Faculty of Mechanical and Manufacturing Engineering Technology

EFFECT OF GRASS FIBRE ON THE MORPHOLOGICAL AND MECHANICAL PROPERTIES OF THERMOPLASTIC CASSAVA STARCH COMPOSITE

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MUHAMMAD AFIF AKMAL BIN KHIRUDDIN

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DEDICATION

The sake of Allah, the Creator.

To Al-Quran, the greatest source of knowledge.

To my beloved parents who never stop giving support and a great source of inspiration.

To my supervisor, the one who has been a constant source of knowledge.

To all my friends who encourage and give their support.

ABSTRACT

Lately, the increasing of environmental issues had led to increasing attention on the development of biodegradable materials. Biopolymer made of renewable natural resources is a good alternative material to replace petroleum-based polymer since they are biodegradable and environmental friendly. Biopolymer from starch-based is one of the most promising due to the wide availability, low cost, renewable, biodegradable and abundant in nature. Cassava is one of the most abundant renewable resource for starch. This starch can be transform into thermoplastic with the presence of heat and shear. However, cassava starch biopolymer have some drawbacks such as poor morphological and mechanical properties that have limit their potential applications. These properties might be improve by using natural fibre as reinforcement for thermoplastic starch (TPS). Several methods have been use to improve the properties of thermoplastic cassava starch (TPCS) such as blending the cassava starch with glycerol together and reinforcement with imperata cylindrica fibre. The imperata cylindrica fibre attained by the extraction of cogon grass plant collected from the cropped wastes. To extract the fibres, imperata cylindrica soaked in water and then cleaned with water and kept dried before being shredded to obtain the fibres. Cassava starch and glycerol were first mixed by using high-speed mixer at 3000 rpm. Different amount of imperata cylindrica fibre (1, 3, and 5 wt%) were incorporated into polymer matrix. Dry-mixing method once again used to mix imperata cylindrica fibre with TPCS mixture using high-speed mixer at 3000 rpm. The homogeneous mixture poured into specified mould and compressed using hot press machine. In term of mechanical properties, tensile testing, impact testing and flexural testing have been carried out for the material. The improvement in mechanical properties in the composites were evidence following the addition of imperata cylindrica fibre into the TPCS. The tensile strength and tensile modulus for the TPCS reinforced imperata cylindrica fibre has increased than the polymer matrix. This finding was accompanied by the decreasing of elongation as more fibre incorporated with TPCS. The impact toughness decreased following the additional amount of imperata cylindrica fibre into TPCS matrix. In terms of morphological, the tensile fracture of TPCS and fibre break structure can be observe in this study. The morphological properties of the composite carried out by using Scanning Electron Microscopy (SEM). This investigation carried out to observe microstructure of cassava starch and reinforced biocomposites with different ratio of imperata cylindrica fibres (0, 1, 3 and 5 wt%). In general, the thermoplastic cassava starch (TPCS) polymer reinforced with imperata cylindrica fibre shows improved properties than the polymer matrix and have high potential in the production of biodegradable product such as packaging material and thin film.

ABSTRAK

Kebelakangan ini, peningkatan isu-isu alam sekitar telah membawa kepada peningkatan penghasilan bahan-bahan biodegrasi. Biopolimer yang diperbuat daripada sumber semula jadi yang boleh diperbaharui adalah bahan alternatif yang baik untuk menggantikan polimer yang berasaskan petroleum kerana ia boleh ter-biodegradasi dan mesra alam sekitar. Biopolimer berasaskan kanji adalah salah satu yang paling terbaik kerana ketersediaan yang luas, kos rendah, boleh diperbaharui, biodegrasi dan banyak terdapat dalam alam semula jadi. Ubi kayu adalah salah satu sumber yang boleh diperbaharui untuk kumpulan kanji. Kanji ini boleh diubah menjadi termoplastik dengan kehadiran haba dan ricihan. Walau bagaimanapun, biopolimer kanji ubi kayu mempunyai beberapa kelemahan seperti sifat morfologi dan mekanikal yang lemah yang mengehadkan aplikasi potensinya. Ciri-ciri ini mungkin bertambah baik dengan menggunakan serat semulajadi sebagai tetulang untuk termoplastik kanji (TPS). Beberapa kaedah telah digunakan untuk meningkatkan sifat termoplastik kanji ubi kayu (TPCS) seperti menggabungkan kanji ubi kayu dengan gliserol bersama dan tetulang dengan serat daun lalang. Serat daun lalang diperolehi daripada tumbuhan rumput lalang yang dikumpulkan dari sisa-sisa tanaman. Untuk mengeluarkan serat, daun lalang, daun lalang direndam dalam air dan kemudian dibersihkan dengan air dan dibiar kering sebelum dipotong untuk mendapatkan serat. Tepung kanji ubi kayu dan gliserol pada mulanya dicampur dengan menggunakan pengadun berkelajuan tinggi pada 3000 rpm. Jumlah serat daun lalang (1, 3, dan 5 wt%) dimasukkan ke dalam matriks polimer. Kaedah pencampuran kering sekali lagi digunakan untuk menggabungkan serat daun lalang dengan campuran TPCS menggunakan pengadun berkelajuan tinggi pada 3000 rpm. Campuran adunan itu dituang ke dalam acuan yang telah dibentuk dan dimampatkan menggunakan mesin. Ciri-ciri mekanikal dan morfologi bahan tersebut dikaji dalam kajian ini. Dari segi sifat mekanikal, ujian tegangan, ujian impak dan ujian lenturan telah dijalankan untuk bahan tersebut. Peningkatan sifat mekanikal dalam komposit adalah bukti berikutan penambahan serat daun lalang ke dalam TPCS. Kekuatan tegangan dan modulus tegangan untuk TPCS serat daun lalang bertetulang telah menunjukkan peningkatan daripada matriks polimer. Penemuan ini diikuti oleh penurunan pemanjangan kerana lebih banyak serat yang digabungkan dengan TPCS. Kekuatan impak berkurangan berikutan jumlah tambahan serat daun lalang ke dalam matriks TPCS. Dari segi morfologi, tegangan patah TPCS dan struktur putus serat boleh diperhatikan dalam kajian ini. Ciri-ciri morfologi komposit yang disiasat dengan menggunakan Mikroskopi Pengimbasan Elektron (SEM). Penyiasatan ini dijalankan untuk memerhatikan mikrostruktur kanji ubi kayu dan biokomposit yang diperkuat dengan nisbah berbeza serat daun lalang (0, 1, 3 dan 5 wt%). Secara umumnya, polimer termoplastik kanji ubi kayu (TPCS) yang diperkuat dengan serat daun lalang menunjukkan sifat yang lebih baik daripada matriks polimer dan mempunyai potensi tinggi dalam pengeluaran produk biodegrasi seperti bahan pembungkusan dan filem nipis.

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ASTM	-	American Society for Testing and Materials
CFRC	-	Ceramic Fibre-reinforced ceramic
CMC	-	Ceramic Matrix Composite
CS	-	Cassava Starch
CTE	-	Coefficient of Thermal Expansion
FRC	-	Fibre-reinforced composite
HAS	-	High Amylose Starch
ICF	-	Imperata Cylindrica Fibre
MMC	-	Metal Matrix Composite
NFC	-	Natural Fibre Composite
NS	-	Normal Starch
PP	-	Polypropylene
PVC	-	Polyvinyl Chloride
PMC	-	Polymer Matrix Composite
SEM	-	Scanning Electron Microscope
SiC	-	Silicon Carbide
TPCS	-	Thermoplastic Cassava Starch
TPS	-	Thermoplastic starch
TPSI	-	Thermoplastic Cassava Starch Imperata Cylindrica

CHAPTER 1

INTRODUCTION

1.0 Background

In this few years, the environmental friendly product's development is rising due to the growth of non-biodegradable waste on land. Apart from that, many kinds of green technology material were invented to counter the problem occur. As the decreasing of petroleum resources and non-biodegradability, scientist and researchers are looking into alternatives for resin system and synthetic fibre (Ramachandra et. al., 2018). In advance, many products in this recent years already used the fibre composites as they are more friendly with the environment and easy to get and cheap in price.

In a recent study, biopolymer of renewable resources is the best option for alternative material for petroleum-based polymer. They biodegradable and more environmental friendly than conventional polymer. Many types of natural resources used to develop lipid, cellulose, protein and starch ranged biopolymer. Across these sources, starch considered as the best resource because of few characteristics which are low cost, renewable source and sufficiently biodegradable (Wattanakornsiri & Tongnunui, 2014). The upper hand of natural fibres, such as low cost, availability, sustainability, recyclability and biodegradability (Edhirej et. al., 2017). By the existence of high-temperature heat and plasticizer, such as water or glycerol, thermoplastic starch (TPS) was produced from the conversion of starch that possesses similar process performance with conventional thermoplastic (Zhang et. al., 2013). The plasticizer used in TPS, which was glycerol to provide the best result in reducing the friction between starch molecules. The thermoplasticity allows the biopolymer to be process by using conventional processing equipment like injection moulding, extruder and compression moulding.

In polymer composites, a lot kind of natural materials have been used as reinforcement, such as natural fibres and natural fillers. The examples of natural fibres are jute, sisal, kapok, hemp, ramie, flax, kenaf, cotton, and coir (Navaneethakrishnan et. al., 2013). While for natural fillers, the natural material used are clay, eggshell and seaweed (Lau et. al., 2018). Natural material as a reinforcement in polymer composites provided more environmental friendly attributes to the composites itself. As of the evolution of more environmental friendly materials, come a new thought by people involving the manufacturing industry that always related to the pollution of the environment in both production and disposal of waste from synthetic polymer.

1.1 Problem Statement

Nowadays, serious environmental problems occur directly increasing as a result of a high consumption of different types of petroleum-based polymer for packaging materials, which disallowed thermoplastic, used to decay in a specific period of time. These wastes can be categorized as non-ready biodegradable material, which cannot breakdown under several conditions, such as sunlight, water, and soil burial. These wastes however can bring a hazardous problems to the environment itself, the society, and also to the wildlife as well. Besides, air pollution is another issue that was being the main talk issue involved. Furthermore, greenhouse gas known as methane gas that caused global warming also can be produced because of the polymer. Another issue that been watched over the years is flash flood. This problem occur as a result by the used of non-biodegradable material since they do not decompose properly and can cause clog of sewage system.

In recent, countries around the world have bring an effort to handle this issue by reducing the usage of plastic bags and change them with paper bags. Hence, this project justification that been carried out is to overcome and solve these issues by developing a biodegradable and renewable polymer composite from natural sources. Cogon grass or in scientific name imperata cylindrica is one of the natural sources that being pick and decided as the best material to be merge with biodegradable polymer composite. This type of species exist in a large amount of habitat and grow wild near the grassland. The leaves of cogon grass can be beneficial material, which can be utilize as building and roof for house. Moreover, it can be use as feed for animals too. They are very useful because the cogon grass consist of fibre in the outer layer of the leave and stem which worked as a reinforcement (Kow et. al., 2014).

Furthermore, partially biodegradable material resulted by the merging of natural material with the petroleum based polymer. Thus, it is highly potential to utilize imperata cylindrica as reinforcement in polymer composite. Therefore, the guidance of this study are (1) to boost the properties of thermoplastic cassava starch (2) to enlarge potential application of imperata cylindrica (3) to overcome incompatibility issue of imperata cylindrica reinforced composite and lastly (4) to invent a fully biodegradable material.

1.2 Research Objective

Recent years, many studies have been come out to find the solution and overcome the obstacle occur involving biodegradable material. Hence, in this study, the major aim of it is to characterize and develop renewable and biodegradable materials based on natural resources. The objectives are:

1. To develop thermoplastic starch reinforced imperata cylindrica fibre composite.

2. To characterize mechanical properties of material using tensile testing, impact testing, and flexural testing.
3. To investigate morphological properties of material using Scanning Electron Micrograph (SEM).

1.3 Significance of Study

1. The finding from this study expected to improve the knowledge in establishing biodegradable polymer from thermoplastic cassava starch and imperata cylindrica.
2. The improvement of biodegradable polymer with strengthen properties in the study to help in solving the environmental problems involving the different materials for petroleum-based polymer.
3. The issues involving petroleum-based polymer like environmental pollution can be avoided by using the derived of imperata cylindrica fibre and cassava thermoplastic starch which are biodegradable and renewable polymer composites.
4. This study also showed the new usability of imperata cylindrica fibre, which is cogon grass waste as reinforcement for biopolymer composites.
5. The imperata cylindrica fibre can be commercialize relevancy, which this type of composite material got a high potential to be use as an alternative material in the packaging industries and also as a short-life products.

1.4 Scope of Study

In this study, imperata cylindrica (cogon grass) and cassava starch were characterized for their mechanical and morphological properties. Then, starch extracted from tapioca plant was used as the based material for the development of thermoplastic cassava starch. Glycerol have been used as a plasticizer on the development of the thermoplastic cassava starch. Mechanical and morphological properties characterizations were performed. The composites development were carried out by the incorporation of imperata cylindrica into the thermoplastic cassava starch and their properties were characterized. The mechanical properties of the thermoplastic composites were characterized by using the tensile, impact, and flexural test, while the morphological properties were carried out by using the Scanning Electron Microscope (SEM) to obtain information about the surface topography and composition. The significant application for the composite being developed in this study is a short-life product. Thus, the potential application of the bio-composite materials is to create biodegradable products. The performance of the product being compared against the current thermoplastic starch and conventional material.

1.5 Structure of Study

The structure of this study is in correspondence with the thesis format of Universiti Teknikal Malaysia Melaka. Each chapter presents study that consists of the introduction, literature review, methodology, results and discussion, and conclusion. The details are as below:

Chapter 1

The problem involving the research and the objectives were clearly shown in this chapter. The significance and the scope of the study also detailed in the chapter.

Chapter 2

This chapter presents an absolute literature review on the related topic of the study. Moreover, research gaps obtained from review also defined in the chapter.

Chapter 3

The methodology used for the preparation of materials, testing procedure, and data collection are present in this chapter.

Chapter 4

This chapter represents the result finding on the investigation of mechanical and morphological properties of imperata cylindrica species.

Chapter 5

The overall conclusions for the whole study is present in this chapter as well as future recommendations for improvement of this study.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Earth nowadays had become a harmful place to live. It is due to the human activities that harmful effects on the biophysical environment. Therefore, the research toward the development of environmental eco-friendly materials had been carried out by many researchers and scientists to reduce this problem. Recently, the evolution of natural fibre composites is becoming more demand from industries sector due to the properties of this material, which is an alternative way of the conventional materials. In fact, the development cost of this material is low because of the abundant of agriculture waste in our country. In advance, many products in this recent years already used the fibre composites as they are more friendly with the environment and easy to get and cheap in price.

The natural fibre was the most popular fibre composite because of the advantages it provided. Sustainable development had specialized green composites as a biodegradable renewable and environmental friendly resources. Wattanakornsiri & Tongnunui, (2014) stated that the advances in green composites depend on thermoplastic starch (TPS) and cellulose fibres. The environmental sustainability is important as the increasing volume of petroleum-derived plastic waste dumps can be reduced. Moreover, green composites cheap in price and abundant across our grassland (Wattanakornsiri & Tongnunui, 2014).

2.1 Polymer

Polymer are well-known as a large molecule, macromolecule or atom that contain of repeated sub units. This both synthetic and natural polymer is an important role in daily life because their properties quite broad range. The range of polymer is from synthetic plastic like polystyrene to natural biopolymer like DNA and protein, which are fundamental to biologic function and structure. Natural and synthetic polymer both created by polymerization of many smaller molecules (monomers). Unique physical properties, such as toughness, viscoelasticity, and tendency to form glasses and semi-crystalline structures rather than crystals. This is the effect of their consequent large molecular mass relative to small molecule compunds (Navaneethakrishnan et al., 2013).

2.2 Biopolymer

In recent years, the medical department have interested in the use of medical application made of biopolymers. The characteristics like biocompatibility, biodegradability, and ease of processing have attract their attention on the use of biopolymers. Nowadays, wide development of biopolymer-based functional composites appear to raise the value of raw biopolymers that gather from natural sources.

In the context on protection of the environment, green and biocompatible materials like bio-composites and biodegradable polymer have attracted attention on producing new type of materials. The area that have shown interest in the use of biopolymer material including pharmaceutical, medical, and biomedical. In biomedical engineering application, they are very useful as drug delivery systems, artificial implants and functional materials in the tissue engineering.

The development of biodegradable polymer blends composites have caused many group of researchers concentrated on the type of composite which are compatible with the problem solution. Some of the biodegradable polymer blends or composites are from corn gluten meal, starch, wheat gluten, and zein (Kim et. al., 2010). However, in a few researches, the strong recommended biopolymer is starch because its characteristic which are ease of availability, low in cost, abundant in agriculture, renewable waste, and biodegradable materials.

2.3 Composite

Composite is the short for composite material or composition material, in which it was defined as a material that made of two or more materials that contain different chemical and physical properties. This composites when merge together, would produced a material that possessed different characteristics compared to the individual component. The main component remain distinct and separate away along the finished structure (Fakirov, 2015). The characteristics of new materials produce, consist a combination from the individual attributes. So, after the combination of component, the materials may become stronger, lighter, and cheaper compared to traditional materials. As for information, composites are not same as alloys, such as brass, nickel, silicon and aluminium (David Kennedy, 2018). Formation of alloys were very difficult. There are hard to differ the component. Some common composite materials are concrete, mud brick, fibreglass and natural composites are wood and rock.

2.3.1 Composite Matrix Material

High performance composite material such as fibre-reinforced composite (FRC) is made of three components. In FRC, fibres act as the discontinuous or dispersed phase, while the matrix act as the continuous or fine interphase region / interface (AZoM, n.d.). These