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Tensile Properties and Water Absorption of Spear Grass Fibre Filled High Density Polyethylene/Thermoplastic Soya Spent Powder Composites

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Abstract: *The study was focused on the tensile properties, morphology, water absorption and thermogravimetric analysis (TGA) of degradable composites which are produced from high density polyethylene (HDPE)/thermoplastic soya spent (TPSS) powder with the addition of spear grass filler. HDPE/TPSS at the ratio of 90:10 was used as matrix in the composites. In this ratio, the tensile strength of the HDPE was not much deteriorated by TPSS. However, significant effect on degradation was observed based on previous research. The addition of spear grass filler has further reduced the tensile strength of the composites, yet the tensile modulus of the composites was improved. Nevertheless, the tensile strength, elongation at break of the composite was improved with the presence of polyethylene grafted maleic anhydride (PE-g-MA) as a compatibiliser. The water absorption shows the increase of the water uptake with the addition of spear grass filler.*

Keywords: Thermoplastic soy spent powder, high density polyethylene, biocomposites, spear grass fibre, compatibiliser

1. INTRODUCTION

Biocomposites are a combination of natural fibres and polymers, currently attracting the interest of both academic and industrial. The matrices from the biocomposites can be natural-based or petroleum-based polymer.[1] The biocomposites are also attractive with their superior mechanical, physical and chemical properties. Most importantly, the fibres are a renewable resource. According to Le Duigou et al.,[2] the utilisation of natural fibres provides alternative end-of-life scenarios to incineration, as they are recyclable and compostable. In recent years, many researches are focusing on biodegradable polymers as composite matrices such as polylactic acid (PLA), thermoplastic starch, celluse and biodegradable polyester. However, the availability of the matrices is poor and the price of biodegradable polymers is expensive compared to petroleum based polymer.

The matrices from the blends of petroleum-based polymer and natural polymer are alternatives to produce a biocomposites with good mechanical properties and low cost. The studies with good mechanical and thermal properties of using polyolefins/starch as blends as matrices are low density polyethylene (LDPE)/corn starch,[3] LDPE/sago starch,[4] LDPE/potato starch[5] and LDPE/rice starch.[6] However, the addition of starch into the plastic has raised the global food issue. The incorporation of crop-based material might increase the food depletion problem of the world. Thus, non-crop based plant product as a blend with plastic is one of the alternative to produce degradable polymers. Soy spent powder blends with high density polyethylene (HDPE) was used in this study. Soy spent powder is mostly a soy carbohydrate fraction in soybean and it is mostly an insoluble carbohydrate after most of soy protein and soy whey, a soluble carbohydrate, are removed from defatted soy flour. Most importantly, soy spent powder is a by-product or residue in the commercial extraction process of soy protein isolate. Therefore, it is an abundant and inexpensive renewable material.[7]

Natural fibres have many advantages including low cost, abundance, low density, high specific properties and lack of residues upon incineration.[1] The natural fibres that are commonly used in biocomposites are sugar cane,[8] bast,[9] fuzzy[10] and jute fibre.[11] In this study, spear grass was used as natural fibre to produce biocomposites. Spear grass is one of the worst weeds of the world as it is considered a pernicious pest plant due to its ability to successfully colonise, spread, and subsequently displace vegetation and disrupt ecosystems.[12]

In the current study, thermoplastic soy spent (TPSS) powder was blended with HDPE. Spear grass fibre was added into the blends. Polyethylene grafted maleic anhydride (PE-g-MA) was used as a compatibiliser in the blends. The tensile properties, thermal properties and water absorption of the specimens were investigated.

2. EXPERIMENTAL

2.1 Materials

HDPE was supplied by Polyethylene Malaysia Sdn. Bhd. Soya powder with a melt flow index of 1.0 g (10 min)$^{-1}$ was purchased from Hasrat Bestari (M) Sdn. Bhd. The moisture content was 3.12% and the protein content was 60%.

Spear grass was collected from the area in Perlis, Malaysia. PE-g-MA with appropriate 3 wt% grafted level was supplied by Aldrich Chemical Company (Milwaukee, USA).

2.2 Preparation of TPSS

Soy spent powder was dried in a vacuum oven for 24 h at 70°C. TPSS was prepared by premixing soy spent powder with 35 wt% liquid glycerol in a kitchen blender with a capacity of 150 g. The mixture was considered ready when the starch was fully covered with the liquid glycerol after mixing for 5 min. The mixture was stored in a drying cabinet for 24 h at room temperature. After 24 h, the mixture was melt-mixed again using heated two-roll mills at 150°C for 10 min.

2.3 Filler Preparation

The spear grass fibre was ground in a table-type pulverising machine at a speed of 2850 rpm and was sieved with a 70-mesh.

2.4 Mixing of spear grass filled HDPE/TPSS composites

HDPE was blended with TPSS, varying spear grass fibre content between 5 and 20 wt%, using a Haake Reodrive 5000 internal mixer maintaining the operating temperature at around 150°C and rotor speed of 50 rpm. The ratio of blends is shown in Table 1. The concentration of PE-g-MA was 30 wt% based on spear grass fibre content. Spear grass filled HDPE/TPSS composites were compression molded by using a hot press. The hot press temperature was maintained at 150°C. Moulded samples were cut into dumb-bell shapes according to ISO 527.

Table 1: Composition of HDPE/spear grass composites.

Materials	Formulation (wt%)
HDPE	100% HDPE
HDPE/5% spear grass	95% HDPE + 5% spear grass
HDPE/10% spear grass	90% HDPE + 10% spear grass
HDPE/15% spear grass	85% HDPE + 15% spear grass
HDPE/20% spear grass	60% HDPE + 40% spear grass

**Similar formulations of HDPE/ spear grass composites were prepared with PE-g-MA as compatibiliser. 50% of PE-g-MA based on spear grass loading was used.*

2.5 Tensile Properties

Five dumbbell-shaped samples were subjected to tensile test. The tensile tests were carried out with an Instron Universal Testing Machine (Model Instron 3366) with a crosshead speed of 50 mm min^{-1}. Five samples were tested and the average was taken. The parameters obtained were tensile strength, elongation at break (Eb) and Young's modulus.

2.6 Water Absorption

Specimens were dried at 80°C in a vacuum oven until a constant weight before immersed into distilled water. The water absorption tests were performed for 30 days at room temperature. Weight gains were recorded by periodic removal of the specimen from the water container and weighing on a balance with a precision of 1 mg. The percentage gain at any time t, M_a as a result of moisture absorption, was determined by the following equation:

$$Ma\,(\%) = \frac{Wf - Wi}{Wi}\ x\ 100\,\% \qquad (1)$$

where W_i and W_f denote the initial weight and weight after exposure to water absorption weight, respectively.

3. RESULTS AND DISCUSSION

3.1 Tensile Properties

Figure 1 shows the comparison of tensile strength of HDPE/TPSS-spear grass fibre composites. It can be seen that the tensile strength of the composites increased up to 10 wt% spear grass fibre and thereafter decreased. The reason is that the fibre had reinforcing effect to the composites. However, the composites with higher filler content might have poor filler distribution in the matrix. The addition of PE-g-MA as a compatibiliser had improved the tensile strength of the matrices and composites. The improvement of the matrices is due to the compatilising effect of PE-g-MA on hydrophilic group of TPSS and hydrophobic group of HDPE. In Figure 1, the compatibilising effect of PE-g-MA increased after the addition of spear grass fibre. This is due to the increased of hydrophilic group in spear grass fibre.

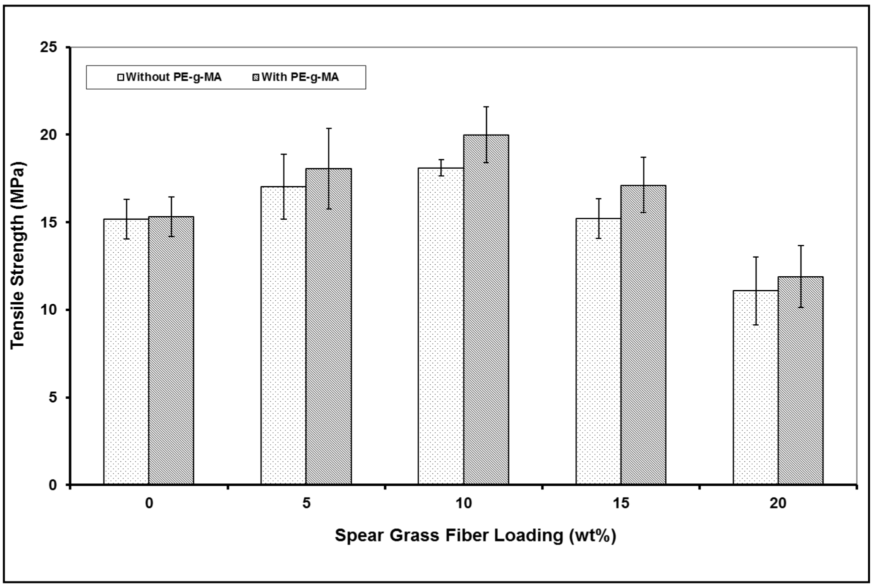

Figure 1: Tensile strength of HDPE/TPSS-spear grass fiber with and without PE-g-MA.

Figure 2 demonstrates the elongation at break (Eb) of the grass fibre filled composites. The results indicate that the Eb was improved with the incorporation of spear grass fibre. The optimum content for the spear grass fibre to achieved maximum value of the Eb was also 10 wt%. The fibre is well distributed in lower loading consequently give reinforcing effect to the composites. The reduction of the Eb at 15 wt% was due to the agglomeration of the filler in the matrix. The agglomeration of the spear grass fibre resulted in the stress cannot be transferred to the matrix under tensile load, therefore the Eb decreased in high fibre content. Nevertheless, the addition of PE-g-MA has enhanced the agglomeration effect of the fibre by increasing the interfacial adhesion between matrix and the fibre.[13]

Figure 3 shows the Young's modulus of the spear grass fibre filled composites with and without compatibiliser. It can be seen that the addition of spear grass fibre had increased the Young's modulus of the composites. This indicated that the fibre gave stiffening effect to the composites. The enhancement of the interfacial adhesion between fibre and the matrix resulted in the increment of Young's modulus.

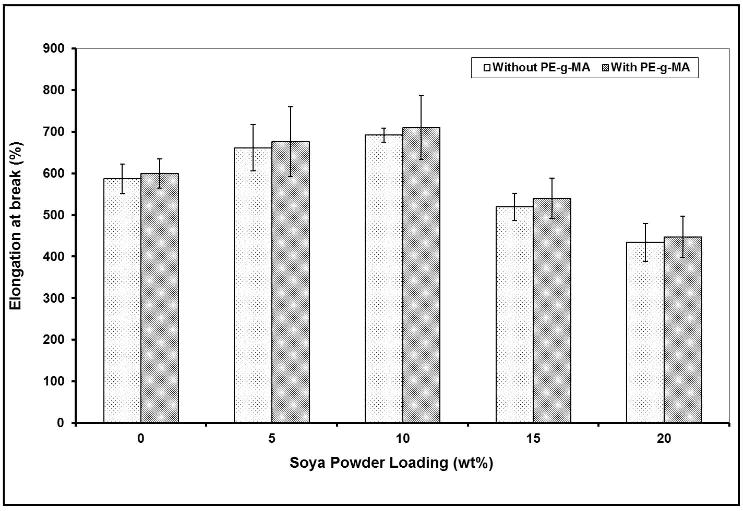

Figure 2: Elongation at break of HDPE/TPSS-spear grass fibre with and without PE-g-MA.

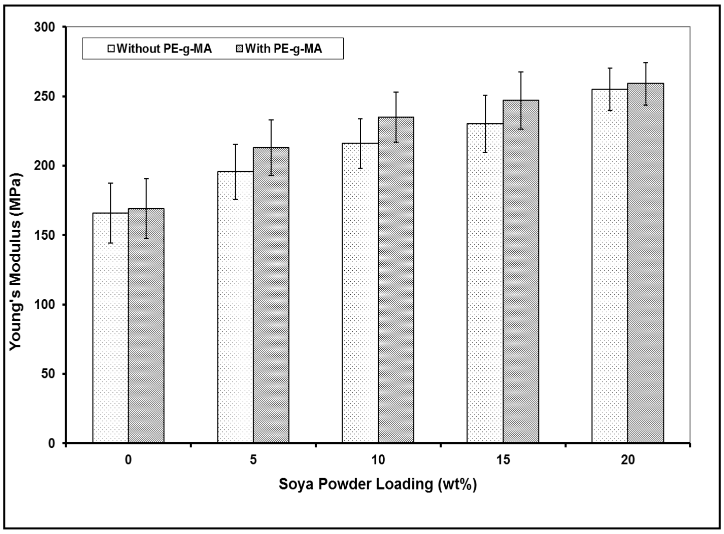

Figure 3: Young's modulus of HDPE/TPSS-spear grass fibre with and without PE-g-MA.

3.2 Water Absorption

Figure 4 shows the variation in water absorption with time of immersion. Moisture uptake increased with immersion time and increasing filler loading. As can be seen in the figure, a rapid water uptake can be observed for all samples at the beginning of the immersion, thereafter increase gradually until 10 days of immersion. After 10 days, the water uptake of all the composites became slower as the equilibrium state was achieved. It can be observed that increasing the spear grass fibre content had increased the water uptake. In the HDPE/TPSS-spear grass fibre composites, the water uptake is mainly contributed by the spear grass.

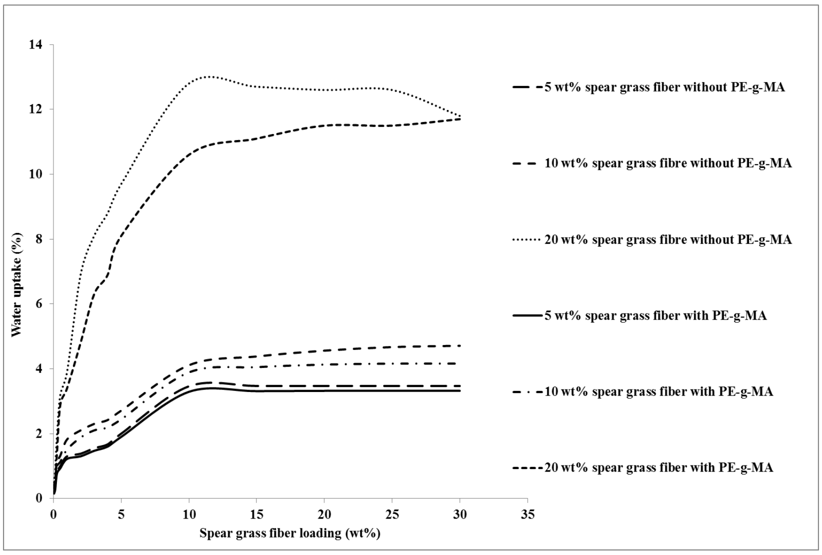

Figure 4: Variation of spear grass fibre content and immersion period of HDPE/TPSS-spear grass fibre.

The decrease in the rate of water uptake with time of immersion could be due to a concentration gradient across the matrix and fibre. Initially, water molecules attach to the spear grass has been found to be strongly bonded as in a hydrate. After some time, the available hydroxyl groups are used up in this way, further water absorbed is held less firmly.[14] The similar result was reported by Danjaji et al.[15] The addition of PE-g-MA had reduced the water uptake of all the composites. This might be due to the linkages formed between the matrix and the spear grass fibre blocked the water penetration into the composites.

4. CONCLUSION

In conclusion, the addition of spear grass fibre in HDPE/TPSS had improved the tensile strength and Eb up to 10 wt% loading. On the other hand, the higher the grass fibre content, the higher the Young's modulus was. The addition of the PE-g-MA had further enhanced the tensile properties of the composites. The water uptake of the composites increased with the incorporation of spear grass fibre. However, the presence of PE-g-MA in the composites had reduced the water uptake for all fibre contents.

5. ACKNOWLEDGEMENT

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