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Water Transport Properties of Thermoplastic Cassava Starch/Beeswax Reinforced with Cogon Grass Fiber

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ABSTRACT

Starch is a renewable material and has advantage such as low cost, non-toxicity and biodegradable. Unfortunately, starch has limitations to commercial because of highly moisture sensitive and limited mechanical properties. Cogon grass is an aggressive weed but has potential to be used as reinforcement material for producing biodegradable polymer composite. The aim of this paper is to investigate the effect of cogon grass fibre on the water transport properties of thermoplastic cassava starch/beeswax matrix. The biocomposites were prepared with various cogon grass fiber loading range from 10 to 40 wt.%. The physical properties of TPCS/Beeswax reinforced with cogon grass fiber were evaluated based on the water transport properties of the material. The result show that the moisture content and and water absorption of the sample decrease when the cogon grass fiber loading increase. This finding was accompanied with decrease in the thickness swelling of the samples, indicating better stability. Overall, the finding from the current study demonstrated that TPCS/Beeswax reinforced with cogon grass fiber has shown improvement in characteristic compared to the original material. In conclusion, TPCS/Beeswax reinforced with cogon grass fiber composite are potential alternative material for biodegradable product such as single-use product.

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1. Introduction

Nowadays, plastic-based materials are being widely used for commercial and household purposes and its proving to be a threat to the environment around the world. However, the development of biodegradable polymer from renewable resources has been promoted by increasing environmental awareness to replace conventional non-biodegradable polymer in various applications. Biodegradable polymer has attracted a lot of attention because of their environmentally friendly and sustainable to nature.

Starch is an example of biodegradable polymer because of their advantage such as low cost, non-toxicity, biodegradability and availability to replace synthetic polymer in plastics industries [1]. In the presence of plasticizer, heat, and shear, starch can be transformed into thermoplastic starch which possess similar thermoplastic characteristics with synthetic polymer in terms of the processing. This thermoplastic starch has been reported to be renewable and fully biodegradable in the previous studies [2-5]. Unfortunately, starch has limitations of highly moisture sensitive and poor mechanical properties which requires further modification to suit the real application as bio-plastic. Reinforcement of thermoplastic starch with natural fiber has been reported to improve the resistance against water. Several types of fiber have been used for this purpose such as sugar palm, sugarcane bagasse, coir fiber, and banana leaf [6-9].

Wax is hydrophobic organic material with medium chain length and have potential to be used to improve to the properties of starch [10]. Among them, beeswax is one of the highly potential material due to the renewable resources. Apart from the application in food processing and cosmetic, beeswax was also reported to be able to reduce the moisture sensitivity of bio-based material [5].

Natural fiber is one of the most abundant resources for cellulose which is known for the strength provided to plants. The involvement of natural fiber in composites as reinforcement has been reported in the previous studies such as flax fiber, kenaf fiber, coir, and jute [11-14]. Further modification of natural fiber into nanocellulose were also reported such as oil palm nanocellulose [15].

Cogon grass (Imperata Cylindrica) is the most abundant green short plant which grows wildly in the rain forests of tropical countries and have no economic rate for agriculture [16]. This plant is also known as invasive species in many areas which affects the cultivated plantation ecosystem. Nevertheless, this plant contain cellulose which is a potential reinforcement for bio-based material. Even though there are previous study reported on cogon grass fiber composites, however, none have been found on using cogon grass fiber as reinforcement for thermoplastic starch/beeswax composites. This study aims to fabricate thermoplastic cassava starch/beeswax reinforced with cogon grass fiber. Secondly, to characterize the physical and environmental properties whether the thermoplastic cassava starch, beeswax and cogon grass fiber is fully biodegradable material and can be safely disposed to the environment.

2. Materials and Methodology

2.1 Materials

The material cassava starch was obtained from Antik Sempurna Sdn Bhd, Malaysia Glycerol used as a plasticizer was purchased from the QReC Chemical. Beeswax used as the protective agent against moisture and water absorption was purchased from Sigma Aldrich chemical. The cogon grass was collected from the field at Ayer Keroh, Melaka.

2.2 Sample Fabrication

The fabrication of TPCS/Beeswax reinforced with cogon grass fiber composites is carried out by using cassava starch, glycerol and beeswax as matrix and cogon grass fiber as reinforcement of the composite. The cogon was dried after soaked in water for the water retting process for 2 to 3 weeks. Then the cogon grass fiber was sun dried for 5 hours before been grinded to smaller size and has been dried again for 5 hours at 100°C inside the oven. The modification of TPCS/Beeswax with cogon grass fiber is performed by incorporating a different amount of cogon grass fiber (10, 20, 30 and 40 wt.%). The loading of the reinforcing fiber is shown in Table 1. The mixture was then placed in a mold and undergoes hot-pressed at 145°C for 60 min by using a compression molding machine. The prepared sample were stored in desiccator until further testing.

Table 1
Amount of cogon grass fiber as reinforcement

Composites	TPCS/Beeswax (%)	Fiber loading (%)
0%	100	0
10%	90	10
20%	80	20
30%	70	30
40%	60	40

2.3 Moisture Content

Five specimens were prepared for moisture content investigation with the uniform size (10mm x 10mm x 3mm). The sample was heated in the oven for 24 hours at 100^{o}C. In determining moisture content, the weight of the samples before (Mi) and after (Mf) heater was determined. The moisture content of Lalang waste was calculated by using Eq. (1).

$$Moisture\ Content\ \% = \frac{M_f - M_i}{W_i} \times\ 100\% \tag{1}$$

2.4 Water Absorption

Five samples were prepared with uniform size (10mm x 10mm x 3mm) for water absorption test and were dried in oven for 24 hours at 100^{o}C. After dry the sample, the weight of the sample before (Wi) immersed was weighed. Then the sample was immersed in 20 ml distilled water for 0.5 hours and stirred gently during the test. Within 0.5 hours, samples were removed from the container and the remaining water was removed by filtering paper on the surface. The sample will be measured the weight after (Wf) 0.5 hour of immersion. The water absorption of the sample was calculated by using Eq. (2).

$$Water\ absorption\ \% = \frac{W_f - W_i}{W_i} \times\ 100\% \tag{2}$$

2.5 Thickness Swelling

In this study was investigated the thickness swelling of the composite. Five samples will be prepared with uniform size (10mm x 10mm x 3mm) and were dried in an oven at 100^{o}C for 24 hours in order to remove the existing moisture. Then the specimen was immersed in 20 ml distilled water for 0.5 hour and stirred gently during the test. The samples were measured before, (Ti) and after, (Tf) immersion using a digital Vernier (Model: Mitutoyo) having 0.01 cm accuracy. The thickness swelling ratio of matrix and composite was calculated by using Eq. (3).

$$Thickness\ swelling\ \% = \frac{T_f - T_i}{T_i} \times 100\% \tag{3}$$

3. Result and Discussion

3.1 Moisture Content

Figure 1 shows the decrease in moisture content from 1.90% to 0.77% respectively when a combination of cogon grass fiber (0 to 40 wt%) into TPCS/beeswax matrix. The decrease in moisture content of the composites might be attributed to better interfacial bonding between matrix and fibres as the resistance to absorb moisture [17]. In addition, this finding might be associated with less hydrophilic character of cogon grass fiber with the TPCS/beeswax matrix [18]. This finding is in agreement with Mali *et al.,* [19], which reported that the use of natural fibers and biodegradable polymers in material production is to increase resistance to moisture.

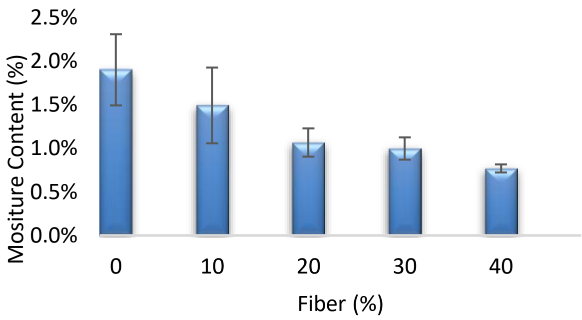

Fig. 1. Moisture content of TPCS with cogon grass fiber composites

3.2 Moisture Absorption

Figure 2 shows the water absorption percentage of TPCS/Beeswax reinforced with different amount of cogon grass fiber. It can be seen that after 0.5h of immersion, TPCS/Beeswax shows 58.68% water uptake. Incorporation of 10 to 40% of cogon grass fiber shows the reduction of water uptake at 34.79%. It is apparent that water uptake of all material decreases with longer immersion time. After 2 hours of immersion in distilled water, TPCS/Beeswax composites continue to show a steady decrease in water absorption with the addition of cogon grass fiber. TPCS/Beeswax matrix show 108.19% of water absorption while TPCS incorporation with 40% cogon grass fiber shows 65.94% of water absorption. In general, it can be seen that incorporation of cogon grass fiber with TPCS/Beeswax decreased the water absorption capacity of the sample. According to Pervaiz *et al.,* [10], natural fiber not only decrease the tendency of thermoplastic starch to absorb water but also makes the composite almost insensitive to water absorption, irrespective of the amount of glycerol and fiber. It also reported when beeswax is incorporated into TPS from corn, the average water absorption values decrease and continue to decrease as the amount of beeswax increases.

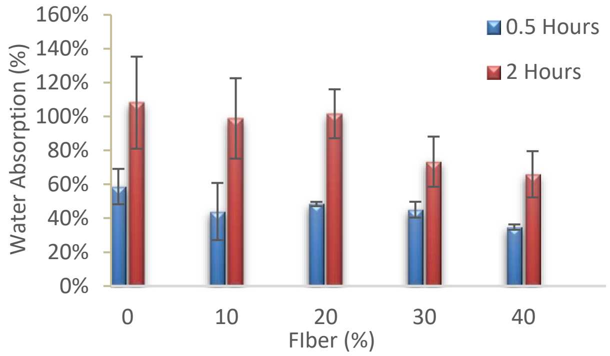

Fig. 2. Water Absorption for TPCS/Beeswax with cogon grass composites

3.3 Thickness Swelling

Thickness swelling is the tests conducted to determine the specimen dimensional stability. Dimensional stability is the degree to which specimen can sustain their original size under various temperature and moisture absorption of surrounding environment [7]. Figure 3 shows the swelling percentage of TPCS/Beeswax and the composites with different percent of fiber (0% - 40% wt). It is clear that the immersion time and the fiber loads influenced the thickness of matrix and the composites. The thickness swelling percentage of 0.5 hour and 2 hours for TPCS/Beeswax is 38.14 % and 41.08%, while percentage for 40 % fiber is 37.21% and 87.71% respectively. The TPCS/Beeswax with 30 wt.% shows the highest swelling after 0.5 hour of immersion time, while 40 % amount of cogon grass fiber shows the highest swelling after 2-hour immersion time. Sample for 30 and 40 wt% of cogon grass fiber was disintegrate and delaminate during the test and it difficult to take the thickness result of the sample. It because disintegrate and delaminate occur due to the presence of the water [8].

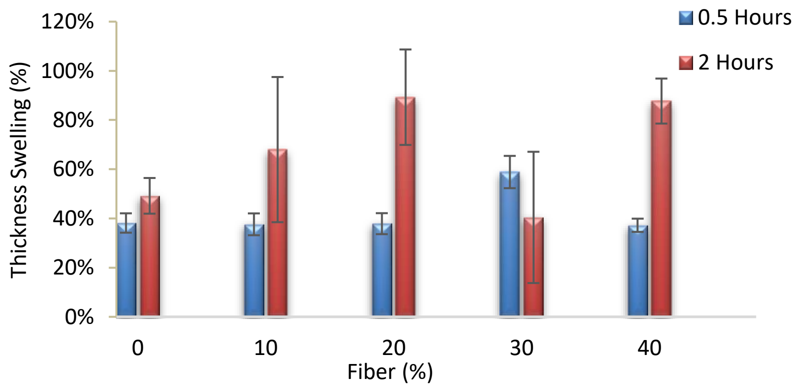

Fig. 3. Thickness Swelling for TPCS/Beeswax with cogon grass composites

4. Conclusion

Incorporation of TPCS/Beeswax with cogon grass fiber were successfully developed using cassava starch, beeswax, glycerol as plasticizer and cogon grass fiber as reinforcement of 10-40% wt by using dry mixing and hot press. The moisture content and water absorption show the similar trend, where the fiber loading is increase. For the thickness swelling results, it was found that the result was affected during the experiment by the delamination and disintegration of the specimen. Overall, this study shows that cogon grass able to reduce the water affinity characteristics of the TPCS, hence, widen the potential application of this material as a new biodegradable alternative.

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