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Effect of Banana Peel Fiber as Reinforcement in Low Density Polyethylene/Durian Seed Starch Blends

Norshahida SARIFUDDIN[a*], Mohammad Anuar Zaki SHAARI[b], Nur' Aishah AHMAD SHAHRIM[c], Ahmad Zahirani AHMAD AZHAR[d] and Hafizah Hanim MOHD ZAKI[e]

Department of Manufacturing and Materials Engineering, Kulliyyah of Engineering, International Islamic University Malaysia (IIUM), P.O. Box 10, 50728 Kuala Lumpur, Malaysia.

[a] norshahida@iium.edu.my, [b] anuarzakishaari@gmail.com, [c]aisydahlia@gmail.com, [d]zahirani@iium.edu.my, [e]hafizahhanim@iium.edu.my

ABSTRACT. The effects of banana peel fiber (BPF) as reinforcement in low density polyethylene (LDPE)/durian seed starch (DSS) blends were studied. The LDPE/TPS ratio was fixed at 90/10 wt.% and reinforced with different content of BPF (from 0 to 40 wt.%). These mixtures were melt compounded using internal mixer and compression molded using hot press machine. After that, the mechanical behavior, physical properties and biodegradation rate of the obtained molded sheets were investigated. From the analysis, the optimum blend ratio of LDPE/TPS is achieved at 10 wt.% BPF with maximum tensile strength of 6.058 MPa. This has been evidenced by scanning electron microscope (SEM), in which the fibers are seem to be embedded within the matrix, thus indicating strong interfacial adhesion between fiber and matrix. In fact, the compatibility between LDPE/TPS blends and BPF has been proved by the formation of hydrogen bond in FTIR results. Furthermore, the samples have also demonstrating biodegradability whereby some surface discoloration and erosion can be clearly seen after being buried in soil for 14 days.

Keywords: *Thermoplastic starch, Banana peel fiber, Low density polyethylene;*

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1. INTRODUCTION

Low Density Polyethylene (LDPE) is one of the common polymers that has been used for many applications such as toys, food packaging, etc. Disposal of used plastic products made from petroleum has become a public concern due to their non-degradability and their potentially hazardous to the environment. One of the solution for non-degradable plastic is to fill the polymer with biodegradable materials such as starch. Starch can be extracted from various botanical sources and it is renewable, abundant and inexpensive natural biopolymer. There are few types botanical sources can be used as starch such as banana and sago. However, it seems that the utilization of durian seed as a source of starch is rarely reported. Durian seed contains 50 - 70% carbohydrate and 20.8% amylose [1] which can be considered high since in general amylose make up 20% of the granule and amylopectin, the remainder. Thus, this study is focused on the utilization of durian seed as a source of starch. By adding starch into synthetic plastic, biodegradable plastic can be achieved.

Normally, interfacial adhesion between LDPE and starch is poor because LDPE is hydrophobic meanwhile starch is hydrophilic and it can reduce the mechanical properties and increase water absorption [2]. One of the possible solution to improve the properties is to add natural fiber in LDPE and durian seed starch blends. Natural fibers as reinforcement for polymeric matrices have been studied during decades due to many

advantages presented by these fibers are abundance and therefore low cost, biodegradability, flexibility during processing, low density, relatively high tensile and flexural modulus and non-toxic. The studies from Naidu et al. [3] did show that, by loading banana peel into polymer matrix composites did increase tensile strength. By adding banana peel fiber into the composites, it is expected that, the eco-friendly and better properties of biodegradable composite can be developed. Thus, this study exploring the effect of banana peel fiber as reinforcement for LDPE/durian seed starch blend.

2. MATERIALS AND METHODS

2.1 Preparation of LDPE/TPS reinforced BPF composite sheet. The seeds for starch were sliced into small pieces (2-2.5 mm). After that, the seeds were put into an oven for 24 hours at 60 °C followed by grinding the seeds by using a grinder and sieved to size of 100 µm. 5 g of durian seeds flour were added into 100 ml of distilled water and soaked and stirred constantly between 6 hours to 8 hours at room temperature. After that, the slurry was filtered and precipitated overnight at 4 °C. Next starch cake was dried for 24 hours in the oven at 40 °C. Finally, the starch was sieved. DSS powder needs was vacuum dried by heating at 80 °C for 24 hours before processing and blending. The chemical composition of DSS is referred [4]. The DSS were then pre-mixed with glycerol by weight ratio of 65:35 using a speed mixer to obtain thermoplastic starch (TPS).

The banana peels were washed by using tap water and were soaked in a solution of 5% citric acid for 10 min. After that, banana peel fiber (BPF) was dried in the oven at 60 °C overnight. The dried peels were ground in the grinder and then sieved to size of 50 µm.

The LDPE/TPS blend (90/10 wt.%) and LDPE/TPS blend with BPF (0 to 40 wt.%) were then melt compounded using internal mixer (Haake Polylab System Thermo Scientific) and press molded using hot press machine (XH-406B). For all compositions, the internal mixer was performed at 50 rpm and 150 °C for 20 min and then compression molded in the electrical heated hydraulic press at 150 °C for 6 min to obtain moulded sheet (150 mm × 150 mm × 1 mm). The materials' abbreviations and corresponding sample compositions are listed in Table 1.

Table 1 The ratio of low density polyethylene, thermoplastic starch and banana peel fiber

Samples	Composition (wt.%)			
	LDPE	TPS	LDPE/TPS	BPF
LDPE	100	-	-	-
LDPE/TPS	90	10	-	-
LDPE/TPS + 10 wt.% BPF	-	-	90	10
LDPE/TPS + 20 wt.% BPF	-	-	80	20
LDPE/TPS + 30 wt.% BPF	-	-	70	30
LDPE/TPS + 40 wt.% BPF	-	-	60	40

Tensile Test. Dumbell specimens of 1 mm thickness were cut from the compression molded sheet. The tensile test was done by following the ASTM D638 standard by using Shimadzu AGS-X universal testing machine. The load used was 5 kN and the test speed is 5 mm/min.

2.2 Scanning electron microscope (SEM) test. The morphology studies were carried out by using scanning electron microscope (JSM 5600). The samples were sputter coated with carbon (Polaron SC515), then taken for microscope images at 5kV.

2.3 Fourier-Transform Infrared Spectrometry (FTIR) Test. In order to classify and observe the functional groups on the sample, Fourier Transform Infrared (FTIR) Spectroscopy (Perkin Elmer System spectrum 100; PerkinElmer, United States) was used with a resolution of 4 cm^{-1} in a spectral range of 4000-600 cm^{-1} using 32 scans per sample.

2.4 Soil Burial Test. Degradation behavior of all compositions carried out by soil burial test using procedures mentioned by Azahari et al. [5] with slight modification. The films measuring 20 mm x 20 mm were cut and weighed. Then, the samples of each composition were buried at depth of 50 mm in different pots filled with composted soil. The samples buried in pots and exposed to natural weather. The physical appearance of samples before and after soil burial test were observed.

3. RESULTS AND DISCUSSION

3.1 Tensile Properties. Tensile strength and elongation at break of LDPE/TPS blends with different BPF content are shown Fig. 1. It was found that by adding BPF into the LDPE/TPS as reinforcement at 10 wt.%, it did increase the tensile strength of the blend up to 6.058 MPa compared to LDPE/TPS which was 5.340 MPa. The increased TS could be attributed to the strong interfacial adhesion of the matrix with the fiber since the hydrophilic character of the system increases as BPF was added to the blend [6]. Thus, the stress transfers well from the matrix to the reinforcement. However, further addition of BPF resulted in gradual decrease of TS. This might be due to the excessiveness of BPF that caused the discontinuity of the matrix due to the phase incompatibility between hydrophilic BPF and non-polar hydrophobic LDPE [7]. This caused stress transfers to the fiber with reduction in stress concentration area as BPF tend to agglomerate and weak interfacial adhesion. The results obtained are supported by surface fracture observed under SEM. The elongation decreased as the fiber loading increased as agreement with Norshahida et al. [7]. This is because the crystallinity of fiber resulted in a decrement the polymer chain mobility and a deformability of a rigid interface between the matrix and fiber which resulted decreased the ductility of LDPE and by adding TPS into the blend, the combination of immiscible phase in LDPE matrix decreased the elongation at break.

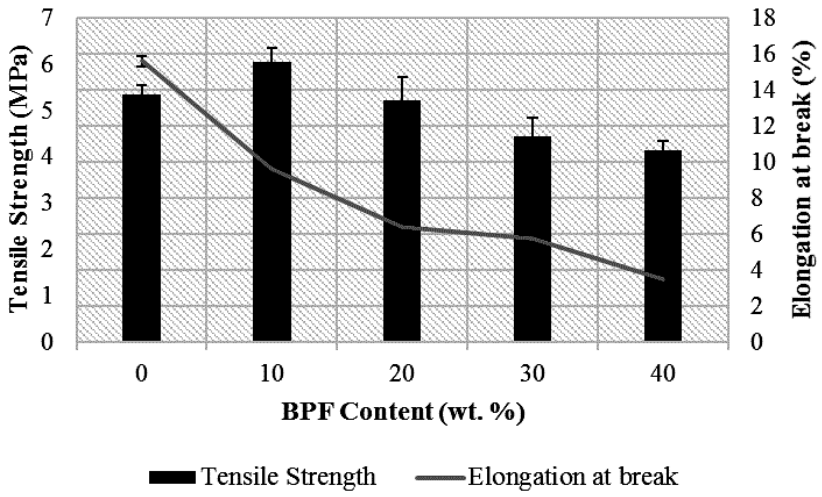


Fig. 1 Effect of banana peel fiber content on the tensile strength and elongation at break of LDPE/DSS blends

3.2 Morphological Study of Tensile Fracture Surfaces. Fig. 2 shows the tensile fracture surface of LDPE, LDPE/TPS and LDPE/TPS/BPF (magnification of 350x). Based on Fig. 2(a), the surface of tensile fracture of LDPE and Fig. 2(b) shows the surface fracture of LDPE/TPS blend with 10 wt.% of TPS. It shows that the TPS was embedded in LDPE resulted the rough surface compared with LDPE morphology. The reason for surface roughness of LDPE/TPS is incompatibility between hydrophobic LDPE and hydrophilic TPS which caused a weak interfacial adhesion [6]. In Fig. 2 (c), fiber agglomeration is detected on the surface and the immiscibility of the two components caused the TS significantly decreased. Fig. 2(d) shows the surface of tensile fracture of LDPE/TPS/BPF blend with 10 wt.% of BPF. It can be observed that the fiber is embedded and well dispersed in the matrix, thus improved the TS of LDPE/TPS blend.

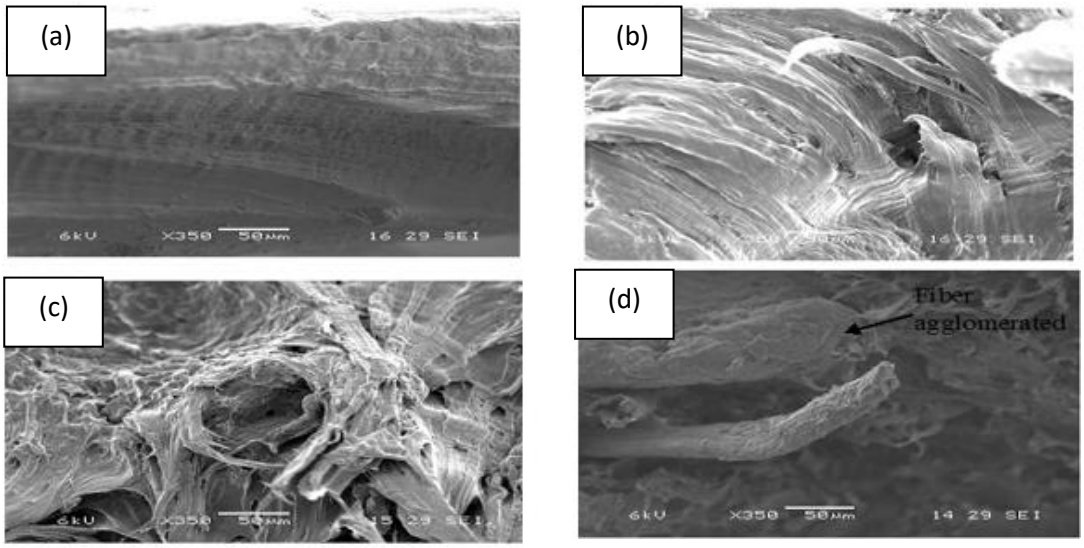


Fig. 2 SEM micrographs of (a) LDPE, (b) LDPE/TPS, (c) LDPE/TPS/10 wt.% BPF and (d) LDPE/TPS/40 wt.% BPF

3.3 Fourier Transform Infrared (FTIR) Analysis. Fig. 3 shows the IR spectra of the composites, whereby there are three significant peaks at 2915 cm^{-1}, 1463 cm^{-1} , 717 cm^{-1} which indicated C-H stretching, -CH_3 bending and -CH_2- vibration, respectively. It showed the functional group of primary matrix, LDPE which is similar to a study done by Norshahida et al. [7]. Next, as shown in Fig. 3(b-c), the peaks observed at 1000 cm^{-1} - 1263 cm^{-1} attributed to C-O-C bond stretching and peak at 1032 cm^{-1} represent anhydroglucose ring O-C stretch [7]. The peaks appeared when TPS firstly added in the composition, as the TPS added, the peaks shifted and it become sharper indicated additional of C-O functional group which related to amylopectin and and amylose of TPS. Other prominent peaks observerd at 3370 cm^{-1} - 3385 cm^{-1} which showed the present of O-H group. The peaks visibled started at Fig. 3(b-c). The change of peaks shape and position due to intermocular of hydrogen bond between TPS and BPF. The greater the compatibility of polymer composite, the greater would be the peak shape and shift.

3.4 Soil Burial Test. Fig. 4 shows the physical appearance of composite samples before and after exposure to soil burial test. The samples undergo 14 days buried in the soils and the samples experienced controlled environment which the soils were kept in the lab but exposed to sunlight and water.

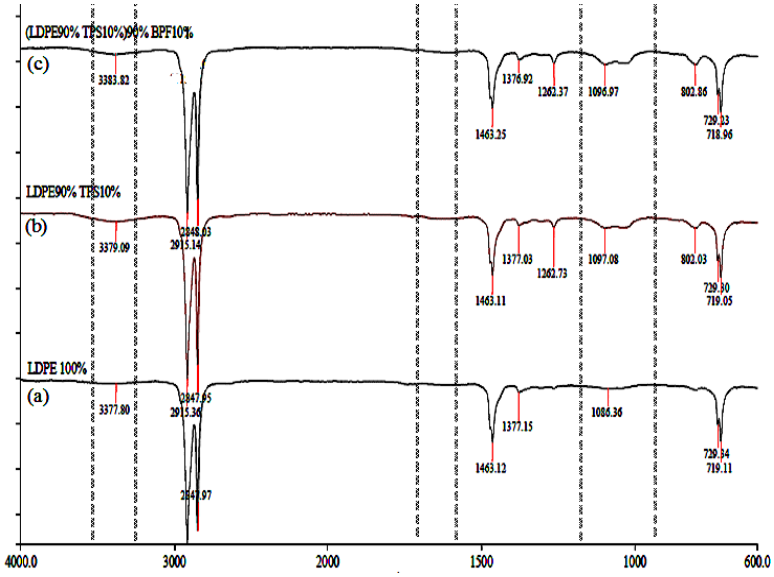
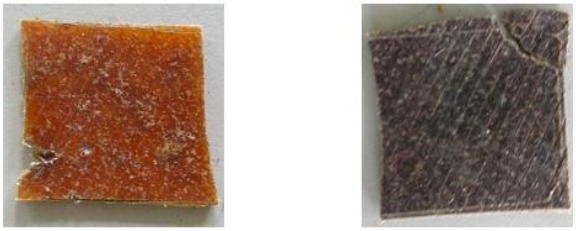


Fig. 3 FTIR spectra of the composites of (a) LDPE, (b) LDPE/TPS and (c) LDPE/TPS/10 wt.% BPF

The weight loss and the observation on samples surface conditions were used to evaluate the biodegradability of the samples. Firstly, for LDPE/TPS blend compositions, it can be seen that as the TPS incorporated into LDPE, the biodegradability rate also increased. Fig. 4(a) showed the surface of sample after 14 days buried in soils where it shows surface discoloration and erosion indication of initial biodegradation of samples. Fig. 4(b) whereas showing a crack and surface erosion on the surface of the sample. It is believed that the fiber absorbed the moisture during exposure and accelerate the biodegradation process.



(a) (b)

Fig. 4 The appearance of (a) LDPE/TPS and (b) LDPE/TPS/10 wt.% BPF samples after subjected to soil burial test

4. SUMMARY

The addition of 10 wt.% BPF to the LDPE/TPS blend was found to increase the tensile strength. The increment in tensile properties have been proved by the compatibility between LDPE/TPS blends and BPF shown in SEM morphology.

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