Faculty of Mechanical and Manufacturing Engineering Technology

THERMAL, PHYSICAL AND ENVIRONMENTAL FRIENDLY CHARACTERISTICS OF BIO BASED COMPOSITES DERIVED FROM SUGARCANE FIBRE AND POTATO STARCH

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In the name of Allah, the most Gracious and the Most Merciful Alhamdulillah, all praises to Allah for the strength and His blessing in completing this Thesis.

&

To my beloved mother

&

To my supportive families

For their Love, Support and Best Pray

ABSTRACT

In recent, development of eco-friendly product have been great progress based on renewable materials due to the problem of non-biodegradable waste particularly the disposable product that gives impact in environmental problems and human being. Hence, to tackle the environmental and sustainability issues, this century has focused greater achievement in green technology in the field of science materials through development of bio-composite. Bio polymer derived from renewable resources is one of the promising material that can be an alternative in replacing petroleum based polymer since it is readily biodegradable and more environmentally material. Starch has been one of the examples of bio-polymer among the biodegradable polymer due to their advantage of abundant resources, low cost, biodegradability and renewability. However, there is limitation on starch usage in commercial plastic production in industry where starch based is poor mechanical properties and water sensitive. Sugarcane bagasse produced from the extraction of sugarcane juice has been the large agriculture waste nowadays. This waste has potential application to be used as reinforcement material for producing bio based composite and also can be an alternative way for the waste management especially in agricultural waste. In this study, several modification methods were employed to enhance the properties of Thermoplastic Potato Starch (TPPS) by incorporating it with different amount of sugarcane fibre (1, 5, 10, 15 wt.%). Consequently, TPPS/sugarcane fibre composites were developed by using dry mixing at 1200 rpm for 6 min and hot press method at 145°C for 1 hour by maintaining the composition of starch and glycerol at ratio 80:20 respectively. The finding shows that the thermal properties of the composite increase for the 15wt.% of sugarcane fibre loading. In terms of physical properties, the addition of sugarcane fibre content from 0 to 15wt.% has decreased the water affinity of the composite. This finding shows that TPPS/SF composite has good resistance of moisture and water and also has high dimensional stability. Furthermore, the influence of sugarcane fibre at varying content (0 to 15wt.%) on the biodegradation characteristic of the TPPS/SF composite were investigated. After soil burial test for 2 and 4 weeks, TPPS/SF composite resulted of the lowest weight loss. It is also evident from the soil burial results that the biodegradation of the composites were enhanced after 4 weeks of burial than 2 weeks with the addition of sugarcane fibre. Overall, the finding from this study presents that the Thermoplastic Potato Starch (TPPS) reinforced sugarcane fibre composite has shown improved in the drawback of the origin material. In conclusion, this material can be commercialized due to the low cost, abundant resources and renewable in the effort of environmental preservation compare to conventional material. Hence, biopolymer composite derived from natural resources have potential application such as plastic packaging and for short life product. In addition, natural waste resources can be utilize as an alternative way to develop composite that are eco-friendly and can contribute towards better waste management.

ABSTRAK

Baru-baru ini, pembangunan produk mesra alam telah menjadi kemajuan yang hebat berdasarkan bahan yang boleh diperbaharui disebabkan oleh masalah sisa yang tidak boleh terurai terutamanya produk pakai buang yang memberi kesan kepada pencemaran alam sekitar dan kehidupan manusia. Oleh itu, untuk menangani masalah pencemaran dan menjaga kesinambungan alam sekitar, negara kini ini telah menumpukan pencapaian yang lebih besar dalam teknologi hijau dalam bidang sains bahan melalui penghasilan bio-komposit. Bio polimer yang diperoleh daripada sumber yang boleh diperbaharui adalah merupakan salah satu bahan yang boleh dijadikan sebagai bahan alternatif bagi menggantikan polimer berasaskan petroleum kerana ia mudah terurai dan merupakan bahan yang lebih mesra alam. Kanji ialah salah satu contoh bio-polimer diantara bio polimer yang lain kerana kanji mempunyai kelebihan dari segi sumber yang banyak, kos yang rendah, mudah terurai dan boleh diperbaharui. Walau bagaimanapun, terdapat kelemahan dalam penggunaan kanji bagi pengeluaran plastik yang komersil dalam industri di mana kanji mempunyai sifat mekanik yang lemah dan sensitif terhadap air. Bagasse tebu yang didapati daripada pengekstrakan jus tebu telah menjadi sisa pertanian yang besar pada masa kini. Sisa ini mempunyai potensi yang boleh digunakan sebagai bahan pengukuhan untuk menghasilkan bio komposit dan juga boleh menjadi alternatif dalam pengurusan sisa terutama dalam sisa pertanian. Dalam kajian ini, beberapa kaedah pengubahsuaian dilakukan untuk meningkatkan sifat-sifat Termoplastik Kanji Kentang (TPPS) dengan mencampurkannya dengan serat tebu (SF) pada kuantiti yang berbeza (1, 5, 10, 15 wt.%). Oleh itu, komposit TPPS/serat tebu telah dihasilkan dengan menggunakan kaedah pencampuran kering pada 1200 rpm selama 6 minit dan kaedah pengacuan mampatan pada suhu yang tinggi iaitu pada 145°C selama 1 jam dengan mengekalkan komposisi kanji dan gliserol pada nisbah 80:20. Hasil kajian menunjukkan sifat-sifat terma komposit meningkat bagi kandungan serat tebu sebanyak 15wt.%. Dari segi sifat fizikal, penambahan kandungan serat tebu dari 0 hingga 15wt.% telah mengurangkan kecenderungan komposit terhadap air. Hasil dapatan ini menunjukkan bahawa komposit TPPS/SF mempunyai rintangan yang baik terhadap kelembapan dan air dan juga mempunyai kestabilan dimensi yang tinggi. Tambahan pula, pencampuran serat tebu pada pelbagai kandungan (0 hingga 15wt.%) terhadap sifat biodegradasi komposit TPPS/SF telah dikaji. Selepas pengujian penanaman komposit dalam tanah selama 2 dan 4 minggu, komposit TPPS/SF menghasilkan penurunan berat bahan yang terendah. Dari hasil penanaman dalam tanah, biodegradasi komposit terbukti meningkat selepas 4 minggu penanaman berbanding 2 minggu dengan penambahan serat tebu Secara keseluruhannya, hasil dapatan dari kajian ini membuktikan bahawa komposit dari Termoplastik Kanji Kentang (TPPS) yang diperkuat dengan serat tebu telah menunjukkan penambahbaikan dalam kelemahan bahan asal. Sebagai kesimpulan, bahan ini boleh dikomersialkan dalam usaha pemeliharaan alam sekitar berbanding dengan bahan konvensional. kerana bahan ini mempunyai kos yang rendah, sumber yang banyak dan

boleh diperbaharui. Oleh itu, komposit biopolimer yang diperoleh dari sumber semula jadi mempunyai potensi dalam aplikasi seperti pembungkusan plastik dan produk jangka hayat pendek. Di samping itu, sumber sisa semulajadi boleh digunakan sebagai cara alternatif untuk menghasilkan komposit yang mesra alam dan dapat menyumbang kepada pengurusan sisa yang lebih baik.

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LIST OF ABBREVIATIONS

SCB	-	Sugarcane Bagasse
NFC	-	Natural Fibre Composite
TGA	-	Thermo-gravimetric Analysis
TPPS	-	Thermoplastic Potato Starch
UV	-	Ultraviolet Radiation
TS	-	Tapioca Starch
SCFC	-	Sugarcane Fibre Composite
HDPE	-	High-Density Polyethylene
PMC	-	Polymer Matrix Composite
MMC	-	Metal Matrix Composite
CMC	-	Ceramic Matrix Composite
NFRC	-	Natural Fibre Reinforced Composites
PU	-	Polyurethane
PP	-	Polypropylene
PVC	-	Polyvinyl Chloride
TPS	-	Thermoplastic Starch
TPCS	-	Thermoplastic Corn Starch
TPCS	-	Thermoplastic Cassava Starch
SEM	-	Scanning Electron Microscopy

XRD	-	X-ray Diffraction
TA	-	Thermal Analysis
FTIR	-	Fourier Transform Infared Spectroscopy
Tg	-	Glass Transition
TPCS	-	Thermoplastic Cassava Starch
CNC	-	Cellulose Nanocrystal
MMT	-	Montmorillonite
PLA	-	Poly Lactic Acid
SF	-	Sugarcane Fibre
DTG	-	Derivative Thermo-gravimetric

CHAPTER 1

INTRODUCTION

1.0 Background

In recent, plastics are widely used in industries of plastic packaging, electric and electronic devices and automotive. However, plastic that comes from non-biodegradable material which produced from petroleum-based fuel gives critical issues in environmental problems and human being (Sahari et al., 2014). Development of biodegradable products has been great progress based on agricultural materials (Curvelo et al., 2001). Hence, to tackle the environmental and sustainable issues, this century has focused on greater achievement in green technology product in the field of materials through development of bio-composite. Nowadays, greater intention has focused on the natural resources to create biodegradable polymers as the alternative of replacement of oil-based polymers (Averous and Boquillon, 2004).

Starch has been one of the most promising bio-polymer among the biodegradable polymer due to their advantage of abundant resources, low cost, biodegradability and renewability. Starch can be thermoplastic material by adding plasticizer under high temperature. Plasticizer agents are one of the significant material in modification the properties of starch to increase its flexibility and processability of thermoplastic materials (Sahari et al., 2014). The uses of natural reinforcing fibres like flax, ramie and hemp into bio-polymer matrix derived from starch have been the new development of bio-composite (Mohanty et al., 2000).

Incorporation of this material can create environmental friendly condition and reduced dependency of conventional fibres like glass fibre which give potential hazards in manufacturing. Thus, the development of environmentally friendly materials is the best way in industry to overcome the environmental issues for both disposal problem and production of synthetic polymer.

1.1 Problem Statement

High utilization of petroleum-based polymer in the human life cause environmental pollution during disposal stage of non-biodegradable products. Plastic bags which are non-biodegradable product are difficult to dispose and recycle into an environment like soil, ocean and lake on the earth where it takes around 300 years to photodegrade (Sangita et al., 2011). Thus, it conveyed difficult issues to the human being, wildlife and environment (Haque, 2017). In addition, environmental pollution was the most concerning issues where plastic bags are being frequently burned and difficult to dispose which can cause toxic fumes to be released into air and lead to the environmental pollution. Every year, around 500 billion of plastic bags were used and as much as one million plastic bags are being disposed every minute and cause serious problem to our environment (Sangita et al., 2011). Thus, many countries have seeks awareness to reduce the usage of plastic bag as an effort to overcome the environmental issues.

Polymer based that derived from renewable resources have been great interest in using nowadays as an effort to replace synthetic polymer based from fossil resources. In this context, one of the interesting groups of materials is based on starch due to their abundant resources (Thuwall et al., 2006).

Potato starch can be transformed into thermoplastic material by addition of the plasticizer under high temperature which resulted in a rigid material. However, there is a limitation on starch usage for commercial plastic production in industry where starch based is poor mechanical properties and water sensitive (Roz et al., 2011). Thus, starch need to be modified to overcome this drawback in making strong rigid composite.

Besides, another problem is problem in handling and managed large quantity of agriculture waste. Nowadays, natural waste resources can be an alternative way in making composite that are eco-friendly materials and contribute towards the better waste management especially in agricultural waste. Sugarcane waste is one of the examples wastes that can be reused as the reinforcement material in developing new composite. Due to the ecological sustainability, sugarcane plant is natural agriculture and renewable resources which provides sugar besides produces other product and co-product (Asagekar and Joshi, 2014). Sugarcane bagasse which produced after extraction of sugarcane juice can be the large agriculture waste nowadays. This waste have potential application to be used as reinforcement material for producing bio-composite (Asagekar and Joshi, 2014). Thus, fibres from the Sugarcane Bagasse (SCB) have numerous advantages as the versatility of raw material in the production of new products due to their low costs, high quality green material and abundant resources. Thus, sugarcane waste has potential that can be utilized as reinforcement material in making bio based composites.

Hence, the project justification in this study is to bring the ideal idea to solve the environmental problem by creating new environmentally material by developing biodegradable polymer which is 100% renewable and comes from natural resources. This study is the best way to manage the abundant wastes of plant sources to create green economy as the aims for the sustainable development in human life being.

1.2 Research Objectives

The objective of this study is to develop and investigated biodegradable and renewable materials based on natural resources. The specific objectives are:

i To develop thermoplastic potato starch reinforced sugarcane fibre composites.

ii To characterize the effect of sugarcane fibre on the thermal properties of Thermoplastic Potato Starch.

iii To investigate the effect of sugarcane fibre on the physical properties and environmental friendly characteristics of Thermoplastic Potato Starch.

1.3 Significance of Study

i The findings from the current study may increase the knowledge in developing of biodegradable polymer from thermoplastic potato starch and sugarcane fibre.

ii The intention in developing of biodegradable polymer by increase its properties in this study might overcome the environmental issues regarding the alternative of environmentally materials in replacing of petroleum-based polymer.

iii The problem that related with petroleum-based polymer such as environmental pollution during processing, recycle and disposal can be eliminated by using fully bio-composite derived from sugarcane fibre.

iv In the context of waste management, this research has discovered a new potentials application of sugarcane waste from its extraction as novel reinforcement for bio-polymer composite.

v In addition, this study also utilizes the potato starch and sugarcane fibre in developing of bio composite. Hence, the addition of sugarcane fibre gives value added for the sugarcane tree other than producing juice.

vi This Natural Fibre Composite derived from sugarcane fibre and potato starch can be commercialized as value-added wastes that can be used as packaging material and for short life product.

1.4 Scope of Study

Potato starch was used as based material for the development of thermoplastic potato starch. Development of thermoplastic potato starch was carried out by using glycerol as the plasticizer. For the development of composite, sugarcane fibre was incorporated into the thermoplastic potato starch and their characteristics were investigated. The thermal properties were characterized by using Thermo-gravimetric Analysis (TGA) and physical properties were carried out by determine the moisture content, water absorption, and thickness swelling. In addition, the environmental characteristics were carried out by using water solubility and soil burial test. The suitable application for the composite which was developed in this study is for short life product. Therefore, the potential application of this biocomposite material is to create biodegradable products by evaluating their performance against the conventional material and the current thermoplastic starch.

1.5 Structure of Thesis

The structure of this thesis is in accordance with the thesis format of Universiti Teknikal Malaysia Melaka (UTeM). This research presents an introduction, literature review, methodology, result and discussion, conclusion and recommendations for future research. The details of the thesis structure are as follows:

Chapter 1

The problems that related to this research and the research objectives were clearly explained in this chapter. The significance of this research and the scope of the study were also elaborated within the chapter.

Chapter 2

This chapter presents an extensive literature review on the previous study which was related to the title of this thesis. In addition, the research gaps were also clarified within the chapter that obtained from the previous works.

Chapter 3

This chapter presents the research methodology used in this study for the preparation of materials, testing procedure, and data collection.

Chapter 4

This chapter presents the result of the Thermoplastic Potato Starch and Thermoplastic starch reinforced sugarcane fibre composites. In this chapter, the result of thermal analysis, physical and environmental testing for Thermoplastic Potato Starch (TPPS) and