UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION AND DEVELOPMENT OF BIOPOLYMER DERIVED FROM ARENGA PINNATA AND THEIR BIOCOMPOSITES

SAHARI BIN JAPAR

ITMA 2013 2

CHARACTERIZATION AND DEVELOPMENT OF BIOPOLYMER DERIVED FROM *ARENGA PINNATA* AND THEIR BIOCOMPOSITES

SAHARI BIN JAPAR

DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA

2013

CHARACTERIZATION AND DEVELOPMENT OF BIOPOLYMER DERIVED FROM *ARENGA PINNATA* AND THEIR BIOCOMPOSITES

By

SAHARI BIN JAPAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

May 2013

DEDICATIONS

For all your advice and encouragement, this thesis is gratefully dedicated to my beloved parent, family and my friends. Thank you very much for your continuous support and effort towards the publication of this thesis.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

CHARACTERIZATION AND DEVELOPMENT OF BIOPOLYMER DERIVED FROM *ARENGA PINNATA* AND THEIR BIOCOMPOSITES

By

SAHARI BIN JAPAR

May 2013

Chairman : Professor Mohd Sapuan Salit, PhD, P. Eng

Institute : Institute of Advanced Technology

This research was carried out to produce a new biopolymer (plasticized SPS) and biocomposites (SPF/SPS) derived from sugar palm tree. The plasticized SPS and SPF/SPS biocomposites were produced by a compression moulding method. Due to unique behavior of starch, the important properties of SPS have been studied in order to explore their potential to be used as a new alternative biopolymer. It was observed that the starches isolated from sugar palm tree contain comparable amounts of amylose (37.60%) and thermally stable than other starches. Then, SPS was added with 15 to 40 w/w% of glycerol to prepare workable bioplastics. Generally, the addition of glycerol decreases the transition temperature of plasticized SPS and the mechanical properties (i.e. tensile, flexural and impact) of plasticized SPS increase with the increasing of glycerol but up to 30 w/w%. Meanwhile, the water absorption of plasticized SPS decreases with increasing of glycerol. The effect of fiber content (i.e. 10%, 20% and 30% by weight percent) on mechanical properties, water absorption behavior and thermal properties of SPF/SPS biocomposites were investigated. The mechanical properties of plasticized SPS improved with the incorporation of fibers. Fiber loading also increased the thermal stability of the biocomposite in this investigation. Water uptake and moisture content of SPF/SPS biocomposites decreased with the incorporation of fibers, which is due to better

interfacial bonding between the matrix and fibers as well as the hindrance to absorption caused by the fibers. Morphological studies through scanning electron microscopy showed homogeneous distribution of fibres and matrix with good adhesion which play an important role in improving the mechanical properties of biocomposites. But the mechanical properties of the biocomposite dropped after being stored for 72 hours at 75% relative humidity and large cracks appear on the surface of the matrix (SPS) due to water absorption. Finally, biodegradable and weathering testing were also studied for both biopolymer and biocomposite. The environmental effect on plasticized SPS and SPF/SPS biocomposite were lost 78.09% and 53.67% tensile strength respectively at the end of 72 h of the weathering testing period. The biodegradation test shows that the plasticized SPS degrades very quickly and losses 63.58% weight at the end of 72 h compared to SPF/SPS biocomposites.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENCIRIAN DAN PEMBANGUNAN BIOPOLIMER YANG DIPEROLEH DARIPADA *ARENGA PINNATA* DAN BIOKOMPOSITNYA

Oleh

SAHARI BIN JAPAR

Mei 2013

Pengerusi : Professor Mohd Sapuan Salit, PhD, P. Eng

Institut : Institut Teknologi Maju

Penyelidikan ini dijalankan untuk menghasilkan biopolimer (SPS terplastik) dan biokomposit (SPF/SPS) baru yang diterbitkan daripada pokok enau. SPS terplastik dan SPF/SPS biokomposit ini dihasilkan dengan menggunakan kaedah pengacuan mampatan. Disebabkan sifat kanji yang unik, sifat-sifat kanji yang penting dikaji untuk meneroka potensinya sebagai alternatif biopolimer yang baru. Hasil penyelidikan menunjukkan bahawa kanji daipada pokok enau mengandungi amilosa yang setanding dan sifat haba yang stabil berbanding kanji-kanji yang diperolehi daripada sumber yang lain. Kemudian, SPS ditambah dengan gliserol sebanyak 15 hingga 40% mengikut berat untuk menghasilkan bioplastik yang boleh digunakan. Secara keseluruhannya, penambahan gliserol menguranggkan suhu peralihan SPS terplastik dan sifat-sifak mekanikal (tegangan, lenturan dan impak) SPS terplastik bertambah dengan pertambahan gliserol sehinggal 30% mengikut berat. Manakala penyerapan air SPS terplastik berkurang dengan pertambahan gliserol. Kesan kandungan gentian (iaitu 10%, 20% and 30% mengikut berat) terhadap sifat-sifat mekanikal, penyerapan air dan haba bagi SPF/SPS biokomposit juga dikaji. Sifat-sifat mekanikal SPS terplastik bertambah baik dengan penambahan gentian. Penambahan gentian juga meningkatkan kestabilan haba dalam kajian ini.

Penyerapan air dan kandungan lembapan SPF/SPS biokomposit menurun dengan penambahan gentian yang disebabkan oleh ikatan yang lebih baik antara matriks dan gentian serta sifat menghalang penyerapan yang disebabkan oleh gentian. Kajian morfologi melalui imbasan mikroskop elektron menunjukkan taburan seragam gentian dan matriks dengan ikatan yang baik yang memainkan peranan penting dalam meningkatkan sifat-sifat mekanikal biokomposit. Tetapi sifat-sifat mekanikal biokomposit menurun selepas disimpan selama 72 jam pada kelembapan relatif 75% dan retakan yang besar dilihat pada permukaan matriks (SPS) yang disebabkan oleh penyerapan air. Akhirnya, ujian biodegradasi dan luluhawa juga dikaji untuk kedua-dua biopolimer dan biokomposit. Kesan alam sekitar terhadap SPS terplastik dan SPF/SPS biokomposit adalah masing-masing mengalami penurunan kekuatan tegangan sebanyak 78.09% dan 53.67% pada akhir 72 jam tempoh ujian luluhawa. Ujian biodegradasi menunjukkan bahawa SPS terplastik terurai dengan cepat dan kehilangan berat sebanyak 63.58% pada akhir 72 jam berbanding dengan SPF/SPS biokomposit.

ACKNOWLEDGEMENTS

First and the foremost, I would like to pay thanks to Allah S.W.T by His mercy who has given me the opportunity in completion of this research project. Also thanks to my beloved mother, father and my family for their support and blessing during my hardness time in completing this research. I am deeply indebted to chairman of supervisory committee, Professor Ir. Dr. Mohd Sapuan Salit and to co-supervisor, Associate Professor Dr. Edi Syams Zainudin and Associate Professor Dr. M A Maleque for their outstanding advices and assistance throughout the years. Special thanks to Ministry of Higher Education for the financial supports under the 10th Malaysia Plan via the MyBrain15 program. Special thanks also to Mr. Ahmad Shaifudin Ismail, Mr. Muhammad Wildan Ilyas Mohamed Ghazali, Mr. Tajul Ariffin Md. Tajuddin, Mr. Mohd Saiful Azuar Md. Isa, Mr. Mohd Zuhri Mohamed Yusoff , Mr. Mohd Zafri Mahdi and all staffs from the Department of Mechanical and Manufacturing Engineering. Lastly, thanks to Mrs. Yusriah Lazim, Mr. Mohd Syukri Ibrahim, Mr. Khairul Azhar Mohammad, Mr. Muslim Haron, Mr. Mohd Fairuz Abd. Manab, Mr. Sairizal Misri, Miss Nurhaniza Mohamad, and to all my friends who had helped in completing this research project.

I certify that a Thesis Examination Committee has met on **02 August 2013** to conduct the final examination of **Sahari Japar** on his thesis entitled **"Characterization and development of biopolymer derived from *arenga pinnata* and their biocomposites "** in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Assoc. Prof. Dr. Khalina Abdan
Department of Biological and Agricultural Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Assoc. Prof. Dr. Rizal Zahari
Department of Aerospace Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Professor Dr. Luqman Chuah Abdullah
Department of Chemical and Environmental Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Professor Dr. Faiz Muhammad
Department of Applied Chemistry
Faculty of Engineering and Technology
Aligarh Muslim University
(External Examiner)

_____
SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Hj. Mohd Sapuan Salit, PhD, P. Eng
Professor
Department of Mechanical and Manufacturing Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Edi Syams Zainudin, PhD
Associate Professor
Department of Mechanical and Manufacturing Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Member)

M A Maleque, PhD
Associate Professor
Department of Materials and Manufacturing Engineering
Engineering Kulliyah
International Islamic University Malaysia
(Member)

_____
BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

SAHARI BIN JAPAR

Date: 02 August 2013

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
AGE	Allyl glycidyl ether modified
CO_2	Carbon dioxide
DP	Degree of polymerization
DSC	Differential scanning calorimetry
DTG	Derivative Thermogravimetric Analysis
FTIR	Fourier transform infrared spectroscopy
INTROP	Tropical Forestry and Forest Products
IRRI	International Rice Research Institute
KBr	Potassium bromide
MF	Medium fibre
LDPE	Low density polyethylene
LIPI	Lembaga Ilmu Pengetahuan Indonesia
PHBV	Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)
PF	Phenol formaldehyde
PLA	Polylactic acid
RH	Relative Humidity
SEM	Scanning electron microscope
SF	Short fibre
SPB	Sugar palm bunch
SPD	Sugar palm frond
SPF	Sugar palm fibre
SPF/SPS	Sugar palm fibre reinforced sugar palm starch

SPS	Sugar palm starch
SPT	Sugar palm trunk
TAPPI	Technical Assn of the Pulp and Paper Industry
TGA	Thermogravimetric analysis
TG	Thermogravimetric
Tm	Melting temperature
Tg	Glass transition temperature
TPS	Thermoplastic starch
TPRS	Thermoplastic rice starch
UP	Unsaturated polyester
UV	Ultraviolet

TABLE OF CONTENTS