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A STUDY ON THE PROPERTIES OF OIL PALM MESOCARP FIBER-REINFORCED BIOPLASTIC

TAN KOK ZHUAN

Thesis submitted in fulfilment of the requirements

for the award of the degree of

Bachelor of Engineering Technology in Energy and Environmental

Faculty of Engineering Technology

UNIVERSITI MALAYSIA PAHANG

JANUARY 2017

SUPERVISOR'S DECLARATION

I hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of degree of Bachelor of Engineering Technology in Energy and Environmental.

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I hereby declare that the work in this thesis is my own except for quotations and summaries in which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

Highest gratitude to
my supervisor, my family members and my friends
for all your care, support and trust on me.
Special dedication to
Faculty of Engineering Technology of
University Malaysia Pahang
on providing all the related environment
and appropriate equipment
on finishing my project.

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Last but not least, I would also like to express my gratitude towards my family members and friends for their support and encouragement which helps me in completing my project.

ABSTRACT

About 10.3 million tonnes of mesocarp fibre are produced annually yet are not utilise properly. In agriculture industry, biodegradable plastics are desirable alternative to the current black low density poly(ethylene) plastic. Therefore, a research on bio-polybag was carried out with the objectives to utilize agricultural biomass for the production of biodegradable polybag and to investigate the properties of obtained polybag in terms of mechanical properties, surface structure, and biodegradability. In our research, Oil Palm Mesocarp Fibre (OPMF) was used due to its great abundance in Malaysia. Polylactic Acid (PLA) was then added and mixed with the OPMF in different ratio to produce bio-polybag. Three main tests which were tensile strength test, Scanning Election Microscopy and accelerated aging test, were carried out to study the morphology and mechanical properties of the bio-polybag. Based on the results obtained, 50wt% OPMF/50wt% PLA was chosen to be the optimum ratio in bio-polybag production due to tensile strength of 8.1 MPa, elongation at break at 2.2%, tensile modulus at 368.18MPa, decomposite rate of 2.88% and SEM test shows many voids and gaps yet with maximum used of biomass material. Hence, 50% OPMF is the most suitable biomass to use as biodegradable polybag.

ABSTRAK

Kira-kira 10.3 juta tan gentian mesokarpa dihasilkan setiap tahun namun tidak menggunakan dengan betul. Dalam industri pertanian, plastik biodegradable adalah alternatif wajar untuk ketumpatan rendah polyethylene) plastik hitam semasa. Oleh itu, penyelidikan bio-polibeg telah dijalankan dengan objektif untuk menggunakan biojisim pertanian untuk pengeluaran polibeg biodegradable dan untuk menyiasat sifat-sifat polibeg diperolehi dari segi sifat-sifat mekanikal, struktur permukaan, dan biodegradability. Dalam kajian kami, Oil Palm mesocarp Fibre (OPMF) digunakan kerana jumlah yang sangat besar di Malaysia. Asid polylactic (PLA) kemudian ditambah dan dicampur dengan OPMF dalam nisbah yang berbeza untuk menghasilkan biopolybag. Tiga ujian utama iaitu ujian kekuatan tegangan, Mengimbas Pilihan Raya Microscopy dan dipercepatkan penuaan ujian, telah dijalankan untuk mengkaji morfologi dan sifat-sifat mekanik biopolybag. Berdasarkan keputusan yang diperolehi, 50wt% OPMF / 50wt% PLA telah dipilih untuk menjadi nisbah yang optimum dalam pengeluaran biopolybag kerana kekuatan tegangan 8,1 MPa, pemanjangan pada takat putus pada 2.2%, modulus tegangan pada 368.18MPa, kadar decomposite daripada 2.88% dan ujian SEM menunjukkan banyak lompang dan jurang namun dengan maksimum digunakan bahan biomass. Oleh itu, 50% OPMF adalah biomass yang paling sesuai untuk digunakan sebagai polibeg biodegradable.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Oil palm residues are considered to be the most abundant biomass and the best options for fuel generation due to their availability in Malaysia (Sabil et al., 2013). Malaysia produces about 47% of the world's palm oil supply and can be considered as one of the world's largest producers and exporters of palm oil (Sabil et al., 2013). Due to the intensive planting and mill operations, Malaysia generates huge quantity of oil palm biomass including oil palm trunks, oil palm fronds, empty fruit bunches (EFB), shells and fibers as residues from harvesting and processing activities. The annual amount of mesocarp fiber generated by the oil palm industry is 10.3 million tonne (Na et al., 2013).

Bio-polybag comes with the term of biodegradable polybag, at which it has the similar function as the polybag available on market, with the capability to decompose and is biodegradable. According to the standard American Society for Testing and Materials (ASTM) D-5488-94d and European Standard EN 13432-2000, biodegradable refers to compounds that decompose into carbon dioxide, water or methane, inorganic compounds, and new cell biomass (Rizzarelli et al., 2016). In the available market today, various products can be found in the market labelling to be biodegradable, but not all matches fully with the significant. According to the EN 13432, each significant organic constituent of a compostable packaging material must be biodegradable. "Significant" constituent is any constituent presenting a concentration higher than 1% of dry weight of that material. This stipulation implies that a concentration of polyethylene of maximum 1% is considered to be as an acceptable contamination of the biodegradable and compostable material, while a concentration higher than 1% would make the material not compliant with the EN 13432 (Müller, 2005).

1.2 PROBLEM STATEMENTS

In Malaysia, polybags used in agriculture today are still non-biodegradable and inorganic, where plastic is the main component and it is bringing a negative impact to the environment (Jalil et al., 2013). In recent years, the recycling rates for most plastic packaging still remain low (Davis & Song, 2006; Hopewell et al., 2009). In this context, the plastics composition complexities together with contamination during use often render recycling uneconomic compared with disposal in landfill. Hence, biodegradability of plastics need to be greatly improved for disposing in landfill.

Conventional synthetic polybags from petroleum sources are non-renewable and non-biodegradable. The petroleum based polybags are often argued over their negative impacts to the environment. Therefore, use of natural fibres and biodegradable polymers in bio-polybag production are encouraged.

In this research, OPMF and PLA are used in the production of polybags and the mechanical properties and morphology of the bio-polybag will be observed.

1.3 OBJECTIVES

The objectives of this project are:

1. To utilize the agricultural biomass for the production of biodegradable polybag.
2. To investigate and evaluate the obtained polybag for surface structure, mechanical properties, chemical properties and biodegradability.

1.4 SCOPE OF STUDY

Based on the objectives of this project, the scopes of study are:

1. Research and utilization of the most usable agriculture biomass for the production of bio-polybag.
2. Evaluation of obtained polybag by using 3 different tests including tensile test, scanning electron microscopy, and accelerated aging test.

1.5 SIGNIFICANCE OF STUDY

Polybag is a plastic that is used to seed plants. Generally, synthetic polybags from petroleum sources are greatly used which are non-renewable. Furthermore, the synthetic polybag ability to disintegrate in the environment is very low. Due to the increased environmental awareness around the world, the use of renewable sources to replace the depleting petroleum sources has been proliferating day by day. Agricultural biomass is extensively explored for the production of bio-polybag. The use of natural fibers in bio-polybag preparation is preferred compared to those of synthetic fibers due to low density, low cost, renewability and biodegradability of natural fibres (Jahan et al., 2012; Tserki et al., 2006).

In this context, oil palm mesocarp fibres (OPMF) is selected as the raw material to produce bio-polybag in present research. Polylactic acid (PLA) which is a biodegradable polymer, is added and mixed with OPMF to produce bio-polybag. To the best of our knowledge, this approach of using OPMF and PLA as the raw materials for bio-polybag preparation, has never been reported. OPMF is a potential agricultural biomass for the production of biodegradable polybag which is anticipated to bring much greater environmental and sustainable benefit. The morphology and mechanical properties of OPMF-PLA bio-polybag are investigated in this research as well.

Over the last 35 years, plastic is the waste component that has seen the most significant growth. Damages to the environment caused by petro polymers are huge. Hence, the development in these bio-based polybags helps in greenhouse gas balances and other environmental impacts over whole life cycles. It is intended that use of biodegradable materials contribute to sustainability and reduction in the environmental impact associated with disposal of oil-based polymers (Song et al., 2009).

CHAPTER 2

LITERATURE REVIEW

2.1 OIL PALM MESOCARP FIBER (OPMF)

The oil palm is a tropical palm tree therefore it can be cultivated easily in Malaysia. The oil palm tree in Malaysia originated from West Africa where it was growing wild and later developed into an agricultural crop (Sumathi et al., 2008). The first commercial oil palm estate in Malaysia was set up in 1917 at Tennamaran Estate, Selangor (Sumathi et al., 2008). The growth of the industry has been phenomenal and Malaysia is now the largest producer and exporter of palm oil in the world, accounting for 52% or 26.3 million tonnes (MnT) of the total world oils and fats exports in year 2006 (Sumathi et al., 2008). Oil palm has now become a major economic crop which triggered expansion of plantation area in Malaysia and Indonesia (Shuit et al., 2009). In terms of the world market, both Malaysia and Indonesia account for 90% of the palm oil world export trade and will likely remain the key players in the palm oil sector, accounting for 28.5 MnT or 85% of the world's palm oil production (Sumathi et al., 2008). This numbers can be clearly verified in Fig. 2.1.

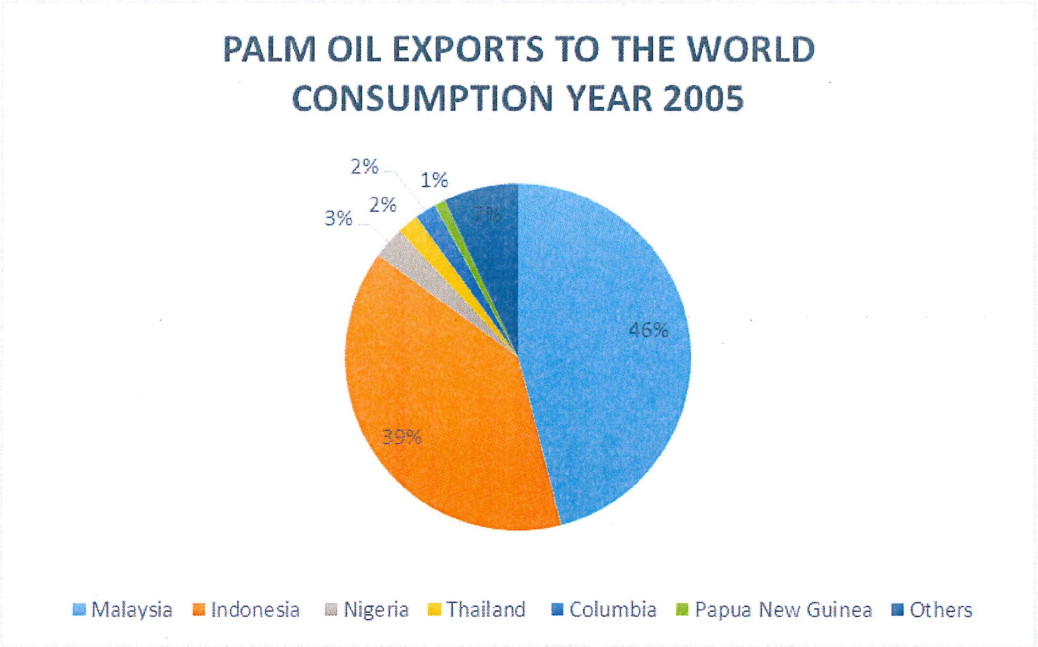

Fig. 2.1. Palm oil exports to the world consumption year 2005

Oil palm mesocarp fiber (OPMF), also known as palm pressed fiber (PPF) is the biomass residue obtained after pressing the palm fruits for palm oil extraction. Oil palm fiber is an important lignocellulosic raw material for the preparation of cost-effective and environment-friendly composite materials (Sreekala et al., 1997). About 11% of OPMF is generated from the palm fruits after the oil extraction (Nordin et al., 2013). Generally, OPMF consists of fruit fiber, crushed kernels and shells. Currently, OPMF is mainly utilized as fuel for steam boilers at the mills (Nordin et al., 2013). Being a lignocellulosic material, OPMF has grabbed attention of researchers due to its potential utilization for bio-polybag production, whereby the fiber can be used to reinforce polymer materials such as thermoplastics (Nordin et al., 2013). Natural fiber-reinforced composites have numerous advantages such as light weight, low-cost, high toughness, and having reasonable strength and stiffness. In the process of extraction of palm oil from palm fruit, a mesocarp fiber is generated as a residue, which is obtained at the nut and fiber separator (Na et al., 2013). In practice this mesocarp fiber is burned in incinerators by palm oil mills, which not only creates environmental pollution problems in nearby localities, but also offers limited value to the industry (Na et al., 2013). The annual amount of mesocarp fiber generated by the oil palm industry is 10.3 million tonne (Na et al., 2013). Approximately 80% of the world primary energy consumption is still dependent on fossil fuel, thus, the substitution by renewable energy sources, in conjunction with other clean energy

sources, appears to be the best and necessary alternative (Kelly-Yong et al., 2007). Therefore, availability of mesocarp fiber is considered to be the best among biomass residues.

2.2 BIO-POLOBAG TECHNOLOGY

In recent times, the excessive consumption of synthetic plastics derived from petroleum has had an adverse impact on the environment because the majority of these synthetic plastics do not degrade in the environment, and incineration of plastics generates CO_2 and dioxin (Maeda et al., 2005). Therefore, eco-friendly biodegradable polymers and plastics have gained increasing attention because of growing recognition worldwide of the need to reduce global environmental pollution. The annual worldwide disposal of approximately 150 million tons of petrochemical plastics in commonly used commodities such as polyolefin in packing, bottle and moulding products is a significant environmental problem, especially with the continuously increasing production and consumption of these materials (Kim et al., 2006).

Bio-polybag, which is also defined as biodegradable polybags and other green alternatives to plastic grocery and shopping bags are becoming more popular. Biodegradable bags can be decomposed by bacteria or other living organisms, at which they are designed to break down after a period of time. They pose less of a hazard to neighbourhood ecosystems and sometimes contribute less, long-lasting, plastic material to landfills (Sara, 2016). Plastic carrier bag is expected to totally degrade within a period of 12 months when exposed to aerobic or anaerobic conditions, including exposure in a landfill or regulated dumping area (Mohee et al., 2008). Biodegradable plastics based on renewable agricultural and biomass feedstock can form the basis for a set of sustainable, eco-efficient products that can compete and capture markets which are currently dominated by by-products based exclusively on petroleum products (Mohee et al., 2008).

Technologies have been developed to speed up the decaying process of poly bags such as polythene (or polyethylene) bags will decay in the environment naturally. Bags have to survive long storage, be strong enough to hold groceries and other items and yet, still be broken down quickly once exposed to wind, water, light, or another trigger to start the decomposition process. Different technologies hasten decay at

different rates (Sara, 2016). Besides that, the breaking down of biodegradable polybag will as well depend on temperature and humidity. It goes slow in cold weather, and high humidity virtually stops the process. The technology involved determines how effectively and how quickly a bag will degrade (Sara, 2016). Figure 2.2 shows bio-polybag technology.

Fig. 2.2. Bio-polybag Technology (a) Corn starch Impregnated Bags **(b)** Photo Sensitive Bags **(c)** Oxo-Biodegradable Bag **(d)** Bags Using Aliphatic Technology

Almost half of the biodegradable polybags used corn starch incorporated into the plastic. The corn starch component will begin to decay when exposed to a microbe rich environment. This breaks the plastic into tiny pieces. When it works well, the bag is totally deconstructed. This does not always happen as advertised. When it does not work, a bag may just become perforated but maintain its basic shape (Sara, 2016).

Photo sensitive bags are designed to decay with prolonged exposure to the ultra violet rays in sunlight. If they're buried in a landfill or find their way into sewers,

the process won't work properly and most of the plastic will remain intact (Sara, 2016).

Oxo-Biodegradable bags are among the most economical to manufacture and the most effective to use. They are completely biodegradable. This happens in a two-step process. First, the bag is oxidized by prolonged exposure to the oxygen in the air. After that, the oxidized fragments convert into carbon dioxide, a harmless biomass and water. It's an elegant process. Somewhat similar to using starch to encourage nature to deconstruct poly bags, ailphatic poly bags also rely on microbes to breakdown the bag into its constituent molecules. Although these bags are effective, they're also expensive to produce (Sara, 2016).

2.3 EXISTING POLYBAGS

There are many types of polybag such as Anti Static poly bag, Drawstring poly bag, Flat poly bag, Foodservice poly bag, Garment poly bag, Gusseted poly bag, Hang Hole poly bag, Header Pak poly bag, Minigrip White Block poly bag, Reclosable poly bag, Slide Seal poly bag, UV Protective Amber poly bag, White Block poly bag, Laddawn poly bag, Elkay Plastics poly bag. Figure 2.3. shows existing applications of poly bag.

a. Drawing poly bag  Source: http://www.millersupplyinc.com/drawstring-poly-bags	b. Clear plastic cookie bag  Source: http://www.millersupplyinc.com/foodservice-poly-bags	c. Mil reclosable poly bag  Source: http://www.millersupplyinc.com/reclosable-poly-bags
d. Bottom Gusset bag  Source: http://www.millersupplyinc.com/gusseted-poly-bags	e. Garment bag  Source: http://www.millersupplyinc.com/garment-poly-bags	f. Reclosable minigrip bag  Source: http://www.millersupplyinc.com/minigrip-white-block-poly-bags

Fig. 2.3. Existing applications of poly bag

2.4 BIOMASS AND ITS PROPERTIES

2.4.1 Oil Palm Mesocarp Fiber (OPMF)

Malaysia is the world's leading palm oil producing country has produced 11.9 million tonnes of palm-pressed mesocarp fiber from 75.5 million tonnes of fresh fruit bunch (FFB) processed in 2005 (Lau et al., 2008). Around 80% of palm oil cultivation are empty fruit bunch (EFB), mesocarp fiber and palm kernel shell (PKS). Oil palm mesocarp fiber (OPMF), also known as palm pressed fiber (PPF) is the biomass residue obtained after pressing the palm fruits for palm oil extraction as shown in Fig 2.4 (Nordin et al., 2013).

Fig. 2.4. OPMF

Source: (http://louisdigital.com/oil-palm/oil-palm-mesocarp-fiber)

About 11% of OPMF is generated from the palm fruits after the oil extraction. Generally, OPMF consists of fruit fiber, crushed kernels and shells. Mesocarp fiber can be used to reinforce polymer materials such as thermoplastics and natural fiber-reinforced composites have numerous advantages such as light weight, low-cost, high toughness, and having reasonable strength and stiffness (Nordin et al., 2013). Due to the intensive planting and mill operations, Malaysia generates huge quantity of oil palm biomass including oil palm trunks, oil palm fronds, empty fruit bunches (EFB), shells and fibers as residues from harvesting and processing activities (Sabil et al., 2013). Every year, palm oil industry produces roughly about 17.08 teragram (Tg) of EFB, 12.9 84 Tg of frond, 8.2 Tg of trunk, 9.66 Tg of mesocarp fiber and 5.3 Tg of kernel shell (Sabil et al., 2013). Table 2.1 shows oil palm chemical composition analysis.

Table 2.1 : Oil palm chemical composition analysis

Components	OPMF
Holocellulose	0.3180
Cellulose	0.3440
Lignin	0.2527
Ash	0.0350
Moisture	0.3700

2.4.2 OPMF WASTE PRODUCTION AND ITS UTILIZATION

Malaysia is the world's leading palm oil producing country has produced 11.9 million tonnes of palm-pressed mesocarp fiber from 75.5 million tonnes of fresh fruit bunch (FFB) processed in 2005 (Lau et al., 2008). About 11% of OPMF is generated from the palm fruits after the oil extraction (Nordin et al., 2013). Generally, OPMF consists of fruit fiber, crushed kernels and shells. Currently, OPMF is mainly utilized as fuel for steam boilers at the mills (Nordin et al., 2013). In the process of extraction of palm oil from palm fruit, a mesocarp fiber is generated as a residue, which is obtained at the nut and fiber separator (Na et al., 2013). In practice this mesocarp fiber is burned in incinerators by palm oil mills, which not only creates environmental pollution problems in nearby localities, but also offers limited value to the industry (Na et al., 2013). The annual amount of mesocarp fiber generated by the oil palm industry is 10.3 million tonne (Na et al., 2013).

2.5 POLYMER USED IN MANUFACTURING BIODEGRADABLE PLASTIC

Polymer degradation takes place mostly through scission of the main chains or side-chains of polymer molecules, induced by their thermal activation, oxidation, photolysis, radiolysis, or hydrolysis. Some polymers undergo degradation in biological environments when living cells or microorganisms are present around the polymers. Such environments include soils, seas, rivers, and lakes on the earth as well

as the body of human beings and animal (Ikada & Tsuji, 2000). General polymers used in manufacturing biodegradable plastic are divided into two types which are natural polymers and synthetic polymers. Table 2.2 shows the classification of biodegradable polymers.

Table 2.2 : Classification of biodegradable polymers

Natural polymers		Synthetic polymers	
Sub-classification	Example	Sub-classification	Example
Plant origin		**Aliphatic polyesters**	
• Polysaccharides	Cellulose, Starch, Alginate	• Glycol and dicarbonic acid polycondensates	Poly(ethylene succinate), Poly(butylene terephthalate)
Animal origin		• Polylactides	Polyglycolide, Polylactides
• Polysaccharides	Chitin (Chitosan), Hyaluronate	• Polylactones	Poly(e-carpolactone)
• Proteins	Collagen (Gelatin), Albumin	• Miscellaneous	Poly(butylene terephthalate)
Microbe origin		**Polyol**	Poly(vinyl alcohol)
• Polycarbonates	Poly(ester carbonate)	**Polycarbonates**	Poly(ester carbonate)
• Poly(3-hydroxyalkanoate)	Poly(3-hydroxyalkanoate)	**Miscellaneous**	Polyanhydrides, Poly(a-cyanoacrylate)s, Polyphosphazenes, Poly(orthoesters)
• Polysaccharides	Hyaluronate		

2.5.1 POLYLACTIC ACID (PLA)

Polylactic acid (PLA) is an aliphatic polyester made up of lactic acid which is 2-hydroxy propionic acid building blocks. It is also a biodegradable and compostable thermoplastic derived from renewable plant sources, such as starch and sugar(Lim et al., 2008). Nowadays, PLA is most common bio-plastic in use today due to it is a very promising material since it has good mechanical properties, thermal plasticity and biocompatibility (Bordes et al., 2009). Historically, the uses of PLA have been mainly limited to biomedical areas due to its bioabsorbable characteristics. Over the past decade, the discovery of new polymerization routes which allow the economical production of high molecular weight PLA, along with the elevated environmental awareness of the general public, have resulted in an expanded use of PLA for consumer goods and packaging applications (Lim et al., 2008). Bio-plastics are expected to contribute more benefits to environmental protection because of it will reduce carbon dioxide emission and biodegradable. Because PLA is compostable and derived from renewable sources, it has been considered as one of the solutions to alleviate solid waste disposal problems and to lessen the dependence on petroleum-based plastics for packaging materials (Lim et al., 2008).

The conversion of lactic acid to high-molecular weight PLA is achieved by a solvent-free process and a novel distillation process (Lunt, 1998). The essential novelty of the process lies in the ability to go from lactic acid to a low-molecular-weight polylactic acid, followed by controlled depolymerisation to produce the cyclic dimer, commonly referred to as lactide. This lactide is maintained in the liquid form and purified by distillation. Catalytic ring opening of the lactide intermediate results in the production of PLAs with controlled molecular weights. The process is continuous with no necessity to separate the intermediate lactide (Lunt, 1998). Figure 2.5 shows the manufacturing routes to polylactic acids.

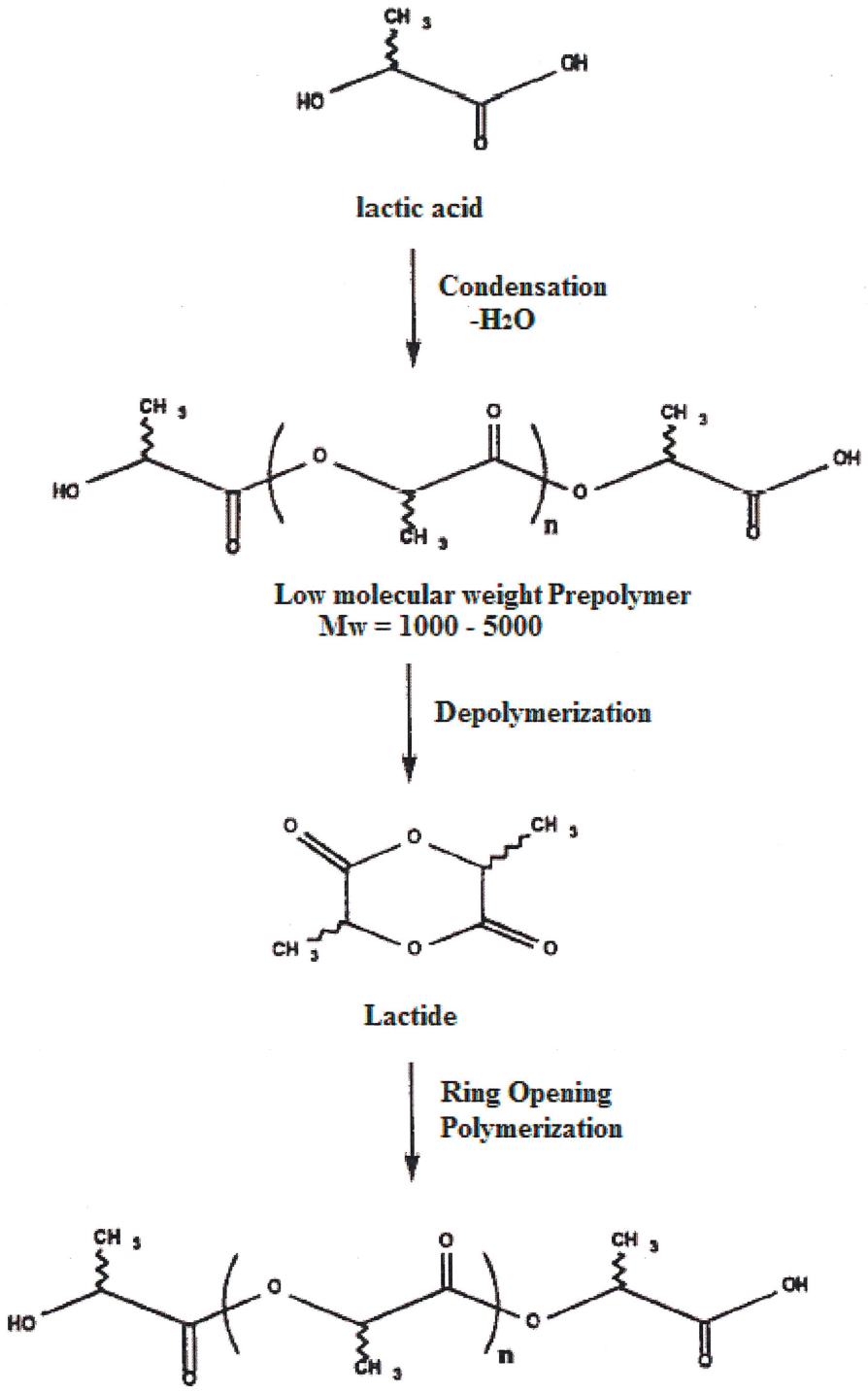

Fig. 2.5. Manufacturing routes to polylactic acids

2.6 EXPERIMENTAL TEST AND EVALUATION

2.6.1 TENSILE TEST

A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, reduction in area, tensile strength, yield point, yield strength and other tensile properties. Tensile test was carried out by a Universal Testing Machine and samples were clamped on it. Crosshead speed of 5 mm/min was used for tensile test (Then et al., 2013).

2.6.2 SCANNING ELECTRON MICROSCOPY

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample (Susan, 2016). The surface morphologies of OPMF and tensile fracture surfaces of PLA bio-polybag was recorded by SEM, MV2300, CamScan Electron Optics Ltd. The scanning electron micrographs were recorded at the magnification of 200–300x (Then et al., 2013).

2.6.3 ACCELERATED AGING TEST

The Accelerated Aging test simulates real-time aging of porous and non-porous materials. Each sample were cut into a mass of 2 to 4g, fully covered with organic soil and were placed into six 100ml test tubes respectively. The samples were inserted into the Redline by Binder (115V) RI 115 incubator for 10 days at 55°C. The change in mass was measured every three days to study the trend of biodegradability and the dry soil was replaced every measurement.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 MATERIALS

The main raw materials used in this experiment were oil palm mesocarp fibre (OPMF) and polylactic acid (PLA). Oil palm mesocarp fibre was collected from LCSB palm oil mills Lepar and polylactic acid was purchased from Sigma-Aldrich (M) Sdn. Bhd. The specific gravity of polylactic acid is 1.24 g/cm^3 (Yaacab et al., 2016). Figure 3.1 shows materials.

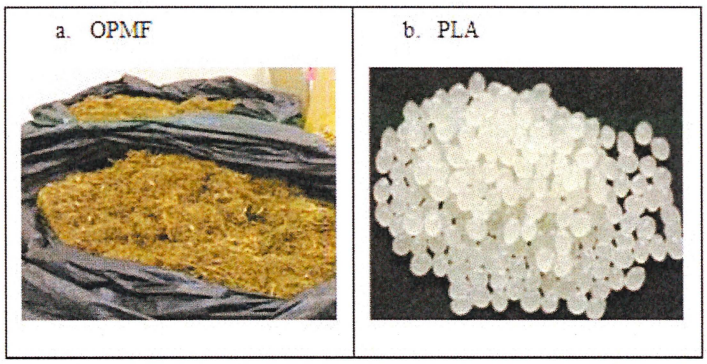

Fig. 3.1. Materials used in this study

3.2 MATERIALS PREPARATION

According to the research done by Then et al. (2013), OPMF was prewashed by distilled water for 24 h and rinsed with hot water at 60°C in order to remove impurities from the material. The samples were then dried in oven at 60°C and ground into powder size of 300 um. Figure.3.2 shows process flow of material preparation.

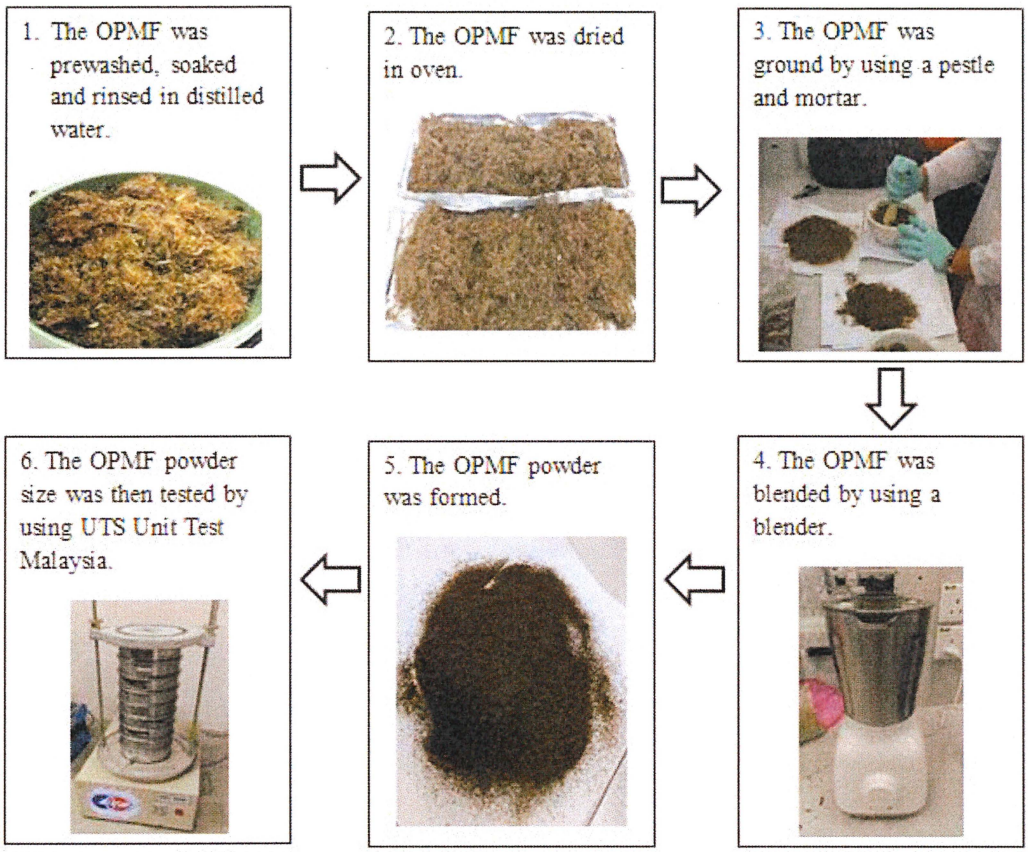

Fig. 3.2. Material Preparation Flow

3.3 EXPERIMENTAL DESIGN

In this study, five ratio of bio-polybags were prepared as shown in Table 3.1. A hundred twenty gram in total samples of each formula was placed into Model sy-50 Plastic Mixer Machine with difference loading of PLA (10-90 wt %). The sample was produced by adding PLA into the mixer at the temperature of 180°C and rotor speed of rotor speed of 5 rpm for 15-20 minutes to start melt the PLA. Then, materials were mixed according to ratio as shown at Table 3.1 and the mixing was continued for 15 minutes. The whole mixing process took around 30-45 minutes.

Table 3.1 : Formulations of PLA bio-composites

Code	Material composition (wt %)	PLA (wt %)
10 OPMF / PLA	10	90
30 OPMF / PLA	30	70
50 OPMF / PLA	50	50
70 OPMF / PLA	70	30
90 OPMF / PLA	90	10

*OPMF = Oil Palm Mesocarp Fiber

The mixed products were then put into the mold and compressed by using Lotus Scientific LS-22025 25 ton Hot and Cold Molding press. The machine was preheated for three minutes then mixed product was compressed for another three minutes at 180°C followed by cooling under pressure for one minute. After that, samples were cut into small pieces according to ASTM Standards D638. Figure 3.3 shows the process flow of experiment design.

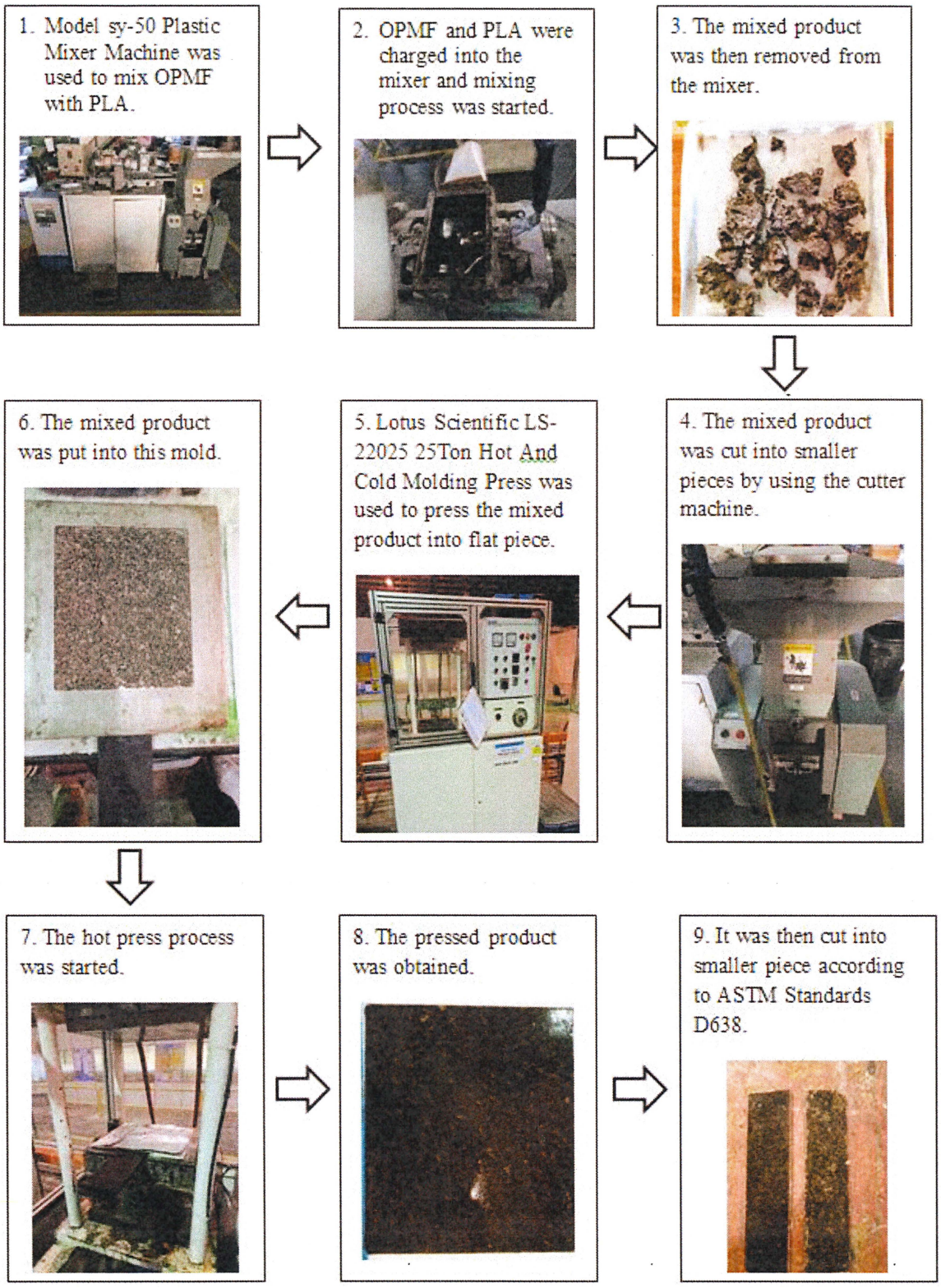

Fig. 3.3. Process flow of experiment design

3.4 CHARACTERIZATION OF BIOPOLYBAG

Three tests will be performed for characteristic analyses of the mechanical and thermal properties of the samples. The tests consist of tensile test, scanning electron microscopy (SEM), and accelerated aging test.

3.4.1 TENSILE TEST

Tensile test machine used was Universal Testing Machine. Tensile test was carried out to investigate the tensile properties which were very important in order to understand the characterization of the samples. In this testing, tensile strength (MPa), modulus of elasticity (MPa) and elongation to break (%) can be determined. The samples were cut into small pieces with dimension of 2.5 cm x 11.5 cm based on ASTM Standards D638 and clamped on the universal tensile strength testing machines (Then et al., 2013). Figure 3.4 shows the machine used in tensile testing.

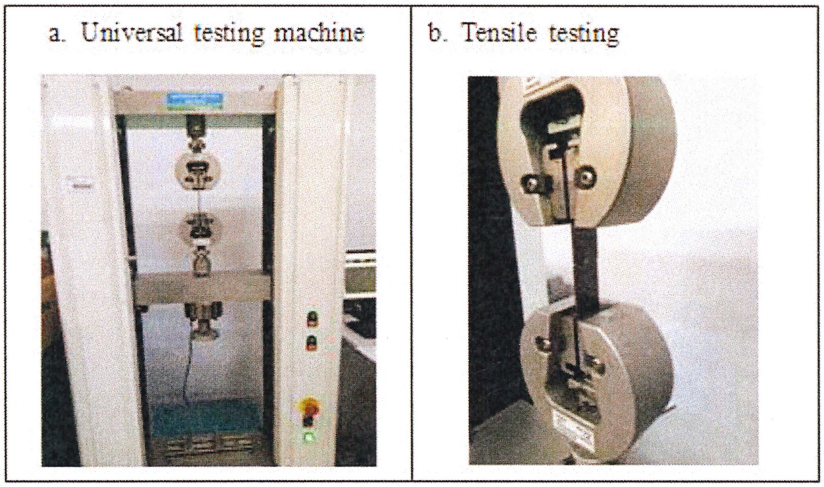

Fig. 3.4. Tensile testing

3.4.2 SCANNING ELECTRON MICROSCOPY (SEM)

The fibre morphology was observed with the aid of SEM, MV2300, CamScan Electron Optics Ltd., UK. Carbon black adhesive was placed on small metal plate, and the surface was smoothened using a glass needle, in order to ensure that the surface was perfectly even, free of holes or lumps. Subsequently, the fibres were carefully distributed on a metal surface and the fibre geometry was investigated after being sputter coated with gold. The flexural test samples were also broken and coated with gold to make the surface conductive. Thereafter, the morphology of the composites was observed under magnifications of 200x (Mamun et al., 2013). Figure 3.5 shows the steps in SEM testing.

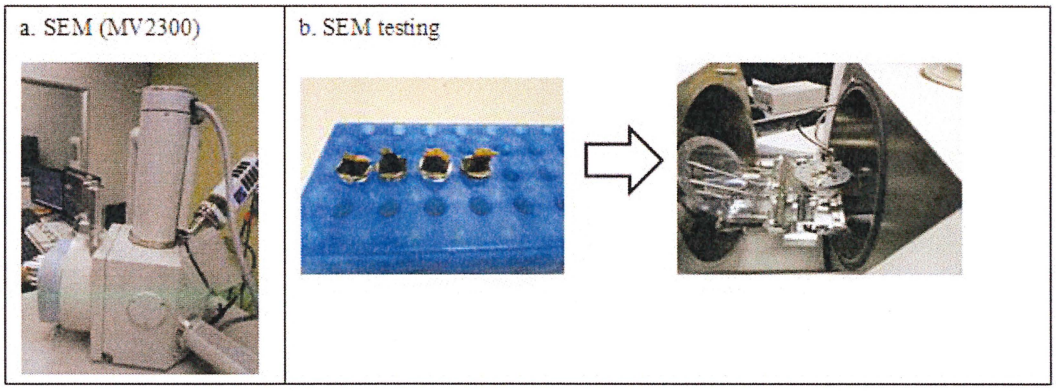

Fig. 3.5. SEM testing

3.4.3 ACCELERATED AGING TEST

The Accelerated Aging test simulated the real-time aging of porous and non-porous materials. First, soil with bacteria content was collected and then 2-4g of samples were weighted. After that, sample was covered with soil in a beaker and then it was put into incubator at 55°C for 10 days. Lastly, the change in mass was measured every 3 days to study the trend of biodegradability and the dry soil was replaced after every data collection. Figure 3.6 shows the steps in Accelerated Aging testing.

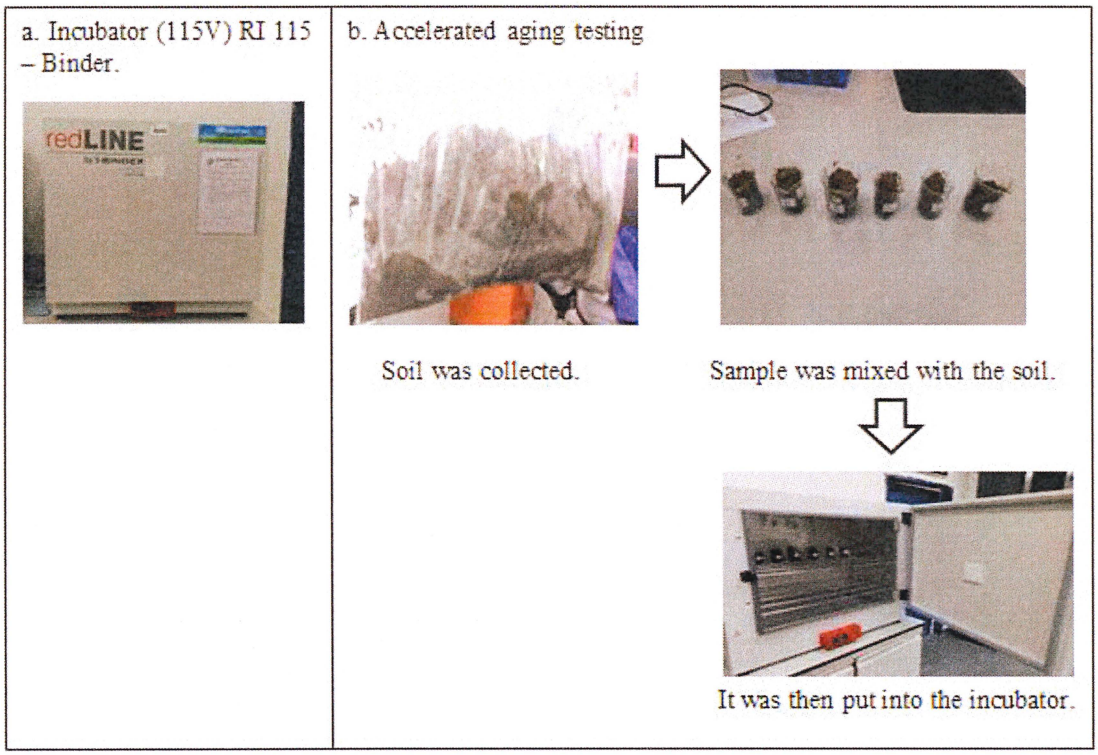

Fig. 3.6. Accelerated Aging test

3.5 RESEARCH FLOW CHART

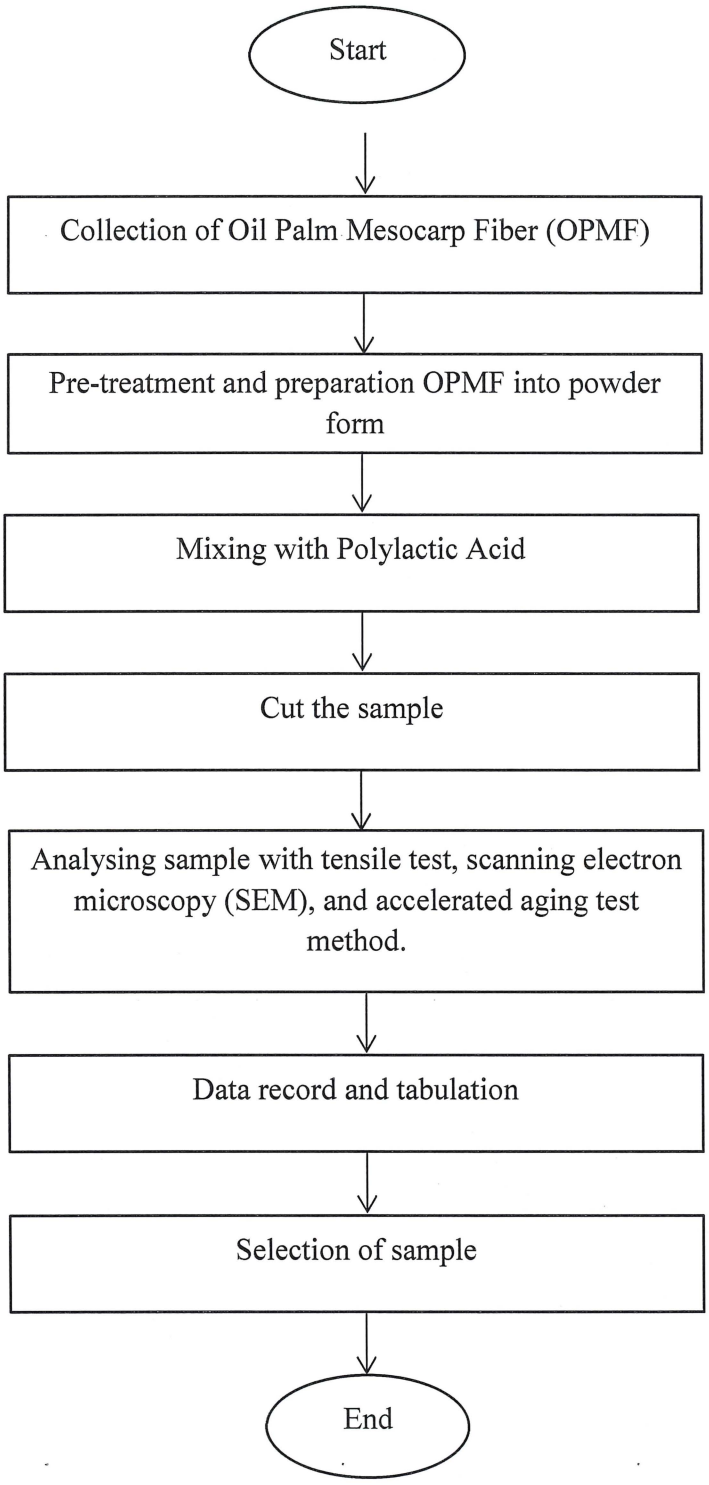

Fig. 3.7. Research Flow Chart

CHAPTER 4

RESULT AND DISCUSSION

4.1 PREPARATION RATIO OF SAMPLES

Oil Palm Mesocarp Fiber (OPMF) was mixed with Polylactic Acid (PLA). This type of bio-polybag showed numerous advantages such as light weight, low cost, biodegradable, and exhibits reasonable strength and stiffness (Then et al., 2014).

Table 4.1 : Ratio of Sample

Code	Material composition (wt %)	PLA (wt %)	Mixing
10 OPMF / PLA	10	90	Yes
30 OPMF / PLA	30	70	Yes
50 OPMF / PLA	50	50	Yes
70 OPMF / PLA	70	30	No
90 OPMF / PLA	90	10	No

*OPMF = Oil Palm Mesocarp Fiber

According to Table 4.1, the ratio of 70 wt % OPMF/30 wt % PLA sample and ratio of 90 wt % OPMF/10 wt % PLA sample cannot be mixed well together. Less amount of PLA implied that there was less dissolution of PLA to be liquid which caused the mixing to be difficult. Figure 4.1 shows the different ratio of OPMF/PLA samples.

Fig. 4.1. Different ratio of OPMF/PLA samples

4.2 TENSILE TEST

Tensile test result graph with different ratio were shown in Appendix A. The tensile strength, tensile modulus, and elongation at break of different ratio Oil Palm Mesocarp Fiber (OPMF)/Polylactic Acid (PLA) bio-polybag are summarized in Appendix B1. According to Fig. 4.2, 10 wt% OPMF/90 wt% PLA sample had a tensile strength of 14.30 MPa and it decreased after increasing the fiber content (30wt% and 50wt%) due to the poor interfacial adhesion between the hydrophobic PLA and hydrophilic fibers (Then et al., 2013). Besides, fiber acted as included filler in the resin matrix, which weakened the composite due to poor interfacial adhesion and obstructed the stress propagation, which leaded to reduction of tensile strength as the filler loading increases (Eng et al., 2014). On the other hand, tensile strength of 30% wt% OPMF/70 wt% PLA sample was 4.80MPa and 50% wt% OPMF/50 wt% PLA sample was 8.10MPa. Based on Fig. 4.3, tensile strength decreased with the increment of composition in biomass.

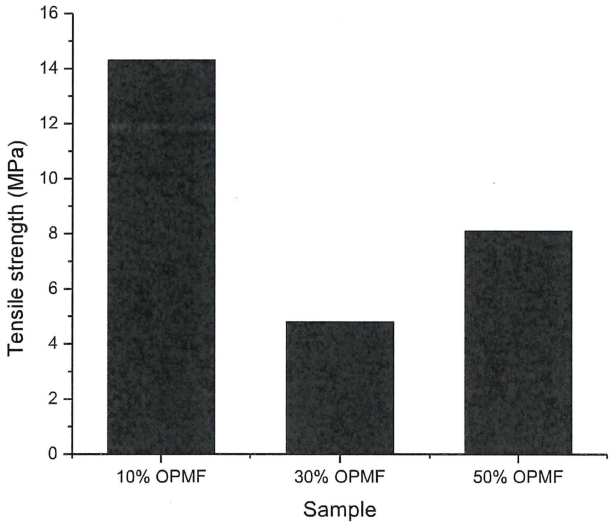

Fig. 4.2. Tensile Strength for each samples

According to Fig. 4.3, the elongation at break of 10 wt % OPMF/90 wt % PLA sample was 5.10% and it decreased at increasing fiber contents (30wt% and 50wt%). The decreased of elongation at break of 30wt% and 50wt% OPMF could be attributed to the presence of OPMF which strained the slippage movement of PLA chain during the deformation and resulting in lower elongation at break thus decreased the chain mobility of PLA bio-polybag films (Zailuddin & Husseinsyah, 2016). This result indicated that the PLA bio-polybag films with 30 wt% and 50wt% of OPMF contents were more rigid than 10wt% fiber contents. The value of elongation at break showed a reduction with increasing fiber content. Increased fiber content in the PLA resulted in composites becoming stiffer and harder. This reduced the composite's resilience and toughness and lead to lower elongation at break (Jacob et al., 2004). The highest elongation with 5.062% was sample with 10% OPMF. This was due to its high composition of plastic in the bio-polybag film.

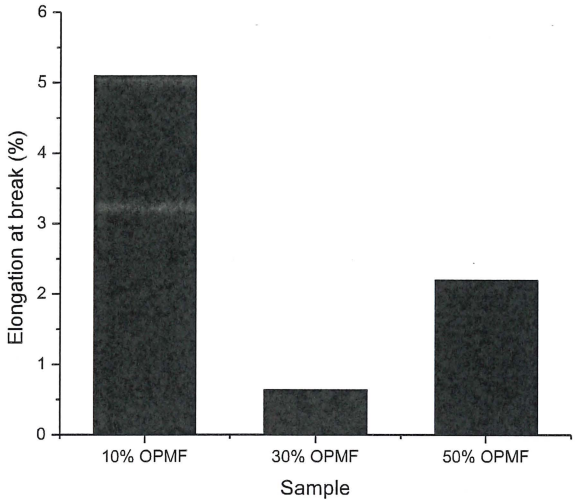

Fig. 4.3. Elongation at break for each samples

For tensile modulus, the value varied due to the difference in strain. The tensile modulus of 10 wt % OPMF/90 wt % PLA sample was 280.39 MPa and it increased at increasing fiber content (30wt% and 50wt%) as shown in Fig. 4.4. The improvement of tensile modulus of PLA bio-polybag films was due to the high rigidity exerted by OPMF. The increment of tensile modulus can also be described to the dispersion and alignment of OPMF in PLA bio-polybag films (Zailuddin & Husseinsyah, 2016).

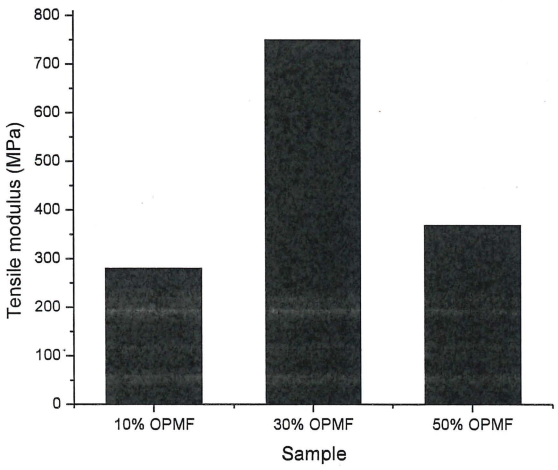

Fig. 4.4. Tensile modulus for each samples

Based on our results, 50wt% OPMF/50wt% PLA was recommended to be the most suitable ratio of bio-polybag sample which was then used to produce biodegradable polybag. This was due to the poor interfacial adhesion between the hydrophobic PLA and hydrophilic fibers which caused the bio-polybag to be more stiffer and harder. Lastly, the composite's resilience and toughness was reduced as well.

4.3 SCANNING ELECTRON MICROSCOPY (SEM)

The scanning electron micrographs (SEM) were recorded at the magnification of 200x. SEM analysis was performed to evaluate the interfacial adhesion between PLA matrix and Oil Palm Mesocarp Fiber (OPMF). Figure 4.5 (a) shows SEM micrographs of 30% OPMF and Figure 4.5 (b) shows SEM micrographs of 50% OPMF. 2 phases (PLA and fibers) were obviously seen in both micrographs. The presence of voids on the fractured surfaces of the PLA bio-polybag which resulted from fiber pull outs was observed. In addition, gaps were also visible between the PLA and OPMF. The presence of voids and gaps were evidences of the poor interfacial adhesion resulting from the lack of compatibility between hydrophilic fibers and hydrophobic PLA. Poor interfacial adhesion can then acted as a stress concentration point upon exertion of external forces and consequently result in premature failure due to poor stress transfer from matrix to the fibers (Then et al., 2013). At low fibers loading (a) it can be clearly seen that the fibers were not evenly distributed throughout the PLA matrix and the gaps between PLA and fibers were large. However, as fibers content increased (b) fibers become more evenly distributed and oriented in the PLA matrix. This may be due to the drastic reductions in tensile strength and elongation at break at low fibers loading but rather small at high fiber loading as discussed in Section 4.2 (Then et al., 2013). Figure 4.5 (a) and (b) showed that the fiber was packed loosely with PLA with a visible gap and holes at their interface region. This indicated that the adhesion between these two phases was poor. Moreover, cavities can also be seen due to the fiber pulled out from the matrix (Then et al., 2014). Hence, this can prove that samples can more easily to degradable compare with without biomass mixing due to it has many small holes, voids and gaps and the presence of voids and gaps are evidences of the poor interfacial adhesion

resulting from the lack of compatibility between hydrophilic fibers and hydrophobic PLA.

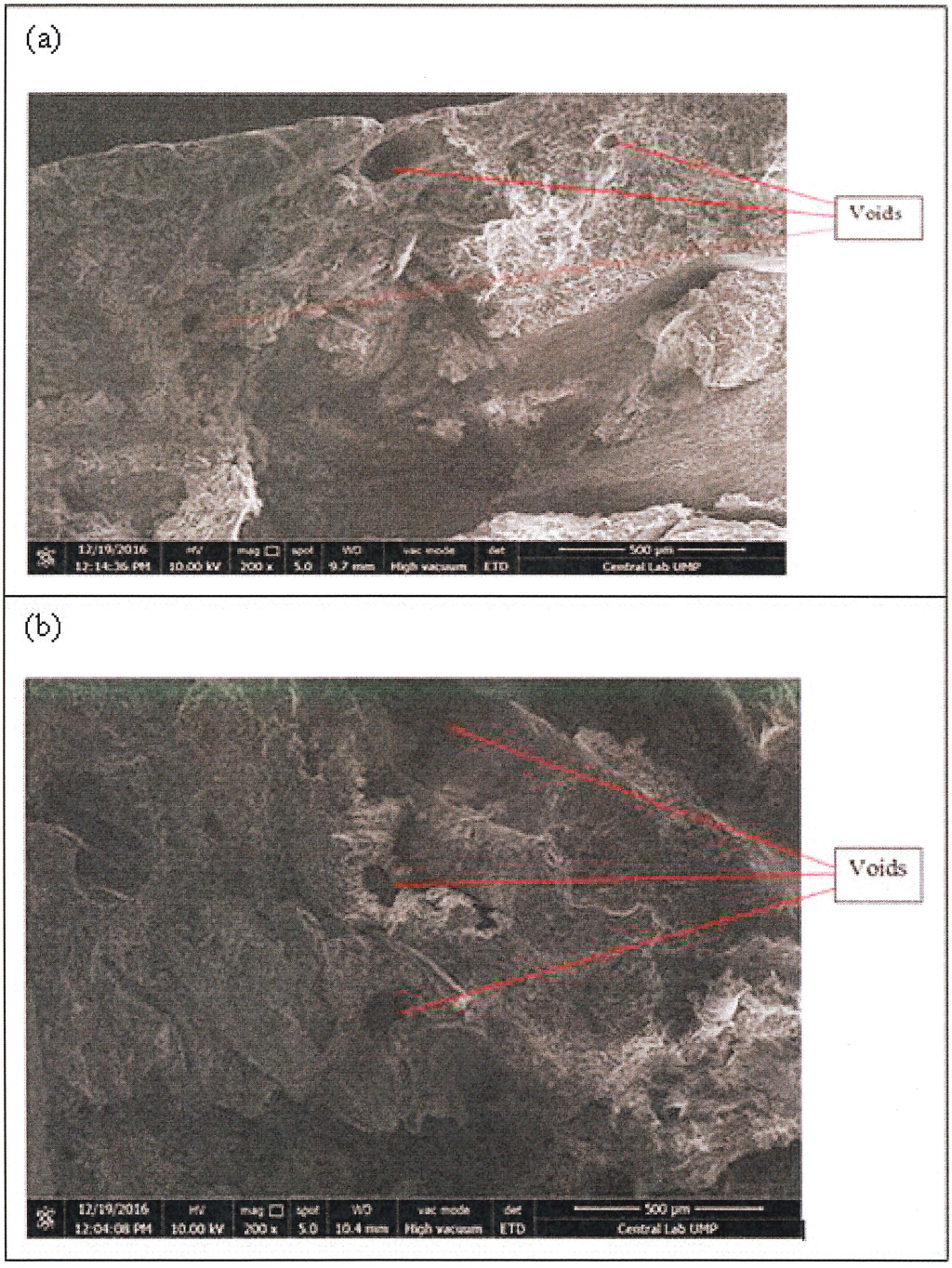

Fig. 4.5. SEM (a) Magnification of 200x SEM micrographs of 30%OPMF, **(b)** Magnification of 200x SEM micrographs of 50%OPMF

4.4 ACCELERATED AGING TEST

In order to understand the biodegradability and aging property, the change in mass over time is the main result to be taken in Appendix B2. The Accelerated Aging test simulates real-time aging of porous and non-porous materials. Based on Fig. 4.6, three different ratio samples shows increased weight on Day-4 then decreased weight on Day-7. For 10wt% OPMF/90wt% PLA sample, its weight was 1.6930 gram on Day-1, then after three days aging test, its weight increased until 1.7395 gram but after seven days, then the weight of sample was decreased to 1.6920 gram. The drop of weight of samples showed that the samples can be decomposed. While during Day-4, the weight of samples showed increasing trend due to the oxidative degradation of samples promoted by proprietary pro-oxidants loaded deliberately into sample, can be assessed by monitoring the increase of the weight of the samples, the carbonyl index (CO_i) due the oxygen uptake and the consequent increase of wettability, as well as the drop in molecular weight and extractability with solvent (Chiellini et al., 2006). Among three samples, 30wt% OPMF/70wt% PLA showed most weight drop which was about 0.2931 gram after seven days. The decomposition was expected to be increasing after day 10 if the test continued at the same condition. Based on results conducted, PLA bio-polybag was proved that it can be biodegradable due to the decreasing weight of samples after ten days during accelerated aging test and it can more easily to degradable and shorten the durability performance of degradable. Because of the low brittle, it was suitable for using it to produce polybag.

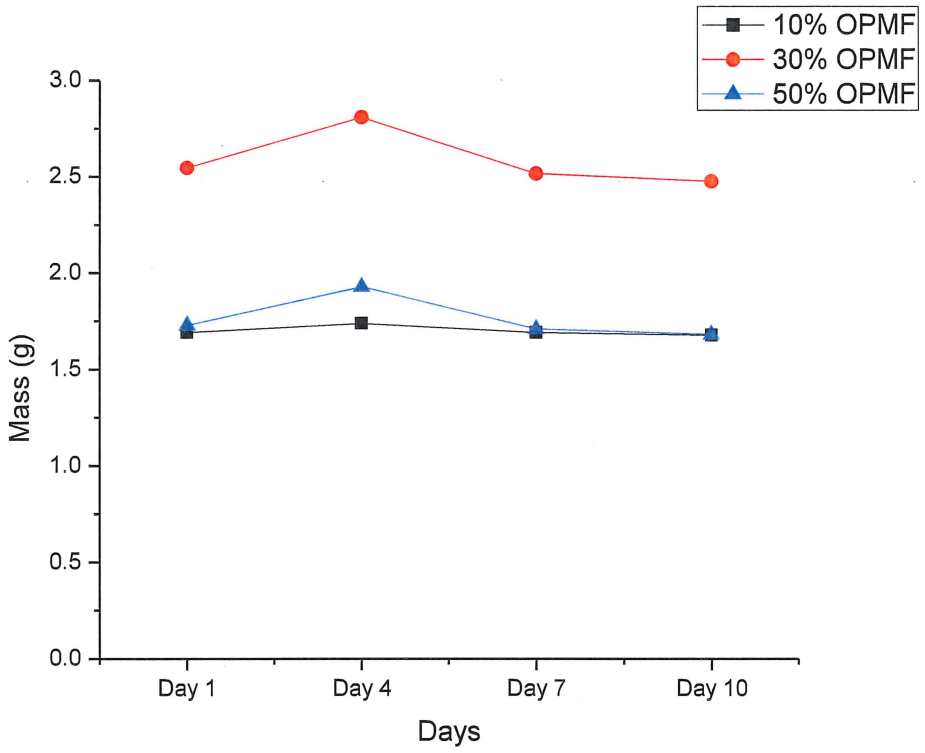

Fig. 4.6. Accelerated Aging Test.

Having to work with budget, the team prioritized which area of cost would receive the most funds needed. In term of the whole project execution, the costs will need to cover majorly for material purchasing, transportation, utility of laboratory's equipment (if any), etc. The team has been given funding from the Faculty of Engineering Technology in the amount of RM3,600 (RM1,200 for each person in the team). Appendix B3 shows the cost analysis. This section of report presents a comprehensive budget of materials purchased by the student, including the unit costs and total costs.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From this study, it can be concluded that Oil Palm Mesocarp Fiber (OPMF) was a potential biomass to produce bio-degradable polybags. 50wt% OPMF/50wt% PLA was chosen to be the optimum ratio in biopolybag production due to tensile strength of 8.1 MPa, elongation at break at 2.2%, tensile modulus at 368.18MPa, decomposite rate of 2.88% and SEM test shows many voids and gaps yet with maximum used of biomass material. Hence, 50wt% OPMF/50wt% PLA was chosen to be the optimum ratio in bio-polybag production based on the following justifications :

- The well dispersion of OPMF in PLA bio-polybag films formed a rigid and stable structure which had successfully improved the tensile modulus of PLA bio-polybag films.
- Poor interfacial adhesion between the hydrophobic PLA and hydrophilic fibers reduced the tensile strength of PLA bio-polybag films.
- Increased OPMF content in the PLA bio-polybag its films successfully reduced the composite's resilience and toughness and thus lead to lower elongation at break.
- The morphology of PLA bio-polybag films was observed through SEM. Presence of voids and gaps which signified the poor interfacial adhesion of PLA bio-polybag proved that the PLA bio-polybag can easily to be degraded.

5.2 RECOMMENDATION

Bio-plastics of agricultural origin are extensively explored nowadays due to their biodegradability which contributes less negative impact to the environment. At current stage of our research, only investigation on the mechanical properties and study on the morphology of the PLA bio-polybag were done. Further investigation of the PLA bio-polybag is recommended to be done. Testings such as Thermogravimetric analysis (TGA), Differential Scanning Calorimetry (DSC), water absorption and softing points can be carried out to investigate the physical and chemical properties of PLA bio-polybag. Furthermore, temperature can be elevated to accelerate the aging process in bio-polybag. Moreover, more specific compositions of bio-composites can be further research, a good example is to study 60% biomass and 40% PLA to investigate its results with the requirement. Lastly, the study of commercialization, costs effectiveness, marketability and unseen benefits of the product by comparing with the current available polybags.

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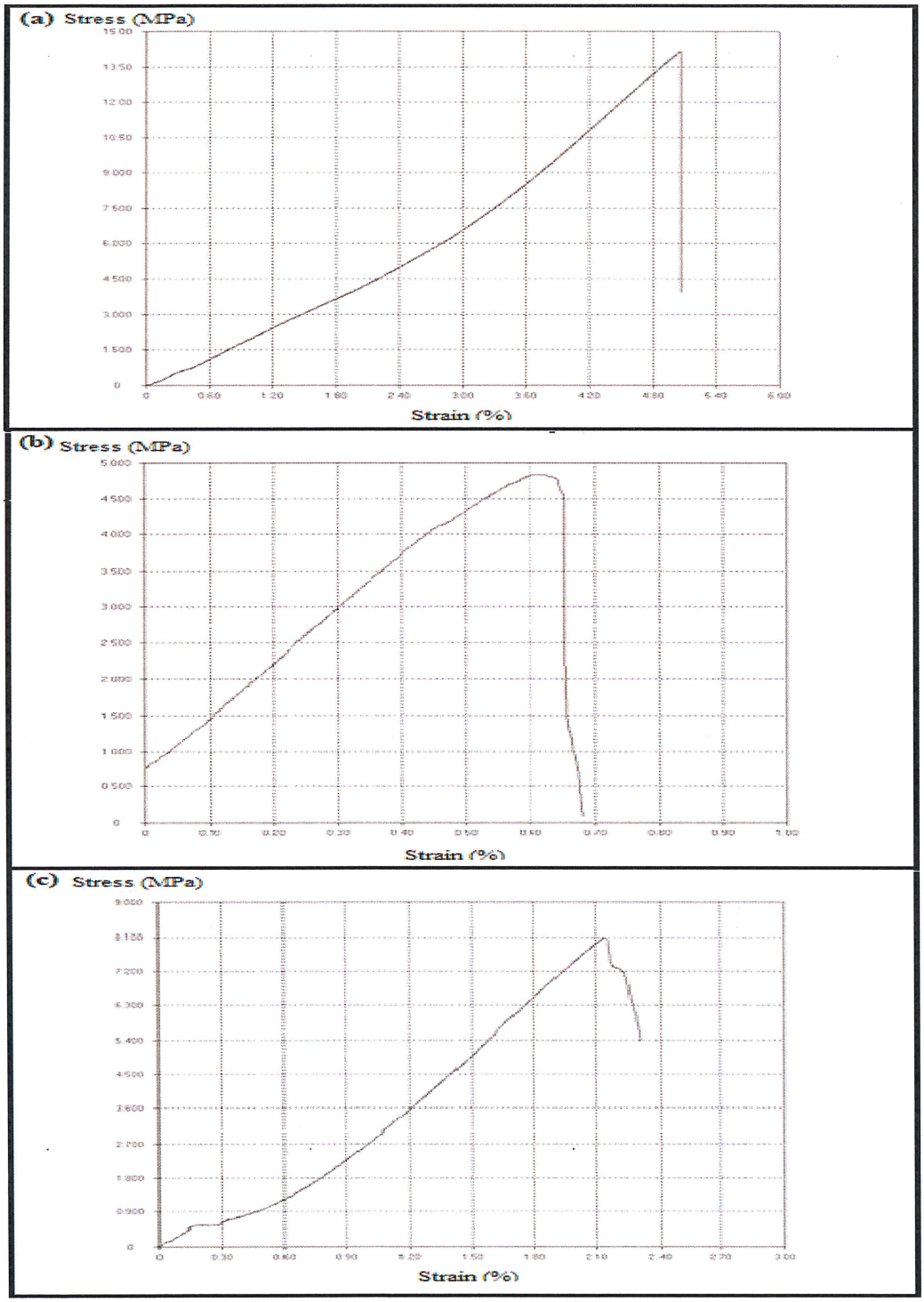
Appendix A

Data Result Testing

(a) Tensile Test Result of 10 wt % OPMF/90 wt % PLA Sample
(b) Tensile Test Result of 30 wt % OPMF/70 wt % PLA Sample
(c)Tensile Test Result of 50 wt % OPMF/50 wt % PLA Sample



Appendix B

Table Results

B1 Tensile strength, tensile modulus, and elongation at break of OPMF/PLA biocomposites

Fiber content, (wt%)	Tensile strength, (MPa)	Tensile modulus, (MPa)	Elongation at break, (%)
10	14.30	280.39	5.10
30	4.80	750.00	0.64
50	8.10	368.18	2.20

B2 Results of Accelerated Aging Test

Code	Day-1 (gram)	Day-4 (gram)	Day-7 (gram)	Day-10 (gram)
10wt% OPMF/90wt% PLA	1-6930	1.7395	1.6920	1.6790
30wt% OPMF/70wt% PLA	2.5481	2.8101	2.5170	2.4640
50wt% OPMF/50wt% PLA	1.7288	1.9291	1.7090	1.6790

*OPMF = Oil Palm Mesocarp Fiber

*PLA = Polylactic Acid

B3 Cost Analysis

Category	Expense / RM
Polylactic Acid (PLA) / 200 gram	RM 2,000.00
Transportation	RM 300.00
Laboratory's Equipment	RM 500.00
Others	RM 200.00
Total	**RM3,000.00**