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PROCESSIBILITY OF WASTE TO WEALTH GREEN POLYMER WITH POLYETHYLENE BY INJECTION MOULDING

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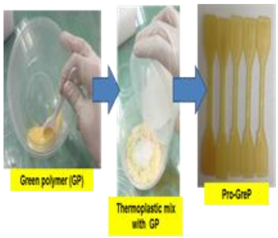
Graphical abstract



Abstract

Green polymer from waste cooking oils is successfully converted into high functionality of hydroxylated green monomer. The green monomer was used crosslinker and known as Green Polymer. Green Polymer is compounded with High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE). These wastes to wealth green polymer are successfully compounded with HDPE and LDPE by melt-mixing used an injection molding machine known as Pro-GreP. The effect of different ratio of compounding materials on the mechanical properties of Pro-GreP was studied by tensile test. Morphological of surface fracture with magnification 100x on Pro-GreP is revealed the homogenous characteristic with high compatibility properties. Finally, the presence of biopolymer provide biodegradable properties, but it also improves the mechanical properties. It can be showed that the tensile strength and tensile strain is decreased than the neat thermoplastic and they were found to decreased with the increasing of biopolymer compounds. However, LDPE are lower in tensile strength and tensile strain than HDPE.

Keywords: Polyethylene, biopolymer, green polymer

Abstrak

Polimer hijau daripada sisa minyak masak berjaya ditukar kepada fungsi tinggi monomer hijau hydroxylated. Monomer hijau telah digunakan crosslinker dan dikenali sebagai Polimer Hijau. Polimer Hijau ini disadurkan lagi dengan polietilena berketumpatan tinggi (HDPE) dan polietilena berketumpatan rendah (LDPE). Ini sisa kepada kekayaan polimer hijau berjaya membuat penyelesaian dengan HDPE dan LDPE oleh cair pencampuran menggunakan sebuah mesin pengacuan suntikan dikenali sebagai Pro-grep. Kesan nisbah jenis bahan pengkompaunan pada sifat-sifat mekanik Pro-grep telah dikaji dengan ujian tegangan. Morfologi permukaan patah dengan pembesaran 100x pada Pro-grep diturunkan ciri bangsa yang sama dengan ciri-ciri keserasian yang tinggi. Akhir sekali, kehadiran biopolimer menyediakan ciri-ciri mesra alam, tetapi ia juga meningkatkan sifat mekanik. Ia boleh menunjukkan bahawa kekuatan tegangan dan terikan tegangan dikurangkan daripada termoplastik yang kemas dan mereka didapati menurun dengan peningkatan sebatian biopolimer. Walau bagaimanapun, LDPE adalah lebih rendah dalam kekuatan tegangan dan terikan tegangan daripada HDPE.

Kata Kunci: Polietilena, biopolymer, polimer hijau

1.0 INTRODUCTION

Polymer is a long and large material that plays an essential and important molecule in everyday life. Polymer can be divide into two properties that is synthetic and natural polymer created via polymerization of many monomers. Polymer in form of plastic make most of the product that we use in our daily life such as knobs, containers, jugs, pipes and so on. Nowadays, most of consuming industries only take polymer that synthesized from petroleum sources or natural gas raw materials such as polyethylene, polypropylene, polystyrene and polyvinyl chloride. However, this type of polymer generally bring disadvantages and harmful because it not environmental friendly due to not undergo the process of biodegradation and dependent on a limited petroleum gas.[1-4]

Biodegradable polymer needed to develop to bring an ecosystem to our daily life. Biodegradable polymer is a material that can easily breakdown due to its ability to undergo degradation within the biosphere on coming into contact with micro-organism, enzymes or under natural environment conditions. Therefore, in this study, biopolymer and thermoplastic will be used to study the influence of synthetic polymer based on depent composition ratio in the polymer composite.[3-7].Thermoplastic are widely used in wide world and is made from petroleum. Polyethylene it was usually used to made milk jugs, plastic bags and refillable plastic bottles.

2.0 EXPERIMENTAL

A few techniques were used to produce specimen based on biopolymer thermoset with thermoplastic HDPE and LDPE as shown in figures 1. Liquid biopolymer thermoset with HDPE and LDPE thermoplastic was mixed together manually until thermoset biopolymer solidified. The proportion of biopolymer thermoset with HDPE and LDPE was start by mixed the thermoplastic HDPE and LDPE with 1%, bioplolymer (wt/wt ratio). The percentages were increased to 1.5%, 2%, 2.5% and 3% respectively. Thermoplastic/Biopolymer was then fed to the injection molding machine (Nissei Horizontal Screw Type Injection Molding NP7 Real Mini from Japan). The mold was designed according to ISO 527 (5A) to produce tensile test specimens. The injection molding machine was available in the Polymer and Ceramic Laboratory, UTHM. Injection molding Nissei Horizontal Screw Type Injection Molding NP7 Real Mini from Japan was used to fabricate polymer composite HDPE and LDPE with 1% biopolymer (wt/wt ratio). Then, the percent of biopolymer will be increased to 1.5%, 2%, 2.5% and 3% respectively. Table 1 contains the main parameters of the injection molding process. The quality of the resulting test bars was adjusted at changing ratio contents.

The tensile test samples were prepared according to ISO 527-2 (5A). The testing are consists of five samples. Universal Tensile Machine AG-I, Shimadzu, 10 kN types with 5 mm/min crosshead speed were used for this testing. A scanning electron microscope (SEM) was used to obtain the image of the surface fracture in different ratio of the samples. SEM of each image was taken at magnification 100x.

3.0 RESULTS AND DISCUSSION

3.1 LDPE Mechanical Properties And Morphology

Table 2 shows tensile test experimental data for all LDPE/biopolymer compounds developed in this work. It can be observed in Fig.1 the mechanical behaviour of LDPE/biopolymer compounds, whose data were plotted according to the numbers given by Table 2. Figures 4 presented the surface of fracture of LDPE/biopolymer compounds.

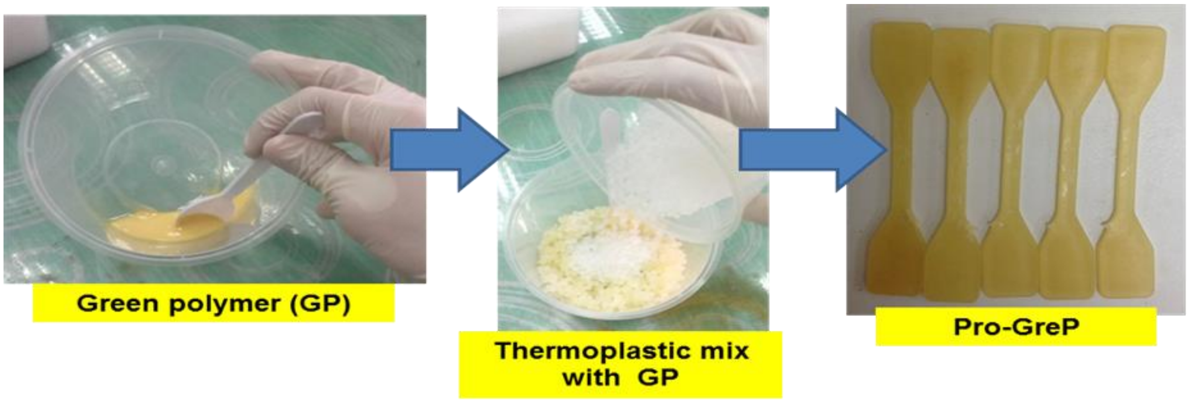
Tensile strength measurements indicated that the more the biopolymer content in the sample increase, the more the mechanical properties values decreased. Analyzing the values for strain, it was noticed that the reduction of biopolymer content gave declined values of mechanical properties, so the point correspondent to pure LDPE sample was eliminated of the scale to allow a better visualization. Only the compounds with 1.0 wt.% biopolymer showed higher values for tensile strength, if compared with pure LDPE. This is probably due to the poor matrix/load interface with low interface with low compatibility and also LDPE crystallinity reduction [2,4-6]. The strength decrease when percentage ration of BP increase, it is may be caused by it belong to the alkyl groups attached to each carbon atom in the linear molecular chain BP and cause strength decrease [7]. The strain decreased with the BP content could be attributed to the phenomenon the BP granule containing hydroxyl group on its surface, whereas LDPE is nonpolar. Furthermore, the presence of moisture by the BP at the LPDE/BP interface weakens the weak interfacial adhesion. Therefore, the BP granules do not elongate along with the LDPE and thus give rise to easy crack generation eventually resulting in fracture of specimen.

3.2 HDPE Mechanical Properties And Morphology

Result for mechanical properties of HDPE/biopolymer compunds are shown in Table 3. Fig. 2 represents tensile test measurements to all compounds of HDPE/biopolymer studied. HDPE/biopolymer presents lower average values for tensile strength and tensile strain compared to pure high density polyethylene. The HDPE matrix provides ductility that exhibit brittle behaviour with a subsequent loss of toughness to the compounding materials. On the other hand, it was noticed that the values of tensile strain was abrupt increased in compounds 2.0 w.t% biopolymer.[1-2,8-9] This can be confirmed by the fracture surface analysis as can be observed Figure 4. The HDPE provides ductility that exhibit brittle behaviour with a subsequent loss of toughness to the compounding materials [10]. The addition of biopolymer generally increases the toughness and decreases the strength of the compound. This could be due to the soft properties of the biopolymer. Tensile strength measurements indicated that the mechanical property values decreases with increasing biopolymer content in the sample which used the crosslinker. The general increment of tensile strain may be referring to the plasticization effect which explains a change in the thermal and mechanical properties of a given polymer by the lowering of rigidity at room temperature. In the other hand, polymer chains which possess a regular structure are able to crystallize under suitable conditions, either from the melt, or from solution. This means, the chain molecules change from a coiled and disordered state to a tightly folded, aligned, and ordered state.

Table 1 The main injection moulding parameters used.

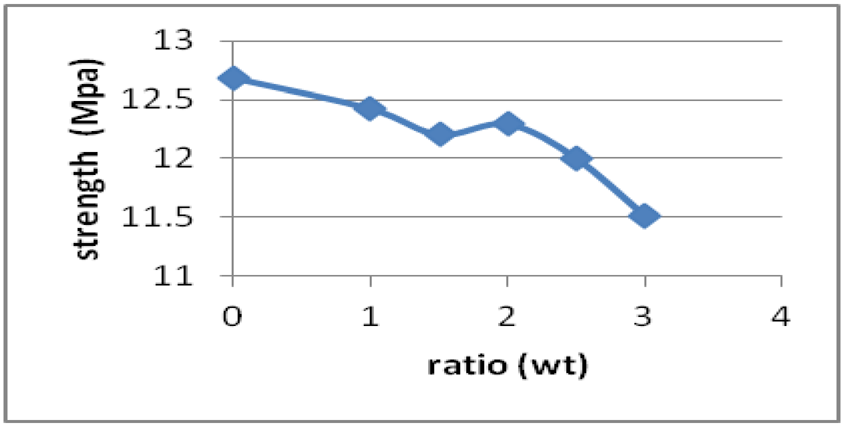
Parameters	LDPE	HDPE
Zone 1	165 ^{0}C	165 ^{0}C
Zone 2	170 ^{0}C	175 ^{0}C
Zone 3	175 ^{0}C	180 ^{0}C
Zone 4	180 ^{0}C	195 ^{0}C
Nozzle	185 ^{0}C	205 ^{0}C
Injection Pressure	48.3 MPa	96.6 MPa



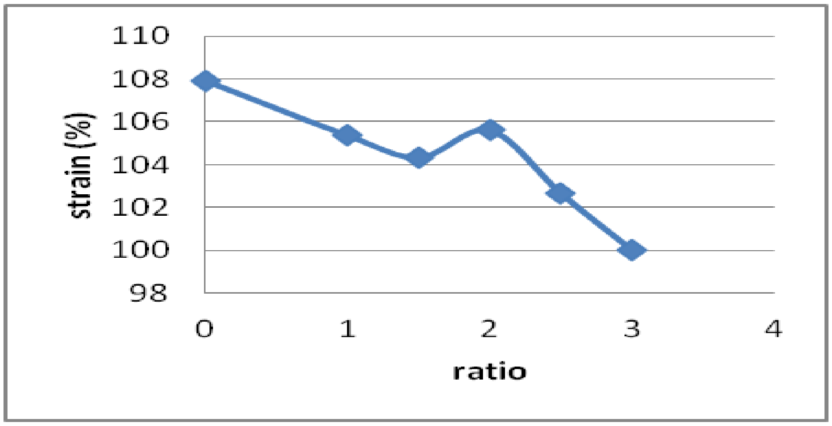
Figures 1 The processing of Pro-GreP.

Table 2 Tensile test for LDPE/biopolymer compounds

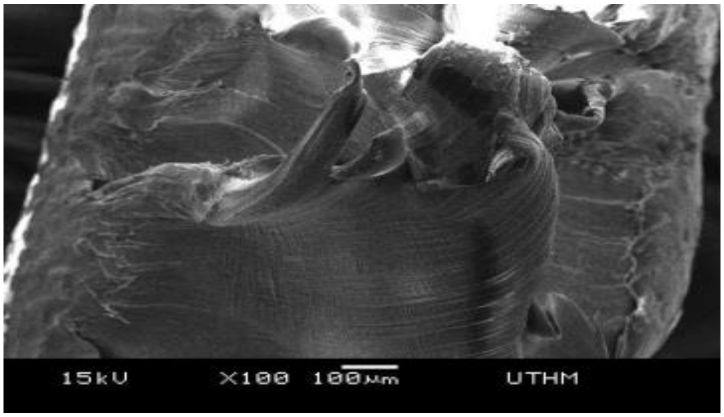
Sample	Tensile strength (MPa)	Tensile Strain (%)
Pure LDPE	12.68	107.92
LDPE + 1.0 wt.% biopolymer	12.42	105.36
LDPE + 1.5 wt.% biopolymer	12.20	104.34
LDPE + 2.0 wt.% biopolymer	12.29	105.61
LDPE + 2.5 wt.% biopolymer	12.00	102.66
LDPE + 3.0 wt.% biopolymer	11.51	100.01



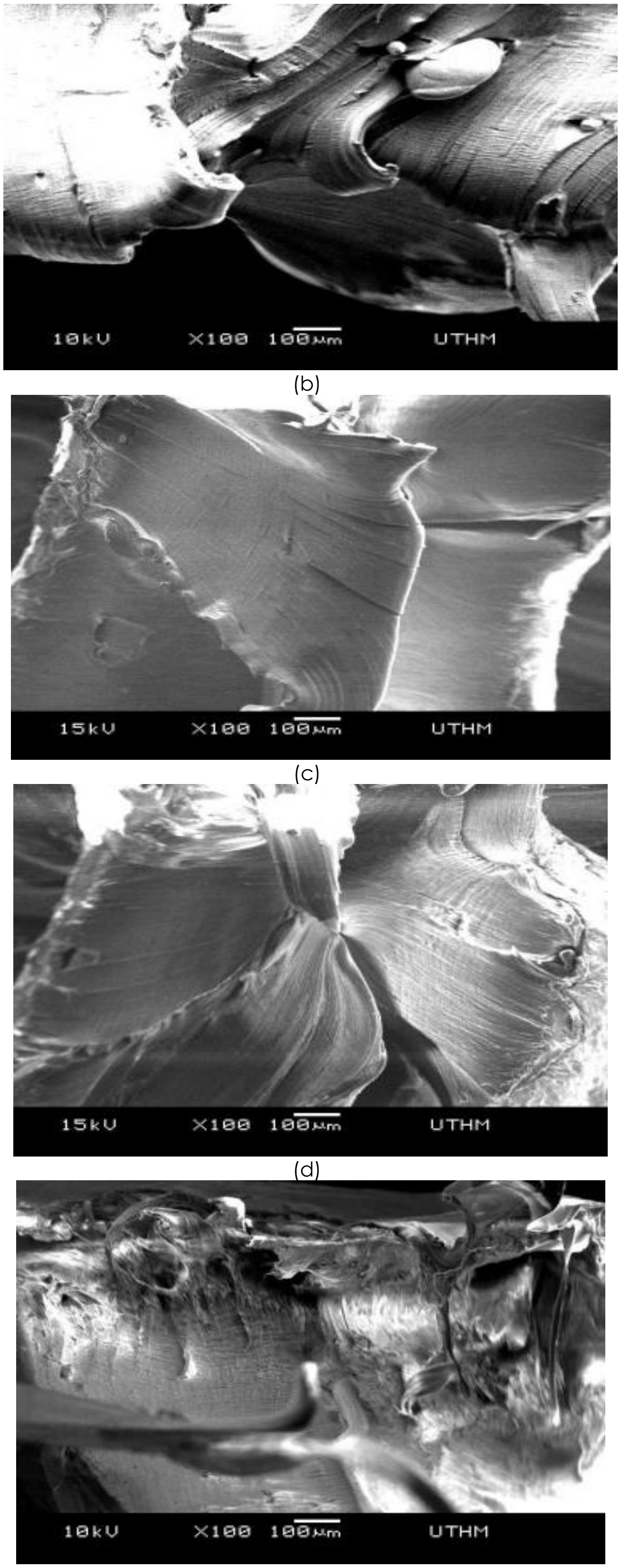
Figures 2 Average for tensile strength of LDPE/biopolymer compounds



Figures 3 Average for tensile strain of LDPE/biopolymer compounds



(a)



(b)

(c)

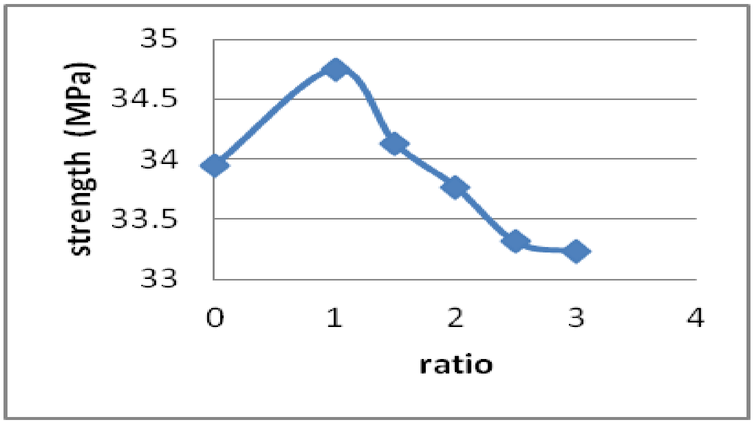
(d)

(e)

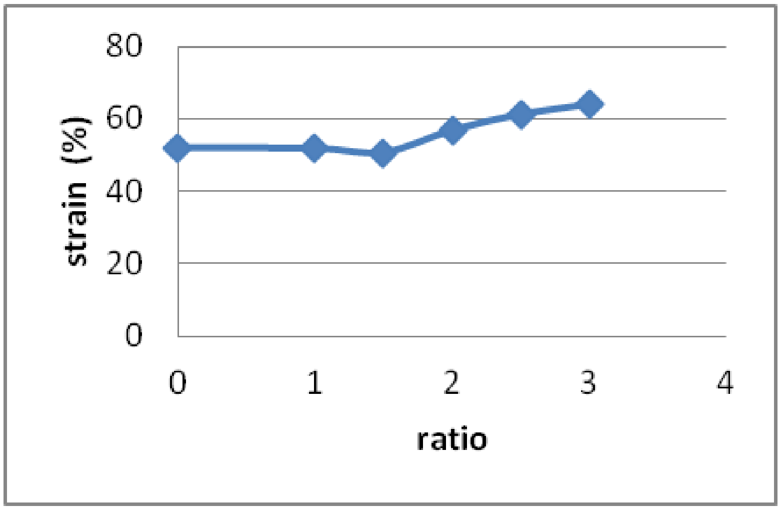
Figure 4 Scanning electron microsopy of fractured surface of LDPE/biopolymer compounds; (a)1.0wt% biopolymer; (b)1.5 wt% biopolymer; (c)2.0wt% biopolymer; (d)2.5wt% biopolymer; (e)3.0wt% biopolymer.

Table 3 Tensile test for HDPE/biopolymer compounds.

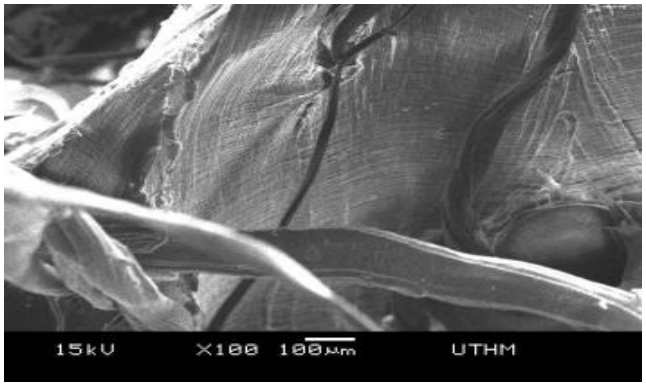
Sample	Tensile strength (MPa)	Tensile Strain (%)
Pure HDPE	33.97	51.99
HDPE + 1.0 wt.% biopolymer	34.75	51.79
HDPE + 1.5 wt.% biopolymer	34.13	50.68
HDPE + 2.0 wt.% biopolymer	33.77	56.87
HDPE + 2.5 wt.% biopolymer	33.31	61.27
HDPE + 3.0 wt.% biopolymer	33.23	64.05



Figures 5 Average for tensile strength of HDPE/biopolymer compounds.



Figures 6 Average for tensile strain of HDPE/biopolymer compounds.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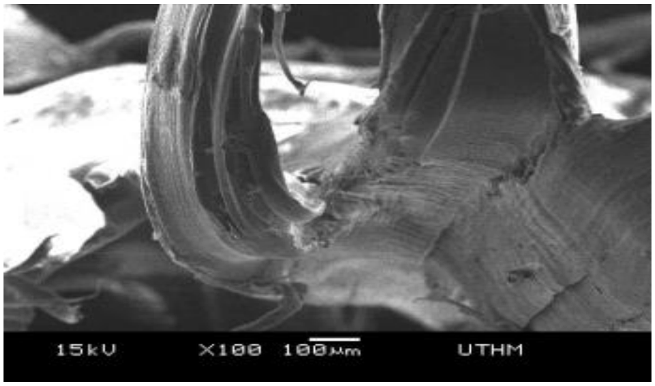
(a)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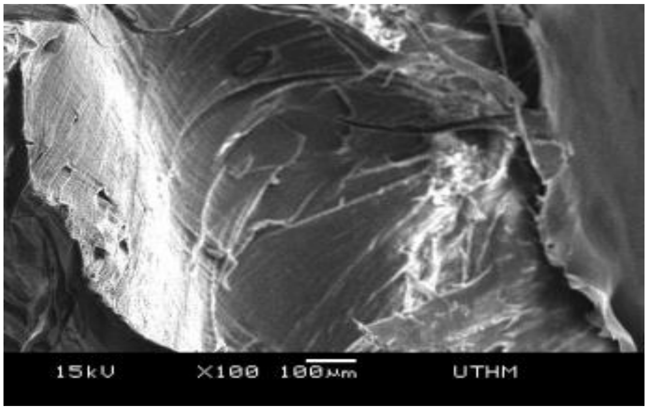
(b)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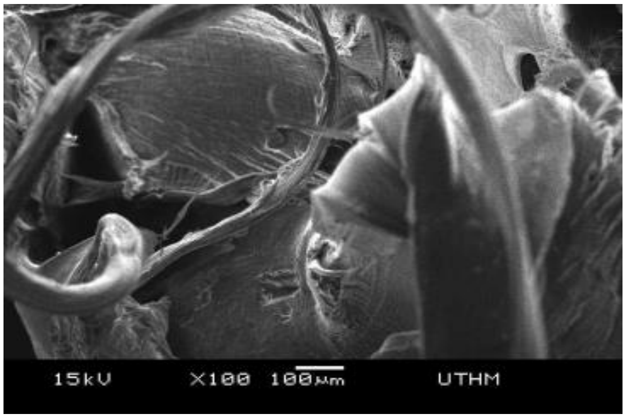
(c)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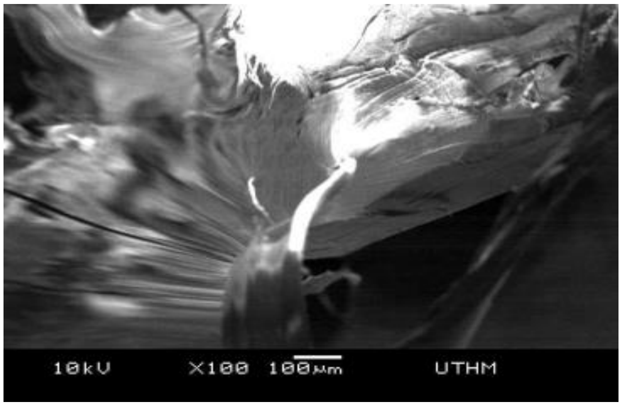
(d)



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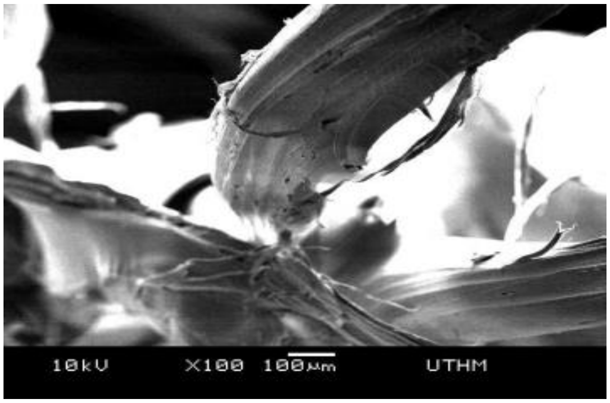

(f)

Figures 7 Scanning electron microsopy of fractured surface of HDPE/biopolymer compounds; (a)pure HDPE;(b)1.0wt% biopolymer; (c)1.5 wt% biopolymer; (d)2.0wt% biopolymer; (e)2.5wt% biopolymer; (f)3.0wt% biopolymer

4.0 CONCLUSION

Melt-mixing was done to initially produce each ratio of the samples. Then by used the injection molding process, new compounding polymers based on different ratio of biopolymer to thermoplastic (HDPE&LDPE) were successfully produced. The initial processing conditions of the standard HDPE and LDPE thermoplastic were used as a base point. For the purpose of this study, thermoplastic with different grade of polyethylene (LDPE and HDPE) were compounded with different of ratio of biopolymer were produced by injection moulding. The mechanical properties were carried out on thermoplastic/biopolymer. It can be showed that the tensile strength and tensile strain is decreased than the neat thermoplastic and they were found to decreased with the increasing of biopolymer compounds. However, LDPE are lower in tensile strength and tensile strain than HDPE. Various structures could be observed through these images but it can be concluded that the biopolymer content in the compound allows it to significantly elongate before breaking. This can be proved via the long strands formed at each fracture. Having this property can allow these compounds to be used in diverse applications which require tough materials for example, as fillers. Therefore, not only does the presence of biopolymer provide biodegradable properties, but it also improves the mechanical properties. By acting as a guideline, this study aids any intention on processing these in-house produced polymers by injection molding. Further research can be done in this area by decreasing the processing conditions to reduce the energy consumption

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