DEVELOPMENT AND CHARACTERIZATION ON PHYSICAL AND ENVIRONMENTAL OF PINEAPPLE LEAF FIBRE REINFORCED THERMOPLASTICS SAGO STARCH COMPOSITE

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

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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 Manufacturing Engineering Technology (Process & Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this “ Development and Characterization on Physical and Environment of Pineapple leaf Fibre Reinforced Thermoplastics Sago Starch Composite, ” is the result of my own research except as cited in the references. The Development and Characterization on Physical and Environment of Pineapple leaf Fibre Reinforced Thermoplastics Sago Starch Composite has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Hafiqh Hakimi bin Mohd Fuzi

Date : 11/1/2023

APPROVAL

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

Signature	:	
Supervisor Name	:	Ts. Dr. Nazri Huzaimi bin Zakaria
Date	:	12/1/2023

DEDICATION

To my precious Allah S.W.T

Who gives me new life, hope and purpose of life

To my beloved father and mother,

Mohd Fuzi bin Ahmad & Rozaini binti Samsudin

To my supervisor,

Ts. Dr. Nazri Huzaimi bin Zakaria

For their continuous advice, support and patirnce while finishing this thesis

And to all my friends,

For their encouragement, cooperation and motivation in completing this thesis

ABSTRACT

Due to the accumulation of non-biodegradable waste, such as disposable items, the demand to design ecologically friendly products has increased recently. Starch is one of the potential candidates since it is readily available, cheap, renewable, and biodegradable. However, the natural properties of sago starch have shown weak mechanical properties. Therefore, the modification of sago starch with glycerol was used to create thermoplastic sago starch (TPSS). Furthermore, the characterizations of the TPSS were investigated, and the best result was obtained from a previous study (Zuraida et al., 2012), which was 75% sago starch and 25% glycerol. Meanwhile, pineapple leaf fibre (PALF) is a flexible plant that may be viewed as a renewable resource for composite production. TPSS was used to create PALF reinforcements with weight ratios of 90:10, 80:20, 70:30, 60:40, and 50:50 TPSS mixes with varying weight percentages of PALF were created using a hot compression moulding at 190˚C for 50 minutes. Several testing, including physical and environmental testing, have been conducted to assess the qualities of bio-composites. The physical test results for moisture content and density shows decreasing pattern when the fibre PALF increase. However, the water absorption shows otherwise when adding fibre content cause the relationship with water increase. While PALF wt% loadings increase, soil burial decreases, despite water solubility statistics suggesting the contrary.

ABSTRAK

Disebabkan pengumpulan sisa tidak terbiodegradasi, seperti barang pakai buang, permintaan untuk mereka bentuk produk mesra alam telah meningkat baru-baru ini. Kanji adalah salah satu calon yang berpotensi kerana ia mudah didapati, murah, boleh diperbaharui dan terbiodegradasi. Walau bagaimanapun, sifat semulajadi pati sagu telah menunjukkan sifat mekanikal yang lemah. Oleh itu, pengubahsuaian kanji sagu dengan gliserol digunakan untuk menghasilkan kanji sagu termoplastik (TPSS). Tambahan pula, pencirian TPSS telah disiasat, dan keputusan terbaik diperoleh daripada kajian terdahulu (Zuraida et al., 2012), iaitu 75% kanji sagu dan 25% gliserol. Sementara itu, gentian daun nanas (PALF) adalah tumbuhan fleksibel yang boleh dilihat sebagai sumber yang boleh diperbaharui untuk pengeluaran komposit. TPSS digunakan untuk mencipta tetulang PALF dengan nisbah berat 90:10, 80:20, 70:30, 60:40, dan 50:50 campuran TPSS dengan peratusan berat PALF yang berbeza-beza dicipta menggunakan acuan mampatan panas pada 190˚C selama 50 minit. Beberapa ujian, termasuk ujian fizikal dan alam sekitar, telah dijalankan untuk menilai kualiti biokomposit. Keputusan ujian fizikal untuk kandungan lembapan dan ketumpatan menunjukkan corak menurun apabila gentian PALF meningkat. Walau bagaimanapun, penyerapan air menunjukkan sebaliknya apabila menambah kandungan serat menyebabkan hubungan dengan air meningkat. Walaupun beban PALF wt% meningkat, pengebumian tanah berkurangan, walaupun statistik keterlarutan air menunjukkan sebaliknya.

ACKNOWLEDGEMENTS

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

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life, and I have finally completed the bachelor's degree Project 1. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for the financial assistance.

My utmost appreciation goes to my main supervisor, Ts. Dr. Nazri Huzaimi bin Zakaria for tremendous support and supervision during my thesis. Under his direction, I was motivated to explore the world of science and writing.

Finally, I would also like to thank my beloved parents for their endless support, love, and prayers. Finally, thank you to all the individual(s) who had provided me the assistance, support, and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

α	-	Amylase
ABS	-	Acrylonitrile-butadiene-styrene
ASTM	-	American society for testing material
CQ	-	Cissus quadrangularis
CMCs	-	Ceramic matric composites
(-COOH)	-	Carboxyl group
˚C	-	Celcius
µm	-	Diameter
Eq	-	Equation
FRCs	-	Fibre-reinforced composites
g	-	gram
g/cm^3	-	Gram per cubic
GPP	-	Glycerol phosphate phosphatases
(-OH)	-	Hydroxyl group
H2S04	-	Sulfuric acid
mm	-	millimetre
%	-	percentage
kg/cm^2	-	Kilogram force per square
Kpa	-	Kilopascal
m	-	Meter
MMCs	-	Metal matric composites
MPOB	-	Malaysia palm oil board
cN/tex	-	Newton per tex
OMCS	-	Organic matric composites
ρ	-	Pressure
PMCs	-	Polymer matric composites
PS	-	Polystyrene
PP	-	Polypropylene
PE	-	Polyethylene

PC	-	Polycorbonate
PVC	-	Polyvinyl chloride
PEEK	-	Polyether-ether ketone
PLA	-	Polylastic acis
®	-	Registered trademark symbol
NaOH	-	Sodium hydroxide
V	-	volume
XRD	-	Xray-diffraction

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CHAPTER 1

INTRODUCTION

This section describes the background of the research that has been performed. This section also represents the problem statement, research objectives, and scope research.

1.1 Background

The increasing understanding of the significance of environmental protection has prompted significant research toward developing more natural materials. Regular fibre composites are getting more serious consideration because they have good qualities. Another way composites can help the environment is by using bio-based polymers instead of polymers made from petroleum (Jumaidin et al., 2020). In Malaysia, the pineapple business focuses on the fruits, while the leaves are primarily composted or burnt, so losing valuable potential sources of fibres. Fibre reinforce plastic composites are a combination of two solid materials: a high-strength and -rigidity material surrounded by a similar substance covering and securing it. The stiff material or reinforcement is often composed of a directed component, such as fibre, rods, or sheets, whereas the surrounding material, also known as the matrix, is typically isotropic (Gowayed,2019). Composites comprised of high-strength fibres such as graphite, aromatic polyamide, and glass are widely used in a variety of applications, including aircraft constructions, vehicle components, building materials, and recreational items (Arib et al, 2006). Due to the fact that these fibres are weaker than carbon and aromatic polyamide, they are less costly and biodegradable.

In the future, a limitation of petroleum resources will influence the availability of raw materials, the value of plastic products, the capacity to manufacture them, their lack of biodegradability, and the need to safeguard the natural environment. Recent research has focused on developing biodegradable polymers from renewable resources. Thermoplastic starch (TPS) is one of the bioplastics becoming looked at as a possible replacement for traditional raw materials TPS is produced from starch, is biodegradable, non-toxic, affordable, and easily obtainable (Dang & Yoksan, 2021). Starch is a primary food source for humans(Perin & Murano,2017). They come in semi-crystalline granules, and each plant has a different set of properties. Each plant has unique granules that are different in size and shape. Each granule's interior is composed of growth rings and crystalline and amorphous lamellae. Granules of starch are composed of the polyglucans amylose and amylopectin (Terlow et al, 2020). Amylose has a simple molecular structure since it is composed of glucose residues connected by α -(1,4) connections to lengthy chains including a few α -(1,6)-branches. Amylopectin, the primary component, has the same fundamental structure, but its chains are indeed shorter, and it contains several α-(1,6)-units. It generates a complex, three-dimensional structure, but its purpose is unclear. Amylopectin has been shown to have many different forms over the years. This review shows two of them, called the "cluster model" and "building block backbone model." The structure of starch granules is discussed both positively and negatively (Bertoft, 2017).

Sago starch has received significant interest as a possible ethanol source in recent years. The sago palm accumulates starch in the pith core of its stem(Uthumporn et al., 2014).Sago starch is extracted from the stem of the native Southeast Asian sago palm (Metroxylon sagu) (Zhu, 2019). According to Azmi et al. (2017), sago starch will always be in demand due to its wide range of industrial applications. For instance, in the food business, sago starch is used to make cendol, keropok, lempeng, sago pudding, and tabaloi cookies. Next, the unique qualities of sago starch include its ease of gelatinization and moulding, availability as a renewable resource, low cost, and high starch concentration of 82.94 % (Nasution et al., 2018). Sago starch may be converted into thermoplastic starch or biodegradable plastic under temperature and shearing action (Nasution et al., 2018).

Recent studies in polymer technology are investigating the use of pineapple leaf substitute (PALF) as a reinforcing element in thermoplastics and thermosets because it is cheap and lightweight (Leao et al., 2010). Since pineapple yield is important for fibre production, pineapple is the largest retailer in the market of grown fibre crops (Asim et al., 2015). PALF is equivalent to most sheet and bark fibres in fineness. PALF is a waste that is readily available in Southeast Asia, India, and South America (Pandey, 2005). However, eating only fruits and leaves that contain fibre is often burned or discarded, contributing to environmental pollution, and wasting a potentially important source of fibre.

The environmental benefits of the fibre-reinforced composite are appealing to producers, consumers, and industry alike. This study aims to development and characterization on physical and environmental of pineapple leaf fibre reinforced thermoplastics sago starch composite.

1.2 Problem Statement

Over the years, everyone has been concerned about the environmental impacts of traditional plastics. Plastics are widely utilized in a variety of sectors, including packaging, electrical and electronic equipment, and the car industry. Plastics are important for product production due to their mobility, light weight, cheap, and aesthetically pleasant characteristics (Cornejo-Ramírez et al., 2018). Besides that, the plastics generated from petroleum resources are non-biodegradable products and harm the environments (Zakaria et al., 2020). As non-biodegradable materials, the disposal of these applications provides a challenging issue after their usage has ended (Todkar & Patil, 2019). Due to all these negative factors, the development of totally biodegradable composites is one of the most viable alternatives to conventional plastics, with the ability to alleviate polymer waste management issues. The goal of this research was to find a solution to this problem by making a biodegradable polymer composite made of 100% renewable materials.

Therefore, in recent times, the production of biopolymers is based on the use of renewable resources; for instance, cellulose, soy, starch, polyhydroxy alkanoates, and polylactic acid (PLA) have all been n investigated as exchange materials to supplant conventional polymers as synthetic (Ghanbarzadeh et al., 2011). Starch is the best raw material for making biodegradable plastics and the composites that they form (Jiang et al., 2020). Starch is the most important polysaccharide polymer used to create biodegradable films due to its capacity to build a continuous matrix and its abundance as a renewable resource (Ghanbarzadeh et al., 2011).

Sago palm also known as (Metroxylonspp) is a plant that is commonly found in the Mukah District, Sarawak. Sago starch is a natural wonder and the most significant raw resource according to its versatility (Ain et al., 2017). By adding heat and shearing force to sago starch, it can be turned into thermoplastic starch. Due to the low temperature at which granular starch reduces, a plasticizer is required during processing (Ahmad et al., 2011). However, thermoplastic starch has disadvantages such as poor mechanical qualities, brittleness, and poor water resistance These limits are due to the hydroxyl group found on the starch molecule, which renders it hydrophilic and performance restrictive (Wahab et al., 2021). To increase the properties of this material, suitable modifications should be made, such as reinforcing it with high-potential natural fibre.

Natural fibre-based composites are being studied a lot because they are good for the environment and have unique properties. Natural fibres are good because they are always available, easy to handle, and biodegradable(Karimah et al., 2021). Pineapple fruits are very important for business, and the leaves are a waste product of the fruit that is used to make natural fibres. PALF will be inspired researchers to explore its potential in composites as a strengthening material (Todkar & Patil, 2019). Next, PALF is a traditional bio-resourced material that has not been wholly used and is also an abundant natural source in Johor, especially in pineapple plantation (Asim et al., 2015).

In addition, producing fully biodegradable material by combining natural fibres, such as PALF, with a polymer matrix based on glycerol would only provide a partial biodegradable product. To make a completely biodegradable substance, it is important to use PALF as a reinforcement in polymer composites that use thermoplastics sago starch as a matrix.

1.3 Research Objective

The main goal of this research is to develop and characterize the physical and environmental composites of thermoplastics sago starch reinforced pineapple leaf fiber (PALF). Specifically, the objectives are as follows:

a) To fabricate sago starch reinforced pineapple leaf fibre composite.

b) To investigate physical properties of thermoplastics sago starch reinforced pineapple leaf fiber composite.

c) To find environmental properties of thermoplastics sago starch reinforced pineapple leaf fiber composite.

1.4 Scope of Research

This study attempts to get a deeper understanding of the characteristics of thermoplastics sago starch reinforced pineapple leaf fiber composite in terms of physical and environmental. The approach of this investigation is based on experimental studies. The study is categorized into several phases. The PALF used in this study was from Josapine type and the PALF was bought from Pontian, Johor.

Sago starch was applied in this investigation was taken from the manufacturing type and in powder form. Thermoplastics sago starch was produced using glycerol as a plasticizer. Then, thermoplastics sago starch will be compressed to determine the appropriate compression moulding parameters, i.e., temperature, pressure, preheat period and compression length. The temperature was between 180°C and 190°C. The pressure was between 10 kg/$cm^2$and 30 kg/cm^2, preheat duration was about 6 minutes to 20 minutes.

Thermoplastics sago starch reinforced pineapple leaf fiber was fabricated with five different fibres loading which are 10% to 50%. The preparation TPSS/PALF composites samples were prepared using a compressing moulding technique with random orientation of the PALF. The composite specimens have been examined for their physical and environmental behaviour.

Density, water absorption, and moisture content testing were conducted to analyse the physical behaviour of TPSS/PALF composites. Soil burial and water solubility testing was used to analyse the environment behaviour of TPSS/PALF composites.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section aim to explain the literature from this study further. This section includes prior research on biodegradable fibres reinforced polymer composites, polymer matrices, thermoplastics starch, sago starch, glycerol, and pineapple leaf fibre (PALF). Finding from previous research and the objectives of this study are also discussed in this chapter.

2.2 Matrix

A composite's fibre system is embedded in a material called the matrix, which is mostly a single, solid piece of material (Lee et al., 2021). It goes all the way through and gives a way to connect and hold reinforcements together to make a solid structure. The matrix phase is also known as the composites' continuous step and can be a polymer-metal or ceramic (Santosh Kumar et al., 2015). According to M.Dawoud & M. Saleh (2019), there are two primary levels of categorization for composite materials. The first criteria for classification are the matrix (binder) component. The three primary composite categories are organic matrix composites (OMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs). Organic matrix composites (OMC) refer to polymer matrix composites (PMCs) and carbon matrix composites, often known as carbon-carbon composites. Next, the second classification criterion distinguishes fibre-reinforced composites (FRCs), laminar composites, and particle composites based on their reinforcing phases.

2.2.1 Polymer Matrix (PMC)

Polymers have replaced common materials such as metals in a variety of applications over the past decade. It is because polymers offer advantages over traditional materials. The most significant are ease of processing, light weight, increased productivity, and lower operating costs. For most of these applications, the polymer's properties are modified with fillers and fibres to meet high strength modulus specifications. The natural fibre is derived from numerous plant and animal sources. Several types of natural fibres are derived from plants containing cellulose. Cotton, linen, jute, flax, ramie, sisal, and hemp are common examples. These fibres are extracted from plant fruits, seeds, leaves, stems, and skin. The protein-based animal fibres include wool, mohair, and silk. The use of natural fibres derived from plants as reinforcing agents in polymer composites has been one of the focal points. Natural fibre reinforced polymer matrix composites could be less expensive, more durable, and friendlier to the environment; however, the full potential of such fibres for polymer composites has not yet been realised. According to Yashas Gowda et al. (2018) review of Polymer Matrix-Natural Fibre Composites, the addition of polymers to composites is advantageous in comparison to natural composites. The advantages of polymer matrix composites are cheap cost, low density, and minor abrasion. The scope and limitations of these materials need to be explored further. The polymer matrices used in the manufacturing of composites are categorised into thermoplastics and thermoset based on the type of bonding they include., as shown in table 2.1

According to Singh et al., (2019), PMC is a composite material include of numerous tiny, continuous filaments kept together by a natural polymer grid. Between the filaments of the matrix material, PMCs are meant to carry loads. The qualities of PALF reinforced polymer have increased considerably in applications like interior parts in the automotive industry.

Table 2.1 The most common polymers used in composites are matrices (Yashas Gowda et al. 2018)

Polymers	
Thermoplastics	Thermoset
Nylon	Phenolic
Cellulose acetate	Epoxy
Polystyrene (PS)	Polyester
polypropylene (PP)	polyamide
polyethylene (PE)	polyurethane
Polycarbonate (PC)	
Polyvinyl chloride (PVC)	
Polyether- ether ketone (PEEK)	
Acrylonitrile-butadiene-styrene (ABS)	

2.3 Natural Fibre

Bio composites are natural fibre-reinforced that are derived from either plants or animals. There are two forms of natural fibre which are plant-based and animal-based. Natural plant-based fibre is composed of cellulose, whereas natural animal-based fibre is composed of protein. (Bhagabati, 2020). Table 2.3 shows how natural fibres are categorised into three categories based on their source: animal, mineral, and plant. According to Varghese & Mittal, (2017), explain that natural fibres are getting a lot of research attention as reinforcement for making polymer composites because they are good for the environment, biodegradable, lightweight, and cheap. Moreover, natural fibres have disadvantages due to their inconsistent characteristics and quality. These fibres have greater variation in their physical and mechanical properties, greater moisture absorption, less durability, less strength, and a lower processing temperature (Peças et al., 2018).

Table 2.2 natural fibre classification. Based on work by Pecas et al (2018)

Natural Fibre		
Cellulose/ lignocellulose	Bast	Flax, Hemp, Jute, Kenaf, Ramie
	Leaf	Abaca, Banana, Pineapple, Sisal
	Seed	Cotton, Kapok
	Fruit	Coir
	Wood	Hardwood, Softwood (e.g., Eucalyptus)
	Stalk	Wheat, Maize, Oat, Rice
	Grass/ Reed	Bamboo, Corn
Animal	Wool / Hair	Cashmere, Goat hair, Horsehair, Lamb wool
	Silk	Mulberry
Mineral		Asbestos, Ceramic fibres, Metal fibres

Currently, natural fibres such as flax, banana, sisal, oil palm, kenaf, jute, cotton, and pineapple leaf fibre, among others, are commonly examined to determine their potential as synthetic fibre substitutes (Zakaria et al., 2020). Natural fibres are non-toxic, have a low density, are easy to work with, biodegrade, and come in a lot of different types. In addition, they have adequate Specific strength characteristics, high tensile strength, and nonabrasive processing, and do not irritate the skin or respiration of customers (Ahmed & Mondal, 2021).

In general, Bio-based composites can be partially environmentally friendly or green, depending on the materials they are made of in Figure 2.1. Green composite means that all its parts come from renewable resources. This could cut down on carbon dioxide emissions and the need for materials made from oil. While partially biodegradable means that either the fibre or the matrix is not made from a renewable resource (Peças et al., 2018). In addition, The performance of natural fibre composites is related to the number of fibres, their length, shape, arrangement, and how well they stick to the matrix (AL-Oqla, et al., 2017).

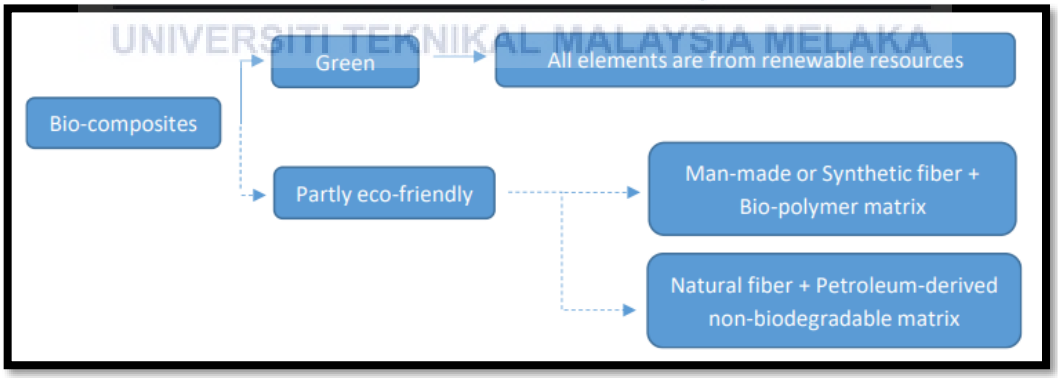


Figure 2.1 Classification of bio-composites

Based on the research from Todor et al., (2018), most of the time, the stages of a natural fibre's life cycle are gathering, processing, making, using, throwing away, and recycling. There are a few things that make it hard to make and use fibres on a large scale. the life cycle of natural replacement is influenced by the composition and shape of the soil, the way microorganisms break it down, how long it lasts and how much sunlight is obtained (Merta et al., 2018). The physical and chemical the qualities of natural fibres vary depending on the plant, where it was produced, the weather, when it was picked, and whether genetically modified organisms (GMOs), pesticides, and fertilisers were used (Khatib et al., 2022).

According to some studies of various natural fibres, the majority of people were unaware of the benefits and associations of pineapple plant waste other than pineapple fruit. (Jain & Sinha, 2021). Among all natural fibres, pineapple leaf fibres have the greatest mechanical strength due to their high cellulose content ranges up to 80˚C(Todkar & Patil, 2019).

2.4 Starch

According to Schwartz & Whistler (2009) in the predynastic century, Egyptians bonded papyrus strips with a wheat starch adhesive, which led to the practical application of starch and starch-based products. The origins of starchy foods are seeds, roots, and tubers (Chandrasekara & Josheph Kumar, 2016). Humans and their predecessors were the earliest people in the cultivation of grains such as rice, wheat, and corn for survival (Reznick et al., 2021). Next, Starch is created in the green leaves of plants from excess glucose released during photosynthesis (Noronha et al., 2018).

Starch is stored in chloroplasts as granules and in storage organs such as the cassava plant's roots, the potato tuber, the sago stem pith, and the seeds of corn, wheat, and rice

(Mérida & Fettke, 2021). According to Ibrahim et al., (2020), starch has received the most research as an eco-friendly polymer derived from renewable plant matter.

2.4.1 Physical and chemical properties of starch

The physical and chemical characteristics of granule starches determine their quality and functions. The understanding of these factors enables the starch selection with the requisite qualities for a given application, as well as the pick out of the of the suitable starch source and modification procedure to acquire the desired functional attributes for a particular end-use. Additionally, amylose is hydrolyzed into oligosaccharides of low molecular weight.However, When there is less amylose in the starch, these effects are lowered concentration and strong swelling power (Seung, 2020). According to Lee et al. (2008), enzymatic transform generates highly branching amylopectin and amylose to form starches with low digestion but a high water solubility, which is productive for the food and drink industry. Starch is the primary carbohydrate store in plants. Extraction of amylose and amylopectin polymers from starch. According to Table 2.2, starches include around 20–30 % amylose and 70–80 % amylopectin. For example, the percentage of amylose in barley is 29.8 %, Wheat is between 21.5-26.6 %, sweet potato is 22.6 %, cassava is 19.8 %, arrowroot provides 20.8 % , yam 32.6 %, ginger 26.5 %, maize 20.9 % , Rice 29.1 % , potato 26.9 %, and triticale 22.2–23.8 % . There are starches with a high amylose content, such as high amylose barley 46.5–48 % and maize 62.8–85.6%, and waxy starches with minimal quantities of amylose, such as waxy barley 9.1 % waxy wheat 0.2 %, and waxy potato 3.4% (Cornejo-Ramírez et al., 2018).

Table 2.3 The amount of amylose and the degree of polymerization (DP) of amylopectin in some starches (Cornejo-Ramírez et al., 2018).

Starch	Apparent amylose (%)	Degree of polymerization (A, B1, B2, B3, B4)
Barley	29.8	≥37, 6–12 and 6–9
Wheat	21.5–26-6	≥37, 25–36, 13–24, 6–12 and 6–9
Rice	29.1	51–69, 21–25, 7–18, 1–5 and 0.1–1.3
Triticale	22.2–23.8	20–27, 12–18, 4–9 and 2–3

Amylose and amylopectin are different types of glucans Figure 2.1. Amylose is a low-molecular-weight polymer (1.03–4.89 x 105), consisting of linear chains connected by α-1,4 glycosides connections. Amylopectin's cluster-like structure and large molecular weight suggest considerable branching. Amylopectin is formed of chains with many branches produced by α-1,6-linked linear glucans units, which make a well-organized structure.

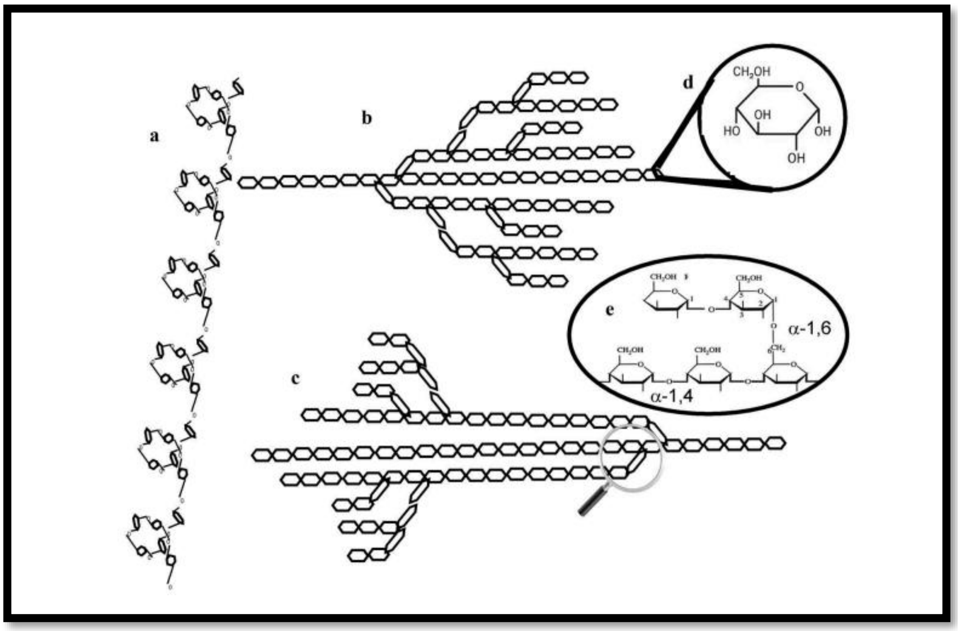


Figure 2.2 Schematic of a) helical amylose and b) complete and c) substituted triticales. d) Glucose unit of both polymers structures and e) linear chain α-1,4 glycosides and branch α-1,6 glycosides (Cornejo-Ramírez et al., 2018).

2.4.2 Starch is Biodegradable

As a naturally renewable, economical, and common material, starch is one of the most used ingredients for biodegradable polymers (Sarkar et al., 2021). Starch films are brittle and difficult to manage, so different plasticizers are usually added to the film-forming solution before casting and drying to make thermoplastic starch (Thakur et al., 2019). According to Ribba et al., (2017), explain that to make thermoplastic starch, different plasticizers are usually added to the solution for making the film before casting and drying (TPS). This eco-friendly material may be produced using two primary methods. Hot press and solution casting are the most popular techniques used in thermoplastic starch development experiments documented in the literature (Jumaidin et al., 2020). Starch is biodegradable, cheap, and physically and chemically modifiable. People will be able to "grow" adequate performance polymers from the ground, and environmental issues will no longer be as serious as they are currently. Physical and chemical techniques are successful for developing starch-based biodegradable polymers with adequate bioavailability, degradation rate, and physical qualities for a variety of applications (Lu et al., 2009).

2.4.3 Starch Based-Bioplastics

From the research of Gadhave et al., (2018), bioplastics derived from starch consist of starch, cellulose, chitosan, and protein. The creation of bioplastic begins with the hydrolysis of starch to make it acceptable for thermoplastic manufacturing. To produce thermoplastic starch (TPS), water and glycerol are added as plasticizers (Jumaidin et al., 2020). These combined substances reduce the starch's melting point and increase its viscosity (Decaen et al., 2020). When consumed, non-toxic starch transforms into a paste and increases in viscosity. However, the newly developed materials are not yet ready for production. The combination is extremely susceptible to moisture and is not particularly resilient. To create a tensile material, additional biopolymers are added to the mixture (Soldo et al., 2020). Commonly added biopolymers include polylactic acid (PLA) and polyhydroxy butyrate. Additives that make the plastic more robust and tensile are one of the challenges of creating starch-based bioplastics. These additives, like starch, must be biodegradable and renewable for the newly created plastic to be deemed compostable (Moshood et al., 2022) An additional benefit of bioplastics derived from starch is their sustainability in the early stages of their existence.

2.4.4 Starch Based Bio Composite

Bio composites are natural fibre-reinforced biopolymers (Ruhul Amin et al., 2019). Recently, several researchers are going to concentrate on the manufacture of polymers that are based on starch. Along with the development of polymer bio composites, the creation of bio composites can be accomplished by adding filler reinforcement to starch-based polymers (Hazrati et al., 2021). Next, this method of reinforcing starch-based materials with natural filler has been an effective strategy for simultaneously improving the mentioned attributes and incorporating novel characteristics (Ilyas et al., 2018).

According to Żołek-Tryznowska & Kałuża (2021), the method of reinforcing starch-based materials with natural filler has been demonstrated to be an effective strategy for simultaneously improving the mentioned attributes and incorporating novel characteristics. In addition, the fact that biodegradable starch-based polymers are presently being offered commercially by firms with recognisable brand names such as Mater-Bi® ® (Novamont, Italy); Bioplast® (Biotech, Germany); Biopar® (Biopolymer Technologies AG, Germany); NovonTM (produced by Chisso in Japan and Warner Lambert in the United States); Cardia BioplasticsTM (Cardia Bioplastics Ltd, Australia); and Plantic® R1 (Plantic (Halley, 2005).

2.5 Sago Starch

The real sago palm (Metroxylon sagu) is one of the potentially exploited food palms that grows well in the tropical rain forests of Southeast Asia (Ahmad et al., 2020). Malaysia is the leading exporter of starch from sago (Metroxylon sagu) palm at 47,000 metric tonnes per year, with 96% of the starch produced from Sarawak. The Sago palm has a crown of compound leaves that terminates in a tall, woody, unbranched stem with non-branching roots that descend directly into the soil (Uthumporn et al., 2014). Next, according to Aole, Toyoda, & Johnson (2018), explain that sago production is a major industry in Malaysia, Indonesia, and Papua New Guinea. This tree has the benefit of being able to survive in wet, acidic, salty clay soils and soil salinity, where most crops fail. Sago palm tree is extremely resistant to difficulties like drought, flood, severe wind, and fire (Zhu, 2019). The knowledge that there are distinctions between the true sago tree, also known as Metroxylon sago, and the Japanese sago tree is significant (Cycas revolute) (Malviya et al., 2010). The latter is a plant native to southern Japan and can be utilised not only for the manufacture of starch but also as a food source. In addition, Metroxylon's supply of sago concentrate has the potential to be substantial, with yields equivalent to potatoes, since each mature sago plant may hold up to 400 kg of dry starch (Ahmad et al., 2020). Additionally, it was said that the manufacturing cost of sago starch is low, the yield is high relative to other starch sources. (Yukiootoyoda & Johnson, 2018). When compared to other starchy crops, the sago palm has one of the greatest productivity rates for producing starch. The incremental cost of producing sago starch is minimal, and the yield is high, as compared to the production of starch derived from other sources. The starch production per unit area of sago coconut is among the greatest of all starchy crops (Ahmad et al., 2020).

2.5.1 Extraction of Sago Starch

The conventional approach to the removal of sago starch can be broken down into two distinct stages, domestic level and small-scale processing plant extraction. the household and community level, which individual farmers practise, sago palms are chopped down and processed in the garden, removing the heavy trunks that need transport. This level of production is known as "domestic level. "The trunk is then cut in half lengthwise once it has been felled with an axe (Paluga & Ragragio, 2016). To remove the pith, a chopper or a small hoe fashioned out of bamboo is often used (Figure 2.3). The combination of fibre and pith has been scrape is placed on the wide end of a sago palm leaf sheath, there is a sieve. At the bottom end of the leaf sheath, there is another sieve. After adding water to the mixture, the water is worked into it by hand. (Figure 2.4). The fibres stay on top of the mesh while the starch granules are carried by the water in suspension moves through the sieve and is collected in an ancient dugout canoe or any other container that is suited for the task. The starch falls to the bottom of the container, and any extra water runs down the sides. Following the completion of the kneading process, the fibrous residues are thrown away, and to remove the starch from the canoe or container, it must first be moistened (Figure 2.5) (A. N. Ahmad et al., 2020).

Figure 2.3 Palm fronds (trunking and suckering palms)

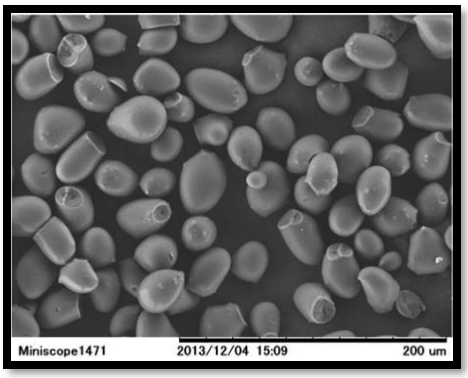
Figure 2.4 Remove the core

Figure 2.5 Fibre and pith mixture that has been scrape

Figure 2.6 The Wet starch is extracted from the canoe or other vessel

2.5.2 Structure Sago Starch

Sago starch is crystalline. Sago starch granules have an oval form resembling a temple bell (Figure 2.7). Using scanning electron microscopy, the structure and size of indigenous sago starch granules from Leyte, Philippines are examined, were found to range from 8 to 240 m in diameter, with a mean value of 37.59 m, indicating that the stroma of an amyloplast formed a septum-like structure and suitable for reuse the temple bell-like shape (Okazaki, 2018).



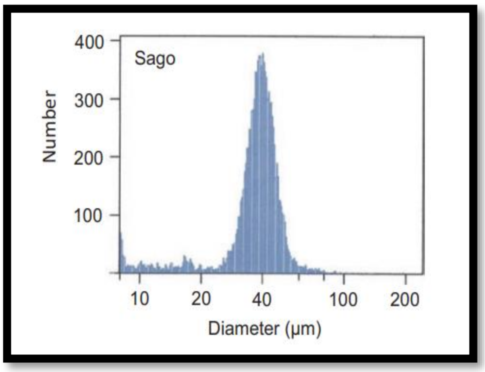


Figure 2.3 Image of sago starch granules from Leyte, Philippines using electron microscope (Okazaki, 2018).

Figure 2.4 Sago starch from Leyte, Philippines, and how big its particles are (Okazaki, 2018)

Using a polarised light microscope to look at sago starch grains allows for a clear view of their crystalline characteristics (Nishiyama et al., 2015) (Figure. 2.9). The appearance of a Maltese cross in sago starch granules (Figure 2.9 B, C) implies the existence of a consistent internal ordering.

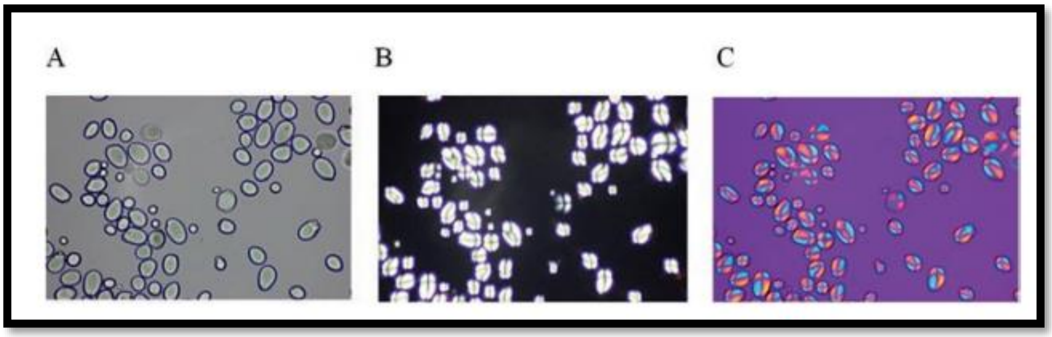


Figure 2.5 Sago starch examine with the light microscope and polarised light microscope (Okazaki, 2018)

According to Nishiyama et al. (2015) They studied nanoscale X-ray diffraction (XRD) patterns of starch granules from corn, potatoes, and sago, and showed that starch is composed of narrow layered domains (Figure. 2.10). XRD is used to compare various starches with the structure of sago starch. They found that the XRD patterns of the strength of the four sago were the same, but the first and fourth circles were different.

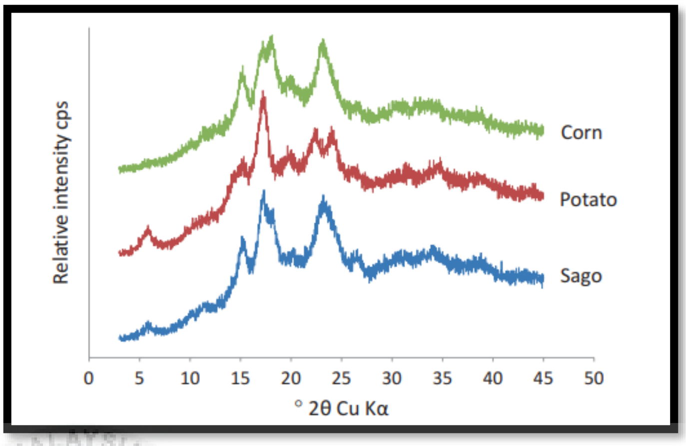


Figure 2.6 XRD pattern of different material (Okazaki, 2018).

XRD is a useful tool to determine the crystallization of sago starch and evaluate its thermodynamics. Weak diffraction peaks characterize Indonesia at 2 = 5.67° and broad peaks at 2 = 15.30°, 17.12°, 18.08° and 23.46° indicate type C. Also, according to Okazaki, (2018), sago starch at various stages of development in Malaysia is type C. However, X-ray diffraction analysis of sago starch was not sufficient to give an idea of the flexibility of the structure in wet and dry processes.

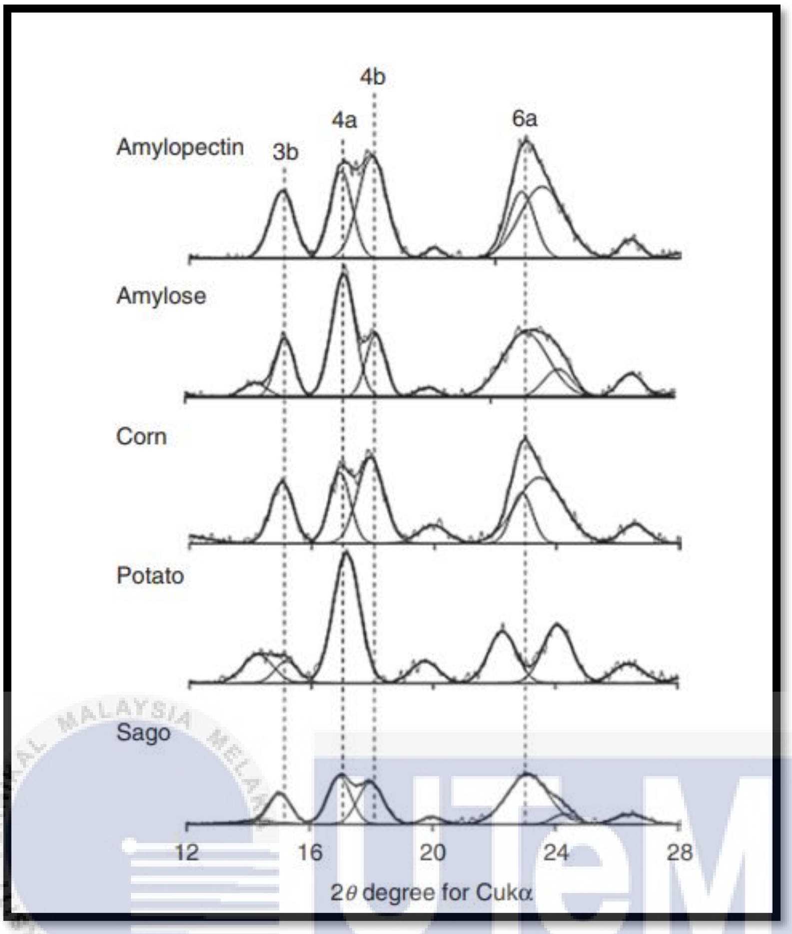


Figure 2.7 Diffraction of X-rays following waveform separation (Okazaki, 2018).

The structure of amylopectin found in sago starch consists of a chain of α(1,4) linked D-glucosyl units linked via α(1,6) bonds. It has a molecular weight of 107-108 and a degree of polymerization of 12,000-40,000, whereas amylose is mainly composed of linear glucose units linked by α-(1,4) bonds and has a molecular weight of 105 – 106 (degree of polymerization in the range of 600–36,000). It is related to amylopectin. This component constitutes approximately 98-99% of the dry weight of the starch. Amylose makes up somewhere between 15 and 35% of the starch's weight. When there is a high percentage of amylose in starch, the stickiness of the starch decreases, and the temperature at which it gelatinizes drops (Okazaki, 2018).

2.5.3 Characteristics of Sago Starch

Gelatinization is characteristic of sago starch. Sago starch is known for its ability to turn into gelatin. Disruption of molecular order in starch granules results in permanent changes in properties such as granule swelling, melting of intrinsic crystallites, loss of polarization, and starch dissolution (Du et al., 2020). Additionally, sago starch requires less heat to gel and has a higher tendency to regenerate (Du et al., 2020). According to Achudan et al. (2020), compared with type A starch, sago starch has a higher gelatinization temperature and lower peak viscosity. Because of this, it can be used as a stabilizer in a variety of ways.

According to Okazaki et al. (2018) looked at granular birefringence (Maltese cross) under polarised light to see how sago starch granules behaved when they turned into gel (Figure 2.12). The areas of sago starch crystallinity are shown by the blue and yellow areas, which show radial alignments. When heated, the crystals lost their colour, which showed that they were no longer aligned in a radial pattern. The lack of crystallinity started on the surface closest to the eccentric hilum and spread from there to the surface farthest away from the eccentric hilum. At a hot stage, the initial, middle, and final gelatinization temperatures for Papua New Guinean sago starch were 78°C, 80°C, and 83°C, respectively.

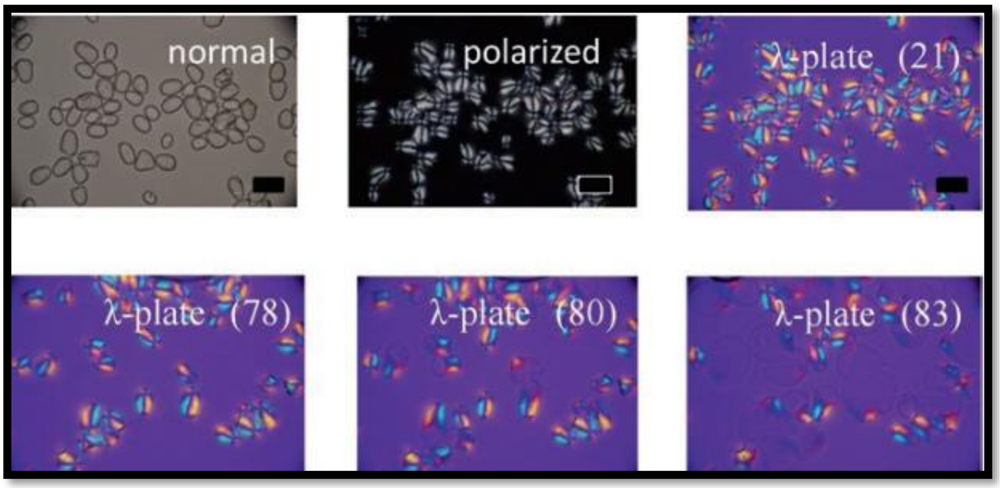


Figure 2.8 Micrographs of sago starch from Papua New Guinea examine with a -plate and normal and polarised light during the gelatinization process. Okazaki (2018)

2.6 Thermoplastics Starch

Thermoplastic starch (TPS) is a plasticizer that combines glycerol, sorbitol, and glucose (Martinez Villadiego et al., 2022). Other chemicals that contain nitrogen, like urea, ammonium derivatives, and amines, can also be used. According to Shanks & Kong, (2012),thermoplastic starch (TPS) has received a lot of attention because it can be shaped like thermoplastics when heated and stretched. However, the structures that are broken are more complicated than those of synthetic thermoplastics. The unique properties of thermoplastic starch make it possible for this biomaterial repeatedly melts and solidifies. This means that it can be used in many ways that traditional plastics can be made. In addition, to being biodegradable and renewable, this can be added to the list of good things about the material. Thermoplastics starch can be made through two main methods. Most studies on thermoplastic starch development use hot press and solution casting as their main methods (Jumaidin et al., 2020).

2.7 Glycerol

Glycerol, also called glycerine in the oleochemical industry, is made when fats are split apart or long-term. It can also be made in a lab using epichlorohydrin and propylene. This petroleum procedure will slowly disappear (Yeong et al., 2012). It is commercially produced by hydrolyzing natural oils and fats extracted from plants and animals. Glycerol is formed by the dephosphorylation of glycerol-3-phosphate by one or more glycerol-3-phosphate phosphatases in yeast and other organisms (GPP). Glycerol is a simple trihydric alcohol that comes in the form of a clear, thick, sweet-tasting liquid. It has no smell. It also attracts and holds water. Even though glycerol and glycerine are often used interchangeably, there are small differences in what they mean (Frigaard, 2018).

Most natural glycerine is made as a by-product when oils and fats are used to make fatty acid, fatty ester, or soap. When oil was split, or hydrolyzed, under high pressure and high temperature, fatty acids and sweetwater were made. 10–20% of the glycerol in the sweetwater. When oil and methanol were mixed in the presence of a catalyst, methyl esters and glycerine were made. Since there is no water used in the process, there is more glycerol. When caustic soda was added to an oil or fat, soap and soap lye were made. The soap lye that is made has between 4 and 20% glycerol in it. This is also called "sweetwater" or "glycerine." Sweetwater or glycerine that comes out of the above three processes as a by-product has impurities and needs to be cleaned up more. Most of the time, crude glycerine is not used directly. MPOB has just put in for a patent on a way to make polyglycerol directly from crude glycerol from biodiesel plants.

According to Kudahettige-Nilsson et al., (2018), glycerol is a plasticizer that is added to materials like plastics, concrete, wallboard, and clay to make them more fluid and flexible. Glycerol is a plasticizer that is added to materials like plastics, concrete, wallboard, and clay to make them more fluid and flexible. Citric acid, glycerol, polyethylene glycol, sorbitol, xylitol, malitol, and urea, which are all plasticizers, have been used as coating agents by mixing with starch and polysaccharides.

2.8 Pineapple Plant

The pineapple (Ananas comosus) is the most economically important member of the Bromeliaceae family. It is a tropical plant with fruit that can be consumed (Jain & Sinha, 2021). Pineapple plant is native to tropical South America and is also widely cultivated in all other tropical and subtropical regions of the world (Pandit et al., 2020a). The leaves of this fruit are precious, as they are the natural fibre with the fewest revisions. It offers a vast array of services and research in various application areas, although pineapple leaves and fruits are typically discarded, burned, or composted. To utilize this affordable resource for valuable materials, long fibres are taken from the leaves of the pineapple plant and utilized to create a variety of composites composed of short and long fibres (Jain & Sinha, 2021).

2.8.1 Structure of Pineapple Plant

Pineapple leaves are spirally arranged in a thick rose-like pattern all around a short stalk. Although leaves are typically spiky, numerous researchers discovered that it was partially or completely devoid of spikes. The pineapple plant is seen in Figure 2.13 (Padzil et al., 2020). As illustrated in Figure 2.13, pineapples have seven component structures: the peduncle, the stem, the many fruits, the crown, the shoots, the roots, and the leaves.

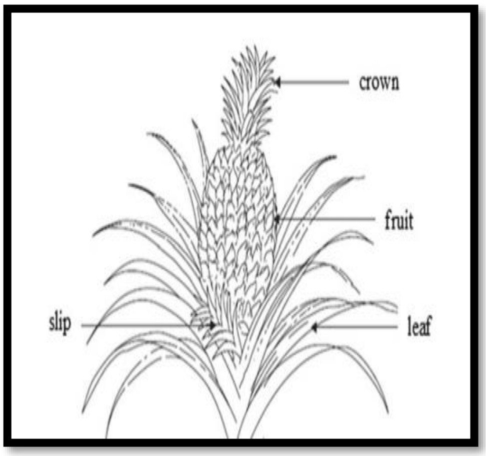
 

Figure 2.9 Pineapple plant and the morphology of pineapple

Next, the plant's sensitivity rises with its growth and stress circumstances because of climatic elements, particularly day length and temperature (Gray&Brady,2016). The plant reproduces primarily through vegetative propagules that form on the stem (stem shoots and ground suckers), peduncle (slips), and fruit cap (crown). The type of planting material impacts the early development of the root system and the length of the first crop cycle, which typically ranges from 12 to 24 months depending on cultivar and temperature(Grossnickle, 2005). After fruit maturity, slips or suckers may be replanted or kept on the plant to provide new growth axes for a subsequent production cycle. The second method is less expensive and shorter because the plant is already established; however, the fruit size is smaller and less consistent, therefore commercial cultivation is normally limited to two or three production cycles (Jain & Sinha, 2017).

2.9 Pineapple Leaf Fibre (PALF)

Annually, tonnes of pineapple leaf fibres are generated, but only a small fraction is utilised for feedstock and energy production (Pandit et al., 2020). Bio-composites are being used more and more in industry, which could help reduce the amount of waste from renewable materials (Christian, 2019). It helps the agricultural industry find a market for things other than food. It is white, smooth, and shiny like silk, and has medium-length fibres that are very strong. Its surface is softer than that of other natural fibres, and it absorbs dye well and keeps its colour (Padzil et al., 2020).

2.9.1 Chemical Composition of Pineapple Plant Fibre

The fibre of pineapple leaves is mostly composed of cellulose, hemicellulose, lignin, and pectin (Jain & Sinha, 2021).The pineapple plant has the largest cellulose content of all natural fibres, making it the strongest and most useful for strength-using items. The chemical composition of fibres directly impacts their properties and applications (Ahmad et al., 2019). Compared to other prevalent natural fibres, pineapple leaf fibres have a greater proportion of cellulose, which contributes to a higher mechanical strength (Jain & Sinha, 2017). The chemical composition of pineapple leaf fibres is displayed in Table 2.6.

Table 2.4 Chemical composition of pineapple leaf fibre (%) (Asim et al. 2015)

Cellulose	68-85
Hemicellulose	16-19
Lignin	5-12
Pectin	1.0-1.3
Moisture content	10-12
Ash	0.8-4

2.9.2 Pineapple Fibre Extraction

Traditionally, PALF is extracted on a long bench using a scraping instrument called "ketam." There are approximately six primary steps, as depicted in Figure 2.14. The PALF scraps are then cleaned under running water and dried in the sunlight (Yusof et al., 2015).

Figure 2.10 Hand scrapping method

In this work, PALF is made using new technology, as shown in Figure 2.14. PALF is taken out of pineapple leaves using a machine called the Pineapple Leaf Fibre Machine 1. (PALF M1). Most extractors and decorticators work like crushers to get PALF out of pineapple leaves. This machine, on the other hand, has blades that scrape off the waxy layer on the leaf instead of crushing it out. Also, the blades were made in a way that had never been done before. An important part of the extraction process is how many blades are used, how big they are, and what angle they need to be at so that the leaf doesn't break (Yusof et al., 2015).

a)

b)

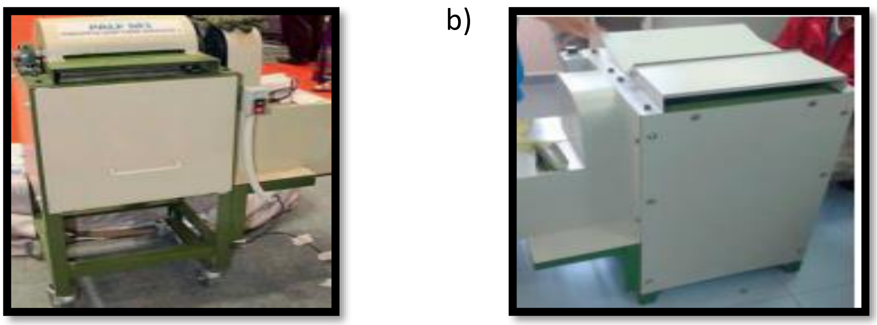


Figure 2.11 a) PALF M1; (b) PALF M2

As can be seen in Figure 2.15, a pineapple leaf is placed in the space between the two blades, which are numbered 1 and 2. When the leaf passes between the blades, it will experience something akin to a grinding motion, and the outer waxy coating will be stripped away during this initial process. During the second phase, when the leaf was being peeled off yet again, it would be ground for the second time, which would remove the entire waxy covering that was left over from the first step. This would take place during the second step. Using the Pineapple Leaf Fibre Machine 2 (PALF M2), as shown in Figure 2.14, the extracted PALF is then cleaned and dried (b). At this point, the remaining green trash that has built up at PALF will be cleaned up and taken away. This machine not only gets rid of green waste, but it also dries the fibre at the same time. PALF M2 is different from PALF M1 in that there is only one rotating drum with blades on it (Yusof et al., 2015).

Figure 2.12 PALF M1 Mechanism

Today's extraction techniques for pineapple leaf fibre are considered waste products of pineapple cultivation. A specialised machine with a metal knife scrapper roller and a serrated roller is used to scrape off the waxy coating, and the pineapple leaf fibre is also retrieved during the retting process. Machine -made PALF is softer, whiter, and brighter than PALF made through traditional processes. As chemical constituents, various pineapple fibers contain cellulose, pentosan, lignin, fats and waxes, ash, nitrogen compounds, and pectin (Pandit et al., 2020).

After extraction, the coarser fibrous strands are broken up by either retting or degumming. First, there is biological natural retting, in which the active ingredients are bacteria or fungi (dew retting).

2.9.3 Fibre Extraction by Retting

Retting is a procedure that uses the activity of microorganisms and water on plants to dissolve or decompose a large portion of the cellular tissue and pectin that surrounds the bark fibre bundles, thus allowing the separation of the fibres from the stem. the relaxation of this fibre can be caused by the removal of the tissue and the rest of the pectic. The leaves are scraped and submerged (Pandit et al., 2020). The leaves are removed and washed with pool water after retting. Push and slide the ceramic plate quickly over the pineapple leaves to expose the fibres. This is an easy way to extract long leaf fibres. Post-harvest metabolism: As part of the sorting system, the quality of pineapples and crowns is the economic standard. Brown spots on canopy leaves result in economic losses (Padzil et al., 2020). Not only is it simple, but it also produces more fibre and small-scale fibres than the traditional process. Wet ball milling was the slowest of the two mechanical milling processes analysed, but produced more PALF filaments (Yusof et al., 2015).

2.9.4 Extraction of Fibre by Chemicals

There are many chemical processes that can be used to remove pineapple gum. These processes include pretreatment (acid immersion, H2SO4), washing, boiling in NaOH solution, washing, bleaching, water extraction, oil extraction, and drying (Pereira et al., 2021). Note that the degumming technique cannot completely remove the gum, as the individual fibers are so short that they cannot be spun (without gum) when separated. Figure 2.17 shows the expected results (Padzil et al., 2020).

Pineapple fibre is chemically degummed by immersing it in a solution of acid, base, or enzyme at different temperatures for different times, all in the absence of oxygen. Hemicellulose, which consists primarily of mixed polysaccharides, is broken down into water-soluble sugars (Padzil et al., 2020). Soapy gums and waxes are converted to soluble soaps, and non-soapy oils are emulsified by soaps and wetting agents. As shown in Figure 2.18, roasting in a boil containing 5% caustic soda for 12 hours produces the best fibre.

Figure 2.13 Sample PALF extract by chemical (Padzil et al., 2020).

Figure 2.14 Sample PALF degumming (Padzil et al., 2020).

2.9.5 Physical Properties of Pineapple Fibre

The physical structure of pineapple substitutes has a rough nature and has a cellular structure with plant material still inside. It is examined with a microscope. They are very crystalline and have a 15° spiral angle. Next, the effect of moisture is that the pineapple fibres get wet, and they become weaker and shorter. The loss of strength may be because water molecules get into the multicellular lignin cellulosic fibres and make them swell up. It loosens the bonds between the final cells, which causes them to slip when a load is put on them. The wetting extension is reduced by 7% in untreated fibres and 12% in degummed fibres.

Moreover, pineapple fibre is a very soft fibre. Pineapple fibres are soft to the touch. Pineapple fibre is white, but it becomes a dull yellow colour and has good shine when it is extracted. Also, pineapple fibre's flexural and torsional rigidity is higher than that of cotton fibre. Pineapple fibre is more crystalline because it is more ordered. The strength and length are about the same as cotton fibre. Based on Table 2.6 is a physical property from (Padzil et al., 2020a)

Table 2.5 Physical characteristics of pineapple fibre

Single cell	
Length (mm)	3-8
Diameter (μm)	7-18
Fineness (tex)	2.5-4
Fibre Bundle	
Length (mm)	10-90
Fineness (tex)	2.5-5.5
Tenacity (cN/tex)	30-40
Elongation (%)	2.4-3.4
Initial modulus (cN/tex)	570-700
Density (g/cm^3)	1.543

2.9.6 Chemical Properties of Pineapple Fibre

The treatment of pineapple fibres with 18 percent sodium hydroxide produces crimps and enhances fracture fibre elongation. More shrinkage occurs along the longitudinal axis (Jain et al., 2021). Next, peroxide bleaching enhances the fineness by 5% to 6% but decreases the tensile strength by 40% to 45%. During bleaching, the fibres also lose their natural form and flavour and become hard. Loss of hemicellulose and lignin is closely connected to changes in the physical characteristics of the fibres, such as changes in orientation angle, decrease in crystallinity, and transitions from cellulose-I to cellulose-II. The brightness of bleached pineapple fibre is around 78%, whereas that of unbleached pineapple fibre is 70%. The breakdown of fibres renders hypochlorite bleaching ineffective. It was discovered that peroxide bleaching of raw pineapple fibre decreased lignin, hemicellulose, and pectin by 27,3 percent, 52,8 percent, and 100 percent, respectively. Pineapple fibre dissolves in 60 percent sulfuric acid in 5 min. Two hours of boiling soda enhances absorption accompanied by a modest decrease in tensile strength and a loss of weight. Pineapple fibres are more resistant to fading when dyed with direct, reactive, vat, and azo dyes than cotton. In addition, the propensity of the fibre to absorb colour is greater than that of cotton. This pineapple fibre may have a relatively high moisture content and a poor reflectivity value owing to the presence of a greenish-yellow pigment. The inclusion of (–OH) and (–COOH) groups improves the fixing of reactive dyes. In addition, research indicates that pineapple fibre may be simply coloured using simple dyes at room temperature. Due to lignin and hemicellulose, which are more than 15 percent amorphous and acidic in nature, the wood is acidic (Padzil et al., 2020). Based on Table 2.8, display the chemical composition of the bundle of pineapple fibres.

Table 2.6 Chemical content of pineapple fibre bundle (Padzil et al., 2020)

Cellulose	55-68%
Hemicellulose	15-20%
Pectin	2-4%

Water- soluble material	1-3%
Fat and wax	4-7%
Ash	2-3%

2.9.7 Application of Pineapple Fibre

Pineapple fibre is used to make cloth, and sometimes it is mixed with silk or polyester to make other kinds of textiles. Pineapple fibre is also used to make tablecloths, bags, rugs, and other types of clothing (Tamta & Mahajan, 2020). In different parts of the world, it is used in different ways. Pineapple fabric has a lot of uses and is good for the environment because of how versatile it is. Weaving, sewing, and other skills are used to make commercial products (Yusof et al., 2015). There is a chance that there will be a big market in Assam and other parts of India outside of the north-east. Compared to PALF, natural fibres from crops like jute, coir, ramie, flax, and hemp are already well-known on the market around the world. PALF can be used to make things like handbags, coasters, and many other home decor items. Cars and train cars are made with PALF copolymer and composites (Pandit et al., 2020).

2.10 Composition Glycerol Plasticized Thermoplastic Sago Starch

TPSS was produced using weight fractions of 40/60, 35/65, and 30/70 glycerol/starch, as indicated by a prior study by Zuraida et al. (2012). At various glycerol/starch ratios, the composition, density, moisture content, and water absorption capacity of functional groups were examined.

Based on Figure 2.19 shows the results of a density test performed on TPSS using different concentrations of plasticizer and starch. The graph shows that the greater the ratio of glycerol to starch, the less dense the material. The densities of 30/70, 35/65 and 40/60 were 1.43, 1.37 and 1.34 g/cm3, respectively. The presence of glycerol altered the structure of the starch network, making the film matrix less dense. The ratio of glycerol to starch also measures the distance between the particles. The low starch to water ratio results in fewer voids and a denser material. The graph demonstrates that a higher ratio of glycerol to starch resulted in less density than a lower ratio. 30/70, 35/65, and 40/60 obtained densities of 1.43, 1.37, and 1.34 g/cm3. In contrast, a larger glycerol/starch ratio increased the water absorption of TPSS in a linear on Figure 2.20. The percentage of water absorbed was 82.5% for the weight ratios 40/60, 35/65 and 30/70, respectively. The inclusion of a higher proportion of hygroscopic glycerol and starch increased the absorption rate of TPSS, and the hydrophilicity of the starch increased the absorption rate further. The amount of amylose in the starch creates a stiff filament network that traps more water in the pores.

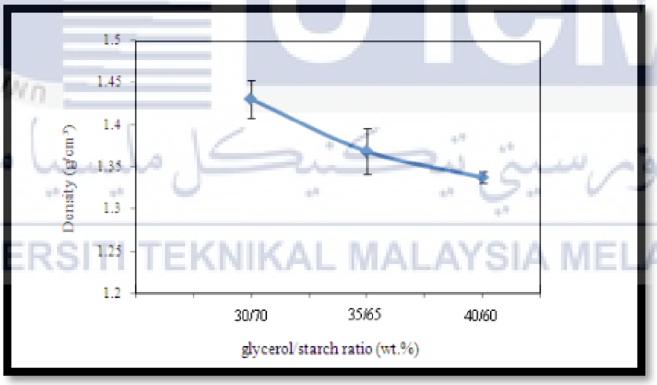


Figure 2.15 Density of TPSS with different ratio

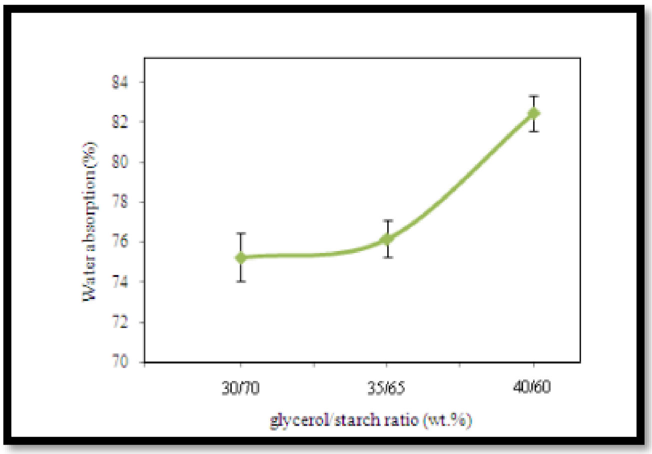


Figure 2.16 Water absorption of TPSS with different ratio

According to (Zuraida et al., 2012), a lower ratio of glycerol to starch reduced the water absorption and moisture content of TPSS. Thus, TPSS with a glycerol/starch ratio of 30/70 is viable.

2.11 Summary or Research Gap

On the idea of the literature review, summarise all facts collected from the researcher`s preceding investigations. Possibility of sago starch being thermoplastic with glycerol. Due to their hydrophilic nature, primary starch based totally substances have vulnerable mechanical properties, specifically elongation, and a low moisture barrier. As a plasticizer, glycerol become utilised to enhance the interfacial adhesion among sago starch. With a decrease amount of glycerol, starch molecules interacted extra strongly. The TPSS is sensible with a glycerol/ sago starch ratio of 30/70 percentage via way of means of weight. Furthermore, Pineapple plant leaves are suited due to the fact they may be the herbal fibre that has passed through the fewest alterations. It has extensive software capacity in composite substances. The manufacture of thermoplastics starch-bolstered pineapple leaf fibre calls for 15 mins of compression moulding (Hot press machine) at 165°C. The liquid become poured right into a mould product of milled steel. This observe evaluates the composition (in percentage) of numerous TPSS/PALF bio-composite general weights. Finally, an outline of the look at used to observe the bodily and environmental traits of thermoplastics bolstered with pineapple leaf fibre and sago starch.

Table 2.7 Summary of previous researches findings

No.	Literature Title	Strength	Weakness	Notable Features	Reference
1.	The study of glycerol plasticized thermoplastic sago starch	XXXX	XX	XXXX	(Zuraida et al., 2012)
2.	Processing of Thermoplastic Starch	XXXX	XX	XXXX	(Jumaidin et al., 2020)
3.	Pineapple Leaf Fibre : Cultivation	XXXX	XXX	XXXX	(Pandit et al., 2020a)
4.	Physicochemical properties of starch from sago (Metroxylon Sagu) palm grown in mineral soil at different growth stages	XXX	XX	XXXX	(Uthumporn et al., 2014)
5.	Recent advances in modifications and applications of sago starch	XXXX	XX	XXXX	(Zhu, 2019)
6.	Glycerol/citric	XXXX	XX	XXXX	(Kudahettige-Nilsson et al., 2018)
7.	Chemical, Physical and Biological Treatments of Pineapple Leaf Fibres	XXXX	XX	XXXX	(Padzil et al., 2020b)
8.	Matrix materials used in composites: A comprehensive study	XXXX	XX	XXXX	(Sharma et al., 2020)
9.	Polymer matrix-natural fiber composites: An overview	XXXX	XX	XXXX	(Yashas Gowda et al., 2018)
10.	Biopolymers and biocomposites-mediated sustainable high-performance materials for automobile applications	XXXX	XX	XXXX	(Bhagabati, 2020)
11.	History and future of starch	XXXX	XX	XXXX	(Schwartz & Whistler, 2009)
12.	A molecular perspective on starch metabolism in woody tissues	XXXX	XX	XXXX	(Noronha et al., 2018)
13.	Reinforcement of starch based biodegradable composite using Nile rose residues	XXXX	XX	XXXX	(Ibrahim et al., 2020)
14.	Characteristic of thermoplastics corn	XXXX	XXX	XXXX	(Zakaria et al., 2020a)

No.	Literature Title	Strength	Weakness	Notable Features	Reference
	starch composite reinforced short pineapple leaf fibre by using laminates method				
15.	Disadvantages of Starch-Based Materials, Feasible Alternatives in Order to Overcome These Limitations	XXXX	XX	XXXX	(Ribba et al., 2017)
16.	Potential of using multiscale kenaf fibers as reinforcing filler in cassava starch-kenaf biocomposites	XXXX	XX	XXXX	(Zainuddin et al., 2013)
17.	Preparation of novel biodegradable starch/poly(vinyl alcohol)/bentonite grafted polymeric films for fertilizer encapsulation	XXXX	XX	XXXX	(Sarkar et al., 2021)
18.	The structural characteristics of starches and their functional properties	XXXX	XX	XXXX	(Cornejo-Ramírez et al., 2018)
19.	Effect of Fiber Loading On Properties Of Sago Starch/Kenaf Core Fiber Biocomposite	XXXX	XX	XXXX	(Sarifuddin et al., 2012.)
20.	Thermoplastic Starch	XXXX	XX	XXXX	(Shanks & Kong, 2012)
21.	Effect of sago starch modifications on polystyrene/thermoplastic starch blends	XXXX	XX	XXXX	(Wahab et al., 2021)
22.	History and future of starch	XXXX	X	XXXX	(Schwartz & Whistler, 2009)
23.	Biodegradable Plastics From Sago Starch	XXXX	XX	XXXX	(Ain et al., 2017)
24.	Natural Fiber Reinforced Starch Based Biocomposites	XXXX	X	XXXX	(Ruhul Amin et al., 2019)
25.	The study of biodegradable thermoplastics sago starch	XXXXX	XX	XXXX	(Z. Ahmad et al., 2011)

No.	Literature Title	Strength	Weakness	Notable Features	Reference
26.	The structure and characteristics of sago starch	XXXX	XX	XXXX	(Okazaki, 2018)
27.	Thermoplastic Starch Processing and Characteristics-A Review	XXXXX	XX	XXXXX	(Zhang et al., 2014)
28.	Green Composites of Thermoplastic Corn Starch and Recycled Paper Cellulose Fibers	XXXX	XX	XXXXX	(Wattanakornsiri et al., 2011)
29.	Thermoplastic starch prepared with different plasticizers: Relation between degree of plasticization and properties	XXXX	XXX	XXXX	(Zuo et al., 2015)
30.	Pineapple leaf fibers for composites and cellulose	XXXX	XXX	XXXX	(Leao et al., 2010)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter contains comprehensive information on specific procedures or techniques used to identify, select the method process and analyze information about this chapter. In this chapter, the technique part allowed the reader to evaluate the whole process and reliability critically. This research will provide in five stages. The first stage is the raw material used in this research. The second stage is the material preparation experiment by using a hand-mixed technique. The third stage is to fabricate the experiment, PALF and TPSS using composition (wt.%). The mixtures of PALF with different wt.% of TPSS was made using Compression Molding (Hot Press Machine) in 50 minutes at 190 °C with different fibre. In the fourth stage, the sample will be cut into specific testing sizes using the table saw cutting machine and used four types of testing: moisture content, density, water absorption, soil burial, and water solubility. The last stage is the analysis of the data. This chapter will summarise the experiment and technique to achieve an extract and precise outcome.

3.2 Flow chart

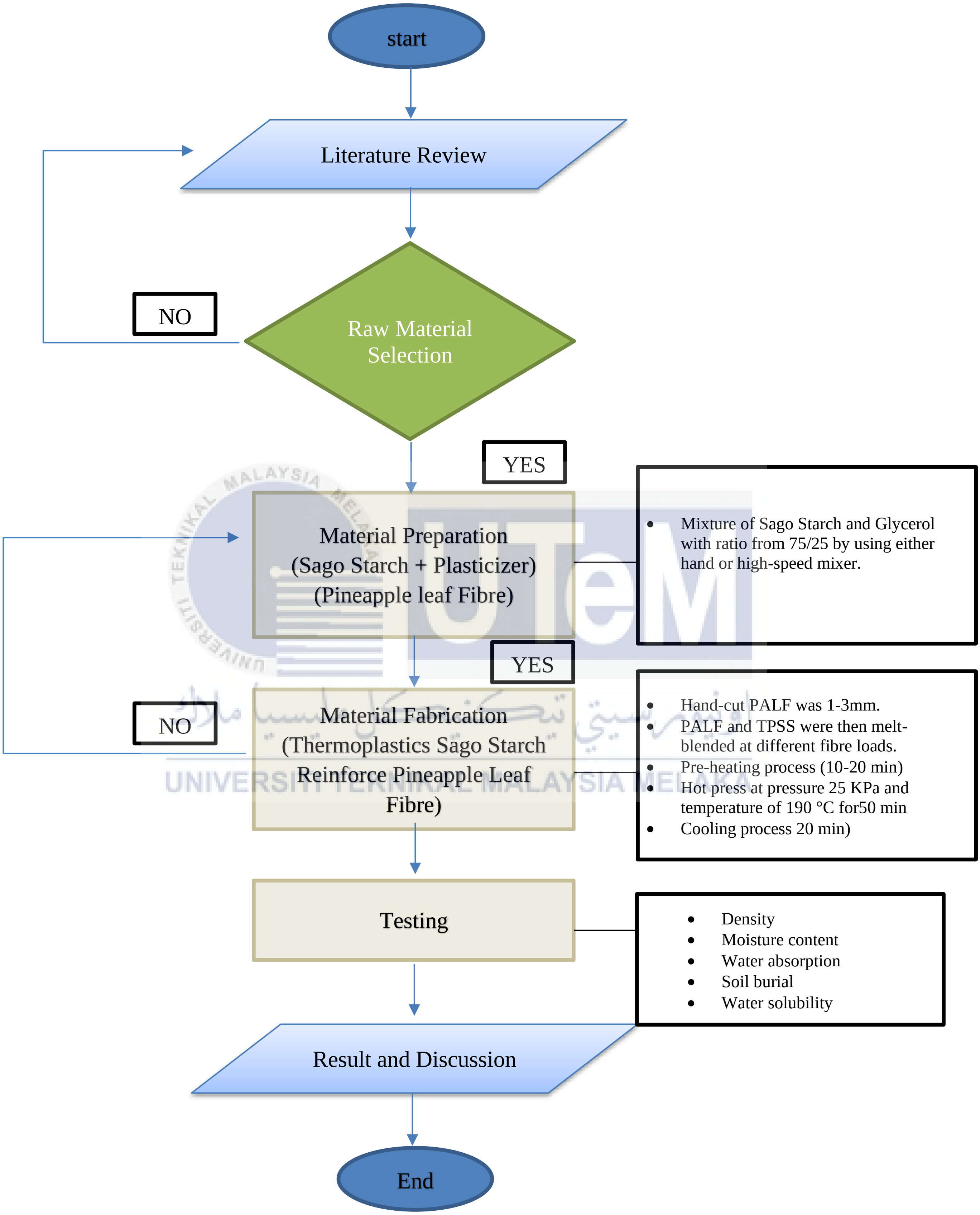


Figure 3.1 Process Flow Chart

3.3 Raw material

The sago starch utilised in this study is powdered and intended for industrial use. Polyscientific Enterprise Sdn. Bhd. Melaka provided sago starch powder and glycerol. Qrec G4018-1-2500 was the glycerol brand utilised. In this investigation, the PALF type was obtained from Josapine cultivars supplied directly from farmed regions in Kampung Parit Puteri Menangis, Pontian, Johor, Malaysia.

3.4 Material preparation

Thermoplastics sago starch was prepared from blended 75 wt.% of sago starch powder and 25 wt.% of glycerol via hand-mixed and high speed blender for about 2 to 3 minutes (Zuraida et al., 2012). Figure 3.1 shows the preparation flow for thermoplastic sago starch. The first step calculates the weight on mild steel mould. The total weight that needs is 40g.Next, PALF was hand-cut into 1-3 mm pieces and grinding process will be do using crusher machine. Figure 3.2 shows the preparation flow PALF with composition TPSS. PALF and TPSS were then melt-blended at different fibre loads. Table 3.1 indicates TPSS/PALF composition (wt.%) with total weight 40 grams. The mixture is weighed using a digital scale before being placed in mild steel mould with fixed length x width x height of 140 mm x 60 mm x 3 mm. After preparing the mixture in the mould, it will be preheated in Figure 3.3 using hot press machine for 50 minutes. The mould is then hot-pressed at 25kg/cm2 and 190°C for 50 minutes, followed by 20 minutes of chilling. The final sample is taken from the H frame 10 tonne mould. Before testing, the finished sample is chopped using a table saw.

Figure 3.1 Preparation flow thermoplastic sago starch

Table 3.1 Compositions of TPSS/PALF bio-composite

Loading	PALF (wt.%)	Grams	TPSS (wt.%)	Grams
10/90	10	4	90	36
20/80	20	8	80	32
30/70	30	12	70	28
40/60	40	16	60	24
50/50	50	20	50	20

Figure 3.2 Preparation flow TPSS/PALF

3.5 Moisture content

Five specimens were prepared for the moisture content investigation as shown in figure 3.3. The samples are chopped into little pieces which are (10 mm x10 mm x3 mm) as showns in Figure 3.4. Next, Figure 3.5 shows the specimens of each composition were heated in an oven for 24 hours at 105˚C. The weight of the specimens before W_1 and after W_2 heating was obtained in order to calculate the moisture content. The moisture content was determined by using (Eq 3.1). A moisture content test was carried out according to (Zakaria et al., 2020a)

$$\text{Moisture Content (\%)} = \frac{(W2 - W1)}{W1} x\ 100 \qquad (3.1)$$

Figure 3.3 Specimen was prepared for the moisture content

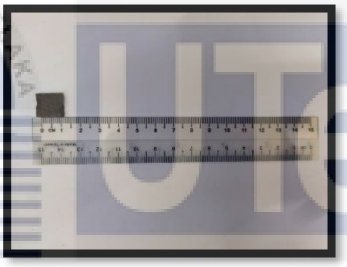


Figure 3.4 Specimen size 10 x 10 x 3 mm

Figure 3.5 Oven electrically heated

3.6 Density

The density test is conducted in accordance with ASTM D792 guidelines (Hashim et al., 2017). The samples are chopped into little pieces which are (10 mm x10 mm x3 mm). The density of the PALF reinforced thermoplastic sago starch composites was determined by using an electronic densimeter (Figure 3.4). Before being submerged in water, all sample weights (m) were recorded. The volume (V) of samples was determined by comparing the quantity of water present before and after immersion. This number was used to determine the density of thermoplastic starch-reinforced PALF composites. The density was determined by using (Eq 3.2). A density test was carried out according to Razali et al., (2019).

$$\rho = \frac{m}{v} \qquad (3.2)$$

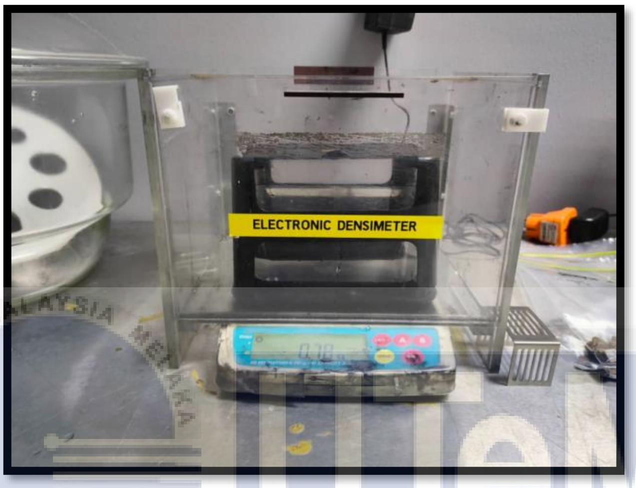


Figure 3.6 Electronic densimeter

3.7 Water absorption

Water absorption test was carried out according to Sarifuddin et al., (2021) and Razali et al., (2019). Water absorption test is conducted in accordance with ASTM D570 guidelines. All samples were first dried in an oven at 105˚C for 24 hours until constant weight was attained and then dipped in the distilled water at ambient temperature. All specimen with size (10mm x10mm x 3mm). Next, figure 3.7 shows the samples were then submerged in water at room temperature (23±1°C) for 30 minutes to two hours. The samples were weighed before (W1) and after (W2) immersion. Using (Eq 3.3), the water absorption of the samples was estimated.

$$\text{Water Absorption (\%)} = \frac{(W2-W1)}{W1}\ x\ 100 \qquad (3.3)$$

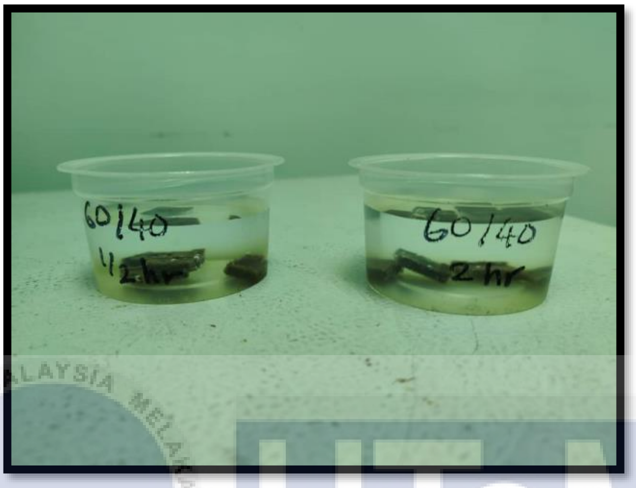


Figure 3.7 Sample were submerge 30 minutes and 2 hours

3.8 Soil burial

Soil burial test was carried out according to Sarifuddin et al., (2021). Five samples measuring (10 mm x10 mm x3 mm) were buried 100 mm below the soil's surface. Figure 3.8 shows the soil buraial process. The samples were buried periodically at 14-week intervals, and each sample was buried in the compost at the same time. The sample was then washed with water and dried at 105°C in a vacuum oven to get an uniform weight. Using (Eq 3.4), the sample’s weight loss was calculated. Where (W1) is the weight before burial and (W2) is the weight after burial.

$$\text{Weight loss (\%)} = \frac{(W1-W2)}{W1} x100 \qquad (3.4)$$

Figure 3.8 Soil burial process

3.9 Water solubility

Water solubility of the samples was determined according to the method by Halimatul et al., (2019). The samples were trimmed to size (10mm x 10mm x 3mm) and dried at 105 ± 2°C before the test to measure their starting weights (W1). The samples were then submerged in 30 ml of distilled water as shown in figure 3.9. The materials were gently mixed from time to time. After 24 hours of immersion, the samples were removed from the beaker and the leftover water on the surface was removed using filter paper. The samples were then dried for 24 hours at 105 ± 2°C to ascertain their ultimate (W2) weight. The (Eq 3.5) was used to compute the percentage of water solubility.

$$\text{Water Solubility (\%)} = \frac{(W2-W1)}{W1}\ x\ 100 \qquad (3.5)$$

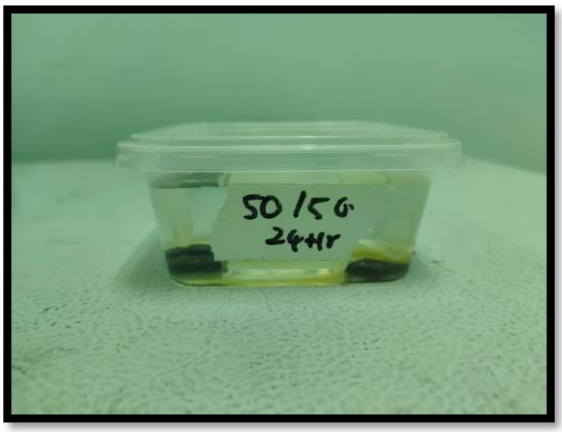


Figure 3.9 Samples were submerged in 30 ml of distilled water

CHAPTER 4

RESULTS & DISCUSSION

4.1 Introduction

This chapter presents the results and discussion taken in expectation of positive results. The experiment will be done used physical and enviromental testing. This chapter will analyse and explain the results of numerous test that were done.

4.2 Moisture content

Before examining a new prospective natural for polymer bio-composites, the moisture content is a crucial quality that must be considered (Zakaria et al., 2020b). A bio-strength, composite's dimensions, and porosity formation may be compromised by a bio-high composite's water content (Jumaidin et al., 2022). Therefore, additional research into the low moisture content of composites is desirable. Figure 4.1 represents the moisture content of TPSS/PALF bio-composites with varying ratios. The graph indicates considerable variations in the moisture content of the samples with decreasing fibre content from 10wt.% to 50wt.% by weight. The higher moisture content of TPSS/PALF samples is 10wt.% which are 0.64%, followed by 0.62%, 0.61%, 0.60 % and 0.58% respectively. In contrast, the high matrix (TPSS) content in the TPSS/PALF bio-composites is responsible for the higher moisture content than the higher fibre concentration. This could be attributable to the hydrophilic nature of the sago starch in the composites (Razali et al., 2019). Furthermore, the addition of glycerol to sago starch produced a mixture (TPSS) with a high hydrophilicity(Pandit et al., 2020b). In addition, these findings are comparable with those reported by Zakaria et al. (2020b), who showed a substantial decrease in the moisture content of PALF reinforced with corn starch bio-composites.

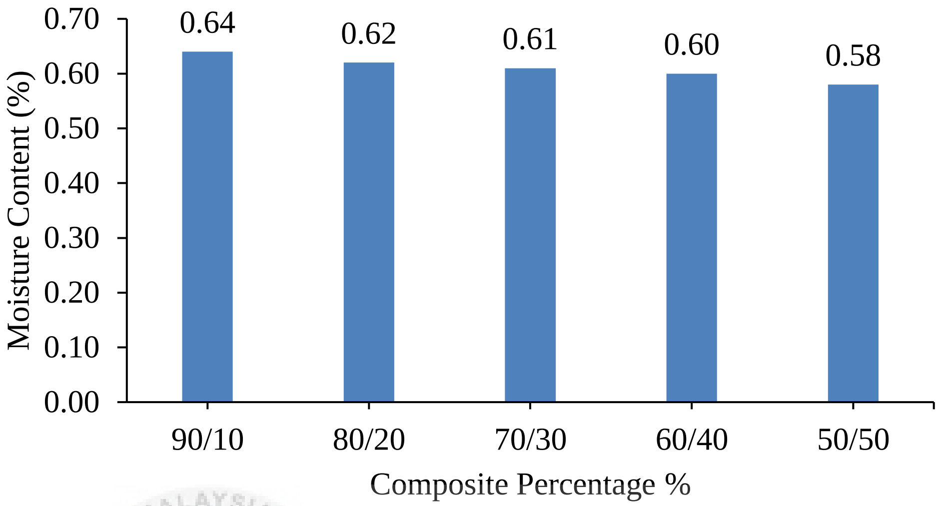


Figure 4.1 Moisture content of TPSS/PALF samples

4.3 Density

The material's weight is one of the most essential factors in the choosing process, since it might affect the quality of the final product (Zakaria et al., 2021). The material's density is the most important factor to consider because of its strong connection to this quality. Figure 4.2 shows the density results of TPSS/PALF bio-composites for various fibre loading. According to Jumaidin et al., (2022), previous research has also shown that the addition of natural fibre reduces the density of composites. The results of a study on the effect of Borassus seed shoot fibre on the characteristics of polyester composites indicate that increasing the fibre content decreases the composites' density (Jumaidin et al., 2022).From this figure, the highest density occurs at 90/10 wt.% fibre loading which is about 1.23g/cm^3 while the lowest value of density is 1.17g/cm^3 with 50/50 wt.% fibre loading, respectively. The difference between lowering the density by more and less is about 6%. Based on what was observed, this can be caused by the formation of voids by the incorporation of fibres into the matrix (Todkar & Patil, 2019). According to research conducted by Zakaria et al., (2021), the addition of PALF replacement material to the thermoplastic starch matrix results in a decrease in density and the production of voids in the composite. This occurs as a result of the manufacturing method and fibre or loading ratio (Mittal & Chaudhary, 2019).We can consider that the density of TPSS/PALF bio-composites is much higher in the matrix (TPSS) than in the fibre (PALF).

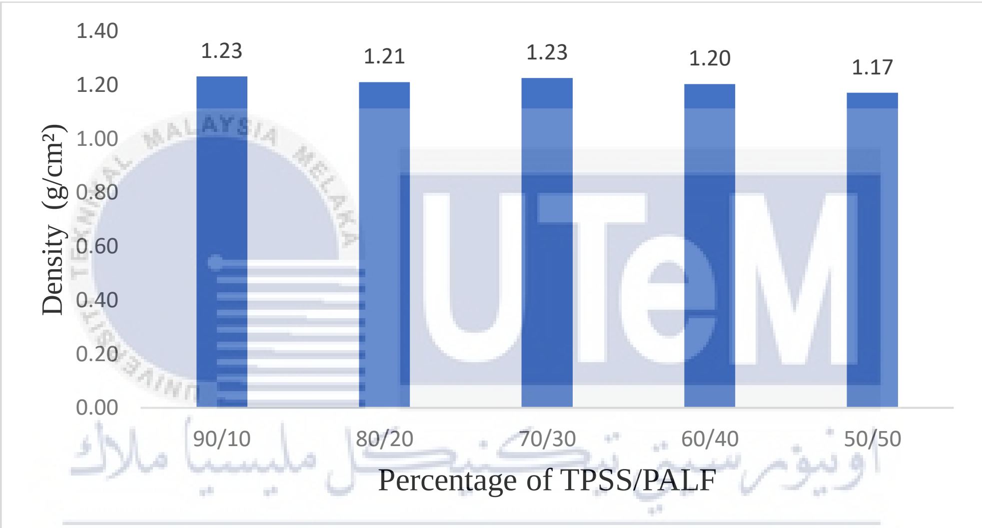


Figure 4.2 The density testing for TPSS/PALF bio-composite

4.4 Water absorption

According to Jumaidin et al., (2022), bio-based materials are known to be water-sensitive; therefore, it is important to review the water absorption characteristics of the totally bio-based material developed in this work. TPSS water absorption is important when determining the material's water affinity when applied in a realistic environment (Zakaria et al., 2020b). Figure 4.3 shows the water absorption of TPSS/PALF samples after 2 periods which is 30 minutes and 2 hours. The TPSS/PALF samples shows higher water intake. This may be due to the hydrophilic characteristics of both the starch matrix and the fibre reinforcing (Zakaria et al., 2021). The lowest result water absorption at 90/10 wt% fibre content about 28.89% and the highest water absorption at 50/50 wt.% fibre content about 46.27%. As result, 30 minutes period shows the lower water absorption rate compare with 2 hours. It has been shown that a longer immersion time results in better water absorption for all mixes since these materials can absorb water. After 2 hours of immersion, the difference in water absorption between the 90/10 mixture and the 50/50 mixture becomes more obvious. This finding is the same as what other studies have found about how PALF absorbs water as they add fibre to their composite (Pandit et al., 2020). Also, the fact that both TPCS and PALF behave in a way that attracts water could be a reason why water absorption is going up.

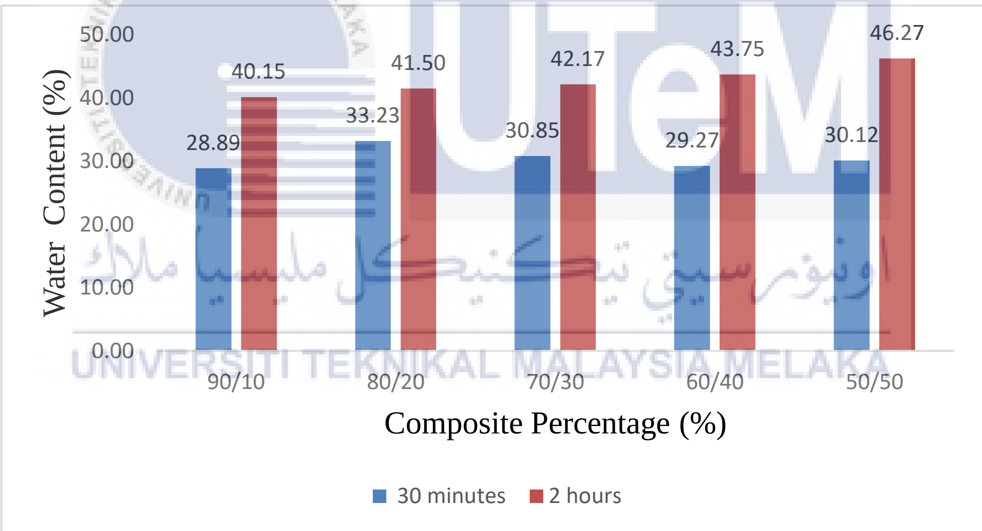


Figure 4.3 Water absorption for TPSS/PALF bio-composite 30 minutes and 2 hours

4.5 Water solubility

According to Halimatul et al., (2019b), the rate at which plastic waste is made is much higher than the rate at which it breaks down. This causes an imbalance in biogeography. This can cause materials cannot to be disposed of in the water. Therefore, bio-based materials are a good solution because they dissolve down quickly when thrown into water (Zakaria et al., 2020b). Figure 4.4 shows the water solubility of the TPSS/PALF bio-composite. It illustrates the composites' resistance to water when immersed and continuously stirred in water. However, water solubility reveals the reductive behaviour of composites when disposed of in water. It was noticed that in general, the water solubility of the fibre content of TPSS/PALF bio composites increase drastically from 32.52 % to 56.84 % when PALF (10 to 50 weight %) is added. Based on these results, a low fibre percentage contributes to a lower water solubility, whereas a high fibre content shows the opposite. This study revealed that PALF can improve the solubility of TPSS/PALF bio-composites. In addition, this research demonstrates that PALF has significantly achieved the biodegradability of TPSS/PALF bio- composites in water, which is beneficial for sustainable waste disposal. But it's important to note that higher water solubility also means that bio-composites are less resistant to water. So, having more PALF may also cause the structure of bio-composites to weaken when they come in contact with water (Jumaidin et al., 2022).

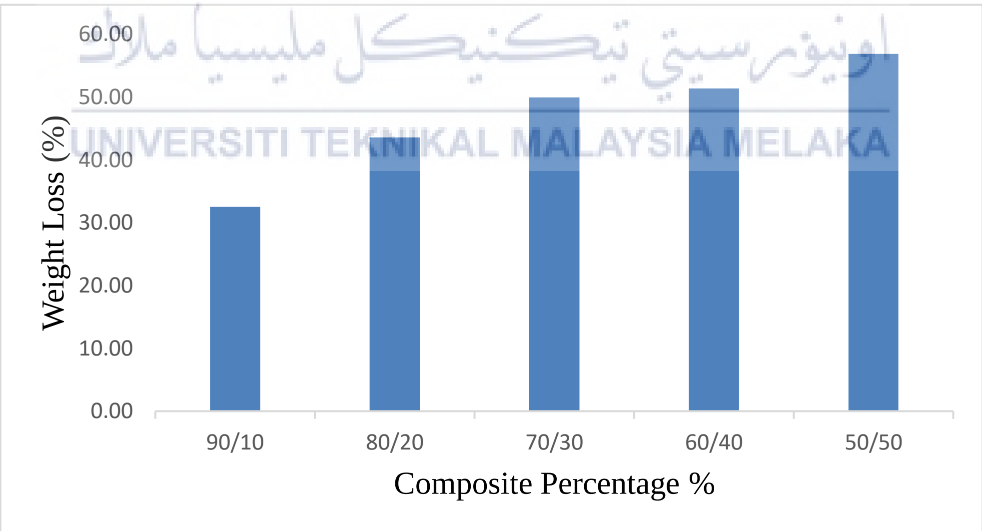


Figure 4.4 Water solubility for TPSS/PALF bio-composite

4.6 Soil burial

Soil burial degradation has been shown to be a successful waste disposal option for biodegradable materials with short service lives (Lv et al., 2018). Material loss in terms of mass is the most significant indicator of the biodegradation by moisture and microorganisms during the period of soil burial as mentioned previous study by Zakaria et al., (2020b). Figure 4.5 clearly depicts the weight loss of TPSS/PALF bio-composites after being buried in soil for 2 and 4 weeks, respectively. As planned, all bio composites showed a more soil burial weight loss after 4 weeks than after 2 weeks. This is due to the activity of the increased microorganisms that happens after a long time of soil burial, which causes the composite to lose more weight. The weight loss of bio-composites was reduced from 62.69 % to 48.53 % following the composition of PALF from 10 wt % to 50 wt % for two weeks and from 71.14 % to 54.75 % after soil burial for 4 weeks. These findings are consistent with recent research by Mittal and Chaudhary (2019), which found that biodegradation involves microorganisms. Other than that, the composites were affected because they were subjected to an attack by microorganisms like bacteria and fungus.

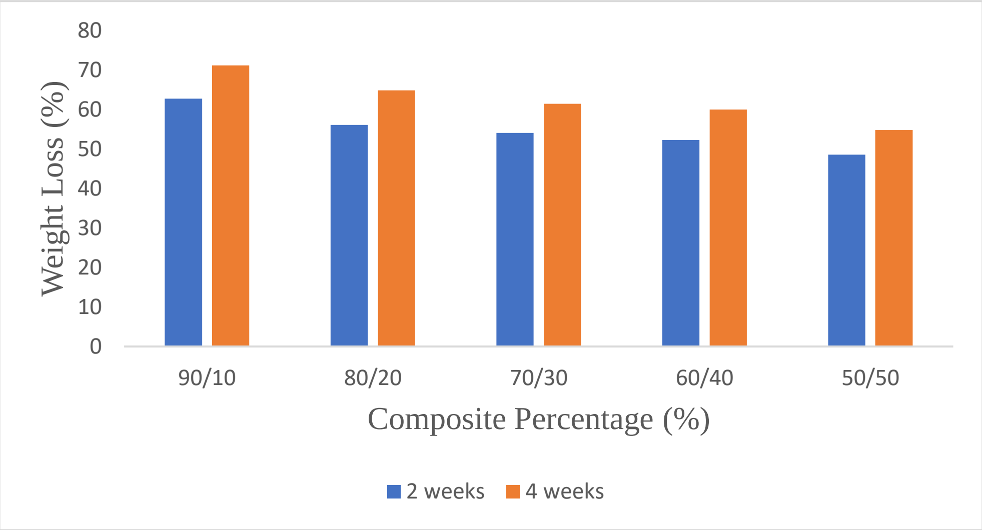


Figure 4.5 The soil burial for TPSS/PALF bio-composite in 2 weeks and 4 weeks

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the conclusion and recommendations for future work for this experiment to improve the data of how to achieve a good quality of strength material on TPSS composition with PALF by using environmental and physical testing which are density, moisture content, water absorption, water solubility and soil burial.

5.2 Conclusion

As stated in the previous chapter, this research must be achieved with three objectives in order to be successful. Bio-polymer composite from TPSS reinforced PALF was successfully prepared by using hot press machine with 5 different percent weight. The specimen was created by combination of TPSS which are 75/25 as a hardener and reinforced with PALF. Next, the composition of TPSS/PALF which are 90% of TPSS and 10% of PALF,80% TPSS and 20% of PALF,70 of TPSS and 30% of PALF, 60% TPSS and 40%, and lastly 50% TPSS and 50% of PALF. The development of pineapple leaf fibre reinforced with thermoplastic sago starch was successful.

Other than that, the physical properties of thermoplastics sago starch reinforced pineapple leaf fibre have been determine by physical testing which are density, moisture content and water absorption. In this study the effect of TPSS reinforced PALF composite on various ratio have been investigated. On density testing 90/10 which are 90% TPSS and 10% is PALF is higher which is about 1.23g/cm^3 than other wt.%. Next, moisture content testing the higher moisture content of TPSS/PALF samples is 90/10 wt.% which are 0.64% than other wt.%. Lastly water absorption the lowest result water absorption at 90/10 wt% fibre content about 28.89% and the highest water absorption at 50/50 wt.% fibre content about 46.27%. Based on results properties of physical TPSS reinforced PALF using physical experiment, moisture content and density shows decreasing pattern when the fibre PALF increase. However, the water absorption shows otherwise when adding fibre content cause the graph increase.

Lastly, the environmental properties of TPSS reinforce PALF have been determine by environmental testing which are soil burial and water solubility. This testing investigates TPSS reinforce PALF how long the disposal rate when in water. The results of soil burial decreases whereby the fibre content increased. Next, for the water solubility the graph shows increase it shows when fibre adding content cause the higher water solubility. It can be concluding the TPSS reinforce PALF have a good interaction on physical and environment testing.

5.3 Recommendation

There is suggestion that could help in this study. Study of the composition sago starch reinforce pineapple leaf fibre and different ratio from this research. According from this study when doing the procedure, there are problems to get good structure on TPSS/PALF. The parameter setting on hot press machine need be accurate setting to improve the composite structure and to avoid the formation of voids on specimen. Next, it will recommend finding another ratio such as higher than 50% to find which ratio are more strength. Lastly, it will recommend making a product using the composite. It can be said that the results of TPSS/PALF composites may be useful since they lead to better use of existing natural fibres and their composites are good for the economy of the country.

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APPENDICES

APPENDIX A Gant Chart PSM 1

No	**Project Task**	**Actual / Plan**	**Week**													
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of supervisor and PSM title	Plan	■													
		Actual	■													
2	Briefing of PSM title	Plan		■												
		Actual		■												
3	Discussing problem statement and objective for the chapter I	Plan			■											
		Actual			■	■	■	■	■							
4	Research and writing of chapter 2, literature review	Plan				■	■	■	■							
		Actual				■	■	■	■	■						
5	Submit and present progression for chapter 2	Plan								■						
		Actual								■	■	■	■			
6	Research and writing of chapter 3, methodology	Plan								■	■					
		Actual										■	■	■		
7	Writing chapter 4 and chapter 5, expected outcome and conclusion	Plan										■				
		Actual											■	■		
8	Submission of PSM I first draft	Plan											■			
		Actual												■		
9	Submission of PSM I second draft	Plan													■	
		Actual													■	
10	Preparation and presentation of PSM I	Plan														■
		Actual														■

Plan	(yellow)
Actual	(green)

APPENDIX B Gant Chart PSM 2

No	Project Task	Actual / Plan	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Discussing and planning tasks with the supervisor	Plan														
		Actual														
2	Purchase raw materials and necessary equipment	Plan														
		Actual														
3	Fabricating process	Plan														
		Actual														
4	Testing	Plan														
		Actual														
5	Data analysis	Plan														
		Actual														
6	Research and writing of chapter 4, result and discussion	Plan														
		Actual														
7	Research and writing of chapter 5, conclusion, and recommendations	Plan														
		Actual														
8	Submission of PSM 2 first draft	Plan														
		Actual														
9	Submission of PSM 2 second draft	Plan														
		Actual														
10	Preparation and presentation of PSM 2	Plan														
		Actual														

Plan	
Actual	