Biocomposites Based on Oil Palm Tree as Packaging Materials

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Abstract

Every parts of the oil palm tree can be utilized to form useful products, including the waste from palm oil processing either intermediates or final biomasses. Utilization oil palm wastes and palm oil product will be presented for the application in the packaging industry, especially as environmental friendly packaging materials. For the development of these new biodegradable packaging materials, product and waste from oil palm tree are compounded to form biocomposites. Empty fruit bunch, waste that is derived after palm oil extraction process, is grinded and compounded with polyethylene to form biocomposites for blow film process. Palm cooking oil (PCO) is used as processing aids/lubricant in the blown film processing of low density polyethylene with empty fruit bunch fiber (LDPE/EFB) to form biofilm. This oil ease the process ability of LDPE/EFB on the conventional blown film thermoplastic machinery. The higher the composition of the PCO the better will be the processability of LDPE/EFB as the resistance to flow is decreased. With PCO composition greater than 2% the processing parameters of LDPE can be used to process LDPE/PCO/EFB into film. Tensile properties of the biocomposite film are found to be dependent on the PCO composition and comparable to the polyethylene film at low PCO composition. As the composition of PCO in LDPE/EFB is increased the tensile strength and elongation at break of the biofilm is decreased

(Keywords: wastes, packaging, biocomposites, biofilm, EFB,PCO,and PE)

INTRODUCTION

There is a paradigm shift imposed lately by the growing environmental awareness by all to look for packaging films that are biodegradable and compatible with the environment due to the increasing awareness among the public of the disadvantage on using synthetic polymers as packaging films. One technique of producing biodegradable packaging films is by combining natural polymers with synthetic polymers (Ray Smith, 2000).Biodegradable packaging films are packaging films that can be decomposed in the soil. They may act as fertilizer and soil conditioner, facilitating better yield and crops. The characteristic of good packaging film are good oxygen barrier, prevent microbial spoilage during extended storage, good tensile strength and able to maintain structural integrity.

Oil palm empty fruit bunch fiber (OPEFB) is a lignocellulosic biomass contains cellulose, hemicelluloses and lignin (R.Chandra, 1998). The major constituents of the fiber were found to be cellulose. Lignin content is comparatively less (Sreekala et. al, 1997). The use of lignocellulosic as the derived fillers have many advantages compared to inorganic fillers, such as lower density, greater deformability and lower cost per unit volume. In Malaysia the amount of OPEFB waste generated by the palm oil industries is very high, estimated to be approximately 8 millions tones per year. Utilization of OPEFB in packaging industry not only help in solving environmental problems related to the disposal of oil palm fibrous wastes but also help packaging industry to produce environmental friendly biodegradable packaging materials that are much sought after.

Many studies on the packaging film have indicated that, LDPE is the most suitable materials for producing film (J.H. Briston 1974). The effects of crystallinity on properties of LDPE are good relative permeability to gases, high tensile strength, good relative impact strength and high elongation. Thus, the combination of OPEFB as natural polymers with polyethylene will produce semi-biodegradable packaging film that can be easily process on conventional thermoplastic extrusion blown film machine.

Processing of biopolymer fibrous film, through blow film technique is not easy since resistance to flow is increased in the extruder thus the addition of lubricant oil as the additive in the process is vital, unlike the processing of non -biodegradable packaging film. (R.N.Tharanathan , 2003).Vegetable oil plays an important role in PE/starch blends during blown film extrusion process as stated by P. Krishna (P. Krishna, 1998) whereby it plays a dual role, as plasticizer which improves the film quality and as prooxidant to accelerates film degradation. In biopolymer film, if the amount of lubricant is not enough, the resistance to flow is increased in the extruder. Work done by M.L. Fishman et al. showed that glycerol can decrease intermolecular attractions between adjacent polymeric chains thus increasing the film flexibility and flow. Glycerol is a hydrophilic lubricant and is compatible with hydrophilic film forming material. Increasing the amount of glycerol, the values of mechanical properties such as tensile strength was decreased due to the greater mobility exhibited by the polymer chain thus decreased the interactions (M.L. Fishman et al., 2006).

2.0 MATERIALS AND METHODS

2.1 Materials

The matrix used in this study was LDPE commercially named as Titanlane provided by Titan Polyethylene (Malaysia) Bhd. grade 260 for blown film process with MFI of 5.05 g /10 min and density of 0.8498 g / cm^3. The filler used in this study was Oil Palm Empty Fruit Bunch Fiber (OPEFB) provided by Malaysian Palm Oil Bhd (MPOB) with average fiber length of 610 micrometer. Palm based cooking oil (PCO) is obtained from MPOB and used as lubricant in the blown film process. Glycerids and fatty acids are the major compositions of palm based cooking oils.

2.2 Preparation of LDPE/EFB/PCO Composites

Blends of low density polyethylene (LDPE) ,with EFB 5% and PCO at various compositions of 1%, 2%, 5%, 10% were compounded in a twin screw extruder, palletized and later used to form packaging films via conventional blow film processing technique. These films were then used to form specimen for various tests.

2.3 Melt Flow Index (MFI) Determination

Melt flow index (MFI)of various formulations was determined on Extrusion Plastometer according to ASTM D1238-01. A load of 2.16 kg and temperature at 190 °C was used.

2.4 Mechanical Test

The tensile strength, elastic modulus, and elongation at break were determined by using Lloyd Tensile Machine. The film was cut in accordance to ASTM D638 - Type V. The

test was carried out at a crosshead speed of 10 mm / min. At least six samples were tested for each formulation.

2.5 Differential Scanning Calorimetry

Differential Scanning Calorimetry , Perkin Elmer DSC 7, was used to study the thermal properties of the film. The sample weighing in between 4-6 gm was heated from 40.00 °C to 220.00 °C at heating rate of 20.00 °C/min.

3.0 RESULTS AND DISCUSSION

3.1 Oil Palm Waste Biocomposites

3.1.1 Effect of Oil Palm EFB on LDPE

Table 3.1 shows the melt flow index (MFI) of various LDPE/EFB/PCO composites. The addition of oil palm EFB to the LDPE decreased the MFI from 5.05gm/10 min to 4.20 gm/10 min indicative of the increasing flow resistance of the compound. Similar observation is reported by Fishman et al where low MFI result in high resistance to flow in the extruder (M.L. Fishman, 2006). This is demonstrated by the inability of the compound to be blown into film at varying processing parameters as shown in Table 3.2. LDPE/EFB cannot be blown because no bubble expansion occurred during processing. At these respective parameters neat LDPE only can be easily blown. The addition of EFB into LDPE hindered the compound from being blown into film on conventional blown film extruder. However, the LDPE/EFB compound can still be processed into packaging

products via compression molding and thermoforming process. Tensile properties shown in Table 3.3 were done on products form via compression molding.

Table 3.1: MFI value of LDPE/EFB/PCO

Materials	Weight percent (Wt %)	MFI value (g/10mins)
LDPE	100	5. 05 g / 10 min
LDPE/EFB5	95/5	4.2 g / 10 min

Table 3.2: Processing parameters for blown film extrusion process for LDPE/EFB

Processing parameters	Parameters			Blown into film
Die head heater 1	145 °C	150 °C	165 °C	Failed
Die head heater 2	140 °C	145 °C	165 °C	
Bend Heater	140 °C	145 °C	160 °C	
Extruding drum heater 1	110 °C	120 °C	120 °C	
Extruding drum heater 2	120 °C	130 °C	140 °C	
Extruding drum heater 3	130 °C	140 °C	150 °C	
Screw speed	500 rpm	500 rpm	500 rpm	

As illustrated in Table 3.3, tensile properties showed that neat LDPE film has higher tensile properties as compared to LDPE/EFB film. The poor performance especially for the elongation at break is attributed to the poor EFB fiber-LDPE matrix interaction or compatibility, as supported by Rozman et al for OPEFB/ PP composites (Rozman et al, 1998). St. Pierre et al. also reported that thermodynamic incompatibility often leads to

poor performance in natural and synthetic polymer blend (St. Pierre et al., 1997). Whereas the melting temperature of LDPE/EFB is unchanged when compared to LDPE as in Table 3.3, indicative of the degree of crystallization is unchanged.

Table 3.3 Tensile and thermal properties of LDPE and LDPE/EFB compression molded films.

Properties	LDPE	LDPE/EFB
Tensile strength (MPa)	9.30	9.10
Elongation at break (%)	125	45
Tm (^{o}C)	107.51	107.49

3.2 Palm Cooking Oil (PCO) as Processing Aids in LDPE/EFB

3.2.1 Melt Flow Index

Melt flow index of LDPE/PCO/EFB composites is increased as the content of PCO lubricant increases, Table 3.4. The values of the MFI exceeded the LDPE value above 1% PCO content. This indicates that the viscosity of the composite is decreased with the addition of PCO. As the viscosity of the LDPE/PCO/EFB decreases the process ability is expected to be improved.

Table 3.4: Melt Flow Index of LDPE/EFB at various PCO compositions

Material Compositions	Weight %	MFI (g/10 min)
LDPE	100	5.05
LDPE/EFB	95/5	4.20
LDPE/PCO1/EFB	94/1/5	5.61
LDPE/PCO2/EFB	93/2/5	5.79
LDPE/PCO5/EFB	90/5/5	7.56
LDPE/PCO10/EFB	85/10/5	11.10

3.2.2 Extrusion Blown Film Process Ability

The processing parameters for the extrusion blown film process of LDPE/PCO/EFB at 93/2/5, 90/5/5 and 85/10/5 weight percent is as the processing parameters for LDPE blown film grade as illustrated in Table 3.2. However, LDPE/PCO/EFB at 94/1/5 is unable to be processed using the LDPE processing parameters although the MFI is above the value of LDPE. The extruded bubble is not able to expand fully thus proper film is unable to be formed. This is probably due to the poor dispersion of the fiber in the LDPE matrix thus creating poor interaction between the fiber and matrix. As the amount of PCO is increased the extruded bubble is able to expand and film is formed probably due to resistance to flow in the extruder is decreased. This is consistent with the increment in the MFI as PCO composition is increased stating the lowering of the viscosity. The role of PCO as the lubricant influenced the melt rheology since PCO is a hydrophilic lubricant thus will facilitate movement of one polymer chain with regard to another and therefore help to reduce the melt viscosity of the compound. With viscosity reduction, improvement in melt flow behavior occurred from the lubricating effect on the surfaces of the globules that is the internal structure of the melt (M.L Fishman et al, 2006).

3.2.3 Tensile Properties of the Blown Film

Figures 3.1 and 3.2 illustrate the variation in tensile strength and elongation at break respectively of LDPE/PCO/EFB biofilm composites.

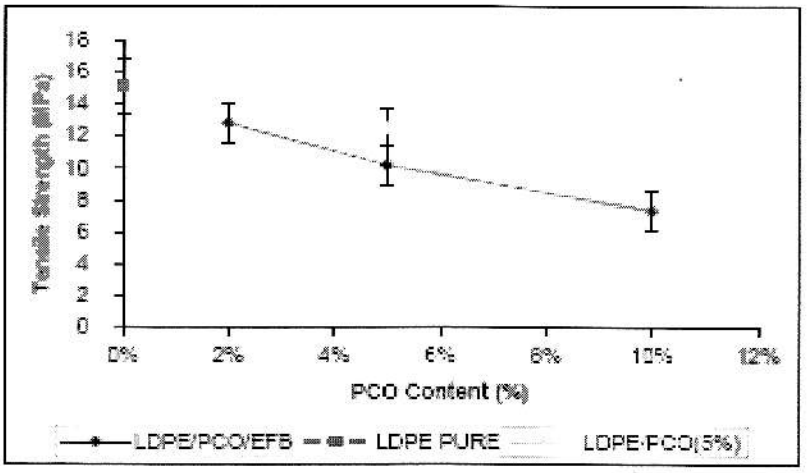

Figure 3.1: Tensile strength at various PCO % compositions.

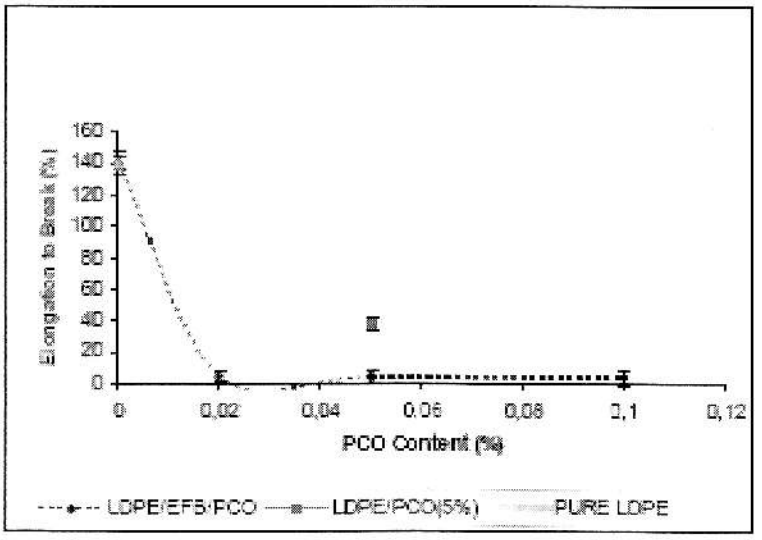

Figure 3.2: Percent elongation at break at various PCO % compositions.

Variations of tensile strength and elongation at break of LDPE/PCO/EFB biofilm composites are shown in the Figures 3.1 and 3.2 respectively. Tensile strength and elongation at break of LDPE/PCO/EFB decrease as the lubricant content is increased. This is due to the role of lubricant which decreases the intermolecular forces between

polymer chains and reduces the tensile strength as reported by Domininck V. et al. (Domininck V, *et al*, 2004). The lubricant also behaves as internal lubricator which helps to lubricate the polymer chains to slide past one another, subsequently reduces the tensile strength (John *et. al* ,2001). It appears that decreasing trend of the tensile strength with lubricant loading also due to the irregular – shaped of EFB fillers, resulting in poor capability to support stress transmitted from the thermoplastic matrix (Mohd. Ishak *et al*., 1998). However, EFB itself helps to reduce tensile strength and elongation to break because during processing EFB did not melt thus retained their shape as rigid filler. If filler distribution is not achieved, less interfacial region is expected to be formed between EFB and the LDPE matrix. Similar to tensile strength, decrement of elongation at break occurred because of some molecular orientation taking place during the blown film process due to the high loading of lubricant (M.L.Fishman *et al*, 2006). Lubricant significantly assists the internal rotation of a polymer chain under strain.

3.2.4 Differential Scanning Calorimeter (DSC)

The melting temperatures (Tm) of different formulations are summarized in Table 3.5. Generally, the *Tm* of LDPE/PCO/EFB decreased with the addition of PCO lubricant. The reduction in melting temperature was due to the improved interaction between EFB and LDPE matrix due to the presence of lubricant (Mohd. Ishak .*et al*,1998). The added PCO lubricant acts as plasticizer in the blend system, thus making the LDPE chain becoming more flexible, easy to move and rotate. This flexibility tends to disrupt the closed arrangement of the LDPE chain in the system thus the crystallinity is disrupted causing reduction in the degree of crystallinity which affects Tm. This chain flexibility effect can

be clearly seen in the reduction of LDPE melt temperature Tm when PCO is added to neat LDPE. As expected, the reduction is insignificant when EFB only is incorporated in the LDPE, consistent to the inability of the EFB to interact with LDPE thus the degree of crystallinity in the LDPE is not disrupted. Therefore, adding EFB to LDPE/PCO system lead to PCO to interact with EFB thus reduced its plasticizing effect on LDPE thus increasing the Tm of LDPE/PCO/EFB, consistent with the obtained results.

Table 3.5 The melting temperature of the blends

Sample	Tm °c
LDPE PURE	107.51
LDPE/PCO(5%)	105.33
LDPE/EFB/PCO (0%)	107.49
LDPE/EFB/PCO (1%)	107.40
LDPE/EFB/PCO (2%)	106.85
LDPE/EFB/PCO (5%)	105.83
LDPE/EFB/PCO (10%)	104.83

4.0 CONCLUSIONS

LDPE/EFB blends at EFB of 5% can be compression molded into packaging products but cannot be blown into film via the conventional extrusion blow film machine. The addition of PCO above 2% improved the blown film process ability enabling the LDPE/PCO/EFB at 5% EFB component to be blown into film on the conventional extrusion blown film machine. PCO had sufficiently high melt strength and extensibility to form good bubble during the film blowing process. The resistance to flow in the extruder of LDPE/EFB is reduced in the presence of PCO lubricant as proved by the lowering in the MFI of the compound. Above 2% PCO, LDPE/EFB can be blown into

film using the neat LDPE processing parameters. Lubricant imparts an adverse effect upon the tensile strength and elongation at break. The melting temperatures of the LDPE/EFB are decreased upon addition of lubricant.

4.0 ACKNOWLEDGEMENTS

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