link particular ceramics. For example, carbon fibre is used to reinforce composite materials having a copper base. Besides, textile composite applications are mostly addressed and used to deal with traditional man-made fiber. Because of the great demand for these materials for battlefield use, traditional man-made and high-performance fiber (Misnon et al., 2014). Furthermore, bioplastic composites such as corn waste fibers can be reinforcement to other natural fibers. The growing concern about sustainability has prompted the hunt for new composites, and there is potential and more research shall be done to bring the composition to the market. Maize waste fibers are lignocellulosic fibers made up of corn cobs, husks, stalks, and stovers that are frequently discarded (Bhalerao & Metkar, 2020).

Advantages and Disadvantages of Composite

Automobiles, golf clubs, plastic, and pipes are just a few of the goods that use composites. The strength of composites is mostly a result of their two main constituents, fibres and resins. Resin distribute weight as needed throughout the composite part, while fibers carry it. Composites are lightweight, have enhanced part-to-part homogeneity, and are easy to consolidate. as compared to the majority of woods and metals. The delicacy procedure is frequently used to make big thermoset parts, like parts with complex geometries, in automobiles and aircraft. When it comes to weight, less is more when it comes to fuel efficiency. Moreover, Composites can be developed to be far more durable than steel or aluminium. Metals are equally strong in all directions. Composites on the other hand, can be built and developed to be strong in a particular direction. Composite also can be strong and light. For example, building airplane body parts that need a very high strength material at the lowest possible weight. Furthermore, Composites can withstand the elements such as weather and harsh chemicals that can corrosion to other materials. Composites are a suitable alternative where chemicals are handled or stored. Compared to most other materials, composites are simpler to mould into intricate patterns. This enables architects to create virtually any shape or form. (Nagavally, 2016).

Composites include drawbacks such expensive fabrication and assembly expenses, high costs for raw materials, inadequate strength in the direction that bears the principal load (out of plane), sensitivity to impact damage, and more difficulty in repairs (Aleksendrić & Carlone, 2015). Non Destructive Testing (NDT methods in composite due to disadvantages of composite. Ultrasonic Testing, setup time, required competence to effectively to achieve reliable testing, a test sample must be used to scan a part. The form of testing is ideal for usage a production line where identical parts are used needs to be tested multiple times.

However, two ultrasonic NDT techniques are commonly utilized in distinct applications which are pulse-echo and via transmission. Thermography testing, this sort of inspection necessitates delicate and expensive instrumentation, highly qualified inspectors to operate the instruments, and a lack of clarity of faults if they are found too deeply beneath the part's surface (Gholizadeh, 2016).

2.3 Matrix / Binder in Composite

A binder or binding agent is any material or substance that holds or draws other materials together to form a cohesive whole, whether it does so mechanically, chemically, or by adhesion or cohesion. For example, the binder is necessary for the attachment of active materials to current collectors, and hence has an impact on anode and cathode stability (Lyness et al., 2018). A composite fibre system is embedded in a matrix, which is a homogeneous, monolithic material. Composites known as reinforcements frequently consist of one continuous component known as a matrix and one or more discontinuous phases. Reinforcing and matrix are the two components of composite materials. Ceramics, metals, or polymers are utilized for the matrix phase and ceramics, metals, or polymers are used for the reinforcing phase. In the meantime, the discontinuous phase varies in hardness depending on the application. (Sharma et al., 2020).

Matrix / Binder Purpose

The matrix's purpose is to remain the reinforcement particles positioned while also supporting them. Reinforcements, in general, have an impact on mechanical and physical properties, as well as any other customized properties that are improved by the matrix material. Furthermore, the matrix's purpose is to redistribute stresses across neighboring fibers and to prevent cracks from forming during fiber failure. Plastic (elastic) strains in the matrix or limited detachment of fibers from the matrix achieve the latter (Mikhjlin et al., 2002).

Type of Matrix / Binder in Composite

Classification of composite materials According to the matrix materials are polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs).

Polymer Matrix Composite (PMCs)

The polymer matrix, which maintains the reinforcing element in place and regulates the majority of degradative processes, is the continuous phase of composites (delamination, impact damage, chemical resistance, water absorption, and high-temperature creep). The manufacture of the binder is the first step in the manufacture of composite polymer materials. The viscosity of the binders is critical in the creation of the composite. The physical state and chemical composition of the binders and composites at various phases of conversion into the solid-state dictate the circumstances of following operations and molding (crystallization, glass transition, curing, vulcanization) (Mikhjlin et al., 2002). Polymer-based composites are commonly used materials because they have strong mechanical qualities and are low in density. Polymer-based materials are employed in a variety of industries, including aerospace, automobiles, sports equipment, construction, and packaging. Nature fibers have recently been utilized as reinforcement materials in the production of PMCs. Biodegradable applications have made use of polymer-based materials. In addition, PMCs have superior mechanical properties, and rigidity, are environmental, recyclable, and have a high surface-to-volume ratio (Ravichandran et al., 2020). Besides, PMCs are the best alternative for making bioplastic. Compared to typical metals or unreinforced polymers, PMCs are more attractive because they are lighter, stronger, and stiffer. They also have the advantage of having their properties and forms customised to fit a particular purpose. PMCs materials also offer a higher strength-to-weight ratio, lower thermal conductivity, dampening, and corrosion (Mohan et al., 2017)

Metal Matrix Composite (MMCs)

Metal or alloy continuous matrices with reinforcement in the form of particles, tiny fibres or whiskers, or continuous fibres make up metal matrix composites. To create MMCs materials, hard reinforcing particles are added to a metal matrix phase (Chawla, 2012). The cutting-edge materials known as Metal Matrix Composites are well-known. In terms of mechanical and thermal properties, such as superior wear resistance and thermal conductivity, MMCs surpass conventional materials. Typically, low-density metal alloys are used as the matrix of MMCs (e.g. aluminium, magnesium, or titanium). Due to their excellent forming and joining properties, low density, high strength, and corrosion resistance, aluminium alloys are frequently used in structural applications in the automotive and aerospace sectors (Sharma et al., 2020). Furthermore, In the powder blending method used to create MMCs, the matrix (base metal matrix and reinforcing powder) is mechanically blended in the appropriate ratio before being subjected to cold pressing, sintering, forging, and extrusion. The technique of making composites by mechanically combining the base metal matrix with reinforced particles is known as mechanical alloying. Hard material particles are dispersed into a relatively soft metal matrix using a high-energy ball mill, also referred to as an attractor. The resulting composite matrix was then further treated using forging and hot static pressing (Kumar et al., 2020).

Ceramic Matrix Composite (CMCs)

CMCs are composed of ceramic fibres, whiskers, and particles that are contained in a matrix formed of another type of ceramic. They are solid compounds with exceptionally strong bonds that are often ionic but occasionally covalent (Sharma et al., 2020). CMS is a class of advanced engineered structural material in which continuous fibres, chopped fibres, whiskers, platelets, or particles are included to reinforce ceramic or glass matrices. There are currently just a few high-temperature applications for CMCs, but they have a wide range of prospective usage in the military, aerospace, and commercial sectors, including energy-efficient systems and transportation. The combination of low density, high modulus, strength, toughness, and strength retention at high temperatures makes CMCs special as well. Many are resistant to corrosion and erosion in high-temperature applications (Rosso, 2006).

Advantages and Disadvantages of Matrix / Binder in Composite

Based on PMCs, the main benefits that allow for the widespread use of glass fibres in composites are high strength, good chemical resistance, availability, good handle-ability, ease of processing, and competitive price. The main drawbacks are low stiffness, sensitivity to abrasion during handling, and low fatigue resistance. (Gupta et al., 2014).

MMCs are recognised as state-of-the-art materials. In terms of mechanical and thermal properties, such as superior wear resistance and thermal conductivity, MMCs surpass conventional materials. The following benefits of MMCs over polymer matrix composites: greater temperature tolerance. Fire resistance. Improved transverse stiffness and strength. However, MMCs have disadvantages compared to PMC which are Fiber-reinforced systems that require sophisticated fabrication techniques (except for casting) and some material systems cause high costing (Gopalakannan & Senthilvelan, 2013).

CMCs are excellent for activities where other materials are insufficient because they can withstand higher temperatures than other material combinations. They can last longer since they are also more resistant to normal wear and tear than other composite materials. However, the CMCs disadvantage is brittle (Rosso, 2006).

2.4 Starch

The powder form of starch has no flavour or odour and cannot be dissolved in cold water, alcohol, or other solvents. Granules of starch, which are highly organised structures, are the most common form of starch. Due to its distinct thermal and functional characteristics, starch can be employed in a variety of food and industrial products (Ratnayake & Jackson, 2008). The chemical formula of the starch molecule is (C6H10O5). Most humans consume two-thirds of their daily caloric intake from the primary plant food resource, while Americans only consume 47% of their caloric intake, and roughly 52% of their caloric calories come from sugar (Kirk-othmer, 2000). Commercial starches are made from tubers or roots, such as potato, sweet potato, and tapioca, as well as seeds, particularly corn, waxy corn, high amylose corn, wheat, and rice (cassava). A polysaccharide, such as starch, is created when a chain of glucose molecules is joined together. The two different kinds of polysaccharides that can be found in starch (a highly branched chain of glucose) are amylose and amylopectin. Amylose has a molecular weight of less than 1x 10-5 and is essentially a linear polymer with (1-4) connections [and 2-5% a (1-6) links]. The molecular weight of amylopectin, a branching polymer with both (1-4) and (1-6) linkages, ranges from 50 to 500 million (Ratnayake & Jackson, 2008).

Purpose of Starch

Starch in biological function is a method for plants to reserve the energy. In an animal's diet, starch serves as a source of sugar. Amylase, an enzyme that breaks down starch and is present in saliva and the pancreas, is used by animals to make energy. To make glue, paste, and innovative bio-batteries, starch can be employed. Additionally, the many aspects of the starch structure are often what determine swelling power, starch solubility, gelatinization, re-degradation, syneresis, and rheological behaviour of starch granules. (Hubbe et al., 2020).

Starch sources.

Three sources of starch with are tapioca, potatoes, corn starch, and sago starch.

Tapioca starch

The cassava plant, which grows in equatorial regions between the Tropics of Cancer and Capricorn, produces tapioca starch in the form of roots. In many parts of the world, the cassava plant is known by several names: yucca in Central America, mandioca or manioca in Brazil, tapioca in India and Malaysia, and cassava or cassava in Southeast Asia and Africa (Breuninger et al., 2009). The grains of tapioca starch vary in size and shape from 5 to 35 m. 17% of it is made up of amylose. A superior starch should be white, have a pH between 4.7 and 5.3, and a moisture content between 10 and 13.5 percent. Because of its high viscosity, tapioca starch is a good binder (Ofman et al., 2004). Hence, this versatile starch can be used to thicken and stabilize fruit pies, soups, puddings, bread, sauces, soy, and meat products.

When used as a binder, tapioca starch will consolidate the bulk and prevent items from drying out while cooking. The benefit of tapioca starch is that it has no fat or cholesterol, making it an excellent option for persons who want to reduce their intake of saturated fat and dietary cholesterol. Additionally, tapioca contains less sodium. This product has 20 mg of calcium and 1.6 mg of iron per serving (Mishra & Rai, 2006). However, the disadvantages of tapioca starch are that it is mostly made up of carbohydrates. This means that diabetics should limit their consumption of tapioca-containing foods. It also provides a concentrated source of calorie. (Huang et al., 2017).

Potato Starch

The starch that has been taken from potatoes is known as potato starch. The cells of potato root tubers contain leucoplasts. The starch is extracted from the potatoes by crushing them, and the grains of starch are liberated from the dead cells. Crushed raw potatoes are used to make potato starch by isolating the starch granules from the cell-damaged material. After that, the starch is cleaned and dried. When dry, potato starch becomes white, powdery, and flour-like (Hashem & Darwish, 2010)**.**

Besides, processed potato starch is regarded as pure in comparison to most other starch forms for industrial uses. When compared to other commodity starches, potato starch has various special qualities that can be directly connected to its granular and molecular structures, such as exceptionally large and smooth granules, high levels of covalently bonded phosphate, long amylopectin chains, and high-molecular-weight amylose. Potato starch is a fantastic source of functional biopolymer for food and materials research because of these qualities. Potato starch, in particular, has a wide range of uses at the wet end, including the production of high-quality paper and the creation of viscous hydrocolloid systems. Furthermore, unlike most cereal starches, the native potato starch granule's well-ordered and dense structure makes it able to withstand enzymatic annihilation by hydrolytic enzymes such amyloglucosidases and α -amylases (Bertoft & Blennow, 2016).

The benefit of potato starch include its ability to increase insulin sensitivity, promote weight loss, and enhance colon and digestive health. Additionally, potatoes are a wonderful source of fibre, which keeps you fuller for longer and can aid with weight loss. By regulating blood sugar and cholesterol, fibre can help avoid heart disease. Additionally, potatoes are a great source of vitamins that support healthy bodily functioning and antioxidants that fight off diseases (Ratnayake & Jackson, 2008).

Corn Starch

Corn starch is the starch derived from corn grain. The starch is extracted from the kernel's endosperm. Corn starch is a fine, white powder made from corn endosperm. The endosperm is the nutrient-rich tissue that exists within the grain. Corn is a gluten-free grain, and corn starch is typically made without the use of any other ingredients. Corn starch is a common food ingredient that is frequently used to thicken sauces and soups, as well as to produce corn syrup and other sugars. Corn starch has the chemical formula (C6H10O5) and is typically composed of 27% amylose and 73% amylopectin. This amylose/amylopectin ratio, however, varies slightly depending on corn variety, environmental, and soil conditions (Lewandowicz et al., 2000).

The properties of corn starch are a white, tasteless, odorless powder that is used in food processing, papermaking, and the manufacture of industrial adhesives; it is also found in many cosmetics and oral pharmaceutical products. It has been used in surgical gloves as a lubricant. Moreover, Because of its wide variety, low cost, large-scale industrial production, and good film-forming properties, corn starch has been used as a renewable material for the development of biodegradable packaging (Zhou et al., 2004). The advantages of corn starch in terms of corn starch polymer are good for print application, low flammability, resistance to ultraviolet rays from the sun, compostable, and recycled by regrinding. Nevertheless, corn starch has low process ability and solubility in common organic solvents limiting its wide range of applications (Chi et al., 2008).

Comparison Between Tapioca Starch, Potato Starch, and Corn Starch

Corn starch, when compared to potato and tapioca starches, held the least amount of water. The viscosity of starches was almost the same at low concentration (0.1 percent, w/v), but increased curvilineal with increasing concentration to 0.5 percent in ascending order for tapioca, corn, and potato starches, and shear thinning behavior was observed at high concentration (5 percent, w/v). Corn starch had a high shear viscosity stability. Tapioca (4.80) had a lower pH than corn and potato starches, which had values of 6.24 and 7.15, respectively. The lower pH of tapioca starch may be due to the presence of more impurities incorporated into the starch during processing. potato starch formed a firm gel comparable to that of corn starch. The gel made from corn starch was brittle, stronger, and more adhesive, with a higher springiness. In comparison, tapioca starch gel was softer, less springy, gummy, and chewy. Hence, all of these starches had distinct properties due to their distinct granules when examined under a microscope. The high viscosity of potato starch can be used to gain an advantage in instant soups and sauces, whereas corn starch's high viscosity stability to acid and heat suggested a variety of potential applications in fermented milk products (Mishra & Rai, 2006).

2.5 Sago Starch

Sago is a type of starch that is commonly extracted from the Metroxylon sagu palm. It's mostly carbs and low in protein, fat, fiber, vitamins, and minerals. Sago starch is also used to treat fiber to make it easier to work with. This is known as sizing, and it helps to bind the fiber and give it a predictable slip for running on metal. The granules of sago starch are oval with a temple bell-like shape, a mean diameter of 37.59 m, and a Maltese cross, indicating the presence of some common internal ordering (Nasution & Wulandari, 2021).

Sago Starch Properties

Sago’s palm contains so much starch, dietary fiber, minerals, and vitamin B that it can be used as a source of energy in the human diet while also improving several beneficial physiological responses. Carbohydrates are the primary source of energy in the diet. The majority of carbohydrates in plants are starch. Sago has a starch content of about 88 percent, which is higher than that of most cereal grains and root plants. Amylose content in sago starch ranges between 21.4 and 30.0 percent. The amylopectins of sago starch have shorter internal chains than other starches. Amylose content and amylopectin internal structure will determine some functional and physicochemical properties of starch. Sago starch is more prone to swelling and has a lower enzyme digestibility than pea and maize starches. Sago starch had a higher gelatinization temperature and a lower peak viscosity than other starches, so it can be used as a stabilizer (Chunwei Du et al., 2020).

Sago starches had a lower gelatinization enthalpy and a higher tendency to regenerate. Sago starches had a lower shear-thinning degree and thixotropy than corn and potato starches, according to rheological results. Sago starch 1 gels had the highest hardness, adhesiveness, springiness, and cohesiveness, suggesting that they could be used as a food stabilizer (Du et al., 2020). In comparison to other forms of starch, sago starch granules are larger and more resistant to enzyme destruction. Furthermore, various forms of starch with pores on the granule surface area are vulnerable to enzyme attack. As a result, pre-treatment may be required before the hydrolysis process, particularly when utilizing enzymes (Azmi et al., 2017).

Sago Starch Process

The following is the procedure for extracting starch from palm stems. First, the locals choose the right palms for starch harvesting, often checking them with an ax cut into the trunk to see if the starch content is sufficient. Felling palms takes a lot of effort, and it's normally done by males. When palms grow far from home, the roots are sometimes moved to a processing place near the residence, usually by rafting. Because the roots are too lengthy and heavy to handle whole, they are frequently chopped into log portions. The logs are then debarked and the pith from the inside of the wood is removed. Typically, wooden pounders with a metal tip are used for this purpose. This practice is carried out mechanically in some parts of Malaysia and Indonesia using raspers. The next step is to remove the starch from the prepared pith and wash it away. The most common strainer for filtering is a fibrous coconut leaf sheath, however, artificial materials like cloth or nylon netting have recently been used. Hand kneading and trampling are also popular methods for processing (Lal, 2003). Figure 1 shows the flow diagram of sago starch.

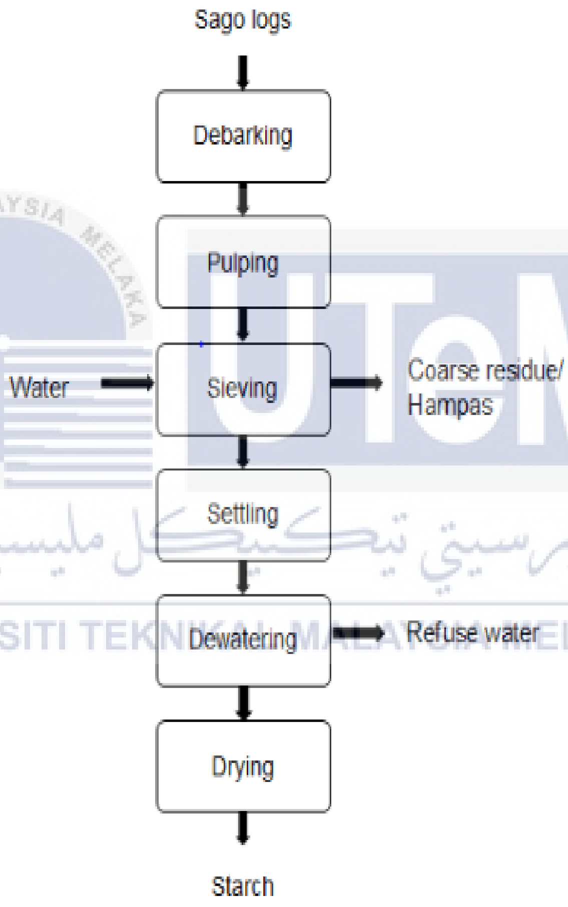


Figure 1. Sago starch process flow diagram

Sago Starch Application

Sago starch is processed for direct food consumption, pharmaceutical product, and fermentable sugar for other different products through bioconversion such as bioplastic. Sago starch has no flavor on its own and is usually flavored with other foods. Because sago has almost no fat or protein, it must be supplemented with foods obtained through hunting, fishing, gathering, or small gardens. Sago starch is durable and can be braided into bags, baskets, cages of various sizes, and rope (Abd-Aziz, 2002). Moreover, in this age of concern for the environment and economy, sago is the crop par excellence for sustainable agriculture and profitability. In addition, Because of its numerous applications in diverse industries, sago starch will always be in demand. Sago starch, for example, is used to make 'cendol' in the food industry. It is also utilized as a stabilizer, thickener, and glue in the non-food industry (Azmi et al., 2017). In addition, sago palms have a high potential for starch production. Sago is a source of starch, which is a well-known and abundant renewable raw material. Sago starch ranks fifth in terms of agricultural revenue in Malaysia, after pepper, palm oil, cocoa, and rubber.

Advantages and Disadvantages of Sago Starch

The benefits of using sago starch are it contains a wide range of solid and liquid components produced as a by-product of the sago starch processing industry. Due to its organic composition and low ash level, numerous products have been attempted, including fermentable sugar, enzyme, mushroom compost, animal feed, and adsorbent. The use of sago residue will not only reduce pollution from the sago processing industry but will also provide a cost-effective waste management strategy for sago processing mills (Vincent, 2020). However, there are some disadvantages of using sago starch which is the extraction of starch from sago pith necessitates a big amount of water, and a large amount of wastewater was emitted from sago mills. The majority of sago wastewater is liquid (94-97 percent). Thus, the solid trash known as 'hampers' will cause several treatment issues. Furthermore, the absence of apparent enforcement on wastewater disposal by the competent authorities resulted in considerable river contamination (Vincent, 2020).

2.6 Plasticizer Agent Glycerol

Plasticizer

A plasticizer is a substance that is applied to another material (typically a plastic or an elastomer) to soften or make it more malleable. Plasticization is the process of altering a polymer's structure to make it more bendable. Plasticization occurs when heat is applied to thermoplastic polymers. Plasticizers are chemicals that are added to plastics to make them more flexible, durable, and pliable. Toys, food packaging, paints, medicines, medical equipment, catheters, blood transfusion devices, personal-care goods, cosmetics, and PVC flooring all include phthalates, which are the most extensively used plasticizers in PVC plastics. In Taiwan, adding "cloudy agents" to foods was a widespread method for food processing. These hazy substances were usually a mix of formulations that worked as emulsifiers to keep emulsion-type foods stable. For reasons of reduced costs and longer preservation duration, plasticizers such as phthalates were contaminated by the hazy agents (Li & Ko, 2012). Plasticizer class of polyhydric alcohols, for example, glycerol.

Glycerol

Glycerol is the simple triol [56-81-5], $C_3H_8O_3$, Mr 92.09, 1,2,3- propanetriol, often known as glycerin. It is an essential step in the metabolism of living organisms and can be found as fatty esters of all-natural fats and oils. Glycerol is a valuable by-product in the production of biodiesel via transesterification, soap via saponification, and hydrolysis reactions. Due to the presence of impurities such as the remaining catalyst, water, soaps, salts, and esters formed during the reaction, the purity of the glycerol obtained is low. Because of the dramatic growth of the biodiesel industry, there has been a surge in interest in glycerol purification and conversion into valuable products in recent year. (Tan, Abldu Aziz, 2013). In addition, glycerol is used in a wide range of applications due to its unique combination of chemical and physical properties, as well as its physiological innocuity.

Physical Properties of Glycerol

Glycerol is a sweet-tasting hygroscopic liquid that is colorless and odorless when pure. It is viscous at room temperature. Cause of its three hydroxyl groups, glycerol possesses beneficial solvent characteristics similar to water and simple aliphatic alcohols. It is entirely miscible with water, methanol, ethanol, and the isomers of propanol, butanol, and pentanol, according to the manufacturer. Acetone, diethyl ether, and dioxane, on the other hand, are restricted. Hydrocarbons, long-chain aliphatic alcohols, fatty oils, and halogenated solvents like chloroform are almost insoluble in glycerol. Glycerol is a significant solvent for the manufacture of medications since it can dissolve a wide range of materials, both organic and inorganic. Like other liquids, the solubility of gases in glycerol is temperature and pressure-dependent (Wernke, 2014).

Chemical Properties of Glycerol

Glycerol is a type of organic compound with the chemical formula $C_3H_8O_3$. It is the same as glycerine, propane-1,2,3-triol, 1,2,3-trihydroxypropane, glycerol, and glycyl alcohol. Glycerol is low-toxicity alcohol composed of three carbon chains, each with a hydroxyl group attached. It is made from either natural or petrochemical feedstocks. Glycerol is almost non-toxic to both humans and the environment. Moreover, under normal storage and handling conditions, glycerol is chemically stable; however, it can become explosive when exposed to strong oxidizing agents such as potassium chlorate. Cause of the presence of primary and secondary alcoholic groups that can be replaced with other chemical groups, glycerol is a reactive molecule with a greater number of reactions. It also undergoes several reactions that result in the formation of other derivatives such as ether, ester, amine, and aldehyde (Tan, Abldu Aziz, 2013).

Glycerol as Plasticizer Agent

Owing to great plasticizing capacity and thermal durability at processing temperatures, glycerol is the most often used plasticizer. As a plasticizer, glycerol improves the ability of bioplastics to absorb water and acts as a crystal-forming agent. Other features of glycerol as natural plasticizers include toxicity and limited mass transfer. According to Thomazine (2005), in the edible film industry, glycerol and sorbitol are both excellent plasticizers. Glycerol to sorbitol ratios of 0:100, 20:80, 40:60, 60:40, 80:20, and 100:0 were investigated. As expected, increasing the plasticizer content from 25 to 55 g plasticizer/100 g gelatin increased flexibility while lowering resistance and water vapor barrier. Due to the stronger plasticizing impact of glycerol, an increase in the proportion of glycerol resulted in a drop in the puncture force, tensile strength, modulus of elasticity, and an increase in the puncture deformation, elongation at break, and water vapor permeability. This trend was explained in terms of the plasticizers' molecular weight, demonstrating that the investigated features may be viewed as functions of the number of plasticizer molecules in the mixture. Besides, according to Lusiana (2019), the water content of bioplastics will grow when more glycerol and sorbitol are utilized, which will decrease the tensile strength of the plastic since it will increase its flexibility. Because the plasticizer molecule disrupts starch compactness, reduces hydrogen interaction, and increases polymer mobility.

Advantages and Disadvantages of Glycerol as Plasticizer Agent

The advantage of Glycerol is it has a strong plasticizing capacity and maintains its thermal stability at processing temperatures. According to Ardi et al. (2015), the development of crude glycerol purification processes utilizing a variety of methods Chemical pre-treatment, methanol removal, vacuum distillation, ion exchange, activated carbon, and membrane separation technology are among the procedures for crude glycerol purification that are discussed in detail. Therefore, the Glycerol purification technique holds promise for using glycerol as a platform for a variety of applications, as well as for converting bio-glycerol to value-added compounds. The abundance of crude glycerol would boost the use of glycerol-based products, elevating glycerol's status as a significant building block chemical in the industry. However, the disadvantages of plasticizer glycerol required high energy, a high cost of regeneration, and are unfeasible for small-scale industry (Kumar et al., 2019).

2.7 Sago Starch Bioplastic Plasticizing with Glycerol

Bioplastics are plastics that can be used in the same way as traditional plastics but can be readily thrown after use since they are destroyed by microorganisms. TPS (thermoplastic starch) is a relatively new biodegradable plastic substance. Biopolymer starch is a low-cost natural biopolymer. Sago is one of the plants that have the potential to be used as a source of starch (Metroxylon sp). However, the structure of native starch needs to be properly changed before such material is produced. Because starch is a polymer with many hydroxyl groups, this is required. Because starch contains so many intermolecular and intramolecular hydrogen bonds, it is not regarded as a true thermoplastic. However, it rapidly melted and flowed in the presence of plasticizers at high temperatures and under shear (Nasution & Wulandari, 2021).

Plasticizers must be added to edible films to overcome the brittle character of the film caused by large intermolecular pressures. Plasticizers are a type of non-volatile molecule with a low molecular weight that is frequently utilized as an additive in the polymer industry. These compounds decrease a polymer's deformation tension, hardness, density, viscosity, and electrostatic charge while enhancing the polymer chain flexibility, fracture resistance, and dielectric constant. Resistance to biological deterioration is another property that is affected. Glycerol is the most commonly used plasticizer (Lintang et al., 2021).

According to Quintana et al (2008), because un-plasticized starch is brittle, adding the plasticizer (glycerol) reduced tensile strength while increasing elongation at break. This is because the plasticizer interferes with the polymeric chain's sliding, increasing the film's flexibility.

Besides, researchers and industry are increasingly looking into biopolymer-based packaging as a potential alternative to synthetic polymer-based food packaging materials. These so-called green packaging materials, or bioplastics, account for around 5%-10% of Europe's current plastic market (about 50,000 t) (Alebooyeh et al., 2012).

2.8 Fabrication of Sago Starch Mixture with Glycerol

Sago starch powder was dried for 24 hours in a vacuum oven at 80°C. The TPSS was prepared at 40/60, 35/65, and 30/70 glycerol/starch weight ratios before being mechanically agitated for 5 minutes. After that, the mixture was kept for 24 hours in an airtight polyethylene bag at a temperature of 20-25oC (relative humidity of 605oC). At 130°C and 100 rpm, the TPSS was melt-blended with a twin-screw extruder (Thermo HAAKE Rheomix 600). The extrudate was then granulated before being compression molded in a hydraulic press heated by electricity (Compression Moulding Machine). The hot press was preheated for 6 minutes at 150°C and then compressed for 3 minutes at 150°C. Cold-pressed for 2 minutes the compression-molded sheet (150 x 150 x 2 mm) (Zuraida, Nur Humairah, et al., 2012).

According to Lintang et al. (2021), for about 10 minutes, a 5 percent (w/v) sago starch solution is agitated until homogenous, then filtered through a filter cloth. The starch suspension is placed in a 1,000 ml cup glass and heated in a water bath solution temperature of 65-70°C for 10 minutes while stirring (30-40 rpm), then gradually added CMC (0.5 percent w/v) while continuing to heat and stir until the starch suspension thickens. The solution is then chilled after adding glycerol as directed in treatment 1; 1.25; 1.5; 1.75; 2; 3.75; (percent v/v). The solution is then poured into a glass plate mold with dimensions of 8 x 7 x 2 cm (length, width, and thickness) and dried for 10-12 hours at 60 degrees Celsius. After removing the film from the mold, it was stored for 12 hours in a plastic container filled with silica gel. In a plastic container, relative humidity is roughly 40-50 percent. After that, the film is divided into sections based on the parameters to be examined. Three x tensile strength and elongation tests were performed, while a circle with a diameter of 7 cm was created for WVTR. 2 cm x 2 cm is the solubility. The film was conditioned for 24 hours in a plastic container containing silica gel before being measured.

Under Kormin et al. (2019), sample preparation for sago starch. Before sample preparation, the starch and Low-density polyethylene were dried in an oven at 70 °C for 24 hours and then chilled in a desiccator for 1 hour to ensure moisture removal. After mixing the sample, it was stored in an airtight plastic container to equilibrate for 12 hours at 25 degrees Celsius before being extruded. A Bra bender twin-screw extruder was used to compound the LDPE/starch blend. The temperature was set at 150°C/150°C/140°C/140°C. The sample was manually put into the extruder as much as it could handle. For each formulation, the extrudes were palletized and stored in an airtight plastic container using a pelletizer machine.

According to Mohamed et al. (2017), In a 150mL beaker, 10g of sago starch was weighed with an analytical balance. Based on the weight of sago starch, it was then mixed with 20% glycerol, which acts as a plasticizer. At 90-100°C, the mixture was mixed with 100mL distilled water to gel the sago/glycerol system. The mixture is stirred in an 80°C water bath until it becomes sticky. The crosslinking agent is then added to the glycerol SS at a rate of 2% depending on the weight of sago starch/glycerol; a similar method was followed with the other crosslinking agents. Malonic acid, glyoxal, dicyandiamide, borax, and PEG are used to crosslink 40 percent glycerol. After the starch had gelatinized, the films were made using the solution casting procedure in the aluminum molds that had been provided. The produced samples were then placed in an oven set to 80°C to form film samples. Malonic acid, glyoxal, dicyandiamide, borax, and PEG were used to crosslink the glycerol.

Moreover, according to Zuraida, Yusliza, et al. (2012), due to a mixture of sago starch with glycerol. starch powder, glycerol, and citric acid are mixed. Sago starch (25 percent amylose) is what it's all about. Glycerol (95 percent purity) was utilized to plasticize the starch, with citric acid and water serving as a co-plasticizer. The material ratios are shown in **Table 1** and glycerol-mono-stearate was used as a lubricant. The components were mixed to make bio-plastic starch (BPS), which was then held for 24 hours at room temperature in airtight polyethylene bags before being processed with a twin-screw extruder (Thermo HAAKE Rheomix 600) for melt blending purposes at a temperature of 130°C and 100 rpm. The extrude was granulated and kept for 48 hours under controlled circumstances before being injection molded according to the parameters listed in Table 2 (Ahmad et al., 2011).

Table 1. Thermoplastic starch with different glycerol's content

Sample	Glycerol (w/w%)
G1	15
G2	20
G3	30
G4	40

Table 2. Injection moulding parameters

Injection pressure	Injection rate	Holding Pressure	Temperature Z1	Temperature Z2	Temperature Z3	Temperature Z4	Temperature Z5
1400 bar	$50\ cm^3/s$	600 bar	110°C	115°C	120°C	125°C	150°C

2.9 Properties of physical on Sago Starch Mixture with Glycerol Based on Past Literature Review

Density

The thermoplastic sago starch (TPSS) density test at various plasticizer/starch concentrations shows higher glycerol/starch ratios resulting in lower density than lower ratios. 30/70, 35/65, and 40/60 had density values of 1.43, 1.37, and 1.34 g/cm3, respectively. The inclusion of glycerol caused structural changes in the starch network, resulting in a less dense film matrix. The particle spacing is also represented by the glycerol/starch ratio. Lowering the ratio resulted in closer spacing between the starch particles, resulting in fewer voids and a denser substance (Zuraida, Nur Humairah, et al., 2012). **Figure 2** shows the density of TPSS with different glycerol/starch ratios.

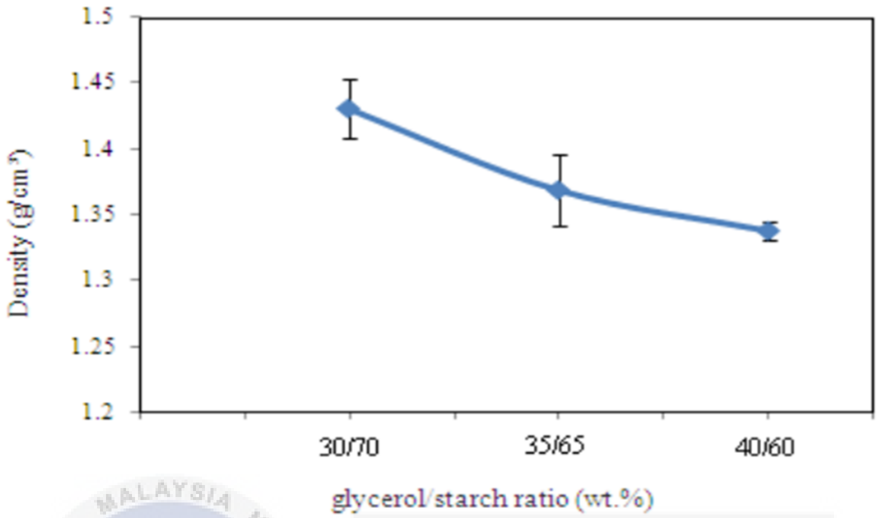


Figure 2. The density of TPSS with different glycerol/starch ratios

Moisture Content

According to Lai et al. (2013), Fresh sago pith wastes (SPW) contains 82 percent moisture by weight, according to moisture content analysis. The CE diameter of the SPW particles is 29.41 um in terms of particle size dispersion. The CE diameter of 50% of the total particles is 24.82 um or less, while the CE diameter of 90% of the particles is 44.82 um or smaller, as per the analysis. In the case of pure sago starch, the results demonstrate that 50% and 90% of the granules have a CE diameter of 27.85 um and 40.91 um or less, respectively, while the mean CE diameter is 28.43 um. In terms of mean CE diameter and particle size distribution, the two samples are comparable. Therefore, Glycerol began to evaporate at 150°C and volatilized when the temperature reached roughly 310°C, which is consistent with the compound's boiling point of 290°C. The temperatures at which SPW fibers (without sago starch) and pure sago starch begin to degrade are 220°C and 275°C, respectively. Sago starch is the most heat-resistant chemical among the three components when it comes to onset degradation temperatures. **Table 3** shows plasticized SPW and their moisture content analysis.

Table 3. Moisture content of SPW

Component	Moisture content (%)
Glycerol	0.68
SPW fiber	7.97
Sago starch	15.14

According to Zuraida, Nur Humairah, et al. (2012), The moisture content and the glycerol/starch ratio have a similar relationship (**Figure 3**). Due to the hydrophilic nature of starch which is directly proportional to voids volume among the starch particles, the maximum ratio of 40/60 yielded 11.5 percent moisture content, whereas thermoplastic sago starch (TPSS) with 35/65 and 30/70 ratios yielded 10.9 percent and 6.2 percent moisture content, respectively.

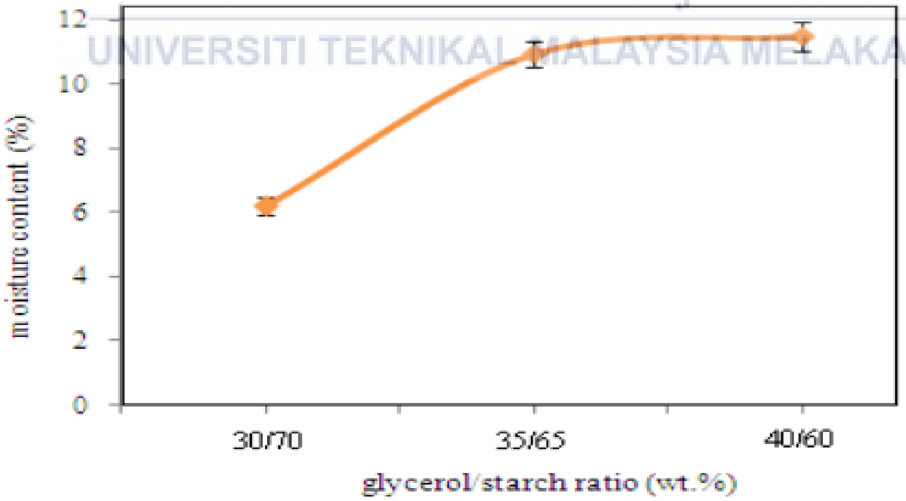


Figure 3. Moisture content of TPSS with different glycerol/starch ratios

Water Absorption

According to Lusiana et al. (2019), Water absorption is another term for water uptake, and bioplastics are predicted to have minimal water absorption. The findings of the response surface methodology RSM analysis revealed the impact of process factors on water uptake response. The influence can be seen as a variable code in the coefficient of the quadratic equation from the water uptake model. Because the nature of glycerol and sorbitol is hydrophilic, enhancing water absorption, and increasing plasticizers tend to create water uptake values that are directly proportionate. **Figure 4** shows that as compared to glycerol, the value of sorbitol water uptake is higher. Sorbitol plasticizer has a lower ability to bind water than glycerol, which is likely to result in a lower percentage of water uptake for sorbitol plasticizer. It is also influenced by the addition of polyvinyl alcohol (PVA) in this study; it is known that the combination of starch and PVA is a hydrophilic polymer since they are both soluble in water, allowing PVA to expand rapidly in water. It may be inferred that adding PVA to starch and using glycerol plasticizers increased the plasticizer's hydrophilic characteristics when compared to using sorbitol plasticizers.

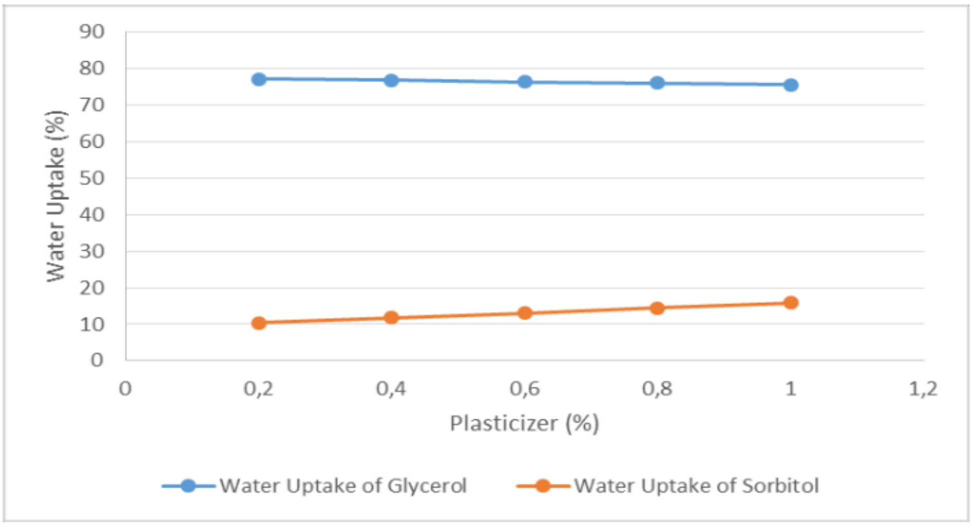


Figure 4. Water uptake of glycerol and sorbitol

According to Sarifuddin et al. (2013), water sensitivity is an important metric for many natural resource-based products. The impact of kenaf core fiber (KCF) loading on the moisture absorption properties of a low-density polyethylene (LDPE)/ thermoplastic sago starch (TPSS) blend. The absorption behaviour of composites is determined by immersing them in water at room temperature and measuring the rate at which water diffuses into the composite. The water absorption capacity of the LDPE/TPSS blend gradually increased after KCF was added. It can be said that the absorption kinetics are quick at the beginning of the process, but gradually the growth rates slow down and eventually approach a plateau. The water absorption at equilibrium is represented by this plateau. Water absorption is of the same order in all of the composites (10–40 wt percent KCF loading). It took around 5 days for samples to reach absorption equilibrium after immersion. Theoretically, because of the hydrophobic property of non-polar LDPE, the presence of LDPE in the composite could significantly reduce water absorption and lessen water sensitivity. However, it's worth noting that the observed increase in water absorption capacity is largely dependent on the presence of KCF and TPSS. **Figure 5** shows the water uptake of LDPE/TPSS/KCF composites at different KCF loadings.

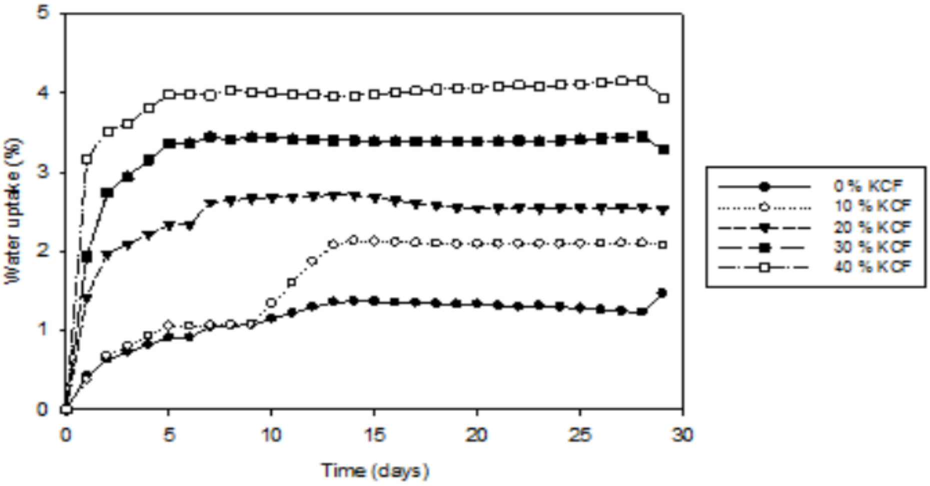


Figure 5. Water uptake of LDPE/TPSS/KCF composites at different KCF loadings

Water solubility

According to Maizura et al. (2007), each film was sliced into 2 x 3 cm pieces and stored in a desiccator with silica gel (0 percent RH) for 7 days. The samples were weighed to the closest 0.0001 g and placed in deionized water beakers with 80 mL. The samples were kept at room temperature (about 25°C) for 1 hour with steady agitation. After soaking, the residual bits of the film were filtered through filter paper and oven-dried to a consistent weight at 60 degrees Celsius. The proportion of total soluble matter (percent solubility) was estimated using three replicates of the samples. **Figure 6** shows the effect of lemongrass oil on the water solubility of film in the presence and absence of glycerol.

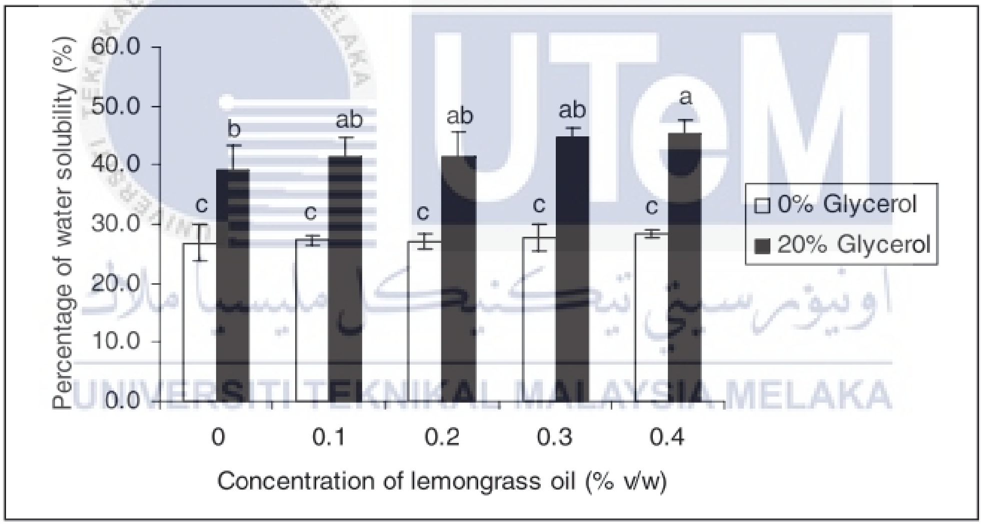


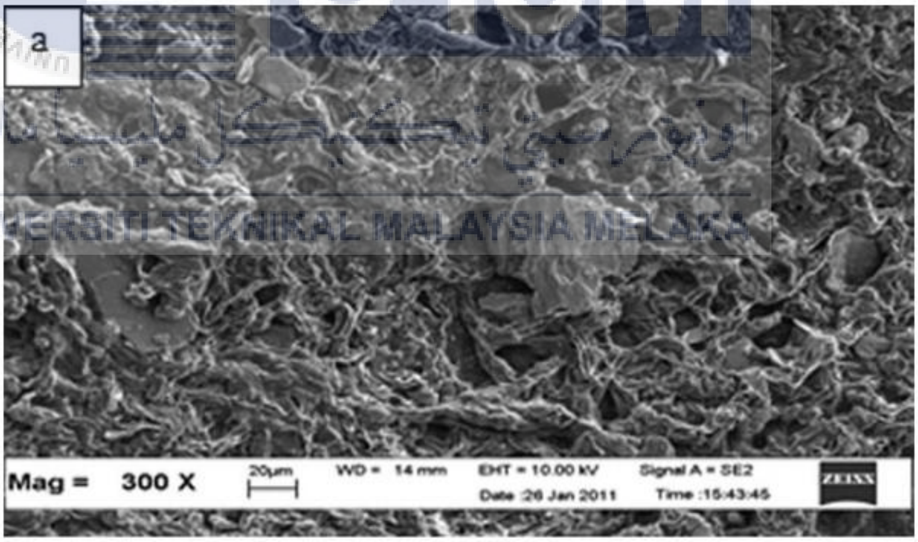
Figure 6. Water Solubility of Lemongrass oil

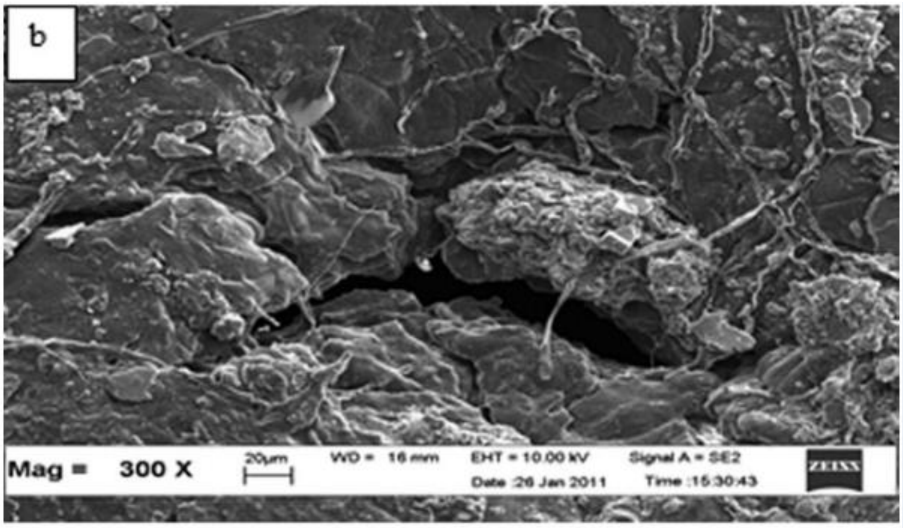
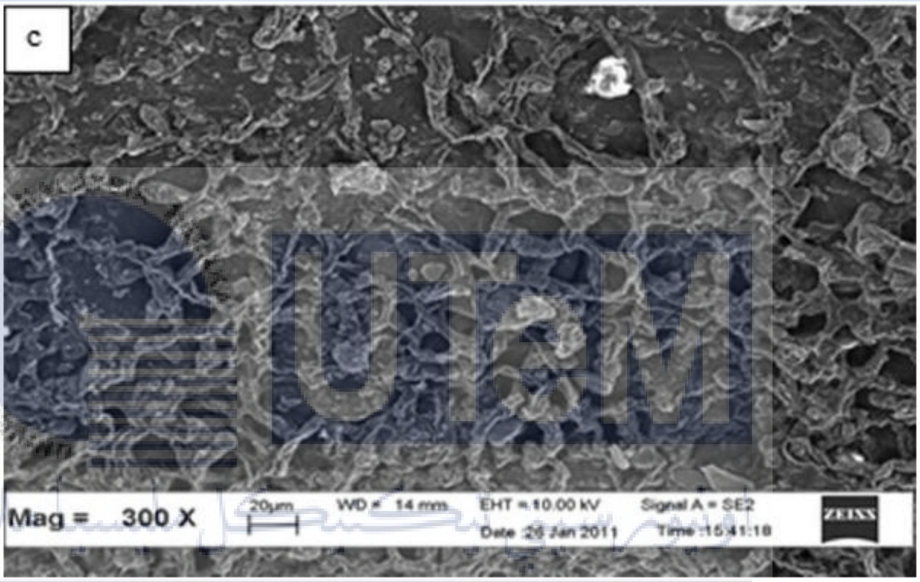
2.10 Properties of Environmental on Sago Starch Mixture with Glycerol Based on Past Literature Review

Soil burial

A modest adjustment was made to the soil burial degradation process. The polymer bags, which had a capacity of around 10 liters, were filled with soil collected from a nearby location and left to decompose naturally in the environment. The plastic samples were cut into dumbbells and buried at a depth of 10 cm in the soil. After 7 days, the degradation of each specimen was determined by carefully removing it and gently washing it with distilled water to remove soil. The specimen's morphology was examined using a scanning electron microscope (SEM). SEM micrographs of sago starch polymeric films after soil burial degradation are shown in **Table 4** In comparison to between result (a) and result(c). Result (b) reveals a poorer surface structure. The variation is attributable to the blends' varied formulas. Films containing a lot of plasticizers degraded more quickly. The plasticizer is hydrophilic, which means it absorbs water and hence increases microbial activity (Ismail & Zaaba, 2012).

Table 4. SEM micrographs on sago starch

Num. of result	SEM micrographs
a	

b	
c	

Beside, according Zakaria et al. (2020), **Figure 7** represents the weight loss of PALF/TPCS bio-composites after soil burial process in two different periods of two (2) and four (4) weeks. The result shows higher weight losses of soil burial in all bio-composites for 4 weeks compared with 2 weeks because the extent of degradation was inversely proportional to the fiber content implying that the composites were completely degradable. Thus, one of the factors is the biodegradation in the composites occurred due to the microorganism involement.

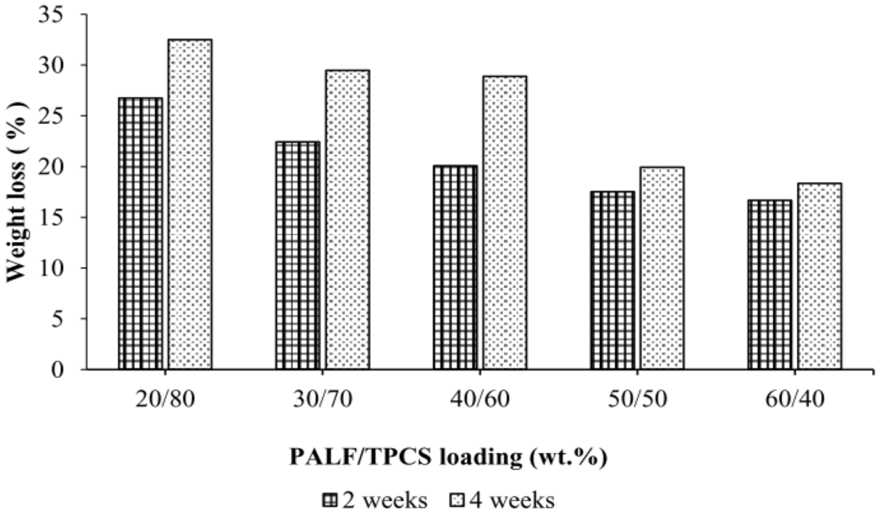


Figure 7. The soil burial for PALF/TPCS bio-composite in 2 weeks and 4 weeks

2.11 Summary

In a conclusion, the goal of biodegradability research is to determine how long bioplastics take to decompose in the environment (Lusiana et al., 2019). There was a long tradition of using fiber as reinforcement materials to form a composite. Since the 1960s, the use of synthetic fibers increased drastically. The use of fiber as a reinforcement material in composites has a long history. The use of synthetic fibers has grown since the 1960s (Shafer, 1962). PMCs have superior mechanical properties, and rigidity, are environmental, recyclable, and have a high surface-to-volume ratio (Ravichandran et al., 2). Hence, PMCs are the best alternative for making bioplastic.

Sago is a species of palm plant native to the wet tropical region with a high carbohydrate content of 84.7 grams per 100 grams and 21.7 grams of amylose. Sago has the potential to be a source of starch-based bioplastics due to its high carbohydrate and amylose content (Lusiana et al., 2019). Moreover, plasticizers like sorbitol and glycerol can quickly and easily permeate the starch network, forming a stronger and thicker film than the un-plasticized film.

Glycerol films, on the other hand, absorb more moisture than sorbitol films at the same plasticizer content, RH, and temperature. Hence, glycerol-plasticized films were better flexible than sorbitol-plasticized films (Mohamed et al., 2017).

In certain biodegradation tests, glycerol plasticizers perform better, whereas sorbitol performs better in others. The highest biodegradation value is 82.38 percent, while the best tensile strength value is 16.12 MPa, 142.05 percent in elongation, tear strength is 12.729 kg/mm, and water uptake value is 10.34 percent for glycerol plasticizer. This is due to the hydrophilic properties of glycerol and sorbitol; glycerol has a greater propensity to absorb water than sorbitol, making glycerol more hydrophilic (Lusiana et al., 2019). Furthermore, according to Ahmad et al. (2011), SEM analysis revealed that thermoplastic starch (TPS) plasticized with 30% glycerol resulted in finer granules than native starch, which had a clean and smooth surface.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Plastic manufacture products usually uses petroleum-based polymers and some of petroleum-based plastics are non-biodegradable. Consequently, the environment will be affected because the waste of non-biodegradable does not decompose. Hence, the biodegradable plastic need to be develop in order to reduce environmental affected (Nagy & Kuti, 2016). One of the renewable resources that can be turned into biodegradable thermoplastic or biopolymer composite is starch. Glycerol was used as a plasticizer to improve the interfacial adhesion of sago starch in this study (Lusiana et al., 2019). Four samples with different concentrations of sago starch and glycerol were fabricated by using hot press machine to make thermoplastic sago starch (TPSS). Due to the research purpose, 5 method of testing which are density, moisture content, water absorption, water solubility and soil burial will be carried out to investigated the physical and environmental characterization on sago starch mixture with glycerol.

3.2 Flow Chart

Figure 8 shows the process flow chart

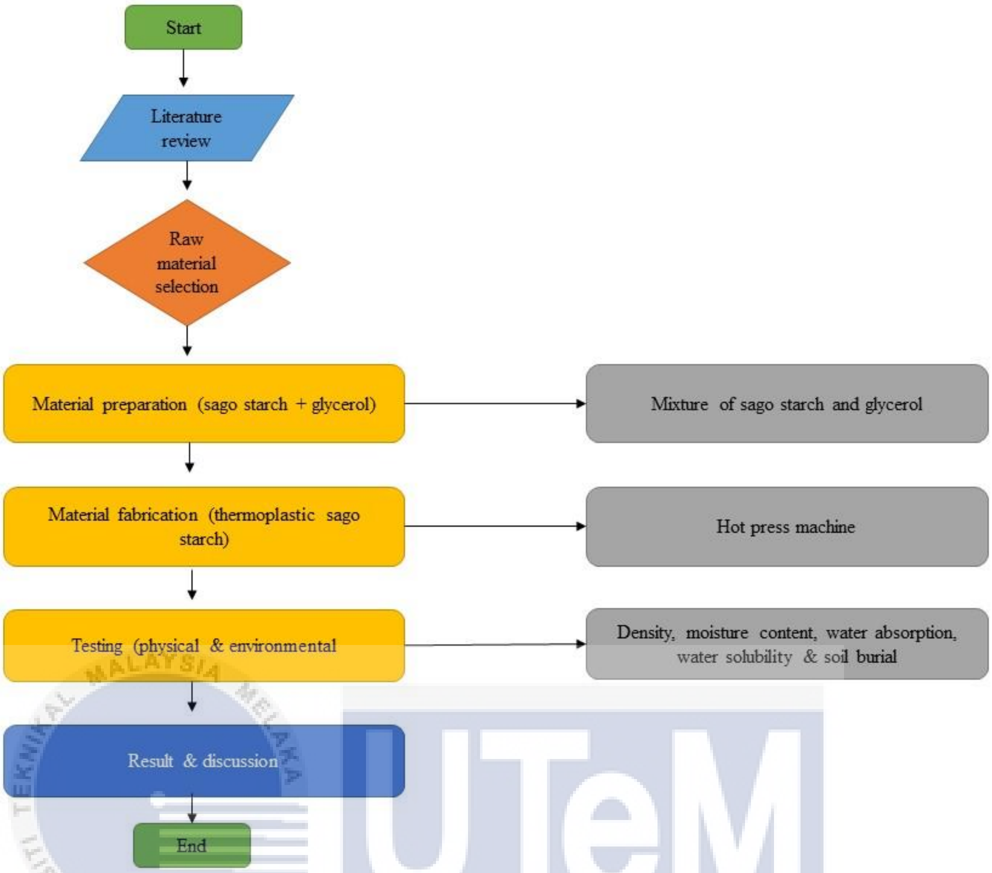


Figure 8. Flow chart

3.3 Raw Material

Sago starch powder (25% amylose) and glycerol (95% purity) with a density of 1.261 g/cm3.

3.4 Material Preparation and Fabrication

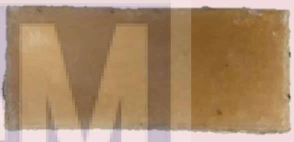
TPSS were fabricate by different concentration of sago starch mixture with glycerol. **Table 5** shows the mixture of sago starch and glycerol in different ratio weight percentage (wt.%) of sample. The mixture sago starch with glycerol was weight by using weight scale (**Figure 9**) to get the weight of percentages for each ratio. These material was mixed manually by hand. After mixed well, the mixture of sago starch and glycerol were in liquid form and need to be left for 24 hours for it become powder form (**Figure 10**). Next, the mixture of sago starch and glycerol were put inside the mold case (**Figure 11**) and were undergoes to the compression moulding machine or hot press machine (**Figure 12**) with start standard parameter at the pressure of 25 kg/cm² and 180°C of the temperature for 43 minutes followed by cooling for 20 minutes. However, because of using different concentration of sago starch mixture with glycerol and different machine factors are used, the temperature and time need to increase in order to make the sample cook-well (**Table 6**). The mixture was compressed and fabricated based on a mild steel mould with fixed length x width x height of 140 mm x 60 mm x 3 mm. After curing, the sample was removed with press machine and using press hydraulic machine (**Figure 13**) to take out the sample from mould. Next, the sample will be cut into specific sample size with are 10 mm x 10 mm by using saw cutting machine (**Figure 14**).

Table 5. Composition of TPSS bio-composite

Loading	Sago Starch (wt.%)	Glycerol (wt.%)	Mixture mass / Mould (g)
60/40	60	40	40
65/35	65	35	
70/30	70	30	

75/25	75	25	

Table 6. Parameter settings for TPSS bio-composite

TPSS loading	**Temperature (°C)**	**Heated time (minutes)**	**Cooling time (minutes)**	**Picture of samples (10mm x 10mm x 3mm)**
60/40	170°C	30	20	
65/35	180	38	20	
70/30	170	48	20	

75/25	180	43	20	

Figure 9. Weight scale

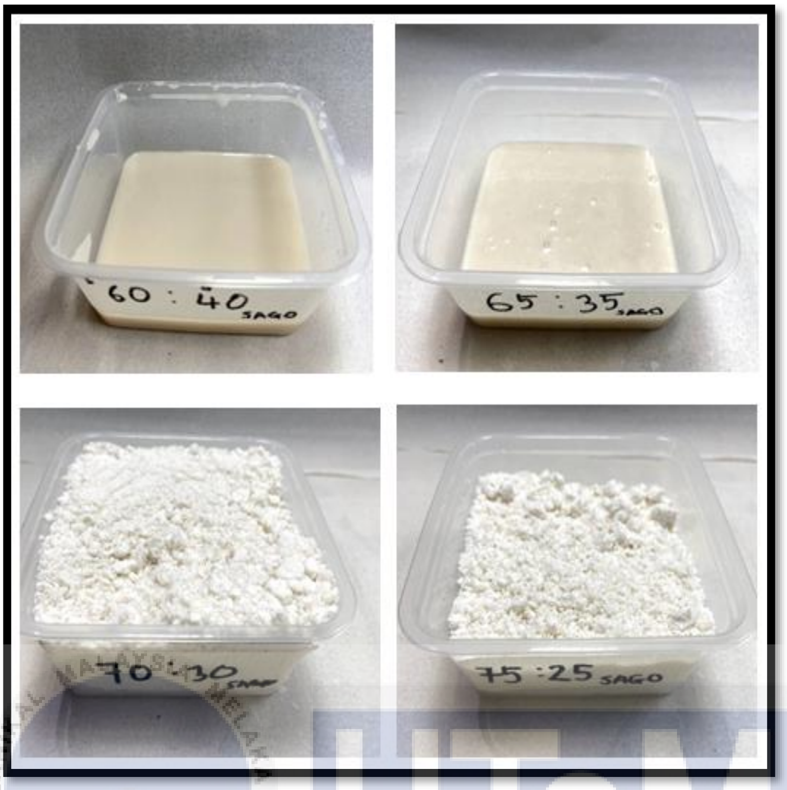


Figure 10. Mixture of sago starch with glycerol

Figure 11. Mould

Figure 12. Hot press machine

Figure 13. Press hydraulic machine

Figure 14. Saw cutting machine

3.5 Density Testing

According to Nasution & Wulandari, 2021, the standard for density test were conduct according to ASTM D792. A density test is to determine the specific gravity of thermoplastic by using the Electronic Densimeter (**Figure 15**). The samples were cut to 10 mm x 10 mm x 3mm. Thus, to get the density, the samples is placed into the Densimeter machine, and this process is repeated 4 times each ratio. Equation 1 shows the formula to calculate density.

$$\text{Density}\ (g/cm^3) = \frac{m}{v}$$

Equation 1

Figure 15. Densimeter scale

3.6 Moisture Content Testing

The moisture content testing of the thermoplastic sago starch sample is followed standard of ASTM G21-70 (Nissa et al., 2019). There are four samples of each ratio with dimension of 10 mm x 10 mm x 3 mm for each mixture were prepared to determine the moisture content. The 4 samples were heated at 105°C in the oven (figure 17) for 24 hours. The samples weight before heating in oven (mi), and after heating (mf) was taken to calculate in order to get the moisture content. **Equation 2** shown the formula to get the percentage moisture content.

$$\text{Moisture Content (\%)} = \frac{\boldsymbol{Mi - Mf}}{\boldsymbol{Mi}} \times \mathbf{100}$$

Equation 2

Figure 16. Hot air oven

3.7 Water Absorption Testing

This test is to determine the moisture content of the thermoplastic sago starch sample as a percentage of its dry weight by using ASTM D 570 (Curvelo et al., 2001). In terms of grams of water bound per grams of the samples on a dry basis, the water absorption capacity was expressed. To get the mean value, the data were gathered three times. For the composites, 4 samples with the size 10 mm x 10 mm x 3 mm was dried in a hot air oven at 105º C for 24 hours in order to removed moisture content. After that, the samples were immersed in water at a room temperature for 0.5 hours and 2 hours. Then, the samples will undergo in hot air oven for 24 hours at 105º C and the weight will be taken (Nanda et al, 2013). The **Equation 3** shown the formula to get the percentage water absorption.

$$\text{water absorption } (\%) = \frac{(\text{before absorption weight} - \text{after absorption weight})}{(\text{before absorption weigt})} X\ 100$$

Equation 3

3.8 Water Solubility Testing

The purpose of the water solubility test (WST) is to determine how much bioplastic is lost when it comes into contact with water or water vapor by using ASTM D 570 (Lusiana et al., 2019). The samples for each composition will be heating in hot air oven at 105℃ for 24 hours. The initial weight (wi) will be taken before the samples were submerged in 30 mL water for 24 hours. Filter was used to remove the excess water on the surface of the samples. Next, the sample has been weight for the final weight of the samples (wf). The percent solubility (percentage of total soluble materials) was computed as shown in **Equation 4**.

$$\text{Water solubility (\%)} = \frac{(\text{initial weight of sample} - \text{final weight of sample})}{(\text{initial weight of sample})} X\ 100$$

Equation 4

3.9 Soil Burial Testing

Soil burial test (SBT) with 5 thermoplastic sago starch samples by using ASTM G21-70. The SBT method is a widely used method for determining the quantitative breakdown of bioplastics. SBT will degradation in characterized soil that was moistened regularly with water. 4 samples with 10 mm x 10 mm x 3 mm were buried at a depth of 10 cm. The samples were dried at 105°C for 24 hours before testing and the initial weight (wi) has been taken. Two experimental sets were carried out for 2 and 4 weeks of predetermined intervals. The samples were taken from the soil and cleaned with water to remove the impurities. Then, the samples were dried for 24 hours at 105°C and weighed to get the final weight (wf) (Nissa et al, 2019). The equation 5 shown the formula to get the percentage of weight loss.

$$\text{Weight loss (\%)} = \frac{(initial\ weight\ of\ sample - final\ weight\ of\ sample)}{(initial\ weight\ of\ sample)} X\ 100$$

Equation 5

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The goal of this study is to look into the possibility of a sago starch mixture with glycerol for biodegradable thermoplastics. This research also to improve the process conditions to manufacture high-performance materials and to investigate the physical and environmental characteristics of these materials. Therefore, the result is based on the five testing method which density, moisture content, water absorption, water solubility and soil burial. Also, the pattern graph of the result will be discussing to get the possibility ratio of sago/glycerol that has potential to be better biopolymer composite.

4.2 Density

The need to lighten materials is one of the biggest reasons behind the production of composites. The ease of handling that can increase performance and save transport costs of the end product makes lightweight materials a best option. Based on **Figure 17**, the highest density occurs at 70/30 wt.% of TPSS which is 1.41 g/cm³, respectively. The lowest value of density is at 60/40 wt.% of TPSS which is 1.32 g/cm³. Hence, based on the result above, the difference in reduction of the density testing result between higher and lower is about 0.09 wt.%. Furthermore, the structural network between the sago starch and the glycerol itself, which affects the density value. Furthermore, the amylose and amylopectin molecules chain inside the sago starch influences the density value. A starch granule's amylose and amylopectin molecules are arranged in an extremely compact manner, leaving no room for water or any other molecules to enter (Kormin et al, 2019). Thus, the increase in sago starch content will increase the content of amylose and amylopectin cause the increment of the density value. The higher of sago starch wt.% can affect the density of the mixture.

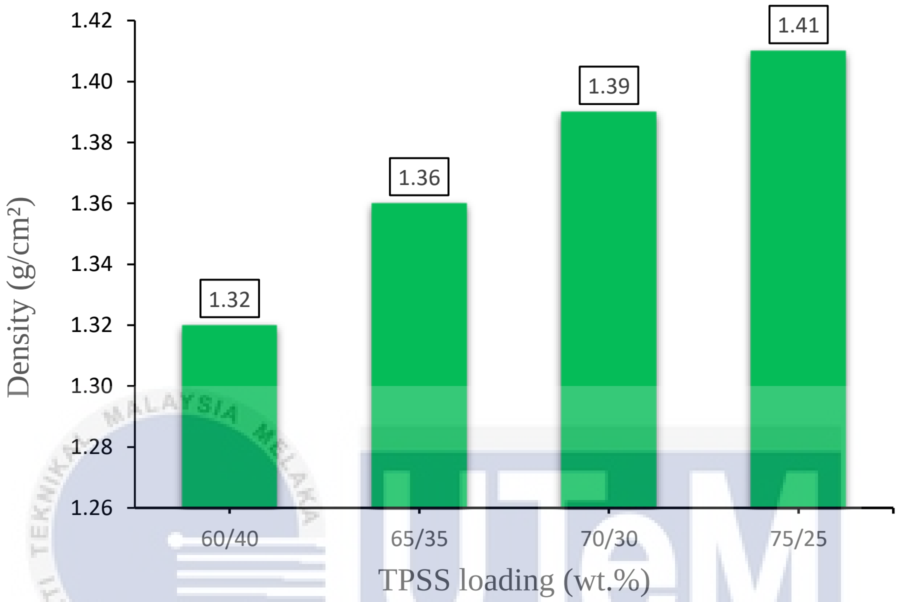


Figure 17. The density testing for TPSS bio-composite

4.3 Moisture

Based on **Figure 18**, a decrement pattern in moisture content from 60/40 wt.% to 75/25 wt.%. The highest moisture content was at 60/40 wt.% with is contribute the lowers TPSS content with 10.54 wt.%. The lowest moisture content was the higher TPSS content which is 75/25 wt.% of TPSS with 5.43 wt.%. Moreover, the 40 wt.% of glycerol in sago starch has shown the highest moisture content value among other mixtures due to sago starch and glycerol behaviour which are hydrophilic materials (Nasution & Wulandari, 2021). The mixture of sago starch and glycerol becomes more hydrophilic with an increased plasticizer (glycerol). Thus, the moisture content percentage will increase when adding more plasticizers.

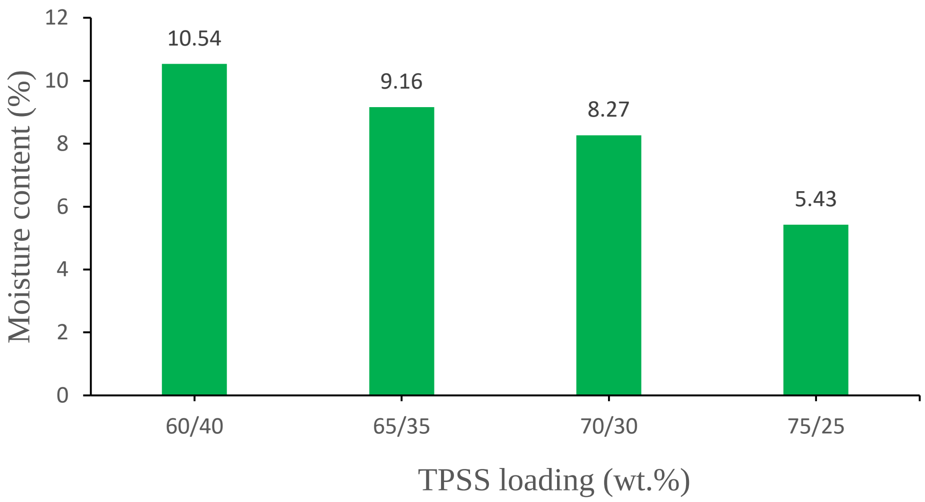


Figure 18. The moisture content in TPSS bio-composite

4.4 Water Absorption

Based on **Figure 19**, there is increment where the water absorption is 26.73% at ratio 60/40 wt.% to 9.75% at ratio 75/25 wt.% of TPSS. It shows that the lower ratio of TPSS there are become higher value of water content with longer immersion time other ratio show lower value of water content at that time when the composite percentange increase. After 2 hours, TPSS show same trend after 2 hours of soaking in water. Therefore, the longer time of soaking had the lowest water uptake because saturation of water absorption in the blend constrained the penetrating of water absorption in the blends. In short, the weak of sago starch molecule interactions, which are demand at higher plasticizer concentrations, effect in a less dense starch network and structure (Kormin et al, 2019). Composite moisture diffusion depends on ratio of mixture, defends against the matrix viscosity, humidity and temperature.

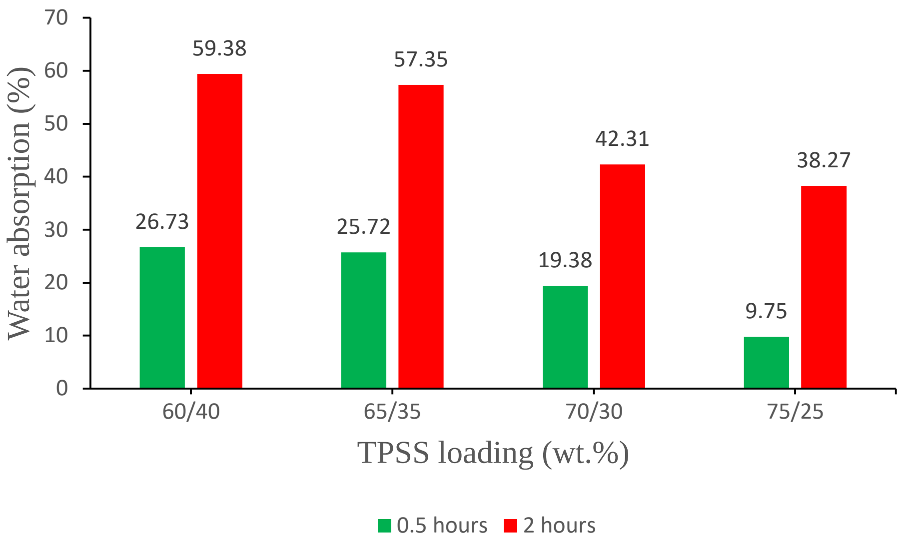


Figure 19. The water absorption for TPSS bio-composite in 0.5 hours and 2 hours

4.5 Water Solubility

Based on **Figure 20**, the water solubility in the TPSS/glycerol, indicating the material's water resistance when immersed and constantly agitating in liquid. The result shows that water solubility steadily decreases from 40.89% to 39.93 % with addition 5 wt.% of sago starch from 60 wt.% of sago starch. Next, it decreased to 38.17 % as the TPSS ratio is at 70 wt.% of sago starch to 37.99 % at 75 wt.% of sago starch. Thus, it show the water solubility decreasing as the TPSS increase (wt.%). The more glycerol level mixture makes the bind of thermoplastic more hydrophilic and immersible (Zuraida et al., 2012). The mixture of glycerol becomes more hydrophilic with an increased plasticizer. Due to the glycerol used in this research in liquid form (95% purity), the higher loading wt.% of glycerol, the homogeneous composition is easier to form (Ismail & Zaaba, 2012).

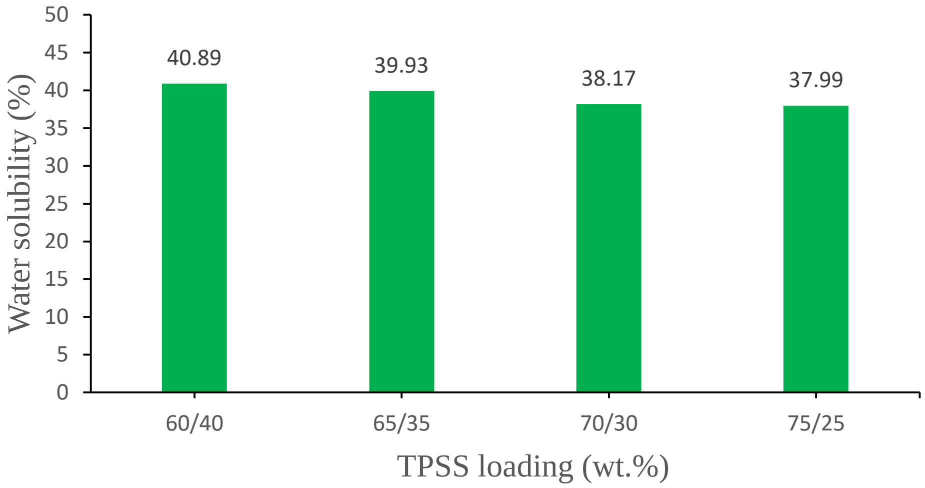


Figure 20. The water solubility for TPSS bio-composite

4.6 Soil Burial

Biodegradation material weight loss can be measured by soil burial testing cause of moisture and micoorganism behavior.**Figure 21. The soil burial for TPSS in bio-composite in 2 weeks and 4 weeks**

shows the weight loss of TPSS after the soil burial for 2 weeks and 4 weeks. Based on the result, it is show that a longer burial time cause a greater loss of which mean that more microorganism activities in the material. The TPSS percentage has decreased the weight loss of bio-composite from % at ratio 60/40 wt.% to 38.64% at ratio 75/35 wt.% for 2 weeks. The result shows that the samples degrades around 40% to 50% of its weight percent in 2 weeks. In addition, it shows that the longer burial time causes a bigger loss of weight of the TPSS material. The 4 weeks result as shown the weight loss from 85.32% at ratio 60/40 wt.% to 72.38% at ratio 75/25 wt.%. The 4 weeks burial show the percentage of degrades around 72% to 85%. Therefore, it can be related the rising hygroscopic function of material shall promote the growth and weight loss of material in microorganism during degradation (Nissa et al, 2019).

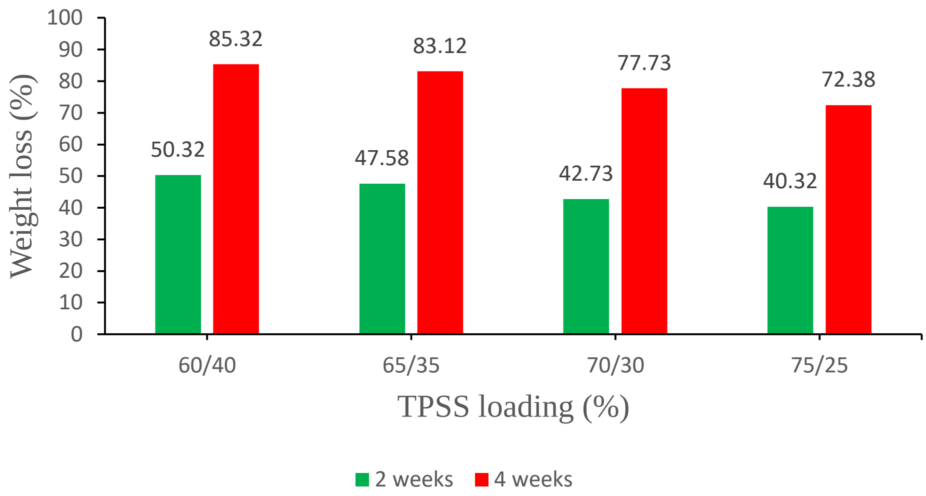


Figure 21. The soil burial for TPSS in bio-composite in 2 weeks and 4 weeks

CHAPTER 5

CONCLUSION

Bio-polymer composite from sago starch mixture with glycerol was successfully fabricated in four sample by using hot press machine. The findings show that sago starch mixture with glycerol were well-suited. Based on the result, it can be deduced that the properties of the TPSS bio-composites are significantly influenced by the ratio wt.% of sago/glycerol. The physical test result for density testing show increasing pattern which are the lowest value (g/cm³) was at 60/40 wt.% of TPSS and the value were increment at 70/25 wt.% of TPSS. The higher loading wt.% of sago can affect the density value of the mixture because the orientation of amylose and amylopectin molecules inside a starch granule is very compact. However, moisture content, water absorption, and water solubility show decreasing pattern from ratio 60/40 wt.% of to 70/25% of TPSS. For moisture content testing result, the percentage of glycerol in sago starch influenced the moisture content percentage due to the glycerol behavior which are hydrophilic material. Furthermore, for water absorption testing result, the longer soaking time had the lowest water uptake because saturation of water absorption in the blend constrained the penetrating of water absorprtion in the blends. Moreover, for water solubility testing result, the more glycerol wt.% of TPSS makes the bind of thermoplastic more hydrophilic and immersible. Last but not least, the environmental result of soil burial test at ratio 60/40 wt.% of TPSS shown the most severe signs of degradation, with a significant weight loss of from 2 weeks to 4 weeks. This can be interpreting that TPSS has experienced biodegradation of composite where it involves degraded species causes molecular weight loss de-polymerization. Therefore, it can be concluding that the ratio of 60/40 wt.% of TPSS has a potential to be better biopolymer composite.

RECONMENDATION

Althought the result was obtained by this research, there are more testing need to be considered before towards for making product because this research is investigated the physical and environmental characterization on TPSS. It is need to goes for more testing which investigated the mechanical and thermal characterization on TPSS. In addition, it might need to makes next step of research on development of TPSS such adding fibres content to bind more the TPSS because the samples of sago starch mixture with glycerol was quite fragile when added more sago starch wt.%.

REFERENCE

Abd-Aziz, S. (2002). Sago starch and its utilisation. *Journal of Bioscience and Bioengineering*, *94*(6), 526–529. https://doi.org/10.1016/S1389-1723(02)80190-6

Abrol, Y. P., & Adhya, T. K. (2017). Technical Summary. *The Indian Nitrogen Assessment: Sources of Reactive Nitrogen, Environmental and Climate Effects, Management Options, and Policies*, 1–5. https://doi.org/10.1016/B978-0-12-811836-8.00001-X

Ahmad, Z., Anuar, H., & Yusof, Y. (2011). The study of biodegradable thermoplastics sago starch. *Key Engineering Materials*, *471–472*, 397–402. https://doi.org/10.4028/www.scientific.net/KEM.471-472.397

Ardi, M. S., Aroua, M. K., & Hashim, N. A. (2015). Progress, prospect and challenges in glycerol purification process: A review. *Renewable and Sustainable Energy Reviews*, *42*, 1164–1173. https://doi.org/10.1016/j.rser.2014.10.091

Azmi, A. S., Malek, M. I. A., & Puad, N. I. M. (2017). A review on acid and enzymatic hydrolyses of sago starch. *International Food Research Journal*, *24*(December), 265–273.

Bertoft, E., & Blennow, A. (2016). Structure of Potato Starch. In *Advances in Potato Chemistry and Technology: Second Edition* (Second Edi). Elsevier Inc. https://doi.org/10.1016/B978-0-12-800002-1.00003-0

Breuninger, W. F., Piyachomkwan, K., & Sriroth, K. (2009). Tapioca/Cassava Starch: Production and Use. In *Starch* (Third Edit). Elsevier Inc. https://doi.org/10.1016/B978-0-12-746275-2.00012-4

Chawla, K. K. (2012). Composite materials: Science and engineering, third edition. In *Composite Materials: Science and Engineering, Third Edition*. https://doi.org/10.1007/978-0-387-74365-3

Chi, H., Xu, K., Wu, X., Chen, Q., Xue, D., Song, C., Zhang, W., & Wang, P. (2008). Effect of acetylation on the properties of corn starch. *Food Chemistry*, *106*(3), 923–928. https://doi.org/10.1016/j.foodchem.2007.07.002

Dang, Z. M., Yuan, J. K., Zha, J. W., Zhou, T., Li, S. T., & Hu, G. H. (2012). Fundamentals, processes and applications of high-permittivity polymer-matrix composites. *Progress in Materials Science*, *57*(4), 660–723.

https://doi.org/10.1016/j.pmatsci.2011.08.001

Du, C., Jiang, F., Jiang, W., Ge, W., & Du, S. kui. (2020). Physicochemical and structural properties of sago starch. *International Journal of Biological Macromolecules*, *164*, 1785–1793. https://doi.org/10.1016/j.ijbiomac.2020.07.310

Ezgi Bezirhan Arikan, & Havva Duygu Ozsoy. (2015). A Review: Investigation of Bioplastics. *Journal of Civil Engineering and Architecture*, *9*(2), 188–192. https://doi.org/10.17265/1934-7359/2015.02.007

Gopalakannan, S., & Senthilvelan, T. (2013). Application of response surface method on machining of Al-SiC nano-composites. *Measurement: Journal of the International Measurement Confederation*, *46*(8), 2705–2715. https://doi.org/10.1016/j.measurement.2013.04.036

Gupta, N., Zeltmann, S. E., Shunmugasamy, V. C., & Pinisetty, D. (2014). Applications of polymer matrix syntactic foams. *Jom*, *66*(2), 245–254. https://doi.org/10.1007/s11837-013-0796-8

Halden, R. U. (2010). Plastics and health risks. *Annual Review of Public Health*, *31*, 179–194. https://doi.org/10.1146/annurev.publhealth.012809.103714

Hashem, M., & Darwish, S. M. I. (2010). Production of bioethanol and associated by-products from potato starch residue stream by Saccharomyces cerevisiae. *Biomass and Bioenergy*, *34*(7), 953–959. https://doi.org/10.1016/j.biombioe.2010.02.003

Huang, J., Wei, M., Ren, R., Li, H., Liu, S., & Yang, D. (2017). Morphological changes of blocklets during the gelatinization process of tapioca starch. *Carbohydrate Polymers*, *163*, 324–329. https://doi.org/10.1016/j.carbpol.2017.01.083

Hubbe, M. A., Lavoine, N., Lucia, L. A., & Dou, C. (2020). Formulating bioplastic composites for biodegradability, recycling, and performance: A Review. *BioResources*, *16*(1), 2021–2083. https://doi.org/10.15376/biores.16.1.hubbe

Ismail, H., & Zaaba, N. F. (2012). Tensile properties, degradation behavior, and water absorption of sago starch plastic films. *Journal of Vinyl and Additive Technology*, *18*(4), 235–240. https://doi.org/10.1002/vnl.20300

Kaczmar, J. W., Pietrzak, K., & Wlosiński, W. (2000). Production and application of metal matrix composite materials. *Journal of Materials Processing Technology*, *106*(1–3), 58–67. https://doi.org/10.1016/S0924-0136(00)00639-7

Kormin, S., Kormin, F., & Beg, M. D. H. (2019). Effect of plasticizer on physical and mechanical properties of ldpe/sago starch blend. *Journal of Physics: Conference*

Series, *1150*(1). https://doi.org/10.1088/1742-6596/1150/1/012032

Kumar, L. R., Yellapu, S. K., Tyagi, R. D., & Zhang, X. (2019). A review on variation in crude glycerol composition, bio-valorization of crude and purified glycerol as carbon source for lipid production. *Bioresource Technology*, *293*(September), 122155. https://doi.org/10.1016/j.biortech.2019.122155

Kumar, S., Singh, R., & Hashmi, M. S. J. (2020). Metal matrix composite: a methodological review. *Advances in Materials and Processing Technologies*, *6*(1), 13–24. https://doi.org/10.1080/2374068X.2019.1682296

Lal, J. J. (2003). Sago Palm. In *Encyclopedia of Food Sciences and Nutrition*. https://doi.org/10.1016/b0-12-227055-x/01036-1

Lewandowicz, G., Jankowski, T., & Fornal, J. (2000). Effect of microwave radiation on physico-chemical properties and structure of cereal starches. *Carbohydrate Polymers*, *42*(2), 193–199. https://doi.org/10.1016/S0144-8617(99)00155-1

Li, J. H., & Ko, Y. C. (2012). Plasticizer incident and its health effects in Taiwan. *Kaohsiung Journal of Medical Sciences*, *28*(7 SUPPL.), S17–S21. https://doi.org/10.1016/j.kjms.2012.05.005

Lusiana, S. W., Putri, D., Nurazizah, I. Z., & Bahruddin. (2019). Bioplastic Properties of Sago-PVA Starch with Glycerol and Sorbitol Plasticizers. *Journal of Physics: Conference Series*, *1351*(1). https://doi.org/10.1088/1742-6596/1351/1/012102

Maizura, M., Fazilah, A., Norziah, M. H., & Karim, A. A. (2007). Antibacterial activity and mechanical properties of partially hydrolyzed sago starch-alginate edible film containing lemongrass oil. *Journal of Food Science*, *72*(6). https://doi.org/10.1111/j.1750-3841.2007.00427.x

Martin, O. J. F. (2019). Molding the flow of light with metasurfaces. *2019 URSI Asia-Pacific Radio Science Conference, AP-RASC 2019*, 32–43. https://doi.org/10.23919/URSIAP-RASC.2019.8738549

Mikhjlin, Y. A., Kerber, M. L., & Gorbunova, I. Y. (2002). Binders for polymer composite materials. *Plasticheskie Massy: Sintez Svojstva Pererabotka Primenenie*, *29*(2), 14–21.

Mishra, S., & Rai, T. (2006). Morphology and functional properties of corn, potato and tapioca starches. *Food Hydrocolloids*, *20*(5), 557–566. https://doi.org/10.1016/j.foodhyd.2005.01.001

Mohan, N., Senthil, P., Vinodh, S., & Jayanth, N. (2017). A review on composite materials and process parameters optimisation for the fused deposition modelling process. *Virtual and Physical Prototyping*, *12*(1), 47–59. https://doi.org/10.1080/17452759.2016.1274490

Nagy, Á., & Kuti, R. (2016). The Environmental Impact of Plastic Waste Incineration. *Academic and Applied Research in Military and Public Management Science*, *15*(3), 231–237. https://doi.org/10.32565/aarms.2016.3.3

Nan, C. W., Shen, Y., & Ma, J. (2010). Physical properties of composites near percolation. *Annual Review of Materials Research*, *40*(July), 131–151. https://doi.org/10.1146/annurev-matsci-070909-104529

Nasution, H., & Wulandari, G. (2021). Characteristics of bioplastics based on sago starch contain betel (piper betle) leaf extract: Effect of glycerol as plasticizer. *IOP Conference Series: Materials Science and Engineering*, *1122*(1), 012099. https://doi.org/10.1088/1757-899x/1122/1/012099

Nissa, R. C., Fikriyyah, A. K., Abdullah, A. H. D., & Pudjiraharti, S. (2019). Preliminary study of biodegradability of starch-based bioplastics using ASTM G21-70, dip-hanging, and Soil Burial Test methods. *IOP Conference Series: Earth and Environmental Science*, *277*(1), 8–15. https://doi.org/10.1088/1755-1315/277/1/012007

Ofman, M. H., Campos, C. A., & Gerschenson, L. N. (2004). Effect of preservatives on the functional properties of tapioca starch: Analysis of interactions. *LWT - Food Science and Technology*, *37*(3), 355–361. https://doi.org/10.1016/j.lwt.2003.09.010

Philp, J. C., Ritchie, R. J., & Guy, K. (2013). Biobased plastics in a bioeconomy. *Trends in Biotechnology*, *31*(2), 65–67. https://doi.org/10.1016/j.tibtech.2012.11.009

Ratnayake, W. S., & Jackson, D. S. (2008). Chapter 5 Starch Gelatinization. *Advances in Food and Nutrition Research*, *55*(08), 221–268. https://doi.org/10.1016/S1043-4526(08)00405-1

Ravichandran, M., Balasubramanian, M., Anand Chairman, C., Pritima, D., Dhinakaran, V., & Stalin, B. (2020). Recent developments in Polymer Matrix Composites - A review. *IOP Conference Series: Materials Science and Engineering*, *988*(1), 0–6. https://doi.org/10.1088/1757-899X/988/1/012096

Rosso, M. (2006). Ceramic and metal matrix composites: Routes and properties. *Journal of Materials Processing Technology*, *175*(1–3), 364–375. https://doi.org/10.1016/j.jmatprotec.2005.04.038

Sharma, A. K., Bhandari, R., Aherwar, A., & Rimašauskiene, R. (2020). Matrix materials used in composites: A comprehensive study. *Materials Today: Proceedings*, *21*(xxxx), 1559–1562. https://doi.org/10.1016/j.matpr.2019.11.086

Tan, H. W., Abdul Aziz, A. R., & Aroua, M. K. (2013). Glycerol production and its applications as a raw material: A review. *Renewable and Sustainable Energy Reviews*, *27*, 118–127. https://doi.org/10.1016/j.rser.2013.06.035

Thomazine, M., Carvalho, R., & Sobral, P. (2005). Properties Physical Properties of Gelatin Films Plasticized by Blends of Glycerol and Sorbitol Results and Discussion. *Food Engineering and Physical Properties*, *70*(3), 172–176.

Wernke, M. J. (2014). Glycerol. *Encyclopedia of Toxicology: Third Edition*, 754–756. https://doi.org/10.1016/B978-0-12-386454-3.00510-8

Yu, J., & Chen, L. X. L. (2008). The greenhouse gas emissions and fossil energy requirement of bioplastics from cradle to gate of a biomass refinery. *Environmental Science and Technology*, *42*(18), 6961–6966. https://doi.org/10.1021/es7032235

Zakaria, N. H., Ngali, M. Z., Selamat, M. Z., Abdul Munir, F., & Aman, M. A. (2020). Characteristic of thermoplastics corn starch composite reinforced short pineapple leaf fibre by using laminates method. *Journal of Mechanical Engineering and Sciences*, *14*(3), 7058–7070. https://doi.org/10.15282/jmes.14.3.2020.08.0553

Zhou, S., Liao, X., Liang, Z., Li, X., Deng, X., & Li, H. (2004). Preparation and Characterization of Biodegradable Microspheres Containing Hepatitis B Surface Antigen. *Macromolecular Bioscience*, *4*(1), 47–52. https://doi.org/10.1002/mabi.200300044

Zuraida, A., Nur Humairah, A. R., Nur Izwah, A. W., & Siti Naqiah, Z. (2012). The study of glycerol plasticized thermoplastic sago starch. *Advanced Materials Research*, *576*, 289–292. https://doi.org/10.4028/www.scientific.net/AMR.576.289

APPENDIX

Appendix 1 – List of ASTM

ASTM D792	Specific gravity can be converted to density (g/cm^3)
ASTM G21-70	To determine the resistance of synthetic polymeric materials to fungal growth.
ASTM D 570	To determine the rate of absorption of water by immersing the specimen in water for a specific period of time.