CHARACTERIZATION AND BIODEGRADABILITY OF EXTRUDED FOAMED POLYPROPYLENE FILLED PINEAPPLE LEAF FIBER BIOCOMPOSITES

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Specially dedicated to my beloved parents,

family and friends

Thanks for encouraging and supporting me.

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"In the name of Allah SWT, the most gracious and most merciful"

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ABSTRACT

Polymer foam biocomposites based on Polypropylene (PP)-Pineapple Leaf Fiber (PALF) were successfully produced by an extrusion foaming process. The compounding of PP with PALF was performed in twin-screw extruder which blend the materials with dicumyl peroxide (DCP) and chemical blowing agent (ADC). The DCP (1%) and ADC (1.5%) were kept constant while PALF content were varied from 0% to 30% by weight. After forming the foam, samples was prepared for water absorption test (ASTM D-2842), density determination and biodegradability test (ASTM G21). The PP-PALF biocomposite foam was characterized using Thermogravimetry Analysis (TGA) and Differential Scanning Calorimetry (DSC). It was found that PP-PALF biocomposite foam is open-cell foam and is proved by the water absorption test which increased linearly with increment of PALF loadings. From the DSC result, it was showed that the percent of crystallinity decreases with increased in filler loading and the melting temperature of the PALF-PP biocomposite foam were not much affected by incorporation of PALF. Finally, the additions of pineapple leaf fiber into each formulation have significantly improved the biodegradability of the biocomposites.

ABSTRAK

Biokomposit polimer berbusa berasaskan gentian daun nenas (PALF) diisi polypropiline (PP) telah Berjaya dihasilkan melalui proses penyemperitan. Proses penyaemperitan PP dan PALF telah dilakukan dengan menggunakan mesin penyemperitan screw berkembar. Bahan mentah ini kemudiannya diadunkan pula bersama-sama dicumyl perosida (DCP) dan agen pembuih kimia (ADC) untuk menghasilkan biokomposit berbusa. Dalam kajian ini, hanya kandungan PALF dipelbagaikan dari 0% hingga 30% daripada berat keseluruhan, manakala kandungan DCP (1%) dan ADC (1.5%) adalah tetap. Selepas proses penyemperitan berbusa, sampel-sampel ini kemudiannya telah menjalani proses penentuan ketumpatan, ujian penyerapan air (ASTM D-2842) dan ujian kebolehuraian (ASTM G21). Proses pencirian juga telah dilakukan ke atas biokomposit berbusa tersebut. Mikrogaf optikal (SEM) pula telah digunakan untuk mengkaji struktur sel biokomposit bebusa tersebut. Pemerhatian menggunakan SEM telah mendedahkan bahawa struktur sel biokomposit berbusa ini terdiri daripada sel-sel terbuka. Dari proses penentuan ketumpatan pula telah menunjukan berlakunya peningkatan ketumpatan bagi setiap komposit berbusa apabila kandungan PALF ditambah. Peningkatan kandungan PALF juga mengurangkan peratusan hablur yang hadir dalam setiap biokomposit berbusa tersebut. Akhir sekali, penambahan PALF juga telah meningkatkan kadar kebolehuraian bagi setiap biokomposit berbusa tersebut.

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LIST OF ABBREVIATIONS

PP	Polypropylene
PALF	Pineapple Leaf Fiber
DCP	Dicumyl Peroxide
ADC	Azodicabonamide
ASTM	American Society for Testing and Materials
TGA	Thermogravimetry Analysis
DSC	Diffential Scanning Calorimetry
SEM	Scanning Electron Microscope
SHSD	Sunflower Hull Sanding Dust
SITRA	South India Textile Research Association
MAPP	Maleic Anhydride Polypropylene
OTMS	Octadecyltrimethoxysilane
ADCA	Azodicarbonate
BPO	Benzyl Peroxide
CAT	di-nbutyltin dilaurate
VTOMS	Vinyl Trimethoxy Silane
CFA	Chemical Blowing Agent
PFA	Physical Blowing Agent
VOC	Volatile Organic Content
HC	Hydrocarbon
CFC	Chlorofluorocarbon
HFC	hydrofluorocarbon
HDPE	High Density Polethylene
LLDPE	Low Linear Density Polyethylene
LDPE	Low Density Polyethylene
EM	Effective Microorganism
∆Hf	Heat of Fusion
Tm	Melting Temperature
Xcom	Percent Crystallinity
Xpp	Crystallinity of PP in the Composite
∆H	Heat of Fusion of Perfectly Crystalline

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The use of polymeric foam in today's world has constantly increased. Many reasons support this growth: light weight, insulation properties, softness, excellent strength/weight ratio, material costs and energy absorption performance. Many times reductions after foaming in material costs are around 30% without compromising the function or required strength, which is one of the advantages that could lead to even wider use of foams in industry. The chemicals used are today environmental friendly and the mechanical and barrier properties can be greatly affected by multilayer constructions; mechanically strong sandwich structures can be produced with solid skin layers, low gas permeability polymers and tie layers support their use for high barrier packages (Krayink *et al*., 1987).

The main applications for foamed plastics can be found in the building, automobile, packaging and sport industries. They include the end products for insulative sheets, floor coverings, and profile for finishing, automobile linings, packaging films, cable wires, interior finishing, shoes and cups (Kumar, 1993).

Because of environmental demands, foamed polymers have also been threatened and raw material and process manufactures have been forced to find solutions for recyclable polymers and alternatives for blowing agents’ deleterious effects on the ozone layer. These challenges have led studies more away from the traditional materials, polystyrene and polyurethane and towards the use of polyolefins, polyethylene and polypropylene (Fox and Goodman, 1993). The tremendous growth in the use of foams in the last three decades has also created a serious problem of waste disposal and to overcome this problem, natural fiber will be added to make the foam biodegradable (Daniel Klempner and Vahid Sendijarevic, 2004).

In Malaysia, agriculture is an important sector of economy. Traditionally, agricultural materials have been shipped away for processing, or disposed of postharvest. Diversification of the industry is crucial in encouraging economic stability and growth. Value-added processing would helps in agricultural diversification. Pineapple Leaf Fiber (PALF), the subject of the present study, is a waste product of pineapple cultivation. Hence, pineapple fiber can be obtained for industrial purposes without any additional cost.

Traditional plastic materials are reinforced by the non-biodegradable fiber, which are both expensive and harmful to the environment. A fiber based biocomposite material contains polymers reinforced with natural fiber. There are number of advantages of using natural fibers in biocomposites, among which are: a) natural fiber will make the material partially biodegradable; b) natural fiber, in this research is PALF is currently disposed of by burning; and c) PALF is a low cost, low density and low energy consumption. Over the past decade, cellulosic fillers have been of greater interest as they improve composites mechanical properties compared to those containing non-fibrous fillers. In recent years, thermoplastic materials have been increasingly used for various applications (Folkes, 1982).

Research on a cost effectiveness modification of natural fiber is necessary since the main attraction for today's markets of biocomposites is the competitive cost of natural fiber. This research attempts to address the following question: do PALF have any influence on the foam properties. Polymer reinforced biocomposites have demonstrated a marked improvement in the physical properties of polymeric materials. Natural fibers have proven to yield many desirable properties when utilized as reinforcing agents in polymer composite (Sui *et al*., 2009).

Since the tensile strength for these natural fibers are low, the composites reach only of about 60 % of the tensile strength of the GF-PP composites. However the Young's moduli are commonly higher than those of GF-PP composites. By considering the economy factors where the natural fiber are abundant and are relatively cheap compare to engineering glass fiber, natural fibers have their significant important in the composite field as reinforcement.

Although there are not many tests carried out for the flexural properties of composites, this property is important to study the fracture behavior. Regarding PALF reinforced polyester, Uma Devi *et al.* (1997) pointed that the addition of fiber made the composite more ductile. In her work, the flexural strength values of the PALF-polyester composites were less than the pure polyester at low weight fractions (10 wt %) of the fiber. Further increased of the fiber loading, the flexural strength had improved by nearly 120 % for composite containing 30mm long fibers. But when reach more than 30 wt %, the flexural modulus decreased. At 40 wt %, the flexural strength decreased cited 13 % of value. To explain this, the author pointed that higher fiber loading encouraged fiber-to-fiber interaction and the fiber were not well dispersed within the resin latex. For this research, the best result was obtained at fiber loading of 30 wt %.

In order to take full advantage of the natural agriculture processing by-product, this study will comminute and compound PALF in Polypropylene (PP) matrix, which will then be foamed to enhance light weight properties of the finished polymer foam biocomposites. Generally, this research is conducted to develop PP/PALF foam biocomposites to attain the desired properties for the application in construction (pellets), packaging (example: egg tray, fruits tray) and furniture industry (synthetic wood).

1.2 Problem Statement

The use of plastic foam creates lots of difficulties and problem such as high cost and environmental pollution. Moreover polymer foams difficult to dispose. Thus, the best solution to overcome these problems is to produce partially biodegradable materials such as polymer foam biocomposite. Creating a cellular structure to produce foam thermoplastics and utilizing inexpensive fillers to manufacture thermoplastic composites are two effective ways of addressing the price challenge and improve biodegradability.

The large consumption of thermoplastics continues to draw deep development effort to improve resin manufacturing, which becomes phenomenal support to the foam industry. It is well-known that thermoplastic foams have lot advantages compared to thermoplastic itself. However, the research and development in thermoplastic foam biocomposite is less conducted. Thus, this study emphasis on the extrusion foaming process for PP/PALF foam biocomposite. This project is mainly to evaluate:

i. Is PALF enhance the physical, thermal and morphological properties and reduce weight of the biocomposite?
ii. What is the effect of PALF loading on the biocomposite foam?
iii. Does addition of PALF improved the biodegradability of the biocomposites?

1.3 Objectives of Study

The objectives of this research are to:

i. To study the cell morphology and cell size of the composite by Scanning Electron Microscopy (SEM).
ii. To investigate the effect of filler loading on physical and thermal properties of PP/PALF foam biocomposites.
iii. To investigate the effect of filler loading on the biodegradability.

1.4 Scopes of Research

The scopes of research are:

i. Preparation of short pineapple leaf fiber (PALF)

ii. Extrusion Foaming

iii. Testing to study properties:

- Density
- Water Absorption of Rigid Cellular Plastics (ASTM D2842)
- Resistance of Synthetic Polymer Material to Fungi (ASTM G21)

v. Scanning Electron Microscope (SEM) to study the cell morphology and cell size

iv. Differential Scanning Calorimetry (DSC)

v. Thermogravimetry Analysis (TGA)

This study focuses on the effect of foaming process condition and the properties of PP/PALF foam biocomposite. Foam biocomposites are prepared by using extrusion foaming technique. Materials used are Polypropylene (PP), pineapple leaf fiber (PALF), azodicarbonamide (ADC) and dicumyl peroxide (DCP). The filler loading varies in order to study the effects on foam properties. The foam biocomposite cell structures are characterized by using Scanning Electron Microscope (SEM).

1.5 Significance of Study

Biocomposite based on polypropylene (PP) and natural filler (pineapple leave fiber) use as synthetic wood that can replace the wood in the furniture industries and packaging such as egg and fruit tray in Malaysia. Due the abundance of natural filler (rice husk, rice straw, kenaf, etc.) in Malaysia, biocomposite simply provides the alternative for wood apart from several other benefits such as biodegradability, low density, renewable resources, non-abrasive and low cost due to low material usage. In addition, foaming is introduced to enhance the light weight of material to suit certain industrial needs. The establishment of structure and properties relationship will help manufacturer to predetermine the biocomposite material properties based on the component composition and processing parameter since this relates to the structural and morphological behavior. In brief, this study is important for development of thermoplastics filled foam biocomposite as it will provide lots of advantages in the related industries.

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