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Effect of Eco-Degradant on Properties of Recycled Polyethylene (RPE)/Chitosan Biocomposites

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Abstract: *The effect of eco-degradant PD 04 on properties of recycled polyethylene (RPE)/chitosan biocomposites was investigated. RPE/chitosan biocomposites were prepared by using Z-blade mixer at processing temperature 180°C and rotor speed 50 rpm. Eco-degradant PD 04 was used as degradant additive to improve the properties of biocomposites. The result indicated that the increasing of filler loading increased tensile strength, Young's modulus and water absorption but reduce the elongation at break. The presence of eco-degradant showed that the tensile strength and Young's modulus were increased but reduce the elongation at break. The water absorption of biocomposites with eco-degradant PD 04 has better water resistance compared to biocomposites without eco-degradant PD 04.*

Keywords: Recycled polyethylene, chitosan, eco-degradant PD 04, biocomposites

1. INTRODUCTION

Polymer composites have been subjected to increase interest, study, and utilisation for some decades. The interest arose toward polymer composites filled with natural organic fillers, especially in conjunction with recycled and/or recyclable polymer matrices. These classes of composites (sometimes indicated as "green composites") shows other interesting features, certainly concerns the costs issues, which are quite reduced since natural organic fillers are usually extracted from wastes.[1] The increasing demand for plastic or polymer products nowadays, a substantial growing percentage of municipal waste streams and poses environmental challenges to our country. While finding substitution material for plastic, this could involve a great cost and effort as it is much anticipated that used plastic can be recycled again and reused as their original product to prevent the waste of potentially useful materials, reduces the consumption of raw materials and reduces energy usage. Therefore, recycled polyethylene (RPE) was used in this study with chitosan as natural biopolymer to improve the properties of composites.[1–7]

Chitosan, with molecular formula poly-(β-1→4)-2-amino-2-deoxy-D-glucopyranose is biopolymers derived from chitin and cellulose, respectively, which are very common natural polysaccharides present in the environment. Chitosan is natural family biopolymer, biodegradable, and non-toxic as well as low-cost materials. Therefore, these biopolymers are extensively used in many scientific and technological applications such as medicine, pharmacology, biotechnology textile and food industry, photographic films, as well as fiber and plastic applications.[8–13]

The most important issue associated with these composites is the interfacial adhesion between the natural reinforcing fillers and matrix polymers[14] and also plastic degradability. Polyethylene is chemically stable in nature and is made primarily of hydrocarbon molecules and this does not easily degrade under ambient condition. In the recent development in area of plastic degradability, it presents an alternative method of disposing used plastic packaging. By incorporating specific additive known commonly as degradant additive, the process of degradation under the action of UV, heat, oxygen, and/or mechanical shear will take place.

This research investigated the effect of eco-degradant on the properties on recycled polyethylene (RPE)/Chitosan biocomposites.

2. EXPERIMENTAL

2.1 Materials

2.1.1 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 show in Table 1 below:

Table 1: Properties of recycled polyethylene.

Recycled polyethylene	
Melt index	5 g/10 min
Density	0.922 g/cm^3
Melt temperature	160°C–180°C

2.1.2 Chitosan

Chitosan, used as fillers in RPE/chitosan biocomposites, was obtained from Hunza Nutriceuticals Sdn Bhd, in powder form. Chitosan is in powder form and the particle size distribution analysed by Malvern Instruments Mastersizer 2000 equipment. The average particle size of chitosan is 85.4µm. The properties of chitosan show in Table 2 below:

Table 2: Chitosan characteristics.

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

2.1.3 Eco-degradant PD 04

Additive used in RPE/chitosan biocomposites is eco-degradant PD 04 supplied Behn Meyer Polymers Sdn. Bhd., Penang, Malaysia and the amount applied is 5 php based on weight recycled polyethylene. The properties of eco-degradant PD 04 show in Table 3 below.

Table 3: Properties of eco-degradant PD 04.

Eco-degradant PD 04		
Typical properties		
Appearance		Light brown free flowing pellets
A typical sample evaluation of plastics shopping bags with eco-degradant PD 04		
1.	Processing method	Film blowing
2.	Processing temperature	190°C –210°C
3.	Sample description	3% eco-degradant PD 04, 80% HDPE, 20% LLDPE
4.	Particle size	3% White Masterbatch 33 micron

2.2 Compounding of Composites

2.2.1 Mixing process

The mixing of the composites was carried out by using Z-Blade mixer at temperature 180°C for speed 50 rpm. RPE and eco-degradant were charged into the mixing chamber for 10 minutes until it completely melts. After 10 minutes the chitosan was added and mixing continued for 20 minutes. The whole mixing progress was conducted for 30 minutes. The formulations for RPE/chitosan biocomposites with and without eco-degradant PD 04 are listed in Table 4.

Table 4: Formulations for RPE/chitosan biocomposites.

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

* 5 php from weight RPE

2.2.2 Compression molding

To produce 1 mm thickness sheet sample, compression molding was done by using compression molding machine model GT 7014 A with temperature 180°C and pressure 170 kg/cm^2. After compression molding, the samples were cut into dumbbell shapes by using Wallace dumbbell cutter.

2.3 Measurement of Tensile Properties

2.3.1 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 25 ± 3°C. Tensile properties for five identical samples of each composition were measured and the average values were reported. Tensile strength, elongation at break and Young's modulus were recorded and automatically calculated by the instrument software.

2.3.2 Water absorption

RPE/chitosan samples of approximate dimensions (25 × 20 × 1 mm) were used for the measurement of water absorption. 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. 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:

$$M_t = (W_N - W_d) / W_d \times 100 \quad (1)$$

where; W_d = Original dry weight
W_N = Weight after immersed

2.4 Morphology Study

Studies of the morphology of tensile fracture surface for RPE/chitosan biocomposites were 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. The fracture ends of specimens were mounted on aluminium stubs and sputter coated with a thin layer of palladium to avoid electrostatic charging during examination.

3. RESULTS AND DISCUSSION

3.1 Effect of Filler Loading on Mechanical Properties

3.1.1 Tensile properties

Figure 1 shows the effect of filler loading on tensile strength of RPE/chitosan biocomposites with and without eco-degradant PD 04. The results show the increasing tensile strength with increasing filler loading from 10 to 40 php for bio composites 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 results in significant improvement in tensile properties of the biocomposites. The improvement in tensile 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 tensile properties demonstrates that eco-degradant has effectively functioned as additive in RPE/chitosan biocomposites.

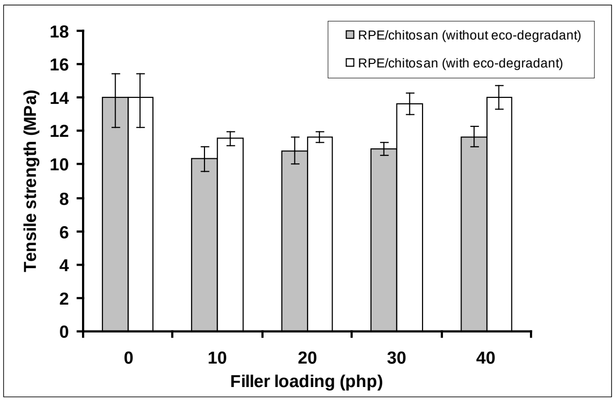


Figure 1: The effect of filler loading on tensile strength of RPE/chitosan biocomposites with and without Eco-degradant PD 04.

The effect of filler loading on elongation at break of RPE/chitosan biocomposites with and without eco-degradant was shown in Figure 2. The elongation at break of both biocomposites decreased 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 restricts deformation capacity of matrix in the elastic zone as well as the plastic zone.

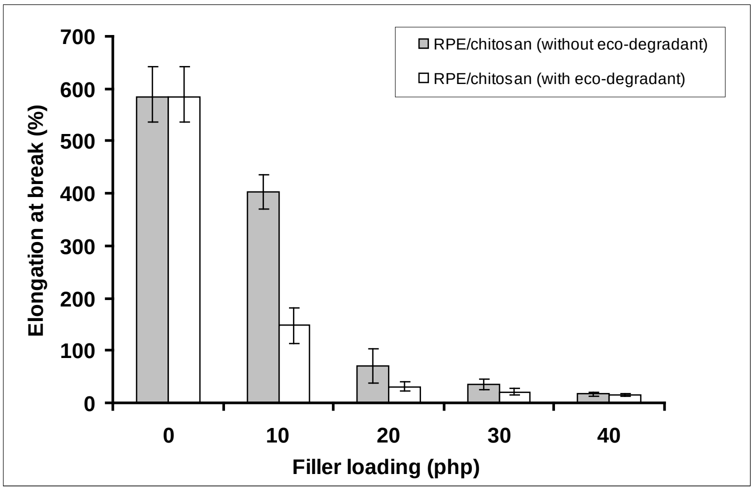


Figure 2: The effect of filler loading on elongation at break of RPE/chitosan biocomposites with and without eco-degradant.

Figure 3 shows the effect of filler loading on Young's modulus of RPE/chitosan biocomposites with and without eco-degradant. The 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 compared to 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 increase, the Young's modulus of the biocomposites with eco-degradant was much superior to the biocomposites without eco-degradant.

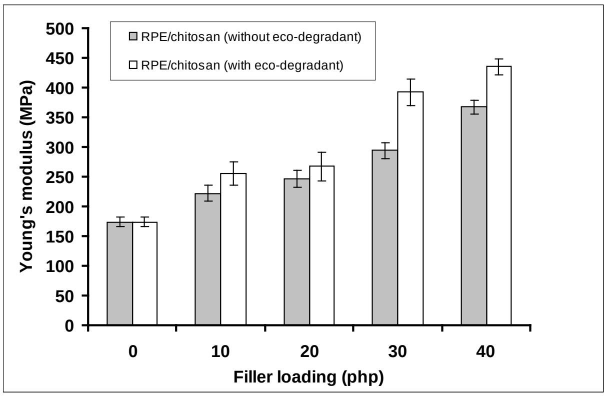


Figure 3: The effect of filler loading on Young's modulus of RPE/chitosan biocomposites with and without eco-degradant.

3.1.2 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 give 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 enhanced adhesion between filler and matrix by the modified of eco-degradant that results in a decrease water absorption. The volume of voids decrease due to enhanced adhesion and therefore water penetration or storage through the interface was restricted.

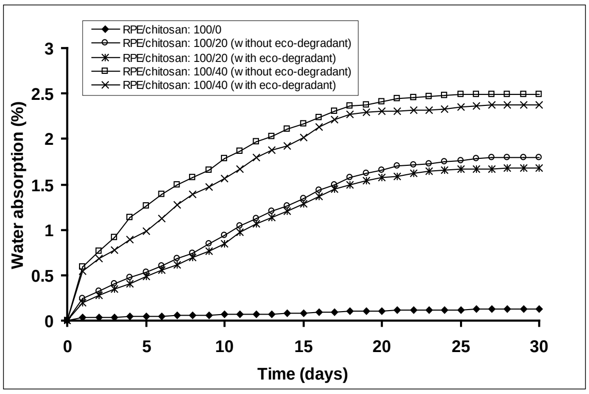


Figure 4: The percentage of water absorption versus time of RPE/chitosan biocomposites with and without eco-degradant at 0, 20 and 40 php.

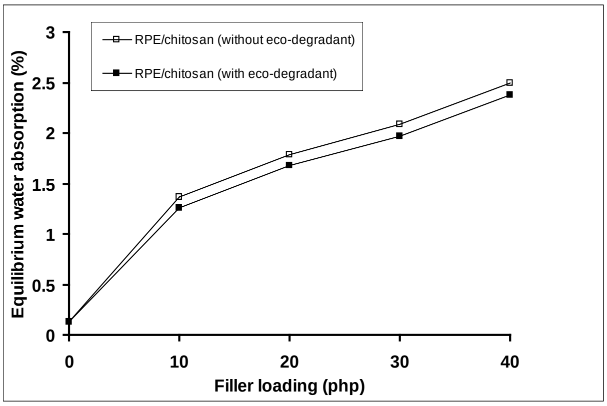


Figure 5: The equilibrium water absorption of RPE/chitosan biocomposites with and without eco-degradant at different filler loading.

3.1.3 Morphological study

Chitosan displayed the particulate and irregular shapes as shown in Figure 6. SEM micrographs of tensile fracture surface for RPE/chitosan biocomposites with and without eco-degradant for 20 and 40 php are shown in Figures 7 and 8. Figures 7a and 7b show the tensile fracture surface micrograph for biocomposites without eco-degradant. Biocomposites with 20 php chitosan shows ductile morphology compared to biocomposite RPE/chitosan 40 php. The morphology biocomposites at 40 php chitosan exhibit better dispersion of chitosan in matrix. This is due to capability of filler to stress transfer between matrixes in biocomposites. The stress is well propagated between the filler and the matrix causing it to have a higher tensile strength. Figures 8a and 8b show the

SEM micrographs of tensile fracture surface of RPE/chitosan biocomposites with eco-degradant at 20 and 40 php. From the figures can be seen that the presence of eco-degradant indicates chitosan well dispersion in RPE matrix. The both micrographs show the rough surface. 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 improved interfacial adhesion between the filler and the RPE matrix with presence eco-degradant.

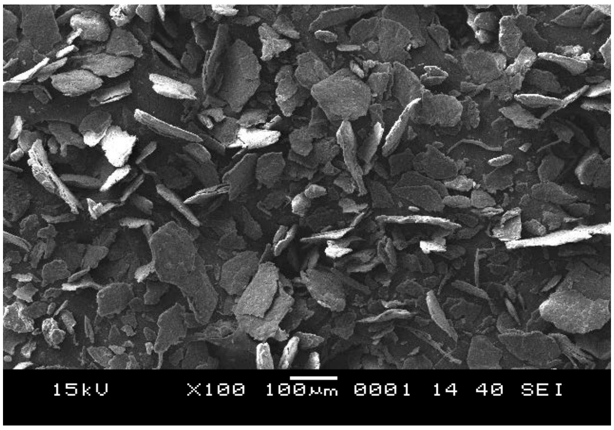
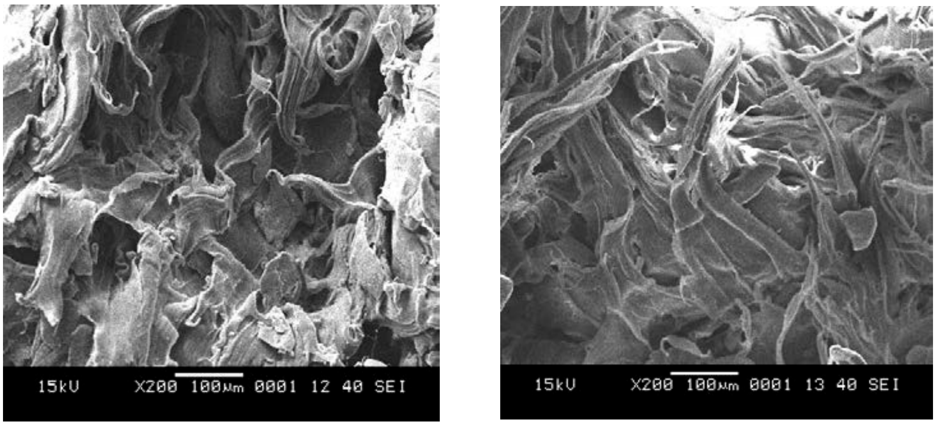
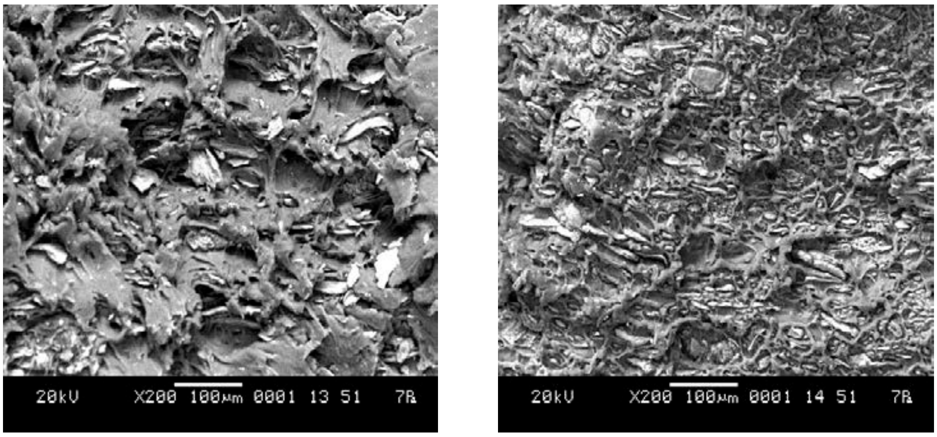


Figure 6: The SEM micrograph of chitosan at magnification 100×.



(a) (b)

Figure 7: The SEM micrograph of tensile fracture surface of RPE/chitosan biocomposites; (a) at 20 php and (b) at 40 php without eco-degradant at magnification 200×.



(a) (b)

Figure 8: The SEM micrograph of tensile fracture surface of RPE/chitosan biocomposites; (a) at 20 php and (b) at 40 php with eco-degradant at magnification 200×.

6. CONCLUSION

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

7. REFERENCES

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