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THE EFFECT OF ECO-DEGRADANT PD04 ON THE PROPERTIES OF RECYCLED POLYETHYLENE/CHITOSAN BIOCOMPOSITES

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ABSTRACT

The effect of eco-degradant PD04 on the properties of recycled polyethylene (RPE)/chitosan biocomposites has been investigated. The recycled polyethylene/chitosan biocomposites were prepared by using Z-blade mixer at 180°C with a rotation speed of 50 rpm. RPE was filled with chitosan at various loading of 0, 10, 20, 30 and 40 per hundred part (php). Whereas, 5 php of eco-degradant PD04 from the weight of RPE was used as degradation additive of the biocomposites. From tensile properties results, it indicates that the presence of eco-degradant has increased the tensile strength and Young's modulus but decrease the elongation at break. The biocomposites with eco-degradant has reduced the amount of water absorption and this indicates that eco-degradant give better water resistance to the biocomposites. The scanning electron microscope (SEM) micrograph of fracture tensile surface shows that the chitosan is well dispersed in RPE matrix with the presence of eco-degradant. The filler was coated with matrix, indicates that the filler is more compatible with the matrix. The biocomposites with eco-degradant have better compatibility, dispersion and adhesion as compared to biocomposites without eco-degradant.

Keywords: recycled polyethylene, chitosan, eco-degradant PD04.

INTRODUCTION

The amount of plastic waste is increasing as the production of polymeric materials grows dynamically and their application is wider. Managing the plastic waste is one of the challenges faced by today's world. Therefore, the interest in studying and utilizing polymer composites filled with natural organic fillers arose, especially studies related to recycled and/or recyclable polymer matrices. These class of composites (sometimes indicated as "green composites") show other interesting features, certainly concerning the costs issues, which are quite reduced since some natural organic fillers are usually extracted from wastes (La Mantia&Morreale, 2006).

Nowadays, the increasing demand for plastic or polymer products leads to a substantial growing percentage of municipal waste streams and poses environmental challenges to our country. To substitute material for plastic, the used plastic can be recycled again and reused as their original product. It is a great effort to prevent the waste of potentially useful materials, reduces the consumption of raw materials and reduces energy usage. Therefore studies on recycled plastic are very important because it will help to decrease the amount of waste.

Polyethylene is lightweight, water resistant, has a good balance of strength and flexibility and can provide some clarity, easy to extrude and heat-seal. However, some of these polymers have disadvantages in such applications, i.e. poor biocompatibility and release of acidic degradation products. A heavy environmental pollution accompanies their uses, because they need hundreds of years to degrade, and the disposal of waste plastics has become a serious problem. Biodegradable materials used as alternative to the petroleum-derived plastics. The natural polymers have undergone reevaluation regarding their ability to biodegrade. Natural biopolymers including starch, cellulose and chitosan were tested, alone or combined with synthetic polymers, for the possibility to form a fully or partially biodegradable film. Biocomposites are polymers that are generated from renewable natural sources, are often biodegradable and nontoxic. Chitosan is well-known abundant natural polymer derived from crustaceans exoskeleton with molecular formula, poly-(β-1→4)-2-amino-2-deoxy-D-glucopyranose, is used as a collective name for a group of partially and fully deacetylated chitin (Majeti& Kumar, 2000; Wang *et al.* 2005; Zainol *et al.* 2009; Choi *et al.* 2007). Thus, chitosan contains a large number of hydroxy and amino groups (Tangpasuthadol *et al.* 2003; Twu *et al.* 2003; Biro *et al.* 2008; Rinaudo *et al.* 1999). It is unique basic polysaccharide with high molecular weight which belongs to the class of modern high-tech biopolymer that finds applications in technology, medicine, agriculture and biotechnology. By incorporating specific additive known commonly as degradant additive, the process of degradation under the action of either UV, heat, oxygen, and/or mechanical shear will take place through formation of free radicals and there after leading to the chemistry of chain scissioning. Eco-degradant PD04 is used as a polyolefins based Controlled Degradation Masterbach. Polyolefins that are incorporated with Eco-degradant PD04 masterbatch would progressively degrade to lower and lower molecular weights. They become brittle, disintegrated and ultimately digested by microorganisms back to the basic elements of carbon dioxide (CO_2), water (H_2O) and biomass.

EXPERIMENTAL

Raw Materials

Recycled Polyethylene:

Recycled polyethylene (RPE) used was grade Titanlene LDF260GG, obtained from Titan Petchem (M) Sdn Bhd(formerly known as Titan PP Polymers (M) Sdn Bhd). The properties of recycled polyethylene is shown in Table-1 below;

Table-1. Recycled polyethylene characteristics.

Recycled Polyethylene	
Melt Index	5 g/10 min
Density	0.922 g/cm^3
Melt Temperature	160-180°C

Chitosan

Chitosan used as fillers in recycled polyethylene and chitosan biocomposites, was obtained from Hunza Nutriceuticals Sdn Bhd. Chitosan is in the form of powder. The particle size distribution analyzed by Malvern Instruments Mastersizer 2000 equipment indicates that average particle size of chitosan is 85.4µm. The properties of chitosan is shown in Table-2 below;

Table-2. Chitosan characteristics.

Chitosan	
Physical properties	
➢ Appearance	Off-white powder
➢ Powder fineness	Finer than 120 mesh size
Chemical properties	
➢ Degree of deacetylation	>90.0 %
➢ Solubility of 1% chitosan in 1% acetic acid	>99.0 %
➢ Viscosity	150-200 mPa.s
➢ Moisture	<10.0%
➢ Ash content	<1.0%

Additives

The additive used in RPE/chitosan biocomposites is eco-degradant PD04, supplied by Behn Meyer Polymers Sdn. Bhd., Penang, Malaysia. Table-3 shows the properties of eco-degradant PD 04;

Table-3. Properties of eco-degradant PD04.

Eco-Degradant PD04	
Typical properties	
➢ Appearance	Light brown free flowing pellets
A typical sample evaluation of plastics shopping bags with eco-degradant PD 04	
➢ Processing Method	Film blowing
➢ Processing Temperature	190-210°C
➢ Sample description	3% eco-degradant PD 04, 80% HDPE, 20% LLDPE 3% White Masterbatch
➢ Particle size	33 micron

Mixing Process

The mixing of the composites was carried out by using Z-Blade mixer at temperature 180˚C for speed 50 rpm. The formulations for RPE/chitosan biocomposite with and without eco-degradant PD04 are listed in Table-4;

Table-4. Formulations for RPE/Chitosan biocomposites.

Materials	Without eco-degradant PD04	With eco-degradant PD04
Recycled Polyethylene (php)	100	100
Chitosan (php)	0, 10,20,30,40	0,10,20,30,40
Eco-degradant PD 04 * (php)	-	5

* 5php from weight RPE

Compression Molding

To produce 1 mm thickness sheet sample, compression molding is done by using compression molding machine model GT 7014 A with temperature 180˚C and pressure 170 kg/cm^2.

MECHANICAL PROPERTIES

Tensile Test

Tensile test was carried out according to ASTM D 638 using an Instron Tensile model 5569. The gauge length was set at 50 mm and the cross head speed of testing at 50 mm/min at temperature 25 ± 3 ˚C.

Water Absorption

RPE/chitosan biocomposites samples of approximate dimensions 25 x 20 x 1 mm were used for the measurement of water absorption according to ASTM D 570. The samples were oven-dried at 80˚C for 24 h, and immersed in distilled water at room temperature until a constant weight was reached. The specimens were

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periodically taken out of the water, wiped with tissue paper to remove surface water and weighed. At least three specimens for each sample were used. A Mettler balance type was used, with precision of ± 1 mg. The percentage of water absorption, (M_t), was calculated according to the following formula:

$$M_t = (W_N - W_d) / W_d \times 100\%$$

Where; W_d and W_N are original dry weight and weight after immersed, respectively.

Morphology Study

The morphology of tensile fracture surface for RPE/chitosan biocomposites was carried out by using a scanning electron microscopy (SEM) model JOEL JSM-6460LA. SEM was used to examine qualitatively the dispersion of chitosan in RPE matrix.

RESULT AND DISCUSSION

Tensile Strength

Figure-1 shows the effect of filler loading on tensile strength of RPE/chitosan biocomposites with and without eco-degradant. The use of eco-degradant improves interaction and adhesion between the filler and matrix leading to better matrix to filler stress transfer. Thus addition of chitosan filler result in significant improvement in tensile properties of the biocomposites. The improvement in mechanical properties achieved can be attributed to high strength and modulus of filler and to improved interfacial adhesion between the matrix and filler. The increase in mechanical properties demonstrates that eco-degradant has effectively functioned as additives in RPE/chitosan biocomposites.

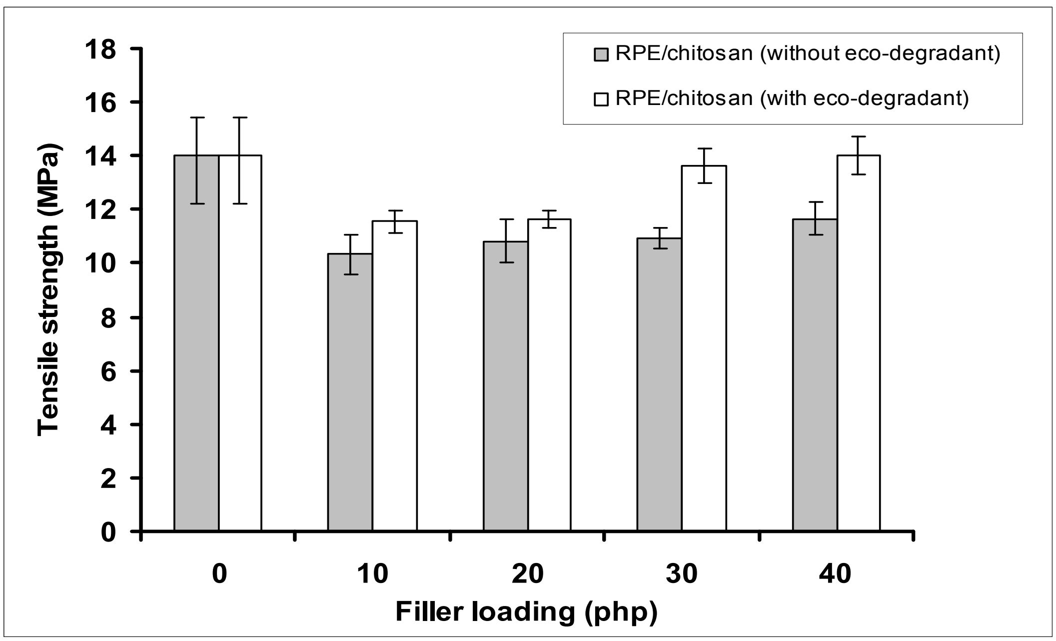

Figure-1. The effect of filler loading on tensile strength of RPE/chitosan biocomposites with and without eco-degradant PD04.

The effect of filler loading on the elongation at break of RPE/chitosan biocomposites with and without eco-degradant is shown in Figure-2. The elongation at break of both biocomposites decreases steadily with increasing of filler loading. The presence of eco-degradant as additive improved tensile strength and reduced elongation at break. It was clear indication of improved adhesion of biocomposites between filler and matrix. The decrease in the elongation at break was much more pronounced for biocomposites with eco-degradant due to the adhesion between filler and RPE matrix which restricts deformation capacity of matrix in the elastic zone.

Figure-3 shows the effect of filler loading on Young's modulus of RPE/chitosan biocomposites with and without eco-degradant. Both biocomposites show similar trend of Young's modulus that increase with increasing of filler loading. The Young's modulus for biocomposites with eco-degradant was higher if compared to that of biocomposites without eco-degradant. The increase in Young's modulus with filler loading clearly indicates the ability of filler to impart greater stiffness to matrix biocomposites. When filler loading increases, the Young's modulus of the biocomposites with eco-degradant was much superior than the biocomposites without eco-degradant.

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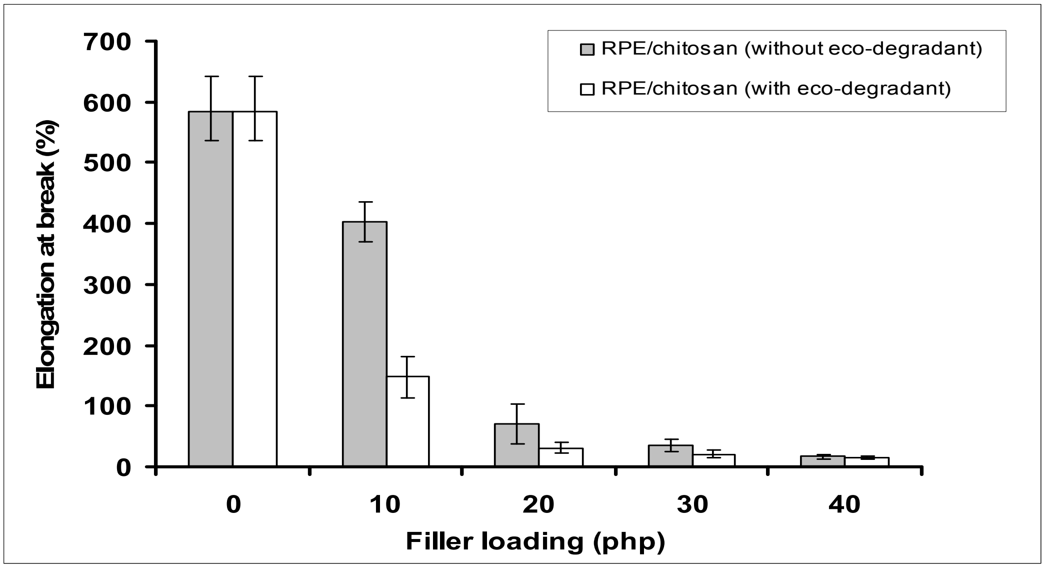

Figure-2. The effect of filler loading on elongation at break of RPE/chitosan biocomposites with and without eco-degradant PD04.

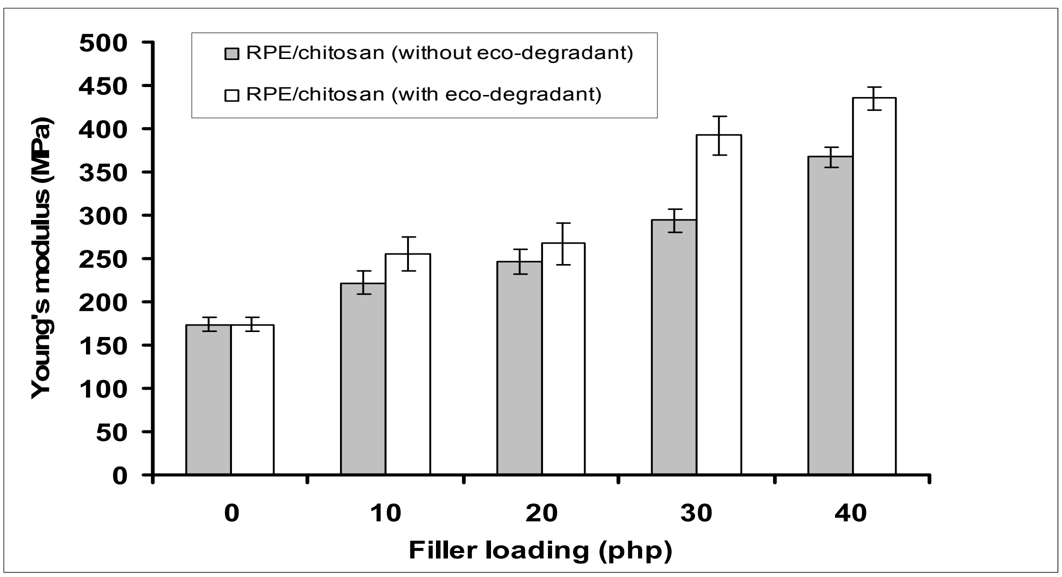

Figure-3. The effect of filler loading on Young's modulus of RPE/chitosan biocomposites with and without eco-degradant PD04.

Water Absorption

Figure-4 shows the percentage of water absorption versus time of RPE/chitosan biocomposites with and without eco-degradant at 0, 20 and 40 php. The biocomposites with eco-degradant have lower percentage of water absorption compared to biocomposites without eco-degradant. Figure-5 shows the equilibrium water absorption of RPE/chitosan biocomposites with and without eco-degradant at different filler loading. The percentage equilibrium water absorption for biocomposites with eco-degradant was 18-33 % with increasing chitosan loading for 30 days. The biocomposites with eco-degradant has reduced the amount of water absorption and this indicates that eco-degradant offers better water resistance to the biocomposites. Eco-degradant helps to promote the interfacial adhesion between the RPE phase and the chitosan phase. The decrease in water absorption of biocomposites would be due to the enhanced adhesion between filler and matrix with the aid of eco-degradant incorporated in the system.

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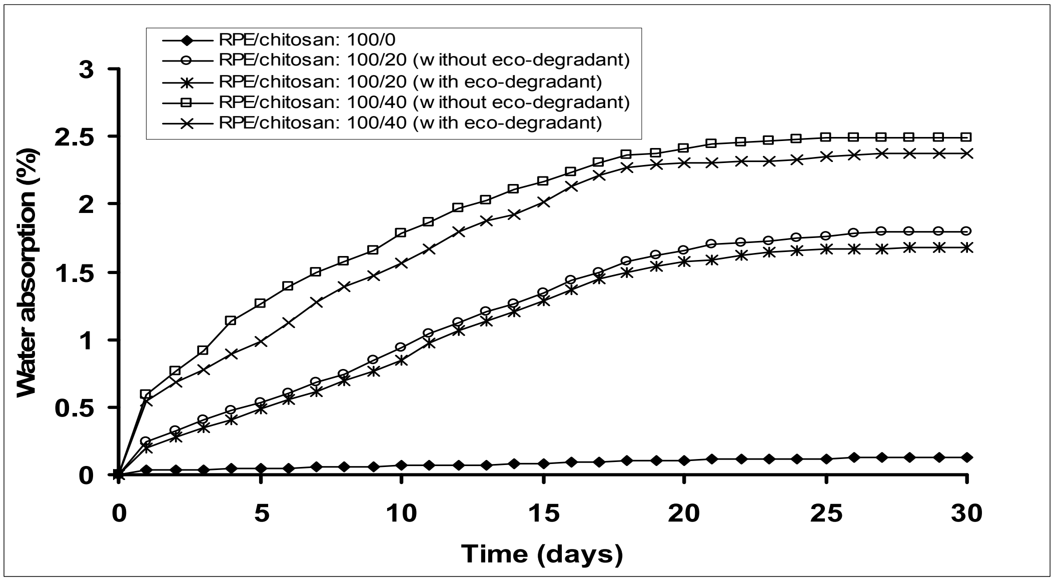

Figure-4. The percentage of water absorption versus time of RPE/chitosan biocomposites with and without eco-degradant at 0, 20 and 40 php.

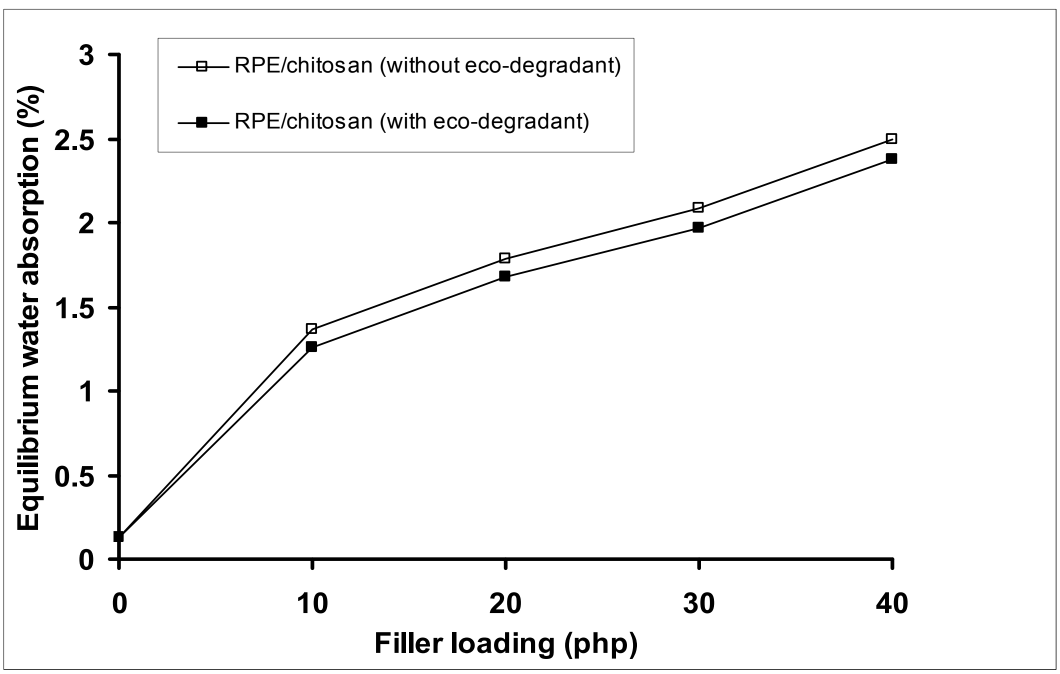

Figure-5. The equilibrium water absorption of RPE/chitosan biocomposites with and without eco-degradant at different filler loading**.**

Morphological Study

Figures-6 and 7 show the SEM micrographs of tensile fracture surfaces of RPE/chitosan biocomposites with eco-degradant at 20 and 40 php. From the Figures, it can be seen that the presence of eco-degradant indicates well dispersion of chitosan in RPE matrix. Both micrographs show rough surfaces. The filler was coated by the matrix. This indicates that the filler was more compatible with the matrix. Therefore, the biocomposites with eco-degradant have better compatibility, dispersion and adhesion as compared to biocomposites without eco-degradant. This is due to the improved interfacial adhesion between the filler and the RPE matrix with the presence of eco-degradant.

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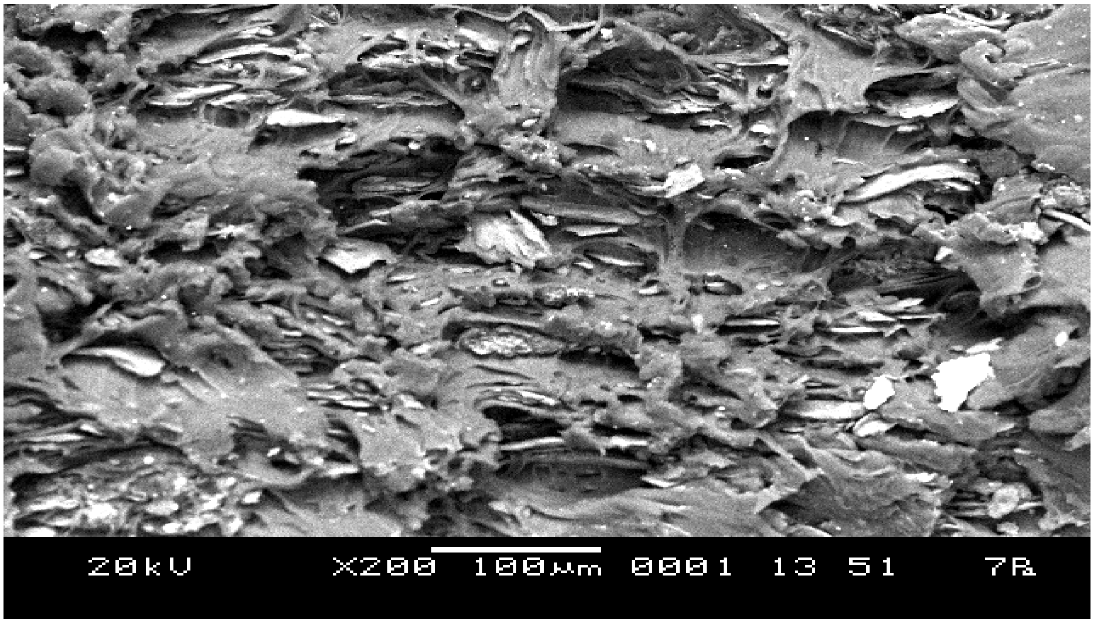

Figure-6. SEM micrograph of tensile fracture surface of RPE/chitosan biocomposites with eco-degradant (20 php) at magnification 200X.

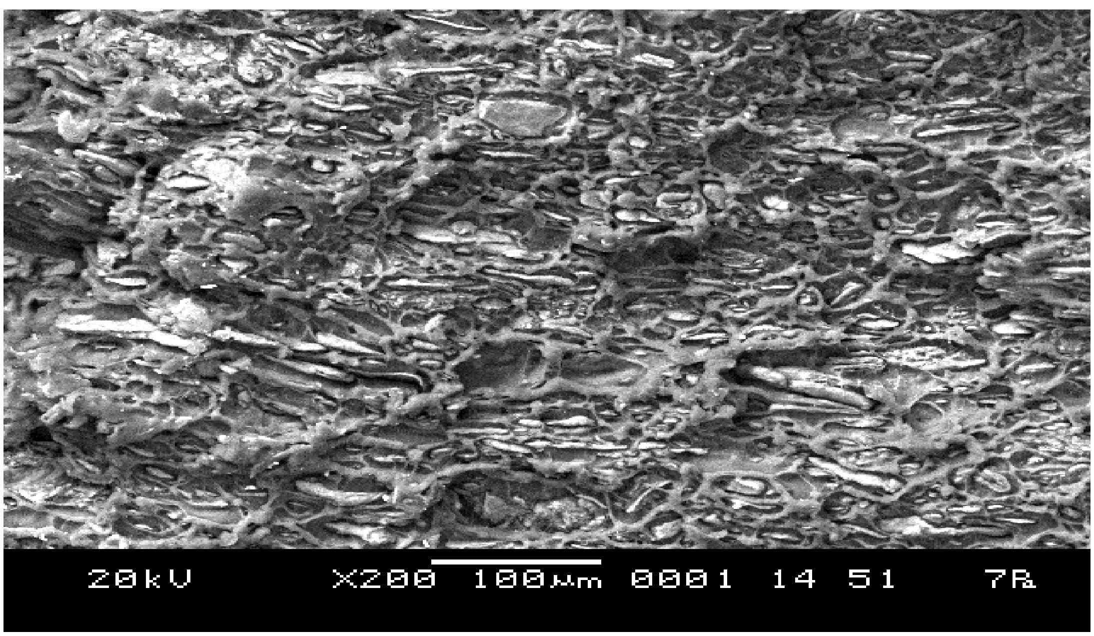

Figure-7. SEM micrograph of tensile fracture surface of RPE/chitosan biocomposites with eco-degradant (40 php) at magnification 200X.

CONCLUSIONS

In order to improve the properties of RPE/chitosan biocomposites, blending of chitosan with recycled polyethylene (RPE) was successfully done. The effect of eco-degradant PD 04 showed increasing tensile strength and Young's modulus with lower elongation at break. The increase in mechanical properties proves that eco-degradant has effectively functioning as additives in biocomposites. The addition of eco-degradant reduced the amount of water absorption. The morphological study of biocomposites with eco-degradant exhibits higher compatibility, well dispersion and adhesion between filler and matrix.

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