

Preparation and Characterization of Wood Plastic Composite Made Up of Durian Husk Fiber and Recycled Polystyrene Foam.

Seong Chun Koay^{1,*}, *Varnesh Subramanian*¹, *Ming Yeng Chan*², *Ming Meng Pang*¹, *Kim Yeow Tsai*³, and *Kean How Cheah*⁴

¹School of Engineering, Faculty of Built Environment, Engineering, Technology and Design, Taylor's University Lakeside Campus, 47500 Subang Jaya, Malaysia

²Centre for Engineering Programmes, HELP College of Arts and Technology, 55200 Kuala Lumpur, Malaysia

³Faculty of Engineering, The University of Nottingham, 43500 Semenyih, Malaysia.

⁴School of Engineering and Physical Science, Heriot-Watt University Malaysia, 62200 Putrajaya, Malaysia.

Abstract. Polystyrene foam is one of the major plastic waste that hardly to recycle. The present research is aims to recycle polystyrene foam as raw material to produce wood plastic composites (WPC). The WPC was produced from recycled polystyrene (rPS) and durian husk fiber (DHF) using melt compound and compression moulding processes. This paper is focus on effect of fiber content on tensile and thermal properties of rPS/DHF composite. The results found the tensile strength modulus of this WPC increased at higher fiber content, but elongation at break was reduced. However, this composites exhibited an early thermal degradation when subjected to high temperature and this was commonly found among WPC. The thermal degradation of rPS/DHF composites yielded high percentage of char residue due to char formation of DHF. Overall, the rPS/DHF composites with 60 phr fiber content able to achieved strength slight above 16 MPa without any chemical treatment additives. This indicates the rPS/DHF composites can be a potential WPC if further modify with to improve its strength.

1 Introduction

Wood Plastic Composites (WPC) is composite material made from wood sawdust and thermoplastic material [1]. WPC also considers as an eco-friendly material that is potential to replace natural wood. Thus, the market demand of WPC around the world is getting increases every year. In 2015, the global WPC production had reached 2,695 kilo tons and the market is expected to grow. WPC is widely found in replacing natural wood products like window fitting, flooring panel, door frame, and furniture. IKEA's ODGER chair is one of the example of WPC furniture that made from recycled plastic and wood fiber [2-3]. The soft wood fiber is the main choice of wood fiber that used to produce WPC. Nowadays, WPC also made from rice husk and recycled plastic, especially in China [2]. The WPC

made from recycling plastic and agricultural waste materials able to ensure the sustainability [4-5].

Natural fiber is the main components in WPC, which up to 80% of fiber can be used in extrusion process and 30 to 40% of fiber can be used in injection moulding [2]. The natural fiber usually obtained from wood and also agriculture crop or waste, such as palm oil empty fruit bunch, rice husk, and corn stalk [6-8]. Durian is a tropical fruit that widely planted across Malaysia. The production of durian in Malaysia alone had achieved 3,800 metric tonnes in year 2016 and amount of durian fruits is estimated to reach 22,000 metric tonnes in year 2020 [9]. Figure 1 shows the durian husk shares up to 70% of a durian fruit and it usually discarded as waste after consumed the flesh [10]. This means it is about 7 tonnes of estimated wet durian husks will be generated for every 10 tonnes of produced durian fruit. The increase of durian produce will generate more durian husk waste. The discarded durian husks usually end up in landfills or burnt which contributed to environmental pollution. From the literature found durian husk actually contains huge amount of lignocellulose fiber and those compositions are similar to wood fiber [11-12]. In regards, this research is underway to utilize durian husk fiber to WPC.

Polystyrene foam is an expanded polystyrene that commonly called as Styrofoam. The polystyrene foam are widely used many industries for packaging and storage purposes, because it is very cheap in production cost, light in weight, high impact absorption and good heat insulation [13]. The usage of polystyrene foam was very high over the world, but the disposal of polystyrene foam into landfills also very high. The main reason is because the recycle rate of polystyrene foam is relatively low due to it is bulky as it made up of 98% of air and only 2% of polystyrene [14]. The recycling process of polystyrene foam is not economic, because the transportation expenses for sending polystyrene from to recycling plant is very high. Thus, industry is less interest on recycling polystyrene foam. For this reason, the present research is working on developing new value added WPC using recycled polystyrene foam and durian husk fiber.

This present paper is focuses on the effect of fiber content on the tensile and thermal properties of WPC made from durian husk fiber and recycled polystyrene foam.

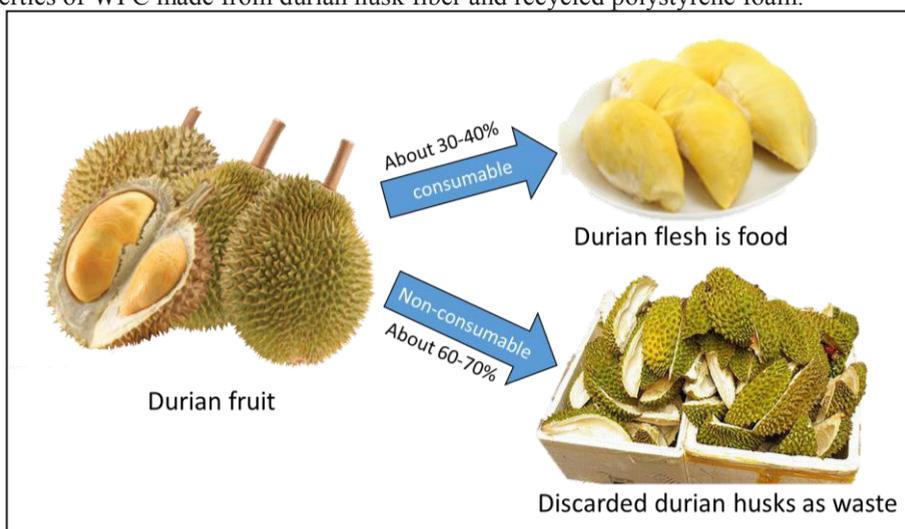


Fig. 1. Parts of a durian fruit.

2 Methodology

2.1 Research Materials

The durian husk was obtained from durian fruit stall at SS2, Petaling Jaya (Selangor). The polystyrene foam used in this experiment was the packaging Styrofoam used for electric appliance and it usually discarded as waste at electric appliance shop. The acetone used in this experiment was supplied by Evergreen Engineering & Resources (Selangor, Malaysia).

2.2 Preparation of Durian Husk Fiber

First, the collected durian husks (DHs) were cleaned with tap water to remove any dirt and cut into small pieces. Next, the small piece of DHs were dried using oven at 70°C. After that, the dried DHs were ground into short fiber using mechanical grinder. Then, the short durian husk fiber (DHF) was sieved into homogenous size of fibers (mesh size of 600 micron). The DHF be dried again before compounding process in order to avoid high moisture content.

2.3 Preparation of Recycled Polystyrene

The collected polystyrene foam was cut into small piece and dissolved in acetone solvent in order to remove air from foam. Then, the dissolute polystyrene foam was filtered and dried using an oven at 70°C to remove acetone. The recycled polystyrene (rPS) was cut into smaller pieces and stored for compounding process.

2.4 Preparation of WPC

The WPC was prepared from rPS and DHF using Haake Rheomix 600p (Brand: Thermo Fisher Scientific Inc). The processing temperature was set at 190°C and rotor speed of 80 rpm. The WPCs were prepared with fiber content of 15, 30, 45, and 60 part per hundred resin (phr). The WPC compound was molded into 1 mm thickness sheet using hot press machine (model: Moore). The molding temperature was similar to compounding process and the pressure was set at 100 kPa. The operating procedures are: i) preheat the compound for 4 minutes, ii) fully compress the compound for 1 minute, iii) cool the specimen to temperature below 50°C, iv) remove the composite sheet from mold. The composite sheet was cut into tensile specimen and the dimensions of tensile specimen were following ASTM D638 standards.

2.5 Testing and Characterization

The tensile testing for the rPS/DHF composite was carried out based on the ASTM D638 standards using an Instron universal testing machine (model 5596). The crosshead speed was set at 5 mm/min and a 15 kN loading cell was used to perform the test. Tensile properties of the composites were automatically obtained through the computerized system. A minimum of 7 specimens were tested for each formulation. Thermogravimetric analysis (TGA) was carried out using Pyris Diamond TGA (brand: Perkin-Elmer). The specimen was prepared in small size with weight from 6 to 8 mg and placed in a ceramic pan. Then, the specimen was undergone thermal scan from 30°C to 600°C and the heating rate was set

at 10°C/min. The TGA analysis was run under nitrogen atmosphere with gas flow rate of 20 ml/min.

3 Results and Discussion

3.1 Tensile Properties

The effect of fiber content on tensile strength of rPS/DHF composites is illustrated in Figure 2. The average tensile strength of neat rPS was recorded at 26 MPa. The addition of fiber caused a drastic decreases of tensile strength on rPS matrix. Generally, the strength of composite materials are highly depending on fiber orientation, length/diameter ratio, and interfacial adhesion [15]. In this case, the DHF was a short fiber and it have random orientation when dispersed in matrix. The short fiber that orientated parallel to direct of applied stress would contributed to improve of strength as part of the stress would share by the fiber. From literature, natural fibers were typically exhibited higher tensile strength and modulus compared conventional plastic [16]. Thus, if the fiber in the composite able to share part of the load, meaning it will increase the strength of the composite. On the other hand, the fiber might also orientated perpendicular to the direct of applied stress and the fiber did not able to share the stress but it might initial the cracking along the fiber-matrix interface. Hence, the strength of the composite will dramatically decreases. The result found the increases of fiber content had increased the tensile strength of rPS/DHF composites. At low fiber content, the amount of fiber orientated parallel to direct of applied stress is less. Thus, the strength of the composite has drastically reduced. However, the increases of fiber content might increases the amount of fiber that able to share the stress. For this reason, rPS/DHF composites shown higher strength at 60 phr of fiber content. The similar observation also reported by many other researchers [17-18].

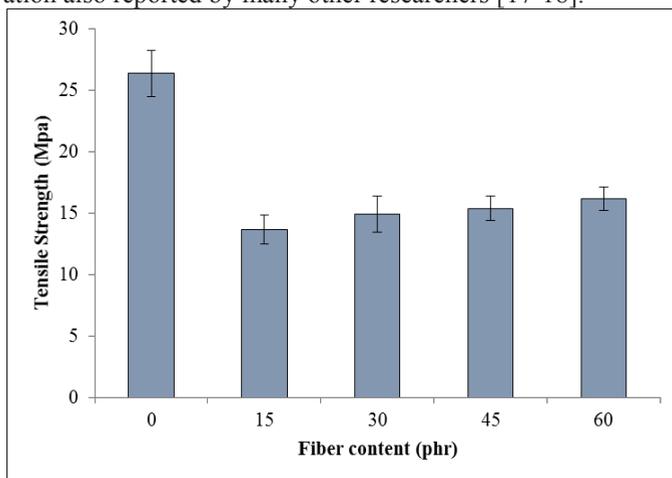


Fig. 2. Tensile strength of PLA/DHF biocomposites with different fiber content.

Figure 3 shows the increases of fiber content increased the tensile modulus of rPS/DHF composites. As mentioned above, the modulus of natural fiber usually higher than plastic material, thus the obtained results trend was expected. The rPS/DHF composites had 32% in average higher tensile modulus compared to neat rPS. The presence of DHF have share part of the stress applied to rPS matrix. Thus, the tensile modulus of composites is increased at more fiber content. Besides, the present of friction between fiber-matrix also reduced the chain mobility of matrix. For this reason, the flexibility of rPS was further

decreased. Then, the composite become more rigid and brittle. Furthermore, Manshor et al. [12] also agreed that presence of more fiber was tend to increase the modulus of composites.

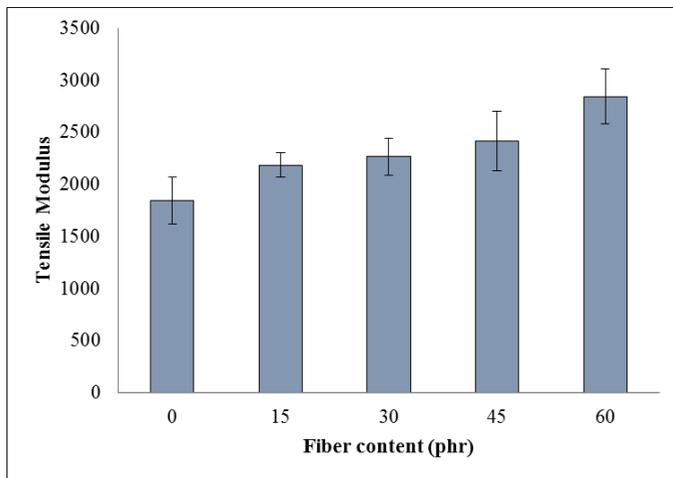


Fig. 3. Tensile modulus of PLA/DHF biocomposites with different fiber content.

The elongation at break of neat rPS and rPS/DHF composites with different fiber content are shown in Figure 4. As expected, the result trend of elongation at break and tensile modulus was in opposite. The rPS was rigid and it exhibited only average of 2.8% of elongation at break. The increases of fiber content was significantly reduced the elongation at break of composites. The increases of fiber content have caused the elongation at break of composites dropped 50% in average. As discussed earlier, the addition of fiber have friction with rPS matrix at interface region. The fiber-matrix friction would reduce the chain mobility of the matrix. Thus, the composites usually more rigid and brittle if fiber content was more. This observation is in agreement with findings of many others researcher [19-20].

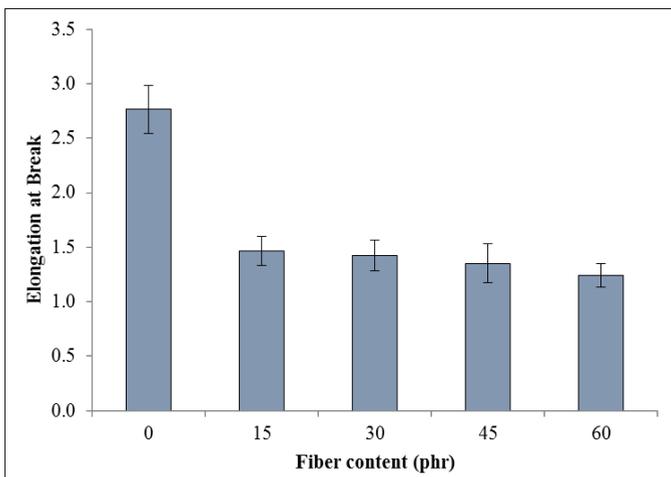


Fig. 4. Elongation at break of PLA/DHF biocomposites with different fiber content.

3.2 Thermal Properties

Figure 5 illustrates the TGA curves of DHF, neat rPS and rPS/DHF composites at selected fiber content. The data calculated from TGA curves are tabulated in Table 1. The

neat rPS exhibited a single step thermal degradation above temperature 300°C. However, DHF was initially showing weight loss above temperature 50°C. This is due to the weight loss of removing moisture and volatile compounds from DHF. Then, the weight loss of DHF was following by thermal degradation of hemicellulose above temperature 150°C. Last, the thermal degradation of DHF was involved cellulose and lignin were started at temperature of 300°C. The cellulose and lignin were decomposed and yields high amount of char residue. For Table 1, the thermal degradation temperature at 5% weight loss ($T_{d5\%}$) of rPS/DHF composites were decreased as the increase of fiber content. This indicates early thermal degradation occurs on rPS/DHF composites due to the weight loss from moisture, volatile compound and hemicellulose of DHF. In contrast, the thermal degradation temperature at 50% weight loss ($T_{d50\%}$) of rPS/DHF composites have shifted to higher temperature when added with more DHF. This was due to the char formation effect that caused the increased of thermal stability of composite at high temperature. As mentioned earlier, the char formation was due to the thermal decomposition of cellulose and lignin. Then, char usually is higher thermal stability and the presence of char in composites material provides a shielding effect which caused the thermal degradation of composite delayed. Hence, the rPS/DHF composites exhibited a better thermal stability at higher temperature. The char formation also contributed to high percentage of residue content of rPS/DHF composites. The similar findings regarding to effect of char formation influenced the thermal properties of composites also reported by others researcher [21-22].

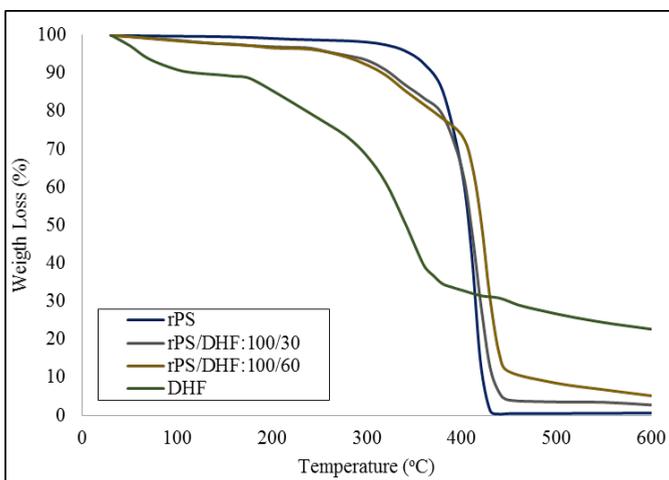


Fig. 5. TGA curves of DHF, neat PLA and PLA/DHF biocomposites at selected fiber content.

Table 1. Formatting sections, subsections and subsubsections.

Samples	Temperature at 5% weight loss (°C)	Temperature at 50% weight loss (°C)	Char residue at 600°C (%)
Neat rPS	348.9	408.1	0.2
DHF	55.5	339.3	22.7
PLA/DHF: 100/30	248.5	409.1	2.8
PLA/DHF: 100/60	245.0	420.4	5.4

4 Conclusion

In conclusion, addition of more fiber content increased the tensile strength and modulus of rPS/DHF composites increased, but decreased the elongation at break. The rPS/DHF composites with 60 phr of fiber content exhibited strength about 16 MPa and modulus of 2842 MPa without any modification. This means rPS/DHF composites can be potential new WPC material. The TGA results shows the composites had early thermal degradation and it was command to WPC. The thermal stability of rPS/DHF composites also increased at high temperature due to char formation.

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