

Characterization of Palm Fiber for Development of Biocomposites Material for Automotive Industries

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Satya Panigrahi
Univ. of Saskatchewan

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ABSTRACT

The physical and optical properties viz., water absorption pattern, density, color and opacity of oil palm fiber-LLDPE composites were studied. The effect of fiber size, fiber loading and fiber treatment on the above parameters were also studied. Alkali treatment on fibers was done to reduce the hydrophilic nature of composites. It was found that the water absorption in most of the combinations followed typical fickian behavior. The rate of water absorption and swelling increased with fiber loading. However alkali treatment on fibers resulted in reduction of water absorption at higher fiber loading only and composites with higher fiber size exhibited higher water absorption. True density of oil palm fiber-LLDPE composites were in the range of 967-1177 kg m⁻³, whereas the bulk density ranged from 942-1122 kg m⁻³. The dielectric constant of the composite was in the range of 3.22 to 6.73. The L*, a* and b* values of oil palm fiber-LLDPE composites were respectively in the range of 42.25-59.69, 5.85-6.30, 15.65-22.06. Opacity of LLDPE specimen of 3 mm thickness was 63.58%. Predicted values of true density of composites were in good agreement with measured values.

INTRODUCTION

Biocomposites are defined as the materials made from natural fiber and petroleum derived nonbiodegradable or biodegradable polymers. Use of natural fiber as filler in polymeric matrix in place of conventional inorganic fillers like glass fiber offers several advantages with regard to their less abrasiveness to processing equipment, environmental friendly nature, lower cost, greater deformability, biodegradability, renewable nature, non-toxicity, flexible usage, high specific strength, low energy cost, positive contribution to global carbon budget, combustibility, ease of recyclability, good thermal and insulating properties, good

electrical resistance, good acoustic insulating properly, worldwide availability etc.

Oil palm (*Elaeis guineensis* Jacq.) is a popular edible oil yielding crop grown in 42 countries worldwide on about 11 million ha. It produces about 55 MT ha⁻¹yr⁻¹ of total dry matter in the form of fibrous biomass ([Hasamudin and Soom, 2002](#)). Among various parts of oil palm tree, empty fruit bunch (EFB) is preferable for fiber in terms of availability and cost. It was reported that the palm oil industry has to dispose about 1.1 ton of EFB per every ton of oil produced ([Karina et al., 2008](#)) and EFB has potential to yield 73% fibers ([Wirjosentono et al., 2004](#)). The only current use of this highly cellulosic material is as boiler fuel, in the preparation of fertilizers or as mulching material. When left on the field, these waste materials create great environmental problems. Technologies for industrial utilization of these waste materials not only conserve environment but also make oil palm cultivation more sustainable. Linear low density polyethylene (LLDPE) is a popular thermoplastic material used mainly for packaging applications. The low processing temperature (less than 130°C) of LLDPE makes composite fabrication possible without partial melting or annealing of the fibers.

The objective of this study was to estimate the physical and optical properties viz., water absorption pattern, density, color and opacity of oil palm fiber-LLDPE composites fabricated by compression molding technique. The effect of fiber size, fiber content and fiber treatment on these properties was studied.

MATERIALS AND METHODS

RAW MATERIALS

The oil palm EFB's were obtained from a local palm oil mill at Pedavegi, Andhra Pradesh, India. The FFB's were steam



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treated at a pressure of 294 kPa for 1 h before stripping the fruits to yield EFB's, in a usual process in the palm oil milling sequence. The initial moisture content of EFB in the order of 65-70% (w.b) was brought down to 35-40% in an electrically heated forced convection cabinet drier. Fibers were extracted from dried EFB using a mechanical decorticator, where the EFB's were subjected to the action of rotating mechanical beaters. The extracted fibers were washed in distilled water to remove field impurities and dried in a hot air oven at 50°C for 48 h and stored in airtight containers for the experiments. The fibers used in this experiment contained 47.6% cellulose, 14.1% lignin, 25.7% hemicellulose and 1.5% ash.

Alkali treatment was done by immersing the fibers in 5% (w/w) NaOH (technical grade) solution for 1 h and washing thereafter in distilled water till such time the traces of alkali was removed. The washed fibers were further conditioned at 50±1°C for 48 h in a hot air oven and stored in airtight containers. The fibers were shredded in a laboratory grinder and sieve analysis was done to separate the shredded fibers into different fractions in a sieve shaker using ASTM standard test sieves. The fibers were separated into three size fractions viz ASTM sieve size 20-40 (425µ-840µ), ASTM sieve size 40-80 (177µ-425µ) and ASTM sieve size 80-200 (75µ-177µ).

Linear low density polyethylene in powder form was used in the experiments (procured from ExxonMobil Chemical Canada, Toronto, ON). The properties of LLDPE were: density-0.938 gcm⁻³, melt flow index-3.3 g 10 min⁻¹, melting point-126.5°C.

COMPOSITE PREPARATION

Mixing of LLDPE and palm fibers were done in a mechanical mixer, equipped with helical blades rotating at 40 rpm, for 10 minutes. The composite mixture was poured to a mould of 200×200 mm size for 3 mm board thickness and compression molded in a hydraulic press equipped with water cooling facility. The compression cycle was: a) preheating the press to 150°C, b) heating the mix in mould for 12 minutes under 850 kpa pressure, c) cooling the mould under same pressure for 15 minutes, d) cooling the mould in the atmospheric pressure for 15 minutes. The specimen thickness was maintained as 3 mm.

WATER ABSORPTION

Test specimens of 77×26×3 mm size were conditioned at 50°C for 48 h and initial mass was noted using a precision balance of 0.01 mg accuracy. Exact sizes of individual specimen were measured using a digital micrometer of 0.01 mm accuracy. The specimens were fully immersed in distilled water filled in a container maintained at constant temperature of 30°C in a temperature controlled water bath. Specimens were taken out at regular interval of 24 h, wiped

to remove surface moisture and measurements on mass, thickness, length and breadth were recorded for a period of 192 h. The mass gain at the time of measurement, expressed as a percentage of the initial specimen mass is termed as water absorption corresponding to the time of immersion in water.

DENSITY MEASUREMENTS

The true density measurement was done in a multi pycnometer equipped with nitrogen gas flushing. Bulk density was estimated as ratio of mass to volume of specimen. The mass was measured in an electronic weighing balance having accuracy of 0.01 mg and volume was calculated from the product of linear dimensions measured using a digital micrometer of 0.01 mm accuracy. Porosity of composite specimen was calculated from the measured values of bulk density and true density using following equation.

$$\varepsilon = (1 - \rho_b / \rho_t) \quad (1)$$

OPTICAL MEASUREMENTS

Color values of the composite specimen were measured using a hunterlab color flex colorimeter model CFLX-45. The surface colors of the rest of specimens were quantified in terms of L*, a* and b* values of CIELAB color space. Opacity is a measure on how much light passes through a material. The lighter the opacity, the lower the amount of light passes through the material. Opacity was calculated using Equation (2) from reflectance measurements of the same specimen with a black backing and a white backing using the same instrument.

$$Opacity = \frac{Y_{black\ backing}}{Y_{white\ backing}} \times 100 \quad (2)$$

RESULTS AND DISCUSSION

WATER ABSORPTION PATTERN

The water absorption of untreated and alkali treated oil palm fiber-LLDPE composites at different fiber loadings and fiber sizes are presented in Fig. 1 and Fig. 2, respectively.

It can be seen that the water absorption of LLDPE-oil palm fiber composites is less than that of LLDPE-sisal fiber composites as reported earlier (Mokoena *et al.*, 2004). The water absorption increased linearly with time of immersion during initial days and thereafter reached a plateau region and maintained constant, which is typical of fickian behavior as observed in previous studies on unsaturated polyester oil palm fiber composites and coir fiber-LDPE/LLDPE blend composites (Choudhury *et al.*, 2007; Khalil *et al.*, 2008).

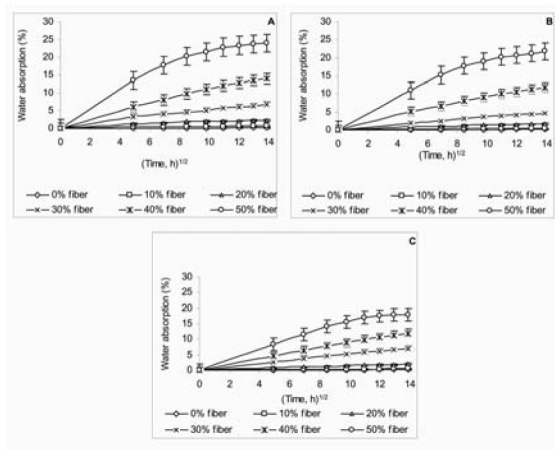


Fig. 1. Water absorption of untreated oil palm fiber-LLDPE composites; Fiber sizes A) 425 μ -840 μ ; B) 177 μ -425 μ ; C) 75 μ -177 μ .

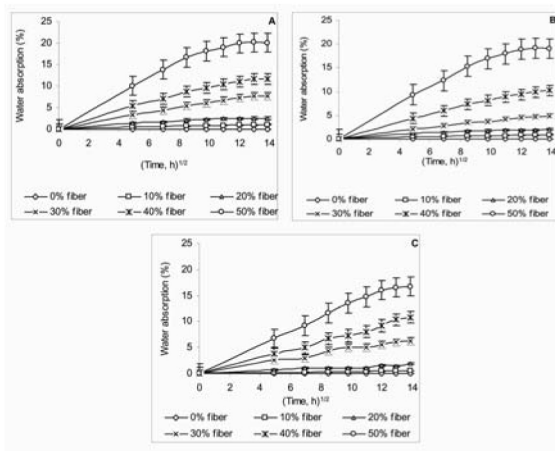


Fig. 2. Water absorption of alkali treated oil palm fiber-LLDPE composites; Fiber sizes A) 425 μ -840 μ ; B) 177 μ -425 μ ; C) 75 μ -177 μ .

The high initial water absorption is contributed by the porous structure of the oil palm fiber which transports the water via the capillaries in the fiber strands into gaps and flaws at the interfaces between matrix and fibers (Badri *et al.*, 2006). The rate of water absorption of oil palm fiber-LLDPE composites was found increasing with fiber loading. Addition of more hydrophilic oil palm fiber caused a deviation from hydrophobic nature of the composites and such deviation was proportional to the amount of fiber added. Generally, composites with a higher proportion of natural fiber absorb more water than those with a lower proportion due to cellulose, lignin and hemicellulose contents of fiber, possessing polar hydroxyl groups in their structure which can form hydrogen bonds with water. Similar trend was observed on natural rubber-oil palm fiber composites by Jacob *et al.* (2005). In another study, the water absorption of polyurethane-oil palm fiber composites increased sharply on

the first day of immersion and remained constant for the next 5 days and the composites with higher fiber content absorbed more water (Badri *et al.*, 2006). In a similar study, it was found that coir fiber-LDPE/LLDPE composites absorbed 5.5% water at the end of 200 h of immersion in water at 25°C (Choudhury *et al.*, 2007).

It was observed that alkali treatment on fibers reduced water absorption of the composites only at higher fiber loadings of 40 and 50%. However, at low fiber loadings, both alkali treated and untreated fiber composites exhibited almost same water absorption. This finding partially agrees with the opinion of Sreekala *et al.*, (2002) that alkali treatment of fibers reduces the water absorption of composites in comparison with other chemical treatments. Alkali treatment on fibers has 3 effects *viz.*, fibrillation or breaking down of fibers into smaller ones and removal of amorphous waxy cuticle layer and activation of hydroxyl groups (Sreekala *et al.*, 2002; Jacob *et al.*, 2005). Fibrillation provides a large surface area, which coupled with activation of hydroxyl groups imparts better mechanical interlocking between fiber and matrix and thus reduce water absorption. Removal of waxy cuticle layer which holds water molecules also reduce water absorption. However in case of oil palm fiber-LLDPE composites, these effects were not significant at low fiber loadings as the concentration of fibers were low to impart a difference between alkali treated and untreated fibers.

Composites with higher fiber size exhibited higher water absorption in case of both untreated and alkali treated fiber composites. It is interesting to note that the difference in water absorption between fiber sizes was predominant in case of alkali treated fiber composites. In case of untreated fiber composites, fiber sizes did not show difference in water absorption at lower level of fiber loadings. The void spaces around the fibers due to poor mixing of the composite mixture in case of long fibers would have caused rapid penetration of water, which can be explained as the reason for high water absorption for long fiber composites. Similar trend was observed for wood flour-plastic composites (Migneault *et al.*, 2009). The effect of fiber size coupled with the effect of alkali treatment in reducing water absorption may be the reason for significant difference in water absorption between fiber sizes in case of alkali treated fiber composites in the present case. The effect of fiber size on water absorption for untreated fiber composites was not predominant at low fiber loadings, as the concentration of fibers were not high enough to make a difference.

KINETICS OF WATER ABSORPTION

Water absorption in polymeric composites is mainly due to direct diffusion of water molecules into the polymer chains, capillary transport into the cracks and flaws in the fiber-matrix interface and absorption into the exposed fiber strands. In general, the water transport behavior in polymer