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Preparation of Polymer Composites using Natural Fiber and their Physico-Mechanical Properties

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Abstract

Use of natural fiber as reinforcing material is the latest invention of polymer science in order to get higher strength with lower weight composite materials having several applications. In this present investigation banana fiber, a natural fiber, is used as the reinforcing material. Low density polyethylene (LDPE)-banana fiber reinforced composites were prepared using both untreated and bleached (treated) banana fiber and LDPE with 7.5, 15, 22.5 and 30% weight content of fibers by using compression molding technique. Physico-mechanical properties (e.g. tensile strength, flexural strength, elongation at break, Young's modulus) of different types of prepared composites were characterized. From this study it is observed that all these values have augmented up to a definite percentage. The tensile strengths and flexural strengths of the composites increased up to 22.5% fiber addition then started to decrease gradually. Young moduli of the composites increased with the increase of fiber addition. Water absorption also increased with the weight of the fiber. Whereas elongation at break decreased with increasing fiber loading. Mechanical properties of bleached banana fiber-LDPE composites were slightly higher than the untreated banana fiber-LDPE composites. Compared to virgin molded LDPE both tensile and flexural strengths and Young moduli of these LDPE-banana fiber composites were significantly higher. All the variable properties like tensile strength, flexural strength, and water absorption capacity showed a very significant role in these polymer composites.

Keywords: Banana fiber, LDPE, Composite, Tensile strength, Flexural strength

Introduction

Use of natural fiber-reinforced thermoplastic composites are gaining popularity in automotive, cosmetic, and plastic lumber applications. Natural fibers offer economical and environmental advantages over traditional inorganic reinforcements and fillers. Economical benefits include lower cost compared to glass fiber and other mineral fillers and lower processing temperatures. Environmental advantages include being derived from annual growth renewable resources and by reduction of petroleum based products (Schemenauer *et. al*., 2000).

Natural fibers such as cellulose, jute, coir, banana, sisal, palm etc. are used as an alternative to synthetic fibers e.g. glass, aramid, carbon, etc. These fibers are advantageous to the synthetic fibers because of having renewable character, acceptable specific strength properties, low cost, enhanced energy recovery and biodegradability. Natural fiber reinforced polymer composites combine good mechanical properties with low specific mass and these composites are having increasing interest for producing structural materials for housing, railways, aerospace etc. Along with other natural fibers, banana fiber is also used widely as reinforcing agent in thermoplastics.

Kazayawoko *et. al.*, (1999) studied on the surface modification and adhesion mechanisms in wood fiber-polypropylene composites. They reported on the effectiveness of maleated polypropylene (MAPP) to improve the mechanical properties (particularly the tensile strength) of the wood fiber-polypropylene composites. Anand *et. al.*, (1997) and Karnani *et. al.*, (1997) also reported the improved result of kenaf fiber reinforced maleated polypropylene composites. Rana *et. al.*, (1998) studied and reported on the effect of compatibilizer on the short jute fiber-reinforced polypropylene composites. Joseph *et. al.*, (2002) studied and reported on a comparison of the mechanical properties of phenol formaldehyde composites reinforced with banana fibers and glass fibers. They observed that the interlocking between banana fiber and phenol formaldehyde resin is much higher than that of glass and phenol formaldehyde resin. Pothan *et. al.*, (2003) reported about dynamic mechanical analysis of banana fiber rein-

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forced polyester composites. They observed the maximum value for 40% fiber content composites. Sandeep *et. al.*, (2007) studied on analysis of untreated and treated banana fibers reinforced low-density polyethylene (PE)/ polycaprolactone (PCL) composites. They treated banana fiber with sodium hydroxide, sebacoyl chloride and toluene diisocyanate solutions separately and reported an improved mechanical properties for alkali treated banana fiber reinforced LDPE/PCL (70:30 blend) composites.

In this research work banana fiber and low density polyethylene have been used to prepare polymer composites. The main goal of this research work was to fabricate different composites and to investigate the performances of the prepared composites by determining their physico-mechanical properties (e.g. tensile strength, flexural strength, elongation at break, Young's modulus etc.).

Materials and Methods

Collection and separation of banana fiber from their plants

Banana trees were collected from the village of Naynabad in the district of Narayangonj. The fresh part of the banana trees were then cut into manageable size and kept under water, where microorganisms were available, so that they rot quickly. Within 20-22 days the trees were completely rotten and the fiber became loose from the other part of the tree. The fiber was then washed several times with fresh water and then the fiber bundles were sun dried.

Raw materials

The main raw materials used for the sample preparation were Low density polyethylene (LDPE) and banana fiber. LDPE is collected from local market. Banana fiber was used as reinforcement agent. Banana fibers were chopped into small pieces (2-3 mm average), with the help of scissors. The sized banana fibers were manually agitated to make the fibers loose from each other and were dried in an oven at around 105^o C for 24 hours.

Light bleaching of banana fiber

For light bleaching of banana fiber, fibers were taken in water solution containing 6% hydrogen peroxide, 4% sodium hydroxide, 4% sodium silicate, 2% soda ash and 1% soap followed by 24 hours storing at room temperature (Choudhury, 2006). Here hydrogen peroxide acts as the main ingredient for bleaching. Finally the bleached banana fiber was washed with water and dried in an oven at around 105^o C for 24 hours.

Composite fabrication and mixing of fiber and LDPE

Different formulations of composites were prepared using LDPE and banana fiber (Table I). The chopped banana fibers (untreated and bleached) and LDPE were mixed homogeneously to get improved quality products. Blender was used to mix fiber and matrix homogeneously where blending was done for one minute at 400 rpm for each specimen.

Table I. Different formulation of composites based on LDPE and banana fiber

Fiber	Formulation of LDPE/ Fiber (%)
Untreated banana fiber	92.5/ 7.5
	85/ 15
	77.5/ 22.5
	70/ 30
Bleached banana fiber	92.5/ 7.5
	85/ 15
	77.5/ 22.5
	70/ 30

Preparation of composites by compression-molding technique

The samples were prepared using Paul-Otto Weber Press Machine (compression molding machine). In this molding process, the die used has a ring of inside diameter 146 mm and outside diameter 158 mm and have two disc (or plates) on each side, each 3.56 mm in thickness. In compression molding, the polymeric materials and the fiber are subjected to heat and pressure in a single stroke. This is accomplished by using a hydraulic press with heated plates. Silicone mold release agent was used on the interior surfaces before pouring the fiber and matrix mixture into the molding device. Sufficient pressure of 50 KN was applied to get the desired shape and possible homogeneity. The applied pressure was measured by using a pressure gauge, set in the device. Heating was done electrically and the temperature was set at 180^o C. The temperature reached to 180^o C after about 35 minutes. After reaching the temperature at 180^o C, it was kept for about 20 min. After completion of heating the initial pressure was set zero and an additional pressure of 50KN was applied to avoid voids and to have a thickness. Cooling was done by tap water through the outer area of the heating plates of the machine. Finally the prepared composite was de-molded and the standard specimens were prepared by cutting them for mechanical testing.

Mechanical testing of the composites

In order to investigate the mechanical properties of the prepared composites the following (a) tensile and (b) flexural tests were performed using an universal tensile testing machine (capacity:10 KN, Hounsfield) at a crosshead speed of 1 mm/min.

a. Tensile test

The static tensile tests of the composites were performed according to ASTM D 638-01 (2002). The test specimens were prepared as per ASTM D 638-01 (2002) and each test was performed until tensile failure occurred except 100 % LDPE composite. Five specimens of each composition were tested and the average values were reported. The tensile strength was calculated from the following equation:

Tensile Strength, $\sigma_{UT} = \dfrac{P}{A}$

Where,

P = Breaking load, N and A = Cross-sectional area, mm.

Using the obtained data stress versus strain curves were drawn and tensile modulus were determined from the initial slope of the stress-strain curves.

b. Flexural strength

Flexural specimen preparation and tests was performed according to ASTM D 790-00 (2002). Three point flexural test set up was used to perform this test. Five specimens of each composition were tested and the average values were reported. The flexural strength (sf) was calculated by using the following equations:

Flexural strength, $\sigma_f = 3PL/2bd^2$

Where,

P= Maximum load on the load-deflection curve, N

L= Support span, mm

b= Width of beam tested, mm and

d= Thickness of beam tested, mm

c. Water absorption test

Water absorption tests of the composites were conducted according to ASTM D570-99 (2002). The samples were dried in an oven at 105^0 C for about 2 hrs, cooled in a desiccator and immediately weighed to the variation of 0.0001 g using Denver Instron balance. The dried and weighed samples were immersed in boiling water for about 2 hrs as described in ASTM D570-99 (2002). Excess water on the surface of the samples was removed and the weights of the samples were taken. Five specimens of each composition were tested and reported the average result. The percentage increase in weight after immersion in water was calculated as follows:

Increase in weight, % = (wet wt. - conditioned wt.) x 100 / (conditioned wt.)

Results and Discussion

Mechanical properties of untreated and bleached banana fiber reinforced LDPE Composites

Banana fiber (untreated and bleached)-LDPE composites with 7.5, 15, 22.5 and 30 wt.% varying fiber loaded different type composites were prepared by compression molding process. The mechanical properties were measured for all of these composites and the results are given below:

The tensile strengths of these composites are shown in Fig. 1. It is found from the figure that tensile strength of the banana fiber-LDPE composites increases with increasing fiber loading upto 22.5 % fiber loading. It is also found from the figure that above 22.5% fiber loading gave no increase in composite tensile strength. It may be due to weak interfacial bonding occured between fiber and LDPE above 22.5% fiber loaded composites. It is further found that bleached banana

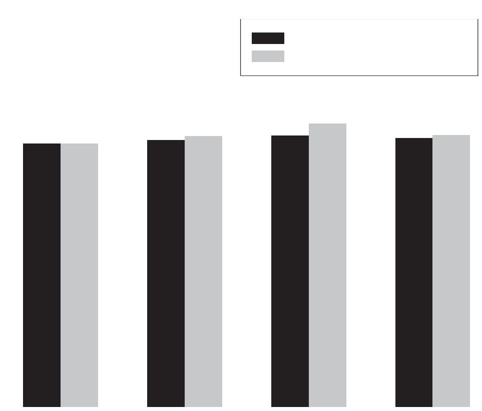

Fig. 1. Tensile strength vs fiber content (wt.%) of untreated and bleached banana fiber reinforced LDPE composites

fiber reinforced LDPE composites show slightly higher tensile properties than untreated banana fiber reinforced LDPE composites. The tensile strength of virgin molded LDPE was 6.60 MPa.

The elongations at break of all composites are shown in the Fig. 2. It is apparent that elongation decreases with the increasing fiber content. Thus, the presence of fiber restricts the slip resulting in lesser ductility and toughness.

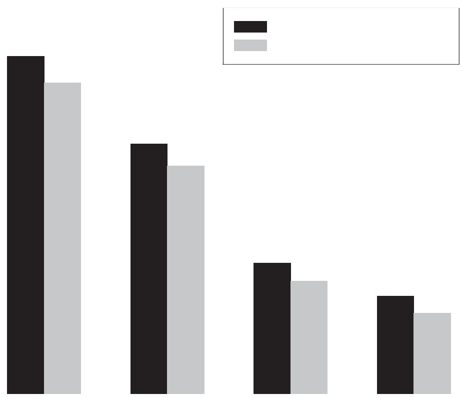

Fig. 2. Elongation at break vs fiber content (wt.%) of untreated and bleached banana fiber reinforced LDPE composites

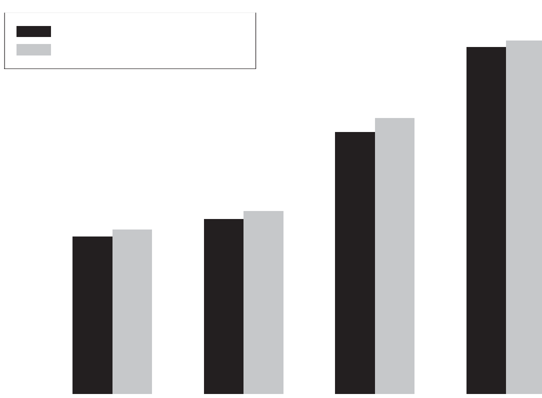

Fig. 3. Young's modulus vs fiber content (wt.%) of untreated and bleached banana fiber reinforced LDPE composites

Fig. 3 shows the Young's modulus vs fiber content (wt.%) curves of untreated and bleached banana fiber reinforced LDPE composites. It is observed that the Young's modulus of the composites increases with the increasing of fiber loading. Young's modulus of bleached banana fiber-LDPE composites are higher than untreated banana fiber-LDPE composites. Young's modulus is a measure of stiffness of a material. Therefore, it is clear from the Fig. 3 that stiffness of the composites increases with the increasing of fiber loading and it also increases for bleached banana fiber reinforced LDPE composites.

The flexural strengths of all composites are shown in the Fig. 4. It is observed from the figure that like tensile strength of the composites, flexural strengths also increases up to 22.5 % fiber loading. The flexural strengths increase for bleached banana fiber reinforced LDPE composites than untreated banana fiber-LDPE composites.

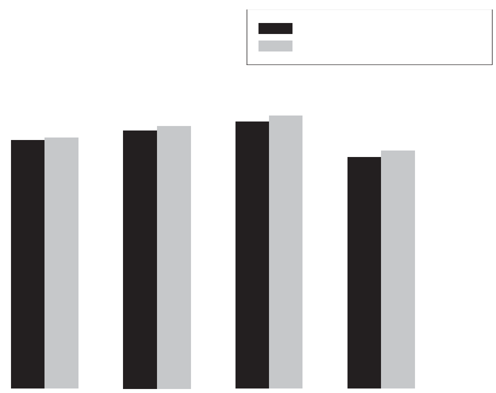

Fig. 4. Flexural strength vs fiber content (wt.%) of untreated and bleached banana fiber reinforced LDPE composites

The flexural strength of virgin molded LDPE (at 0% fiber) is 6.32 MPa. It is observed from fig. 4 that above 22.5% fiber loading the flexural strengths of the banana-LDPE composites decreases with increasing fiber loading due to weak interfacial bonding between fiber and matrix. It is also clear from the figs. 1, 3 and 4 that compared to molded virgin LDPE (0% of fiber) both tensile strength, flexural strength and Young moduli of the LDPE-banana fiber composites are significantly higher. Up to 22.5 % fiber loading, the short fibers are finely distributed and the interfacial bonding between the fiber and matrix is high and so the tensile strength, flexural strength and Young moduli are high. After that may be the fiber are coagulated as bundle of fibers in the composites and so the interfacial bonding between the fiber and matrix is poor.

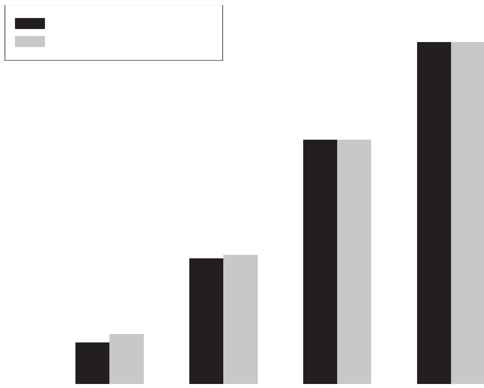

Fig. 5. Flexural strength vs fiber content (wt.%) of untreat ed and bleached banana fiber reinforced LDPE composites

Water absorption of the composites

The effect of fiber addition on water absorption (by % basis) in boiling water condition of LDPE-Banana fiber (untreated and bleached) composite is shown in Fig. 5. It shows that the water absorption increases with the increase of fiber addition and with the increase of time. It is also found that the water absorption is approximately same for both the untreated and bleached banana fiber-LDPE composites. It is assumed that water absorption is due to fiber content. The fiber is embedded in LDPE Matrix in case of low percentage of fiber thus the exposure to water is low, so for low percentage of fiber the water absorption is lesser. But with the higher percentage of fiber, it is exposed and inter connected, so the water absorption is more.

Conclusion

From this research study it is revealed that the tensile strength, flexural strength and young moduli of the untreated and bleached banana fiber-LDPE composites increases with increasing fiber loading up to 22.5 %. It is observed that the mechanical properties of bleached banana fiber-LDPE composites are slightly higher than the untreated banana fiber-LDPE composites. It is also observed that the tensile strength, flexural strength and young moduli of the LDPE-banana fiber composites are significantly higher than molded virgin LDPE (at 0% of fiber). Water absorption increases with increasing fiber loading, so coating is needed to improve the dimensional stability of the composites. Finally, it can be concluded that banana fiber can be used as reinforcing agent successfully.

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