Journal of Polymer Science and Technology 2(2) 2017:62-66
ISSN: 2550-1917

MECHANICAL AND PHYSICAL PROPERTIES OF NATURAL RUBBER/HIGH DENSITY POLYETHYLENE HYBRID COMPOSITES REINFORCED WITH MENGKUANG FIBER AND EGGSHELL POWDER

FATIN FARAH HANIM AYUB[1], WAN ZARINA WAN MOHAMED[1,3], MOHD RAZI MAT PIAH[1], AZIZAH BAHARUM[1,2]*

[1]*School of Chemical Sciences and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia 43600, Bangi, Selangor, MALAYSIA*

[2]*Polymer Research Center, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi , Selangor, MALAYSIA*

[3]*Faculty of Science and Biotechnology, Universiti Selangor, 45600 Bestari Jaya Selangor, MALAYSIA.*

**Corresponding author: azeiss@ukm.edu.my*

ABSTRACT

This research was conducted to study the effect of addition of eggshell powder on physical and mechanical properties of natural rubber/high density polyethylene/Mengkuang fiber/eggshell (NR:HDPE:(MK/KT)) powder hybrid composite. The preparation of composite utilized the method of melt blending, which was blended for 18 minutes at 135 ºC and rotor speed 50 r.p.m. The composites of NR:HDPE:(MK/KT) were prepared with 60:40:20 weight ratio. The mengkuang fiber/eggshell powder hybrid composites were prepared with 5, 10, 15, 20 weight % of fiber. Mechanical properties of the composites were investigated using tensile test and impact test. Results obtained indicates that hybrid composite of NR/HDPE with 15:5 weight ratio of MK/KT filler had the optimum performance. The tensile test shows a maximum tensile strength of 4.2 MPa for hybrid composite NR/HDPE with 15:5 weight ratio of composition of filler. Whereas, the impact test shows a maximum impact strength of 2.1 MPa for hybrid composite of NR/HDPE with composition of 10:10 MK/KT filler. The addition of eggshell powder has reduced the water uptake. Morphological study on the composites shows a good fiber distribution throughout the hybrid composites and the addition of the eggshell powder promoted better fiber-matrix interaction. In conclusion, the addition of eggshell improves the mechanical properties of the composites.

Keywords: hybrid composites; eggshell powder; mengkuang fiber

INTRODUCTION

Hybrid composite with particulate filler has been widely studied. Hybrid composite is defined as the combination of two or more different type of fillers in a common matrix. Hybridization offers many advantages. One of the advantages of hybrid composites is cost reduction because filler with low cost can be used to enhance the properties of composites. Hybrid composites containing waste raw materials can also be made to produce composites with good mechanical properties [1].

Polymer matrix composite material is one that uses organic polymer as matrix and fiber as reinforcement. Normally, strength and modulus of fiber are much higher than the matrix. Natural fibers which are normally used as a filler in polymer composite have many advantages, for example they have low density, they are recyclable and biodegradable [2]. The problem of using natural fiber that must be considered is the compatibility of the fiber with matrix. Natural fibers are hydrophilic in nature so they are not compatible with hydrophobic matrices. This incompatibility will lead to poor wetting of the fibers with the matrix and a reduction in mechanical performance. Incorporation of fillers with eggshell powder was used to reduce agglomeration and to enhance the mechanical properties of the composites. The total filler used in this study was varied and the highest percentage of filler used was 20%.

Eggshell is chosen because it has low density compared to mineral calcium carbonate and can reduce cost since most filler are much less expensive than the matrix resin [3]. Another advantage of using eggshell powder is that they can also increase the viscosity of the material and promotes a better interaction between matrix and filler. Increased viscosity can reduce agglomeration of natural fiber and the dispersion of the filler will improve.

In the present work a detailed investigation on natural rubber/HDPE/mengkuang fiber (MK) and eggshell powder (KT) has been studied. The effect of filler loading on the mechanical and physical properties of the composites was investigated. The mechanical properties was investigated through tensile test while the physical properties was observed via water absorption test. Morphological examination was conducted to study the interaction between the matrix and the filler via the fracture of surface specimen.

EXPERIMENTAL

Material

Natural rubber with grade SMR-L was obtained from the Malaysian Rubber Board. High-density polyethylene (HDPE) was supplied by Etilinas Polyethylene Sdn. Bhd. Mengkuang leaves and eggshells were obtained locally and processed at Universiti Kebangsaan Malaysia.

Preparation of MK Fibers

Mengkuang leaves were cut into (2×2) cm^2 and dried under the sunlight for 4 days. Then, the dried leaves were ground using Refec Granular, Model DF-15 fiber-cutting machine. The MK powder was washed until the green solutions turn clear. The MK fiber was soaked in water for 72 hours. After 72 hours, the MK fiber was dried in an oven at 80ºC. Next, the MK fiber was sieved using sieve shaker to obtain fiber size between 125-250 µm.

Preparation of eggshell powder

Eggshells were washed and then dried under the sunlight for 24 hours. The dried eggshells were ground using a blender. Then, the eggshell powder was sieved using sieve shaker to obtain a size of less than 125 µm.

Preparation of Hybrid Composites

The composition of filler and matrix is summarized in Table 1. NR/HDPE composites with with weight ratio 60/40 were prepared. The blending conditions used were temperature (135 ºC), rotor speed (50 rpm) and mixing time (18 minutes). Eggshell powder was first added into the internal mixer followed by MK fibers. NR was added in the third minute and then followed by HDPE in the fifth minute. The composites obtained were hot pressed at temperature of 145 ºC and pressure of 70 N/m^2 for 15 minutes. After that, the composites were cooled for at least 15 minutes to retain the shapes of the composites. The composites with thickness of 1 mm and 3 mm were prepared to investigate the mechanical and physical properties of the composites.

Received: 5th August 2017; Accepted: 20th August 2017

Table 1 Composition of filler and matrix

Composites	Ratio of matrix (NR/HDPE)	Mengkuang fiber (%)	Eggshell powder (%)
A	60/40	20	0
B	60/40	15	5
C	60/40	10	10
D	60/40	5	15
E	60/40	0	20

Tensile test

The test was conducted using universal testing machine (INSTRON model 5566). The composites with thickness of 1 mm were cut according to ASTM D412 standard using a dumbbell cutter. The specimens dimension was 75 mm × 12 mm. The crosshead speed and load cell used was 50 mm/min and 1kN.

Water Absorption Test

The test was conducted according to ASTM D570 standard. First, the specimens were dried in an oven at temperature 80ºC. Then, the specimen weight, length and thickness were measured. The specimens were soaked in distilled water for 24 hours at room temperature. The specimens dimension was 65 mm × 12 mm × 3 mm. The weight gain of the sample was measured as percentage of water uptake using the following formula:

$$\text{Water uptake (\%)} = \frac{W_t - W_0}{W_0} \times 100$$

where W_t is weight of composites after immersion and W_0 is weight of composites before immersion.

Morphological Examination

Morphological examination was conducted using scanning electron microscope (SEM). The investigation was performed on the fractured surface from tensile test specimens.

RESULTS AND DISCUSSION

Tensile Strength

Result for tensile strength is provided in Fig. 1. The tensile strength of hybrid composites was varied. Addition of 5% eggshell powder increased the tensile strength. A further addition of eggshell powder to 20% has reduced the tensile strength. Therefore, the most optimum of filler loading is at MK: KT 15:5, with the highest tensile strength 4.2 MPa.

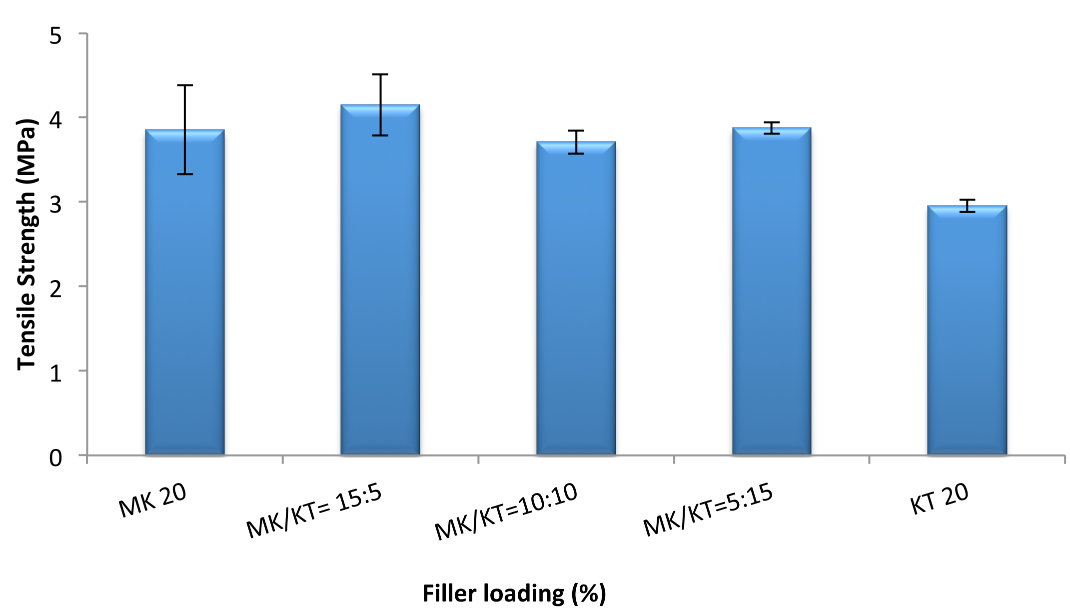

Fig. 1 Effects of filler loadings on the tensile strength

The results of tensile strength of hybrid composites show an improvement compared to NR/HDPE/MK blend. The enhancement of the tensile strength indicated that the eggshell powder has filled the microspores between mengkuang fiber and the matrix and gives a well dispersion of the filler in the matrix. Study of tensile strength of EFB/jute by Jawaid et. al [4] reported that hybridization enhanced mechanical performance of hybrid composites compared to individual fiber composites. Bashir et al. [5] highlighted that a well dispersion of filler in the matrix can improve the tensile strength of composites. A further addition of eggshell powder resulted a slight decrease in tensile strength. This could be attributed to the formation of cavities around the filler particles, which could reduce matrix-filler adhesion. A poor adhesion between filler and matrix will reduce the stress transfer ability in composites and causes failure to the sample [6].

Tensile Modulus

Fig. 2 shows effects of filler loadings on the tensile modulus. Addition of 5% eggshell powder increased the tensile modulus. This shows that the composite has a good adhesion between the filler and matrix [7].

The tensile modulus decreased with further addition of eggshell powder to 20%. This could be due to the restricted movement caused by the filler when eggshell powder is added. Addition of eggshell powder has reduced the rigidity of the hybrid composites. Formation of agglomeration will lead to insufficient homogeneity and also the rigidity of the composites. The incorporation of eggshell powder led to lower intermolecular interactions at the interfaces of the composites. Hence, the tensile modulus of the composites decreased.

Elongation at Break

Fig. 3 shows the effects of filler loadings on the elongation at break. The elongation at break increased with increasing filler loading. Addition of eggshell powder to 15% has increased the elongation at break. Hybrid composites have increased the elongation at break compared to individual fiber composites. The increased in the elongation at break with softer composites after the addition of the

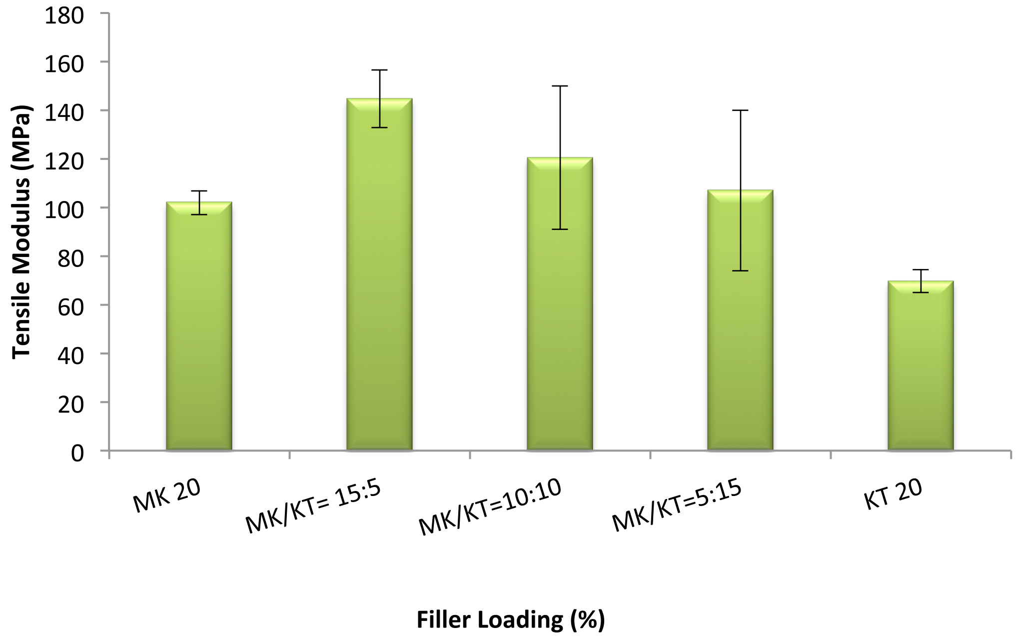

Fig. 2 Effects of filler loadings on the tensile modulus

eggshell powder caused much greater elongation experienced by the filler than the elongation of the specimen [5]. High elongation material arrest the propagation of cracks in a composites [9].

The elongation at break decreased with 20% filler loading. This could be due to the formation of agglomeration thus lead to low adhesion between matrix and filler [9]. The decreased in elongation at break indicates the incapability of the filler to support the stress transfer from polymer filler to matrix [10].

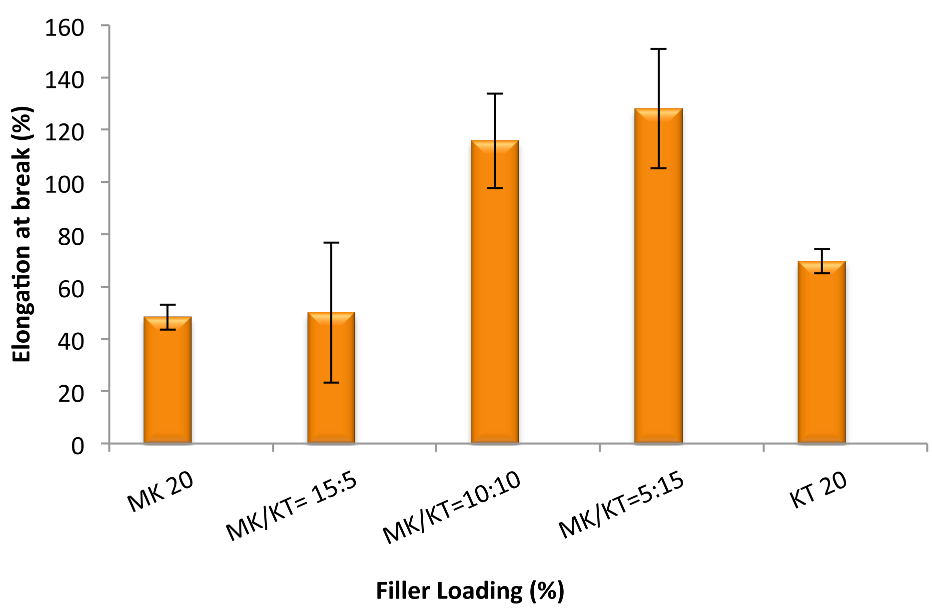

Fig. 3 Effects of filler loadings on the elongation at break

Water Absorption Test

Fig. 4 shows the percentage of water uptake versus exposure time with different filler loadings. NR/HDPE/MK composites has the highest percentage of water uptake because mengkuang fiber is rich with cellulose. Cellulose content will increased the water uptake due to the hydrogen bonds that form between OH group from cellulose and water [11,12]. Hence, the weight of the NR/HDPE/MK increased.

It can be seen that, the composites with higher eggshell powder content show less water absorption. This is due to the higher filler content in the composites that can absorb less water. The eggshell powder content has reduced the water uptake because it has filled the microspores between the matrix and fiber.

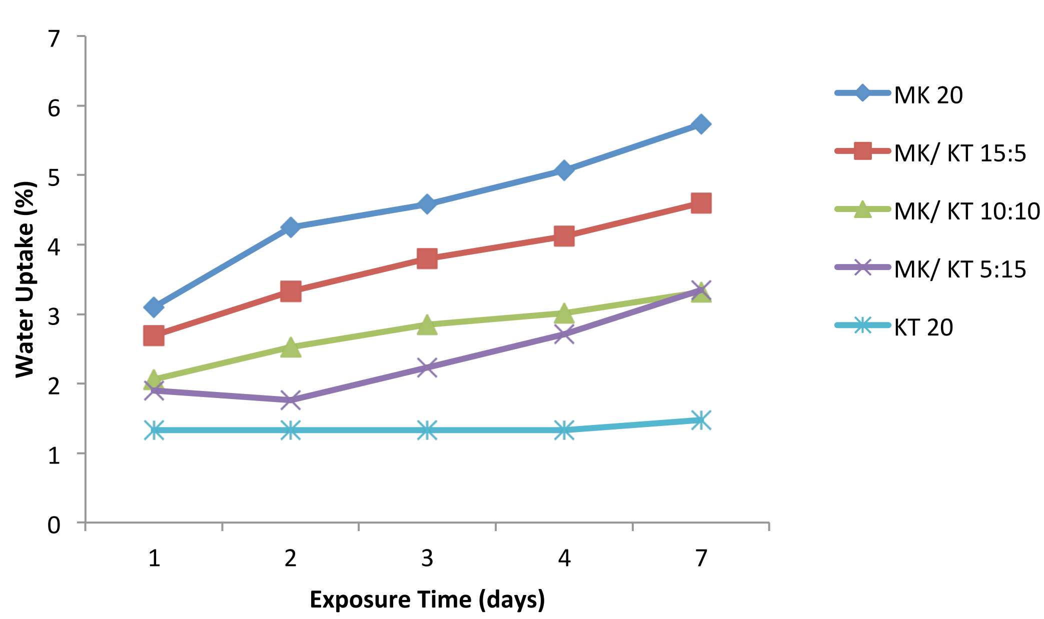

Fig. 4 Percentage of water uptake versus exposure time with different filler loadings

Morphological Observation

The fractured surface morphology from tensile specimens of the composites was studied using scanning electron microscopy (SEM) analysis. Fig. 5(a and b) shows the micrographs of composites with individual filler. From the Fig. 5(a and b), fiber pull-out is observed. Fiber pull-out decreases the mechanical strength of the composites [13]. Formation of agglomeration occurred causing poor interaction between filler and matrix. Hence, the mechanical properties of the composites also decreased.

Fig. 5(c, d and e) shows the micrographs of hybrid composites at different filler loadings under the same magnifications. From Fig. 5c, addition of eggshell powder to 15% shows a formation of agglomeration. Agglomeration has caused the poor interaction between the filler and the matrix. The composites also have low tensile strength due to the formation of agglomeration. From Fig. 5c and d, it can be seen that the composites surfaces seems packed and less microspores formation between the fiber and the matrix was observed. The dispersion of the filler for hybrid composites with 5% eggshell powder was better than the 10% eggshell powder. Fiber pull-out was observed at composites of 10% eggshell powder thus produced low mechanical strength compared to hybrid composites with 5% eggshell powder. Good interaction between filler and matrix will improve the mechanical properties of the composites [14].

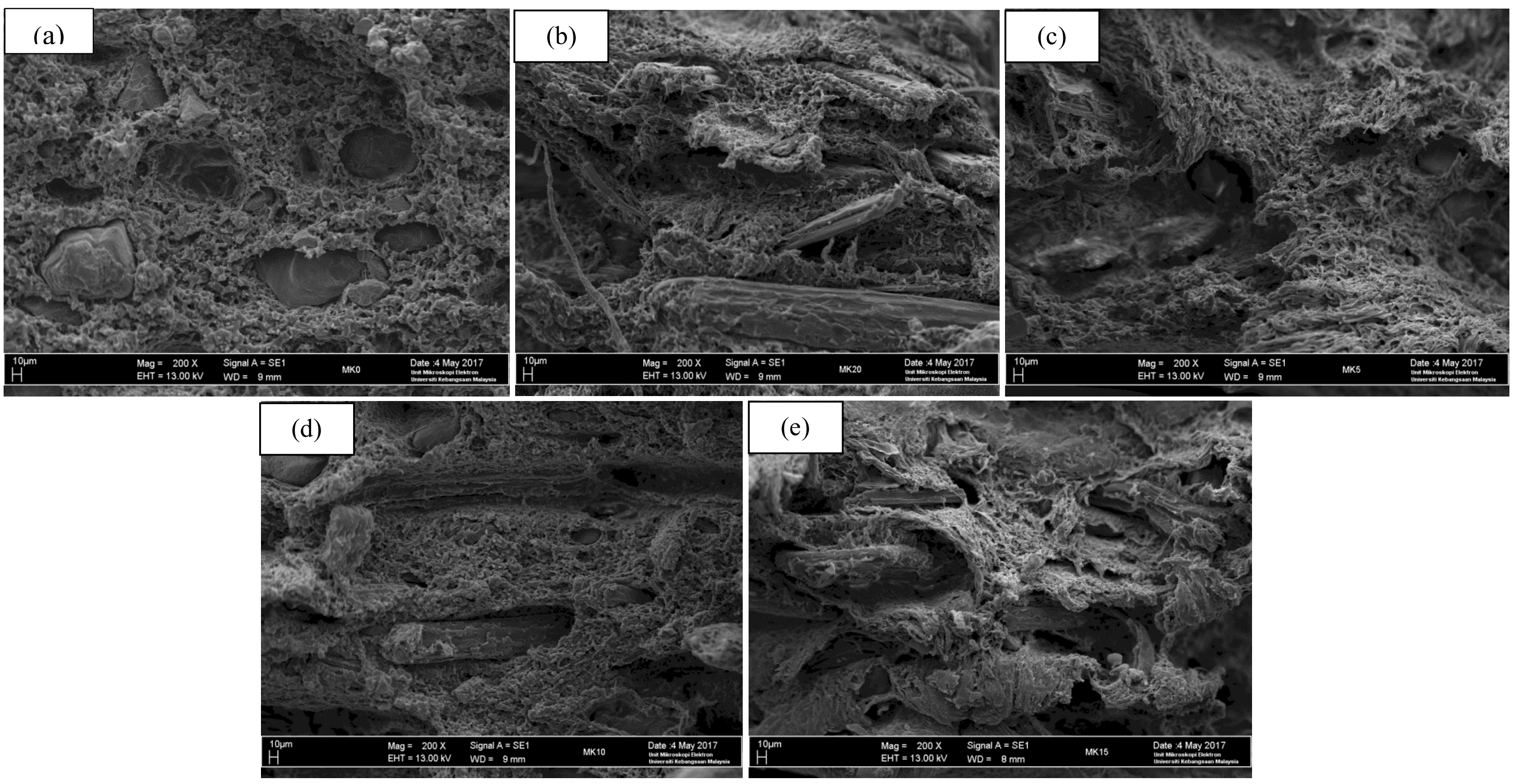

Fig. 5 SEM micrographs (200x) of individual fiber composites and hybrid composites at different fiber loadings: (a) 20% KT fiber loading (b) 20% MK fiber loading (c) MK:KT 15:5 fiber loading of hybrid composites (d) MK:KT 10:10 fiber loading of hybrid composite (e) MK:KT 5:15 fiber loading of hybrid composite

CONCLUSION

The addition of eggshell powder has improved the mechanical and physical strength of the hybrid composites. The optimum fiber loading was identified at MK:KT 15:5 fiber loading with the tensile strength and tensile modulus of 4.2 MPa and 144.7 MPa. Water absorption test showed that the hybrid composites has low water uptake after addition of eggshell powder. Morphological observation for hybrid composites shows a well dispersion of filler compared to individual filler composites. Eggshell powder has filled the microspores between the fiber and matrix. Therefore, this study proved the suitability of addition of eggshell powder as filler in hybrid composites.

ACKNOWLEDGEMENT

The authors would like to acknowledge Universiti Kebangsaan Malaysia for the facilities, equipment and funding support (FRGS/2/2014/TK04/UKM/02/1 and 03-31-02-SF1000) for making this study successful.

REFERENCES

[1] Ashori, A. 2009. Hybrid Composites from Waste Materials. *Journal of Polymers and the Environment* 18(1): 65-70.
[2] Venkatesh, R. P., Ramanathan, K. & Raman, V. S. 2016. Tensile, Flexual, Impact and Water Absorption Properties of Natural Fiber Reinforced Polyester Hybrid Composites. *Fibers & Textiles* 24(3(117): 90-94.
[3] Hassan, S. B. & Aigbodion, V. S. 2015. Effects of Eggshell on the Microstructures and Properties of Al–Cu–Mg/Eggshell Particulate Composites. *Journal of King Saud University – Engineering Sciences* 27(1): 49-56.
[4] Jawaid, M., Khalil, H. P. S. A., Bakar, A. A. & Khanam, P. N. 2011. Chemical Resistance, Void Content and Tensile Properties of Oil Palm/Jute Fiber Reinforced Polymer Hybrid Composite. *Materials and Design* 32: 1014-1019
[5] M. Jawaid & Khalil, H. P. S. A. 2011. Cellulosic/Synthetic Fiber Reinforced Polymer Hybrid Composites: A Review. *Carbohydrate Polymers* 86: 1-18.
[6] Haq, M., Burgueño, R., Mohanty, A. K. & Misra, M. 2008. Hybrid Bio-Based Composites from Blends of Unsaturated Polyester and Soybean Oil Reinforced with Nanoclay and Natural Fibers. *Composites Science and Technology* 68: 3344–3351.
[7] Toro, P., Quijadajose´, R. L., Arias, L. & Yazdani-Pedram, M. 2007. Mechanical and Morphological Studies of Poly(Propylene)-Filled Eggshell Composites. *Macromol. Mater. Eng.* 292: 1027–1034.
[8] Sreekalaa, M. S., Georgeb, J., Kumaranc, M. G. & Thomasa, S. 2002. The Mechanical Performance of Hybrid Phenol-Formaldehyde-BasedComposites Reinforced with Glass and Oil Palm Fibers. *Composites Science and Technology* 62: 339–353.
[9] Siti Shuhadah & Supri, A. G. 2009. Ldpe-Isophthalic Acid-Modified Eggshell Powder Composites (Ldpe/Esp). *Journal of Physical Science* 20(1): 87–98

[10] Busu, H. Anuar, S. H. Ahmad, R. Rasid & Jamal, N. A. 2010. The Mechanical and Physical Properties of Thermoplastic Natural Rubber Hybrid Composites Reinforced with Hibiscus Cannabinus , L and Short Glass Fiber. *Polymer-Plastics Technology and Engineering* 49(13): 1315-1322

[11] Perez-Fonseca, A. A., Robledo-Ortiz, J. R., Ramirez-Arreola, D. E., Ortega-Gudino, P., Rodrigue, D. & Nunez, R. G. 2014. Effect of Hybridization on the Physical and Mechanical Properties of High Density Polyethylene-(Pine/Agave) Composites. *Materials & Design* 64: 35-43.

[12] Boopalan, M., Niranjanaa, M. & Umapathy, M. J. 2013. Study on the Mechanical Properties and Thermal Properties of Jute and Banana Fiber Reinforced Epoxy Hybrid Composites. *Composites Part B: Engineering* 51: 54-57.

[13] Anuar, H., Ahmad, S.H., Rasid, R., & Daud, N. S. N. 2006. Tensile and Impact Properties of Thermoplastic Natural Rubber Reinforced Short Glass Fiber and Empty Fruit Bunch Hybrid Composites. *Polymer-Plastics Technology and Engineering* 45: 1059–1063.