Soil Buried Linear Low Density Polyethylene/Polyvinyl Alcohol/Kenaf Filler (LLdpe/Pvoh/Knf) Composites: Assessment of Tensile Properties and Morphological Feature

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Abstract. The effect of soil burial duration on the tensile properties and morphological feature of linear low density polyethylene/polyvinyl alcohol/kenaf filler (LLDPE/PVOH/KNF) composites was investigated. A Thermo Haake internal mixer was used to fabricate LLDPE/PVOH/KNF composites with KNF content of 0, 10 and 40 parts per hundred resin (phr), respectively. The tensile properties (tensile strength, tensile modulus and elongation at break) and morphological feature of the composites were evaluated before and after 3 months and 6 months of soil burial period. The results revealed that the tensile properties decrease with prolonged period of soil burial. Field emission scanning electron microscopy (FESEM) micrographs showed presence of cracks and pores on composite samples after soil burial exposure.

1. Introduction

Plastics like polyethylene (PE), polypropylene (PE) and polystyrene (PS) are used worldwide in a variety of packaging industry due to its good mechanical properties, easy to process and reasonably priced [Sam and Ismail, 2014]. Nevertheless, the rapid growing in production of plastics has resulted negative impact to environment because of their resistant to degradation when buried in landfills for decades [Ismail et al. 2011]. In order to minimize environmental pollution, several efforts have been done in order to enhance the biodegradability of plastic products. For instance, some researchers blending the plastics with synthetic biodegradable polymers like polyvinyl alcohol (PVOH) [Ismail et al. 2009; Pang et al. 2015]. In addition, numerous researchers introduce natural resources (lignocellulosic materials) as cheaper alternative into non-degradable plastics [Sam and Ismail, 2014; Pang et al. 2016a].

Lignocellulosic materials like kenaf fiber have been extensively used as filler in plastic composites owing to their biodegradability, high stiffness and strength, as well as cost effective [Sarifuddin et al. 2013; Pang et al. 2016b]. The degradation of fiber-plastic composites depends on a few factors
including the fiber loading, degradability of each component, and quality of the fiber-matrix interface [Abdul Khalil et al. 2010]. Generally, the addition of fiber increases the degradation of composites and could lead to a mechanically weakened polymer [Abdul Khalil et al. 2010; Ismail et al. 2011; Anankaphong et al. 2015].

This study aimed to investigate the degradation behavior of LLDPE/PVOH/KNF composites after exposed to soil burial test. The tensile test and surface morphology were measured to characterize the changes after soil burial exposure for a predetermined time.

2. Experimental Method

2.1 Materials

Linear low density polyethylene (LLDPE) and polyvinyl alcohol (PVOH) were purchased from PT. Lotte Chemical Titan Nusantara, Indonesia and Sigma-Aldrich Sdn. Bhd., Malaysia, respectively. Kenaf (KNF) was supplied by National Kenaf and Tobacco Board (LKTN), Kelantan, Malaysia. KNF was ground to particle size of ≤ 75 μm, prior to be used as filler in LLDPE/PVOH blend.

2.2 Preparation of composites

KNF was dried in oven at 80 °C for 24 hours prior to composites preparation. The weight ratio of LLDPE and PVOH was kept at 60:40 (by weight percent) for all loadings of KNF being studied such as 0, 10 and 40 parts per hundred resin (phr). LLDPE/PVOH/KNF composites were melt-blended with a rotor speed of 50 rpm at 150 °C, using a Thermo-Haake internal mixer (Model: R600/610). Subsequently, the composites were undergoing compression molding at 150 °C to form into a 1 mm thickness molded-sheet, using an electrically heated hydraulic press (GoTech Compression Machine, Model: KT-7014 A).

2.3 Soil burial test

A simple soil burial test was carried out to determine the degradation rate of composites and is conducted according to the method used by Sam et al. (2011) and Ismail et al. (2011). LLDPE/PVOH/KNF composites (dumbbell-shaped) were placed inside a polybag, covered by soil and was subjected to natural soil burial. The location for soil burial test was at Universiti Sains Malaysia with latitude 5°8’N and longitude 100°29’E. The effect of short-term response to soil burial test (3 and 6 months) was chosen, attributed to the present of biodegradable materials like KNF and PVOH. After 3 and 6 months of soil burial exposure, the composite samples were retrieved, cleaned and washed with distilled water to remove soil debris on the surface. Next, the samples were dried in oven (60 °C) until reaching a constant weight, and placed in desiccator.

2.4 Tensile test

The tensile test was conducted in accordance with ASTM D638 on the composite samples before and after soil burial exposure, using a universal testing machine (Model: Instron 3366). The test was carried out with a crosshead speed of 5 mm / min at 25 ± 3 °C. A total of five samples were tested to obtain the mean values of tensile properties such as tensile strength, tensile modulus and elongation at break.

2.5 Field emission scanning electron microscopy (FESEM)

Field emission scanning electron microscope (FESEM, Zeiss Supra-35VP) was employed to evaluate surface of specimens before and after subjected to soil burial test. Prior to surface examination, the
specimens were sputter-coated with gold (thin layer) to avoid electrostatic charging and poor resolution.

3. Results and Discussion

3.1 Tensile properties

Table 1 shows the tensile properties (tensile strength, tensile modulus, elongation at break) of LLDPE/PVOH/KNF composites at different KNF loadings; before, after 3 and 6 months being buried in natural soil. As expected, the tensile strength, tensile modulus as well as elongation at break decreased with increasing soil burial duration. Furthermore, it is clearly presented in Table 2 that the composites exposed to 6 months soil burial exhibited lower tensile properties retention. The reduction in tensile properties and their retention over the 6 months soil burial exposure could be due to PVOH and KNF leached out from composites, resulting from the interaction with moisture. Subsequently, the composites start to lose their structural strength and thereby diminished its stress transfer ability. Moreover, the possibility of microorganism attack on composites surface could lead to further degradation, and in turn deteriorates the composites’ tensile properties. Similar finding was reported by Ismail et al. (2011), who stated that the microbes attack on linear low density polyethylene/thermoplastic sago starch (LDPE/TPSS) resin may be responsible for the fine cracking and tearing that led to further degradation, and hence results in lower tensile properties. Meanwhile, according to Sam and Ismail (2014), degradation of composites in the soil environment was mainly attributed to microorganism consumption and moisture interaction.

Table 1. Tensile properties of LLDPE/PVOH/KNF composites at 0, 10, and 40 phr KNF loading, before, after 3 and 6 months soil burial.

| KNF loading (phr) | Tensile strength (MPa) | Tensile modulus (MPa) | Elongation at break (%) |
|-------------------|------------------------|-----------------------|-------------------------|
|                   | Control | After 3 months | After 6 months | Control | After 3 months | After 6 months | Control | After 3 months | After 6 months |
| 0                 | 9.3 ± 0.05 | 9.0 ± 0.19 | 8.5 ± 0.19 | 666.4 ± 11.06 | 552.9 ± 59.33 | 512.9 ± 40.38 | 7.5 ± 0.49 | 7.3 ± 0.21 | 6.6 ± 0.12 |
| 10                | 8.6 ± 0.17 | 8.3 ± 0.23 | 7.9 ± 0.22 | 796.5 ± 23.71 | 580.4 ± 66.81 | 559.5 ± 58.97 | 6.5 ± 0.56 | 6.2 ± 0.18 | 5.7 ± 0.11 |
| 40                | 7.1 ± 0.15 | 6.5 ± 0.26 | 6.2 ± 0.16 | 1169.0 ± 25.54 | 806.0 ± 13.85 | 675.2 ± 25.95 | 3.0 ± 0.13 | 2.6 ± 0.18 | 2.2 ± 0.24 |

Table 2. Retention of tensile properties for LLDPE/PVOH/KNF composites at 0, 10, and 40 phr KNF loading, after 3 and 6 months soil burial.

| KNF loading (phr) | Retention for 3 months (%) | Retention for 6 months (%) |
|-------------------|-----------------------------|-----------------------------|
|                   | Tensile strength | Tensile modulus | Elongation at break | Tensile strength | Tensile modulus | Elongation at break |
| 0                 | 96.7            | 83.0             | 96.8             | 92.3            | 77.0             | 88.4             |
| 10                | 96.0            | 72.9             | 95.3             | 91.9            | 70.2             | 87.3             |
| 40                | 92.3            | 68.9             | 88.3             | 78.3            | 57.8             | 73.8             |

3.2 Morphological analysis

Figure 1 illustrates the FESEM micrographs of LLDPE/PVOH matrices and LLDPE/PVOH/40 phr KNF composites before, after 3 and 6 months soil burial exposure, respectively. For both LLDPE/PVOH matrices and LLDPE/PVOH/40 phr KNF composites, higher degradation effect was observed with increasing soil burial duration. Comparing Figure 1 (b and d) and (c and e), it is
noticeable that the addition of KNF to LLDPE/PVOH matrices contributes to higher degradation rate after soil burial exposure. After 3 months soil burial exposure, there is presence of fine cracks on LLDPE/PVOH matrices surface (Figure 1c). However, more cracks and micro-pores are found on the surface of LLDPE/PVOH matrices after 6 months soil burial (Figure 1e). The pores on matrices surface possibly due to leaching of PVOH from the blend. Consequently, the matrices lose its strength with prolonged soil burial exposure.

On the other hand, Figure 1 (d and f) demonstrate the degradation surfaces of LLDPE/PVOH/40 phr KNF composites after 3 and 6 months soil burial. The composites surface shows the existence of large pores after 3 months and 6 months exposure. In Figure 1(f), it is visible that the large pores formed are deeper and KNF was seen exposed to the surface. The presence of large pores could possibly due to the leaching of both PVOH and KNF, due to the interaction with moisture in soil. These pores may act as stress concentration points and hence lead to the deterioration in tensile properties. Furthermore, it can also be a channel for moisture and/or microorganism to diffuse or enter into the polymer. This finding is in agreement with the lower tensile properties and its retention after prolonged soil burial exposure.

![Figure 1. FESEM micrographs of LLDPE/PVOH matrices (a) before, (c) after 3 months, and (e) after 6 months soil burial; and LLDPE/PVOH/40 phr KNF composite (b) before, (d) after 3 months, and (f) after 6 months soil burial, respectively.](image)

4. Conclusion

After subjected to soil burial exposure, the tensile properties (tensile strength, tensile modulus and elongation at break) of LLDPE/PVOH/KNF composites were decreased. As revealed from tensile
results, greater reduction in tensile properties of LLDPE/PVOH/KNF composites with prolonged soil burial duration. Moreover, FESEM analysis shows formation of crack and pores on composite surface after soil burial exposure.

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References

[1] Sam ST and Ismail H 2014 Journal of Vinyl & Additive Technology 20 42
[2] Tan Z, Yi Y, Wang H, Zhou W, Yang Y and Wang C 2016 Applied Science 6 147
[3] Ismail H, Majid RA and Taib RM 2011 Pertanika Journal of Science & Technology 19 189
[4] Ismail H, Ahmad Z, Nordin R and Rashid A 2009 Polymer-Plastics Technology and Engineering 48 1191
[5] Pang AL, Ismail H and Abu Bakar A 2015 Biore 10 7302
[6] Pang AL, Ismail H and Abu Bakar A 2016a Procedia Chemistry 19 505
[7] Muniyasamy S, Anstey A, Reddy MM, Misra M and Mohanty A 2013 Journal of Renewable Materials 1 253
[8] Sapuan SM, Pua FL, El-Shekeil YA, and AL-Oqla FM 2013 Material & Design 50 467
[9] Sarifuddin N, Ismail H and Ahmad Z 2013 Journal of Physical Science 24 97
[10] Pang AL, Ismail H and Abu Bakar A 2016b Biore 11 5889
[11] Abdul Khalil HPS, Bhat I and Sartika MY 2010 Biore 5 2278
[12] Anankaphong H, Pentrakoon D and Junkasem J 2015 International Journal of Polymer Science 2015 368341
[13] Sam ST, Ismail H and Ahmad Z 2011 Polymer-Plastics Technology and Engineering 50 851