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A Study on Moisture Content of Bamboo Fiber Reinforced HDPE Composite at Different Temperature

Md. Shaharul Islam[1, 2] , Md. Hafizur Rahman[1], G M Arifuzzaman Khan[1], M Shamsul Alam[1], Md. Helal Uddin[1]

[1]Department of Applied Chemistry & Chemical Engineering, Islamic University, Kushtia-7003, Bangladesh.
[2]Department of Chemistry, Bangladesh Army University of Engineering & Technology(BAUET), Qadirabad Cantonment, Natore-6431, Bangladesh.

ABSTRACT

Natural fibers are becoming a competitive option as reinforcement of polymeric composite materials due to their bio-based character, good specific mechanical properties, low cost and inexhaustible supply. The aim of this study was to make the Bamboo fiber and high density polyethylene (HDPE) composite and to measure the wet loss of the composite due to removal of moisture content at 105 ^{0}C, 125 ^{0}C and 135 ^{0}C temperature. Bamboo fiber were extracted from bamboo culm and treated with 0.5 M NaOH. Bamboo fiber-reinforced HDPE composites were prepared employing melt blending technique followed by heat press molding with various weight fractions (5, 10, 30 and 40 wt. %) of the treated bamboo fiber with HDPE. A systematic investigation of the thermal behavior on the moisture content of the composites was carried out. It was observed that at 135 ^{0}C temperature more moisture removed from the composite compared to 105 ^{0}C and 125 ^{0}C temperature. It also revealed that the weight loss of the composite increased with the increase in the Bamboo fiber loading (5% to 40%).

Keywords: Bamboo Fiber, HDPE, Composite, Reinforcement.

***Correspondence to Author:**
Md. Shaharul Islam
Department of Applied Chemistry & Chemical Engineering, Islamic University, Kushtia-7003, Bangladesh; Department of Chemistry, Bangladesh Army University of Engineering & Technology(BAUET), Qadirabad Cantonment, Natore-6431, Bangladesh

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Introduction:

In current years, the development of bio-composites from biodegradable polymers and natural fibers have drawn great interests in the composite science, because they could allow complete degradation in soil or by composting process and do not produce any toxic or harmful ingredients [1–16]. The world wood plastic composites market has been reached to double digit growth since 2003 with a identical trend projected up to 2010 [17]. Current product line includes lumber, decking and railing, window profiles, wall studs, door frames, furniture, pallets, fencing, docks, siding, architectural profiles, and automotive components. With increased wood costs and competition of wood resources from traditional wood sectors, developing alternative, environmentally friendly fiber sources for plastic composite is highly needed. High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a thermoplastic polymer produced from the monomer ethylene. It is sometimes called "alkathene" or "polythene" when used for HDPE pipes [18]. With a high strength-to-density ratio, HDPE is used in the production of plastic bottles, corrosion-resistant piping, geomembranes and plastic lumber. HDPE is commonly recycled, and has the number "2" as its resin identification code. In 2007, the global HDPE market reached a volume of more than 30 million tons [19] . On the other hand Bamboo is plentifully available in many countries. Currently, the total bamboo forest area in the world has reached 22 million hectares. The available bamboo fiber in the world is over 30 million tons per year [20]. More than 80% of this resource is distributed in Asian countries, especially India and China. Bamboo is one of the rapid renewable plants with a maturity cycle of 3–4 years. Bamboo has outstanding mechanical properties in correspondence with its weight due to longitudinally aligned fibers [21, 22]. The potentiality of this material for traditional composite panel manufacture has been explored [23, 24]. However, excellent mechanical properties have not been well drawn for polymer-based composites. The use of bamboo fiber in such products can help to suppress the demand for wood fibers and environmental influences associated with wood fiber harvesting. Technological performance of bamboo/plastic composites depends mostly on fiber quality, fiber–matrix interface, and fiber–polymer mixing ratios. Little attraction interfacial bonding between the hydrophilic bamboo fibers and hydrophobic polyolefin restrict the reinforcement imparted to the plastic matrix by the fiber component. Limited study has been carried out on interfacial adhesion in bamboo polymer composites. Okubo et al. [21] fabricated composites utilizing poly-lactic acid and bamboo fibers extracted by steam explosion method with micro-fibrillated cellulose from wood pulp as an enhancer. The improvements in tensile strength, tensile modulus and chemical resistance of bamboo fibers after coating with polymers were reported by Kumar and Siddaramaiah [25]. Saxena and Gowri [26] investigated the effect of surface treatment on the properties of bamboo/epoxy, and bamboo/polyester composites. An improvement in the properties was seen when the surfaces of bamboo fibers were modified with polyester amide polyol, which acts as a bridge between the fibers and polymer matrix. Thwe and Liao [27] observed the effects of Maleated polypropylene (MAPP) on tensile and flexural properties of bamboo fiber reinforced HDPE. The properties of bamboo fibers extracted by a combination of chemical (alkaline treatment) and mechanical methods were evaluated by Eshpande et al. [28] as they applied extracted bamboo fibers as reinforcement in polyester composites.

The objective of this study was (a) to investigate the feasibility of bamboo used as a reinforcement material for high density polyethylene (HDPE) composites; and (b) to study the effect of temperature on the moisture content and degradation of synthesized composites.

Materials and Methods:

Materials: HDPE having an average molecular weight of 200,000 g/mol (HD6761 resin, density 952 kg/m3) from Samia Scientific Zone, Dhaka, Bangladesh was used in the study as matrix. Bamboo fibres extracted from raw bamboo culms by alkali treatment were used in this work. The bamboo culm was collected from Kushtia, Bangladesh. Sodium hydroxide (NaOH) reagent used for the treatment was analytical grade reagent (Mark Germany) obtained from Samia Scientific Zone, Dhaka, Bangladesh.

Bamboo fiber extraction: Raw bamboo culm was slice into strips of about 15 cm long. The bark was scraped off and the strips were rinsed with water and dehydrated in an air blast oven at 85 °C for 3 h. The strips were soaked in 0.5 M NaOH in 1 dm^3 of water maintained at room temperature for 3 days. For the loosening of the fibers, the strips were then subjected to a pressure of 2 MPa. Fibers were obtained by manually scraping the pressed strips. The extracted fibers were rinsed with water and dried in an oven at 65°C for 24 h before cutting to (15 ×15) cm^2 in dimension.

Molding of HDPE Bamboo fiber composites: Composite fabrication process was completed in two steps. In the first step HDPE films approximately 0.2–0.3 mm in thickness were prepared by 2 polished stainless steel (SS) sheets in a hot press molding machine. Molding machine is accomplished by hydrolic press and hot plate. Molding temperature and pressure can be as high as 240^0C and 250KN, respectively. SS sheets were kept for 10 min at 175^0C and 50KN pressure there after it was cooled by tap water. For the second step, square Bamboo fiber of (15 ×15) cm^2 in dimensions were cut and dried in an oven at 65^0C for 24 h to remove moisture. The prepared HDPE films were also cut into the same dimension like fabric. A rectangular stainless steel (SS) mold with 15 ×15- cm square cavity and 10 mm depth was used for composite fabrication. The mold was packed by Bamboo fiber in between the HPDE films maintaining fixed weight fraction of Bamboo fabric in composite. A mold releasing spray (BONEY-Mould release silicon spray, manufacturer-London chemicals Ind. England) was used for easy opening the mold. The mold was then placed on a hot press molding machine and composite was fabricated as like HDPE film making.

The bamboo HDPE composites were then dried in an oven for 6 hours and the weight loss of the composites of varying percentage of fiber at different temperature (105^0C, 125^0C and 135^0C) were measured by electric balance.

Result & Discussion: Four types of composite (Bamboo fiber with HDPE) have been prepared using fiber load 5%, 10%, 30%, and 40% by heat press molding machine. Prepared composites were cut into 5 mm thick, 10 mm width and 15 mm length and subjected to an air oven at 105 ºC, 125 ºC and 135ºC for 6h. The losses of weight during heating have been calculated by electric balance.

Percentage of wet loss of the composite was calculated using the following equation-

$$W = (W_i – W_f/W_i) \times 100$$

Where W_f is the weight of the composite in grams (g) after drying, W_i is weight of composite before drying in grams (g) and W is the Percentage of wet loss from the composite.

Table 1 shows the weight loss of the composite of 5%, 10%, 30% and 40% bamboo fiber load in the composite at 105^0C. On the other hand table 2 and 3 represents the weight loss of the composite of 5%, 10%, 30% and 40% bamboo fiber load in the composite at 125^0C and 135^0C respectively.

It was noted from the figure 1 that higher the temperature higher the weight loss for all types of fiber loading Composite. However, weight loss for the 40% fiber loading composite is more prominent at 135 ºC as at high temperature more moisture removes from the Bamboo fiber HDPE composites.

Table 1: The initial and final weight of composite sample is given below in different percentage at 105º C temperature.

Types of composites	Initial weight (gm)	Final weight (gm)	Loss of weight (%)
5% fiber loading	1.2960	1.2931	0.23
10% fiber loading	1.9437	1.9350	0.44
30%fiber loading	2.5370	2.5240	0.52
40% fiber loading	1.3430	1.3339	0.68

Table 2: The initial and final weight of composite sample is given below in different percentage at 125º C temperature.

Types of composites	Initial weight (gm)	Final weight (gm)	Loss of weight (%)
5% fiber loading	2.1917	2.1852	0.29
10% fiber loading	2.7303	2.7174	0.47
30%fiber loading	2.9524	2.9245	0.95
40% fiber loading	2.9776	2.9389	1.29

Table 3: The initial and final weight of composite sample is given below in different percentage at 135º C temperature.

Types of composites	Initial weight (gm)	Final weight (gm)	Loss of weight (%)
5% fiber loading	1.7805	1.7670	0.75
10% fiber loading	2.2874	2.2675	0.87
30%fiber loading	2.6708	2.6371	1.26
40% fiber loading	1.5668	1.5392	1.87

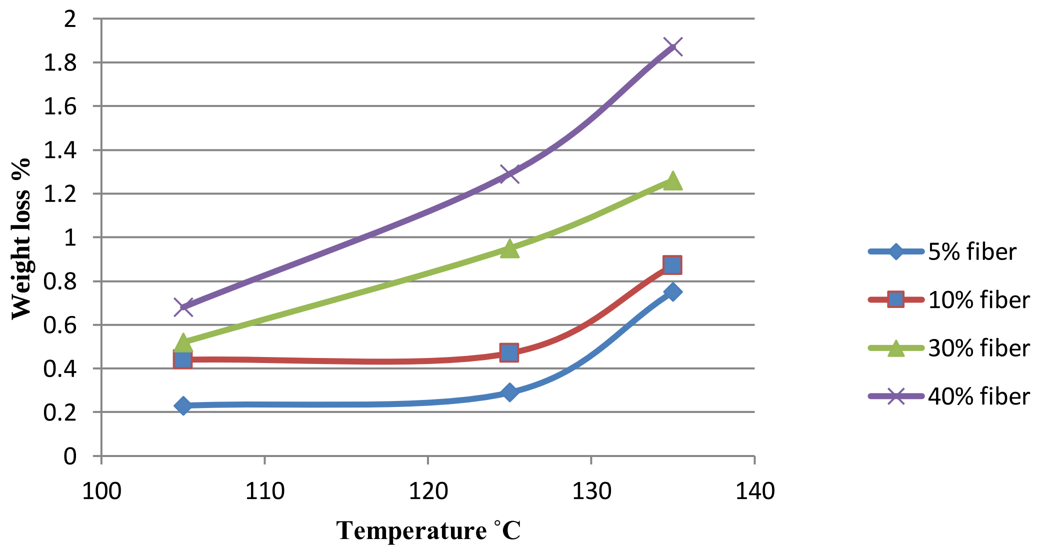

Fig. 1: Weight loss of the composite at different temp.

Figure 1 represents the weight loss of the composites at different temperature.

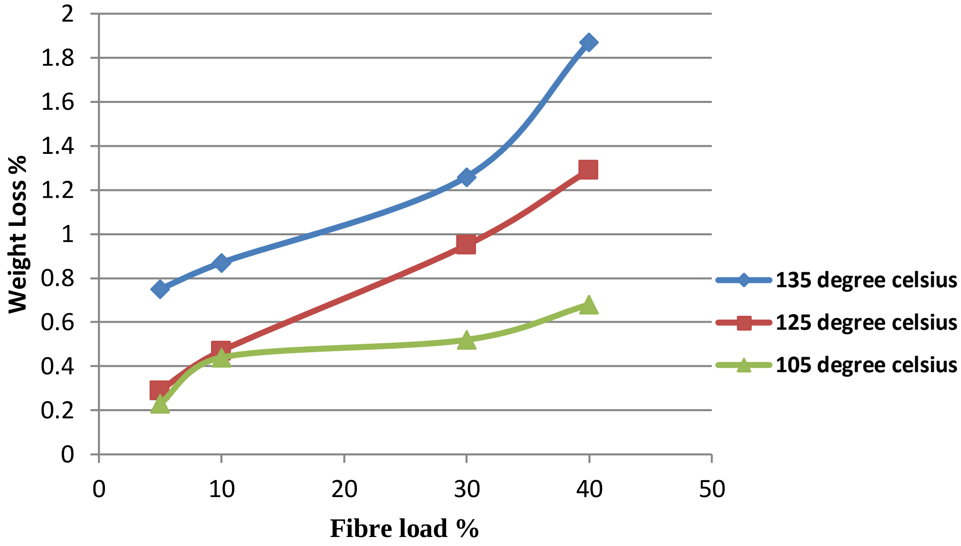

Fig. 2: Weight loss of the composite for different % of fiber load.

Figure 2 illustrate the weight loss of the composite for various wet fraction of bamboo fiber.

From Figure 2, we observed that the weight loss of 40% fiber loading composite (Bamboo fiber with HDPE) are higher in comparison with 5%, 10% and 30% fiber loading composites. It may be due to the more moisture content of more fiber loading composite. It is also seen from the plots that the loss of weight for all the samples follow a similar trend. According to some previous studies, the surface of natural fibres contains hydroxyl groups which have high affinity for water molecules [29, 30]. Therefore, the percentage of the loss of weight increases as the weight fraction of bamboo fiber increases in the composite samples with the temperature. Because higher the weight fraction of Bamboo fiber in the composite higher the possibility to gain the moisture and consequently the loss of weight is increased with the increase in temperature. Additionally, the absence of fibres is believed to reduce micro-voids and entrained air [31]. These factors are responsible for the less weight loss for the composite of least bamboo fiber loading.

Conclusion: Bamboo is one of the strongest building materials. It is subjected to greater variability due to various conditions, such as years of growth, season, soil and environmental conditions and the location of bamboo culm within the bamboo. Bamboo composites are comparable to those of wood and other natural products. Considering the fact that bamboo is a rapid growing fibrous plant available in abundance, bamboo composites can find various applications. Pure HDPE and bamboo fiber composites were prepared using melt compounding compression molding. Detailed studies have been carried out on the moisture content of the composite at various temperatures for different weight fraction of bamboo fiber. From the above experiment we see that the bamboo (HDPE) composite are more stable than other composite. It is stable at high temperature. This composite are easy to make because bamboo fiber are available and easy to get in our country. So bamboo (HDPE) composite are beneficial for us. The water desorption test also reveals that weight loss by all the composites increases with increasing bamboo fiber loading and temperature. Finally we may conclude that treated bamboo fibres are suitable for reinforcing HDPE.

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