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Wood Plastic Composites Prepared from Biodegradable Poly(butylene succinate) and Burma Padauk Sawdust (*Pterocarpus macrocarpus*): Water Absorption Kinetics and Sunlight Exposure Investigations

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Abstract

Wood plastic biocomposites of biodegradable poly(butylene succinate) (PBS) and Padauk sawdust was successfully prepared by using a twin screw extruder and an injection molding machine. The effects of water absorption and sunlight exposure on some properties of the composites were investigated. Water absorption of PBS composites was found to follow the Fick's law of diffusion, while the diffusion coefficient increased with increasing wood content. Maximum water absorption of around 4.5% was observed at 30 wt.% sawdust. Optical micrograph indicated the swelling of wood particles by around 1% – 3% after 30 days of water immersion. The tensile and flexural strengths reduced slightly both under the water immersion and sunlight exposure. After 90 days of exposure, the composites clearly looked paler than the non-weathered ones. Thermal scan indicated the reduction of crystalline region due to the plasticization effect derived from water molecules.

Keywords: wood plastic composites, biodegradable polymers, Fickian diffusion, mechanical properties, environmental degradation

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1 Introduction

Over decades, fossil-based Wood Plastic Composites (WPC) have been widely applied for natural wood substitutions. However, their non-biodegradable part is still the environmental problem after non-durable utilizations[1–3] such as food utensil or WPC toy. In the last decade, biodegradable poly(lactic acid) (PLA) was applied as polymer matrix for biodegradable WPC production[2–4]. Numerous papers signified that adding wood fiber to the brittle-natured PLA led some notable toughness reductions. Huda *et al*.[1] reported that the biodegradable PLA was stiffer and more brittle, when the wood sawdust was added at only 20 wt.%. PLA was also less tough when 30 wt.% bamboo fiber was added, which reflected as a remarkable reduction of the tensile elongation at break[4]. With the presence of rubber wood sawdust, the impact strength of PLA decreased by around 40%[2]. These disadvantages downgraded and limited the PLA-based WPC applications. An alternative way is the use of another biodegradable poly(butylene succinate) (PBS), which offers more benefits than that of PLA, such as higher impact resistance and better thermal stability[5,6]. Literature reviews indicated that PBS was capable to be reinforced by many agricultural wastes. Liu *et al*.[7] reported that the mechanical strength and modulus of PBS/jute fiber gradually increased, when jute fiber was added at 20 wt.%. The stiffness and impact strength of PBS were also found to be improved when coconut, sugarcane bagasse, curaua and sisal fibers were incorporated[8]. PBS/wood composites was found to have higher toughness compared to that of PLA-based WPC, such as kenaf bast fiber-filled PBS[9], PBS/sisal fiber[10] and jute fiber reinforced PBS com-

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posites[11].

In Thailand, there are large amounts of wastes generated annually from wood industry. Burma padauk wood (*Pterocarpus macrocarpus*) is one of the commercial wood applied as furniture and building materials, which is usually abandoned from the sawmill process. It was categorized as a hardwood with high mechanical strength, thus the use of Padauk sawdust as reinforcement in PBS seems to be a suitable and sustainable way of waste utilization, and value creation. In the real applications, WPC are exposed to moisture and sunlight, which directly affect some properties of WPC. Thus, the current paper monitors some changes in thermal, physical and mechanical properties of PBS/Padauk sawdust composites under water absorption and sunlight exposure.

2 Materials and methods

2.1 Raw materials

An extrusion/film grade PBS (FZ91PD) with a density of 1.26 $g \cdot cm^{-3}$ and a melting range from 112 ˚C to 116 ˚C was used as a polymer matrix. Fine particles of Burma padauk (*Pterocarpus macrocarpus*) sawdust was obtained as waste from Mow Heng Li sawmill (Ayutthaya, Thailand), which was further ground by using a blade-type cutting mill and sieved to the top cut sizes of 30 mesh (around 590 μm). Fig. 1 illustrates the particle size distribution of Padauk sawdust. Its average particle size was 230.6 μm, while the D10, D50 and D90 were 184.4 μm, 253.6 μm and 392.1 μm respectively. The sawdust was applied to PBS from 0 wt.% to 30 wt.%.

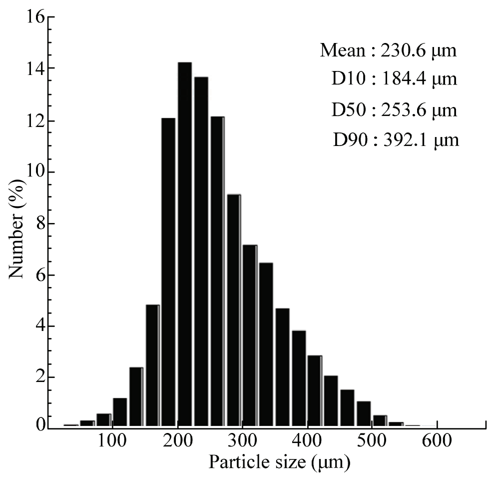

Fig. 1 Particle size distribution of ground and sieved Padauk sawdust.

2.2 Preparation of PBS/Padauk sawdust composites

Firstly, PBS pellets were dry-mixed with wood sawdust by using a high speed mixer (Thermo, PRISM Pilot 3) at the speed of 500 rpm for 30 s. The dry-blended compositions were then extruded by using a twin screw extruder (Lab Tech Engineering, LTE- 26-40) at a screw speed of 80 rpm and at a temperature range of 140 ˚C to 160 ˚C for temperature zones 1 to 5 respectively. They were then processed by using an injection molding machine at 150 ˚C to 160 ˚C to prepare standard specimens for subsequent testing and characterization.

2.3 Testing and characterizations

The particle size distribution of Padauk sawdust was evaluated by using a laser particle size analyzer (Malvern mastersizer 2000). To estimate the influence of water uptake on the WPC properties, the specimen was immersed in distilled water for 90 days. For water absorption test, specimens were removed from the water and the surface water was wiped off using blotting paper. The weight of each specimen was measured at different time intervals during immersion. Both the testing procedure and the specimen size were conducted following the method described in ASTM D 570. The values of the water absorption in percentage were calculated using Eq. (1)[12]:

$$WA(\%) = 100\frac{(W_t - W_0)}{W_0}, \quad (1)$$

where WA is the water absorption at time t, W_0 is initial weight and W_t is the weight of specimen at a given immersion time t.

The tensile test was conducted according to ASTM D 638 by using a Universal Testing Machine (INSTRON, 5966). Rectangular bar of 12.7 mm in width, 96 mm in length and 3 mm in thickness was injected for the flexural test under a three-point bending mode. A support span of 50 mm was carried out at room temperature following the procedure of ASTM D790. All of the mechanical test reports were performed on the soaked and sunlight exposed composites, and the reported values were averaged from the results obtained from at least five tested samples.

The microscopic observation of the composites before and after water immersion was investigated by using a polarizing optical microscope (Nikon, Eclipse 50i Pol). A Field Emission Scanning Electron Micro-