Properties of eco-friendly composites: palm kernel shell treated with sodium bicarbonate filled recycled high-density polyethylene.

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Abstract. Palm kernel shells (PKS) treated by commercial sodium bicarbonate (SB) filled recycled high-density polyethylene (rHDPE) were produced using melt compounding. These environmentally friendly composites were prepared using twin-screw extruder by varying untreated and treated filler loading (0, 10 and 30 php). In this study, the tensile properties of untreated rHDPE/PKS and treated rHDPE/PKS-SB were investigated. The composites were subjected to tensile test and the fracture surfaces were observed under scanning electron microscope (SEM). The results showed that SB treatment improved the filler-matrix adhesion and interaction of composites. Meanwhile, the SEM micrographs on the fracture surfaces confirmed that SB treatment which may influence the tensile properties of these composites.

1 Introduction

The increasing polymer waste in modern days has led to plenty environmental issues. With the effort to reduce the usage of non-degradable petroleum-based polymer, addition of natural filler is one of the solutions. Thermoplastic composites filled with natural fillers offer attractive properties such as lightweight, high specific mechanical properties, biodegradability, recyclability and low cost [1]. There are researches report on the use of natural fillers to produce composites and their respective applications [2]. The common natural filler are chitosan [3], hemp [4, 5], sisal [6], rice husk [7] and etc.

The palm kernel shell (PKS) is the waste residue generated from palm fruit processing in Malaysia. The palm kernel nuts that contain kernel oils are cracked down to kernel and kernel shell. The kernel is served for oil extraction; while the kernel shell is considered as waste. Therefore, the huge amount of PKS generated annually has led to disposal issue. In order to resolve this issue, PKS can be processed and utilized as an alternative to synthetic filler. The

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PKS has high potential to be used as filler in polymeric composites as it contain 50.70 % lignin, 20.80 % cellulose and 22.70% hemicellulose [8].

Though the natural fillers demonstrate attractive properties, their hydrophilic properties are not compatible with the hydrophobic properties of polymers. This cause the poor adhesion between filler and matrix. Surface modification offers solution to improve the interaction between filler and matrix [9]. Alkali treatment is one of the widely used surface modification that can modify the filler surface and increase the interfacial bond strength between filler and matrix [10]. However, the inappropriate disposal of chemical waste after treatment may endanger the environment. Thus, Fiore and co-workers [11] had proposed an environmentally friendly treatment that involved the use of sodium bicarbonate solution instead of strong alkali. Their study discovered the treated fibre composites showed notable improvement of mechanical properties.

The main objectives of this research were to study the effect of PKS loading on the tensile and morphological properties of rHDPE/PKS composites. Surface modification using commercial sodium bicarbonate (SB) was used with the aim to improve the properties of composites.

2 Experimental

2.1 Materials

The recycled high-density polyethylene (rHDPE) flakes were supplied by Titan Petchem (M) Sdn. Bhd., Pasir Gudang, Malaysia. The palm kernel shell (PKS) was provided by Malpom Industries Sdn. Bhd., Nibong Tebal, Malaysia. The fibres on raw PKS was first removed and cleaned thoroughly. Then, it was dried in the oven at 80°C for 24 hours to remove the moisture. A grinding machine was used to grind the PKS into fine particles. The PKS powder was then subjected to sieving process and only the PKS with size smaller than 75 μm was selected.

2.2 Filler treatment

Commercial sodium bicarbonate (SB) as known as baking soda, NaHCO₃ was chosen as surface treatment. It was acquired from a local retail shop. Sodium bicarbonate surface coating was applied using a solution method. 20 g of SB was dissolved in 500 mL distilled water. The solution was manually stirred at regular interval until all the SB was dissolved. Thereafter, 200 g of PKS were added into solution. The mixture was stirred manually for about one minute and left to stand for 120 hours under room temperature. After that, the mixture was rinsed with distilled water and dried in oven for 24 hours at 50 °C.

2.3 Preparation of eco-friendly composites

The rHDPE/PKS composites were prepared by using twin-screw extruder. The filler and matrix were pre-mixed before compounding. Then, they were poured into hopper of extruder, with a fixed feeding rate that continuously feeding the filler and matrix from hopper into extruder barrel. The processing temperature was set at 180 °C with screw speeds of 50 rpm. The extrudates were cooled in water bath and cut into pellet by the means of a pelletizer machine. By using compression moulding, the rHDPE/PKS pellets pressed into sheets of 1 mm. The pellets were preheated for 12 minutes, compressed for 4 minutes and cooled for 4 minutes. Then the composites were cut into dumbbell shape. The formulation of untreated
rHDPE/PKS and treated rHDPE/PKS-SB composites at different filler loading was shown in Table 1.

**Table 1.** Formulations of Untreated rHDPE/PKS composites and Treated rHDPE/PKS eco-friendly composites.

| Materials       | Untreated rHDPE/PKS Composites | Treated rHDPE/PKS-SB Composites |
|-----------------|---------------------------------|---------------------------------|
| rHDPE (php)     | 100                             | 100                             |
| PKS (php)       | 0, 10, 30                       | 10, 30                          |

\*php = part per hundred of polymer

**2.4 Tensile Test**

Tensile tests were conducted by using an Instron 5569 and according to ASTM D638 [12]. A gauge length of 50 mm was used, with cross head speed of 15 mm/min. The test was performed under room temperature. For each formulation, 10 samples were tested, and an average was obtained. Tensile strength, elongation at break and Young’s modulus for the composites were recorded.

**2.5 Scanning Electron Microscope**

The fracture surfaces of the composites were observed under a scanning electron microscope (SEM), model JSM 6260 LE JOEL. The fractured ends of specimens were mounted on aluminium stubs and sputter-coated with a thin layer of platinum to avoid electrostatic charging during examination.

**3 Results and discussion**

**3.1 Tensile Properties**

Fig. 3.1(a) illustrates the average values of tensile strength of untreated rHDPE/PKS and treated rHDPE/PKS-SB composites with sodium bicarbonate. The increasing of PKS content in rHDPE matrix had decreased the tensile strength of untreated rHDPE/PKS composites and treated rHDPE/PKS-SB composites. The weak interaction between PKS and rHDPE resulted in poor stress transfer thus reduced the tensile strength of the composites. However, it was discovered that the tensile strength of treated rHDPE/PKS-SB composites was higher than untreated rHDPE/PKS composites. The mildly alkaline sodium bicarbonate solution was capable to remove the lignin on the surface of PKS [10]. The removal of lignin on the surface of filler after alkali treatment contributes to change the tensile strength of filler [13].

Meanwhile, Fig. 3.1(b) shows the elongation at break of rHDPE/PKS-SB composites decreasing with the rise of filler loading. The presence of rigid PKS had decreased the ductility of rHDPE/PKS composites. Besides, the elongation at break of treated rHDPE/PKS-SB composites were higher compared to untreated rHDPE/PKS composites. This can be attributed to the enhanced interaction of matrix molecular chain onto the surface of treated PKS filler as a consequence of improved compatibility on the interface [9].

On the other hand, the Young’s modulus (Fig. 3.1(c)) of treated rHDPE/PKS-SB composites were higher than that of untreated rHDPE/PKS composites and continued to
increase with increase of PKS loading. The addition of PKS increased the stiffness of rHDPE/PKS composites, thus led to higher Young’s Modulus. It was noticed that the SB treated PKS improved interaction between PKS and rHDPE and showed stiffening effect.

![Fig. 3.1 Effect of filler content on the (a) tensile strength, (b) elongation at break, (c) Young’s Modulus of untreated rHDPE/PKS composites and treated rHDPE/PKS-SB composites.](image)

### 3.2 Morphological Study

Fig. 3.2 (a) shows the SEM micrographs of tensile fracture surface of treated rHDPE/PKS-SB composites at 10 php of PKS loading. It can be seen in the micrograph of treated composites that PKS fillers were embedded in the matrix. Under the tensile stress, some of the PKS filler were detached from the matrix. This stress concentration weakened the tensile properties of rHDPE/PKS composites. The SB treatment had successfully improved the interfacial bonding between PKS and rHDPE. As a result, it enhanced the tensile strength and modulus of elasticity of composites. Fig. 3.2 (b) presented the fracture surface of rHDPE/PKS-SB composites at 30 php PKS loading. It showed the rough fracture surface and the detachment of PKS filler from the rHDPE matrix. This is indicated that imperfect bonding occurred between the rHDPE matrix with increasing of PKS filler loading. The interaction and adhesion were also poor, which led to detachment of PKS. This result showed the lower tensile strength of the composites at higher filler loading.
4 Conclusion

In this study, the rHDPE/PKS were successfully prepared at different PKS loading. It was discovered that presence of PKS had deteriorated the tensile strength and elongation at break of the composites but enhanced the Young’s modulus of composites. The environmentally friendly alkali treatment, sodium bicarbonate was capable to enhance the properties of rHDPE/PKS composites. The improved interfacial bonding of rHDPE and PKS were evidenced in SEM micrographs.

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