

# Kenaf Powder Filled Recycled High Density Polyethylene/ Natural Rubber Biocomposites: The Effect of Filler Content

C. X. Viet<sup>1</sup>, H. Ismail<sup>1\*</sup>, A. A. Rashid<sup>1</sup>, T. Takeichi<sup>2</sup>

<sup>1</sup>School of Materials & Mineral Resources Engineering, Universiti Sains Malaysia, Engineering Campus, 14300, Nibong Tebal, Penang, Malaysia

<sup>2</sup>Department of Environmental and Life Sciences, Toyohashi University of Technology, Japan

Received 22 June 2011; accepted 25 May 2012, available online 13 Sep 2012.

**Abstract:** The performance of kenaf powder (KP) as filler for recycled high density polyethylene (rHDPE)/natural rubber (NR) thermoplastic elastomer (TPE) composites was investigated. The composites with different filler loading were prepared in a Haake internal mixer. Increasing KP loading in rHDPE/NR/KP biocomposites reduced the tensile strength, elongation at break but increased the stabilization torque and the tensile modulus. SEM study of fracture surface indicated that fibrillation of rHDPE was reduced and detachment of kenaf powder from polymer matrix was present particularly at high filler loading. These observations were responsible for the deterioration of tensile strength and elongation at break of rHDPE/NR/KP biocomposites. Water absorption study also showed that the water absorption of these biocomposites increased with increasing KP content.

**Keywords:** Recycled HDPE, natural rubber, kenaf, biocomposites, water absorption.

## 1. Introduction

Thermoplastic elastomers (TPEs) have the unique characteristics of rubber elasticity at ambient temperature and plasticity at high temperature. Among the different types of TPEs, those prepared by the physical blending of polyolefin (Polyethylene) and natural rubber (NR) had gained considerable attention due to the simple preparation and easy attainment of the required technical properties. In addition, it has attracted a lot of attention as an environmentally conscious material since TPE is suitable for material recycle. It can be recycled up to several times without significant loss of properties [1].

The incorporation of various types of filler into a TPEs matrix was carried out either to improve properties or further reduce the cost of materials or to achieve both objectives simultaneously. Recently, fillers (bio-fibers or powders) derived from renewable natural resources such as banana, sisal, hemp, jute, pineapple, bamboo, cotton, coconut, rice husk and kenaf have become strong competitors to inorganic fillers. These fillers offer several advantages including low density, low cost, relative non-abrasiveness, high filling levels, recyclability, biodegradability, and renewable nature [2]. Especially, kenaf (*Hibiscus cannabinus*) is well known as a cellulosic source with economical and ecological advantages. Kenaf is used as a raw material to be alternative to wood in pulp and paper industries for avoiding destruction of forests and also used as non-woven mats in the automotive industries, textiles, fibreboard [3].

In this study, kenaf core powder was used as a filler to produce biocomposites based on rHDPE/NR blend.

The effect of filler content on mixing, tensile properties and water absorption of the reinforced biocomposites was investigated.

## 2. Experimental

### 2.1 Materials and Sample Preparation

rHDPE was obtained from Zarm Scientific and Supplies Sdn Bhd, Penang with melt flow index of 0.237 g/10 min. Natural rubber used was grade SMR L from the Rubber Research Institute of Malaysia (RRIM). Kenaf powder was produced by grinding kenaf core in a table-type pulverizing machine and sieved to obtain the powder size in range of 32 to 150  $\mu\text{m}$ .

Table 1 Formation of KP filled rHDPE/NR biocomposites

Materials	Composition (phr*)
Recycled high density polyethylene (rHDPE)	70
Natural rubber (SMR L)	30
Kenaf powder (KP)	0, 10, 20, 30, 40

\* part per hundred resin.

Formulations of KP filled rHDPE/NR biocomposites are given in Table 1. All materials were fed into a Haake Polydrive Rheomix at a rotor speed of 50 rpm with a temperature of 165°C for 12 min. The rHDPE was first charged into the mixer to start melt mixing. After 3 min, NR was added to melted rHDPE. The KP was added at

\*Corresponding author: hanafi@eng.usm.my

sixth minute as the last component and the blend was left for 6 min for further mixing. The composites were then compression-molded at 165°C into 1 mm sheet for preparing test samples.

## 2.2 Mechanical Testing

The tensile properties were measured using an Instron 3366 machine at a cross-head speed of 50mm/min according to ASTM D 412. At least five specimens for each sample were tested to obtain the tensile strength, tensile modulus and elongation at break of the composites.

## 2.3 Water Absorption

Water absorption test was done by immersing the samples in distilled water at room temperature (25°C). The water absorption was determined by weighing the samples at regular intervals on an electronic balance. The percentage of water absorption,  $M_t$  was calculated by

$$M_t = 100 \times (w_n - w_d) / w_d \quad (1)$$

where  $w_d$  and  $w_n$  are original dry weight and weight after exposure, respectively.

## 2.4 Morphology Study

The tensile fracture surface of the biocomposites was investigated with a Supra-35VP field emission scanning electron microscopy (SEM). The samples were coated with a thin layer of Pd–Au, to prevent electrostatic charging during evaluation

## 3. Results and Discussion

### 3.1 Mixing and Stabilization Torque

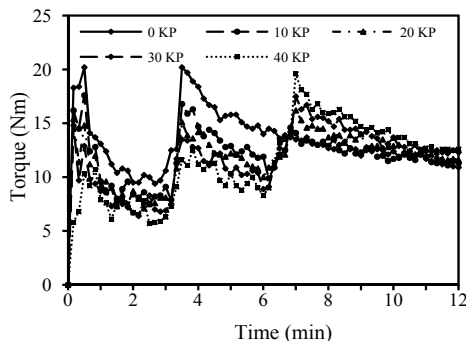


Fig. 1 Torque development for rHDPE/NR/KP biocomposites.

The torque-time curves of biocomposites are shown in Fig. 1. rHDPE was charged into the mixer at the beginning. As rotors started, an increase in torque was registered because of the resistance exerted by the rHDPE against the rotors. The torque maximum showed a decrease with filler loading due to subsequent decrease in the charge quantity of polymer matrix into the mixer. At the third minute, at which cold NR was charged into the mixing chamber, a sharp peak was registered. This abrupt rise in torque represented the loading peak of NR. The KP addition increased the mixture viscosity, which resulted in a higher torque value at sixth minute.

Upon completion of filler dispersion, the torque started to decrease gradually, which might be due to a reduction in viscosity as the stock temperature increased.

Fig. 2 shows the stabilization torque of rHDPE/NR/KP biocomposites at the end of mixing stage (12 min). It can be seen that stabilization torque increased gradually with increasing filler loading. This was due to the higher filler content, the higher interfacial interaction between filler and matrix, which caused the reduction of the mobility of polymer chains and thus increasing the viscosity and stabilization torque [4].

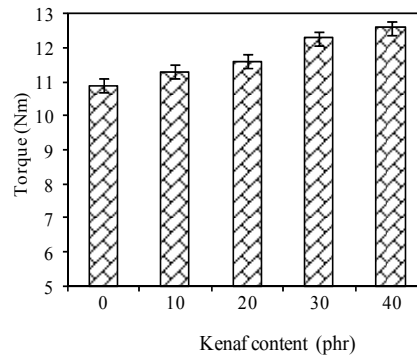


Fig. 2 Stabilization torque at 12 min of rHDPE/NR/KP biocomposites.

### 3.2 Tensile Properties

Fig. 3 shows the effect of KP content on tensile strength of the blends. The effect was extremely reduced at the 10 phr, a further addition of KP resulted in a proportionate decrease in tensile strength. The reduction of tensile strength might be due to the irregular shape of KP where their capability to support stress transmitted from the polymer matrix is rather poor (Fig. 4). Agglomeration of the filler and dewetting of the polymer at the interface aggravated the situation by creating stress-concentration points, which account for the weakness in the composites and the reduction in tensile strength [5].

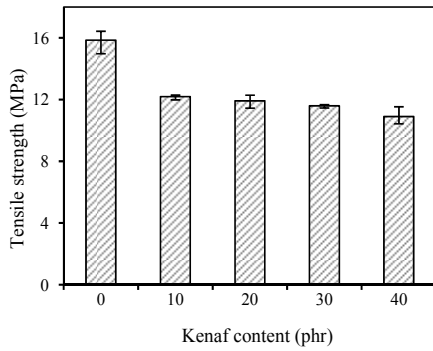


Fig. 3 Tensile strength vs. KP content of rHDPE/NR/KP biocomposites.



Fig. 4 SEM micrograph of kenaf powder.

The effect of filler content on elongation at break of the composites is depicted in Fig. 5. It can be seen that the incorporation of KP into the rHDPE/NR blend resulted in a reduction of elongation at break. This may be attributed to the decreased polymer chain mobility or deformability of a rigid interface between the filler and the matrix.

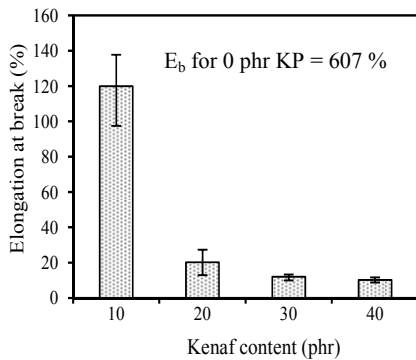


Fig. 5 Elongation at break vs. KP content of rHDPE/NR/KP biocomposites.

Tensile modulus increased with increasing filler loading, as shown in Fig. 6. The addition of KP was expected to increase the modulus resulting from the inclusion of rigid filler particles in the soft matrix.

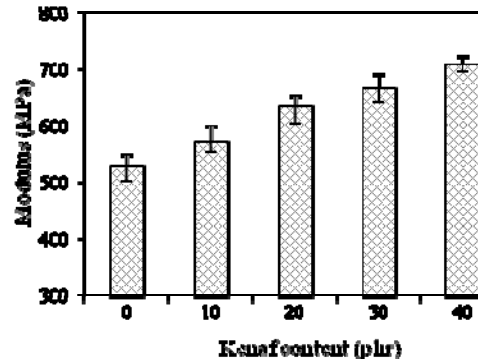


Fig. 6 Tensile modulus vs. KP content of rHDPE/NR/KP biocomposites.

### 3.3 Water Absorption

Fig. 7 shows the effect of KP loading on water absorption of KP filled rHDPE/NR biocomposites. Obviously, the water absorption increased with increasing filler loading. Natural fibers being lignocellulosic are highly hydrophilic in nature and are permeable to water. Incorporation of lignocellulosic filler into polymeric composites thus generally increases the rates of water sorption ability by forming hydrogen bonding between water and the hydroxyl group of cellulose, hemicellulose and lignin in the cell wall [6].

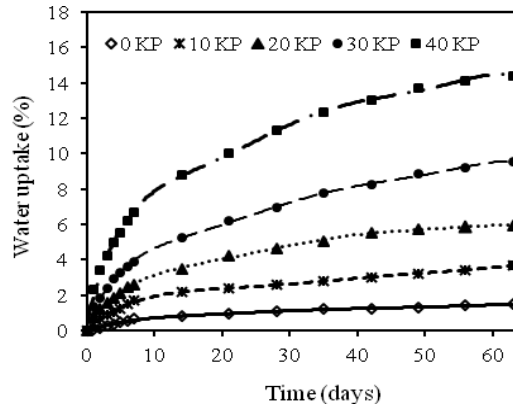


Fig. 7 Water absorption vs. time of rHDPE/NR/KP biocomposites.

### 3.4 Morphology Study

Scanning electron microscopy (SEM) was used to examine the tensile fracture surface of rHDPE/NR biocomposites based on 10, 30 and 40 phr of KP. SEM micrographs of the fracture surface of KP filled rHDPE/NR biocomposites are shown in Fig. 8 a (10 phr), b (30 phr) and c (40 phr). It can be observed that at lower filler content, sample had high fibrillation and deformed in ductile mode. However, at higher filler content, many

detachments of KP from the matrix as well as the formation of voids can be seen clearly in Fig. 8b and 8c. These features were evidences of poor interfacial adhesion between fiber and matrix. Therefore, lower tensile strength and elongation at break as well as higher water adsorption were obtained for the composites at high filler loading.

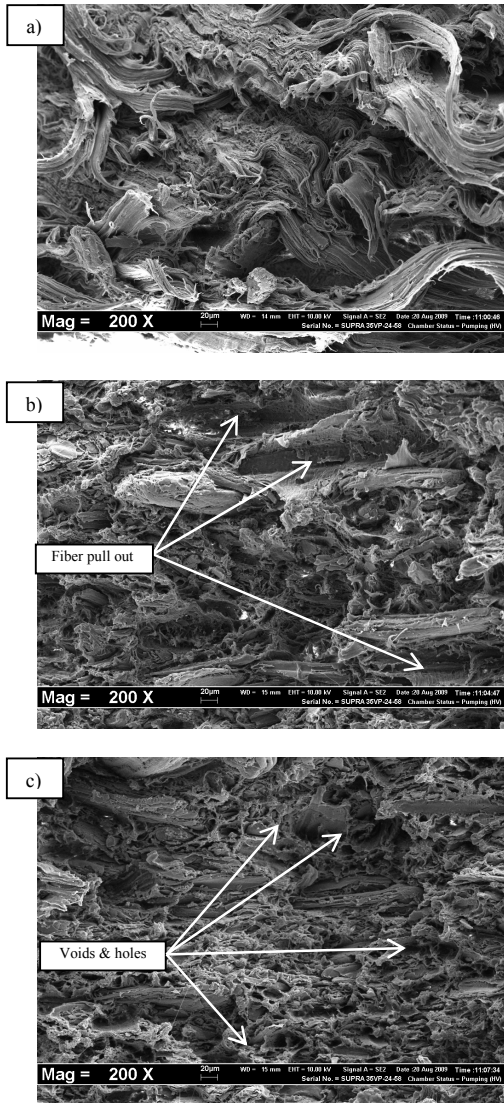


Fig. 8 SEM micrographs of rHDPE/NR/KP biocomposites at different filler content: a) 10 phr , b) 30 phr, and c) 40 phr.

#### 4. Conclusion

The processability and mechanical properties of rHDPE/NR/KP biocomposites were studied with respect to filler content. It was found that the incorporation of kenaf core powder into rHDPE/NR blend increased the stabilization torque and the tensile modulus but decreased the tensile strength, elongation at break of the composites. The poor performance of ultimate properties was attributed to the poor filler-matrix adhesion. Water absorption of kenaf filled rHDPE/NR biocomposites also increased with increasing filler content.

#### REFERENCES

- [1] Grigoryeva, O., Fainleib, A., Starostenko, O., Tolstov, A., and Brostow, W., (2004), Thermoplastic elastomers from rubber and recycled polyethylene: chemical reactions at interphases for property enhancement, *Polymer International*, 53(11), p. 1693-1703.
- [2] Bledzki, A. K., and Gassan, J., (1999), Composites reinforced with cellulose based fibres. *Progress in Polymer Science*, 24(2), p. 221-274.
- [3] Nishino, T., Hirao, K., Kotera, M., Nakamae, K., and Inagaki, H., (2003), Kenaf reinforced biodegradable composite. *Composites Science and Technology*, 63(9), p. 1281-1286.
- [4] Ismail, H., Salmah, and Nasir, M., (2001), Dynamic vulcanization of rubberwood-filled polypropylene/natural rubber blends. *Polymer Testing*, 20(7), p. 819-823.
- [5] Jamil, MS., Ahmad, I., and Abdullah, I., (2006), Effects of rice husk filler on the mechanical and thermal properties of liquid natural rubber compatibilized high-density polyethylene/natural rubber blends. *Journal of Polymer Research*, 13(4), p. 315-321.
- [6] Jacob, M., Varughese, K.T., and Thomas, S., (2005), Water sorption studies of hybrid biofiber-reinforced natural rubber biocomposites. *Biomacromolecules*, 6(6), p. 2969-2979.
- [7] Manufacture