CHARACTERIZATION AND BIODEGRADABILITY OF FOAM BASED ON COCONUT FLESH WASTE-FILLED HIGH DENSITY POLYETHYLENE

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ABSTRACT

Polymer foam biocomposites based on HDPE/coconut flesh waste were successfully produced by an extrusion foaming process. The compounding of the HDPE with coconut flesh waste was performed via a twin screw extruder which blends the materials with dicumyl peroxide (DCP) and chemical blowing agent (ADC). Five formulations with varying amount of coconut flesh waste were extruded at setting temperatures of 170˚C at the melting zone whereas temperature of 190˚C was set at the end of the die zone. This research studies the effect of different filler loading, the incorporation of DCP as crosslinking agent and ADC as the blowing agent on morphology (cell structure) of the foam samples. From the optical micrographs of Scanning Electron Microscope (SEM), it was obvious that closed-cell foams were developed. Plus, from the SEM images obtained it can also be concluded that as the filler loading increased, distorted and irregular cell geometry was formed. Density determination by Mettler Toledo Density Meter revealed that density increment was achieved by all foam samples as the filler content increased. From the Differential Scanning Calorimeter (DSC) result, it was noticeable that the percent of crystallinity decreases with increased in filler loading and the melting temperature of the biocomposites were not much affected by the incorporation of coconut waste. Finally, the additions of biodegradable coconut flesh waste into each formulation have significantly improved the biodegradability of these composites.

ABSTRAK

Biokomposit polimer berongga berasaskan hampas isi kelapa diisi polietilena berketumpatan tinggi (HDPE) telah berjaya dihasilkan melalui proses penyemperitan. Proses penyebatian HDPE bersama hampas kelapa (CW) telah dilakukan dengan menggunakan mesin penyemperit skru berkembar. Bahan-bahan in kemudiannya telah juga dicampurkan bersama-sama dengan Dicumyl Perosida (DCP) dan agen perongga kimia (ADC). Lima formulasi dengan jumlah penambahan hampas isi kelapa yang berbeza-beza telah diadunkan bersama-sama dengan DCP dan ADC, menggunakan proses semperitan pada suhu yang telah ditetapkan iaitu 170˚C pada zon leburan dan suhu akhiran 190˚C. Kajian ini dilakukan bertujuan untukmengenalpasti kesan penambahan hampas isi kelapa, DCP dan ADC terhadap struktur sel komposit berongga yang dihasilkan. Dengan menggunakan mikrograf optikal (SEM), adalah jelas bahawa penambahan hampas isi kelapa ke dalam komposit berongga ini telah menyebabkan geometri sel menjadi tidak sekata. Pemerhatian menggunakan SEM juga telah mendedahkan yang struktur sel komposit berongga ini terdiri dari sel-sel tertutup. Dari proses penentuan ketumpatan pula telah menunjukkan berlakunya peningkatan ketumpatan bagi setiap komposit berongga apabila kandungan hampas isi kelapa ditambah. Peningkatan kandungan hampas kelapa juga telah mengurangkan peratusan hablur yang hadir dalam setiap komposit berongga tersebut. Akhir sekali, penambahan hampas isi kelapa juga telah meningkatkan kadar kebolehuraian bagi setiap komposit berongga tersebut.

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LIST OF ABBREVIATIONS

ADC	:	Azodicarbonamide
ASTM	:	American Standard of Testing and Materials
CFA	:	Chemical foaming agent
CO_2	:	Carbon dioxide
CW	:	Coconut waste
DCP	:	Dicumyl peroxide
DSC	:	Differential scanning calorimetry
GCMS	:	Gas chromatography mass spectrum
GF	:	Glass fiber
HDPE	:	High density polyethylene
LDPE	:	Low density polyethylene
LLDPE	:	Linear low density polyethylene
N_2	:	Nitrogen gas
PFA	:	Physical foaming agent
PP	:	Polypropylene
TGA	:	Thermogravimetric analyzer
ZnO	:	Zinc oxide

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Basically speaking, foam is actually a word derives from the medieval German word for “froth” (Lee *et al*., 2007). In other words, foam refers to spherical gases voids dispersed in a dense continuum.

Foams are found virtually everywhere in our modern world and are used in a wide variety of applications such as disposable packaging of fast-food, the cushioning of furniture and as insulation material.

The foaming methodology usually consists of introducing a gaseous phase into a melt, then foaming the gas, and subsequently solidifying the melt before gaseous bubbles condense or collapse back to liquid state. The gas bubbles are generated in spherical shape by virtue of either entrainment or nucleation. Since the spherical form has the lowest surface energy for a given volume, it is the ideal shape for the weak (gaseous) phase to sustain within a dense (liquid or solid) phase. In other words, the gas which is considered to be the weak phase need to counterbalance the summation of both the surrounding pressure and structural force, in order to survive in the form of bubble.

The same foaming methodology also implies to polymeric foam. Polymeric foams are also made up of a solid and gas phase mixed together to form a foam. By combining the two phases too fast for the system to respond in a smooth fashion, foaming will occurs. The resulting foam has a polymer matrix with either air bubbles or air tunnels incorporated in it, which is known as either closed-cell or open-cell structure.

Closed cell foams have a cellular structure in which continuous air bubbles are entrapped within a continuous macromolecular phase. The foam polystyrene coffee cup, for instance, consists entirely of closed foam cells. Open cell foams, on the other hand, have a cellular network in which continuous channels are available throughout the solid macromolecular phase for air to flow through at will. The polyurethane seat cushion is a very good example of open cell foam. Furthermore, closed cell foams are generally rigid, while open cell foams are generally flexible (Klempner and Sendijarevic, 2004).

Most polymeric foams are produced by one of the several known foaming techniques which include, extrusion, compression molding, injection molding, reaction injection molding or solid state method, in which, pressurized gas is forced into a solid polymer at room temperature followed by depressurization and heating to above its glass transition temperature, Tg.

When talking about biodegradable polymers, one cannot escape from relating it to another quite well-known term that is ‘biocomposite’. The birth of biodegradable polymers has enabled the development of biodegradable composites.

Basically, biodegradable polymers are a new generation of polymers made from various natural resources that are environmentally safe and friendly. These polymers offer a wide range of products. It can be made into thin films for making shopping bags, composting bags, mulch film and landfill covers. It can be foamed into biodegradable foam to make packaging foam and biodegradable food service boxes and cups.

Biodegradable foaming and conventional thermoplastic foaming are different in many ways. First, resins from biodegradable foams are based on natural resources while resins from thermoplastic foams are petroleum-based. Biodegradable foams exhibit properties that are water soluble, degradable, and moisture sensitive whereas thermoplastic foams are non-water soluble, non-degradable, and do not exhibit much effect with moisture.

Biodegradable foams offer several advantages over conventional thermoplastic foams. For example, the disposal of biodegradable foam to landfill may accelerate waste degradation decreasing landfill space usage. This is achievable, since, in biodegradable foam less resin is required and the biodegradability properties can be improved through the incorporation of natural filler, such as coconut waste. This is due to the fact that if the useful properties of both materials, polymeric foams and natural filler, are combined, it could actually yield synergism properties. Hence, the development of polymeric foam biocomposites is very crucial in order to solve concerns, such as the extremely high price of resin made from oil and enormous plastics waste in limited landfill.

Currently, the use natural **cellulose-based filler** as possible engineering materials have attracted increasing attention of researchers. This is because natural cellulose-based filler offer advantages, in which it can be recycled in a timely way through biological, thermal, aqueous, photochemical, chemical, and mechanical degradations (Prasad, 1998). In simple terms, nature builds a lignocellulosic (agro-based resources) from carbon dioxide and water and has all the tools to recycle it back to the starting. Due to this reason, it is believe that if a lignocellulosic (in this case, coconut flesh waste) filler and add it into a polymer foam, nature with its arsenal of degrading reactions will starts to reclaim it at its first opportunity. Thus, through this mean, it can actually improve the biodegradability of the polymeric foams. In addition, cellulose-based filler have already proven to yield many desirable properties when utilized as reinforcing agents in polymer composites (Sui *et al*., 2009).

Apart from that, the incorporation of cellulose-based fiber not only improved processability, physical, chemical, and electrical properties of the final compound, but, it also include reduction of cost of the moulding compound, (Katz and Milewski, 1978).

As for the polymeric foams, high density polyethylene (HDPE) promise positive outcome as a foam material. The reason for choosing HDPE as the resin for this polymeric foam biocomposite is due to the fact that polyethylene (PE) is the most widely used plastic throughout the world, and high density PE (HDPE) is the most widely used type of PE. Furthermore, HDPE have been used extensively, particularly for materials handling applications, such as boxes, crates, and pallets. HDPE have been extensively used because of their good mechanical and processing properties (Brydson, 1999). Plus, HDPE are much cheaper than other thermoplastic foams, especially polypropylene (PP) (Harper, 1996).

1.2 Problem Statement

The term biodegradable polymer refers to the susceptibility of a polymer to decomposition by living things or by environmental factors. The potential of biodegradable polymers and more particularly that of polymers obtained from agro resources such as the polysaccharides, for example starch, has long been recognized. For instance, biodegradable polymers could preserve petrol resources replacing some polymers based on fossil resources for some applications, in agreement with the concept of sustainability. Nowadays, however, these polymers, which are largely used in product packaging applications, especially food industry, have not found extensive applications in widespread packaging applications or agriculture, to replace conventional plastic materials.

Currently, cellulose –based filler are attracting more attention of the plastics industry than their counterpart, which are synthetic filler. The term filler refer to solid additives, which are incorporated into the plastic matrix generally to enhance properties or reduce cost (Katz and Milewski, 1978). The advantages of natural filler over synthetic filler are their low cost, low density, acceptable specific strength properties, ease of separation, carbon dioxide sequestration and biodegradability (Nagai, 1995). Looking at the trends nowadays, natural filler are now emerging as a realistic alternative to glass-reinforced plastics. Hence, this research tends to examine the following issues:

i. The effect of various composition of coconut flesh waste (CFW) on thermal properties of HDPE/CFW composite foam.
ii. The morphology of the composite at different loading of coconut flesh waste (CFW).
iii. The effect of different composition of coconut flesh waste (CFW) on water absorption properties of HDPE/CFW composite foam.
iv. The effect of various composition of coconut flesh waste (CFW) on biodegradability properties of HDPE/CFW composite foam.

1.3 Significance of Study

Logically speaking, the reduction on dependent oil-based products can be accomplished through the incorporation of filler into the polymeric product itself. Like mentioned previously, filler especially, natural filler are much more cheap. Thus, since Malaysia possesses abundance source of natural filler, biocomposites simply provide the alternative from the dependent on oil-based products. In fact, the introduction of polymer foam means less resins are required. Hence, in order to take the full advantage of the natural agriculture by-product (in this case coconut flesh waste), this study will comminuted and compounded coconut flesh waste in HDPE matrix, which will then be foamed to enhance the light weight properties of the finished polymer foam biocomposite.

Last but not least, the significances of this study are also to examine the properties of coconut flesh waste as potential cellulose-based filler for HDPE and in the same time investigating the effect of coconut flesh waste loading on the thermal and physical properties of HDPE/CFW foam biocomposite.

1.4 Objectives of Study

The main aim of this study is to characterize the HDPE/CFW foam biocomposite and in the same time investigating the effect of coconut flesh waste loading on the biodegradability of the foam biocomposite developed. A side from that, the following objectives is also to be achieved:

i. To determine the processability of coconut flesh waste loading to be used in the foam biocomposite and characterizing the microstructures using scanning electron microscopy (SEM).

ii. To study the effect of coconut flesh waste loading on thermal properties of the HDPE/CFW foam biocomposite.

iii. To study the effect of various coconut flesh waste loading on water absorption properties of the HDPE/CFW foam biocomposite.

iv. The effect of various composition of coconut flesh waste (CFW) on biodegradability properties of HDPE/CFW composite foam.

1.5 Scope of Study

This study tends to focus on the effect of foaming process condition on the properties of HDPE/CFW foam biocomposite. The HDPE/CFW foam biocomposite were extruded with an extrusion foaming technique. The materials used are high density polyethylene (HDPE), coconut flesh waste (CFW), azodicarbonamide (ADC), and dicumyl peroxide (DCP). The ADC decomposition temperature and loading of crosslinking agent were fixed, whereas loading of CFW was varied in order to study their effect on the formed foam properties.

Plus, the HDPE/CFW foam biocomposite were characterized by using scanning electron microscopy (SEM). Apart from that, density measurements were conducted in order to investigate the differences in density for various formulations.

The effects of various composition of coconut flesh waste (CFW) on biodegradability properties of HDPE/CFW composite foam are also studied. Last but not least, thermal properties and the crystallinity of the HDPE/CFW biocomposites are also analyzed using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA).

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