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Short Communication

Physico-mechanical properties of chemically treated palm and coir fiber reinforced polypropylene composites

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ABSTRACT

In this work, palm and coir fiber reinforced polypropylene bio-composites were manufactured using a single extruder and injection molding machine. Raw palm and coir were chemically treated with benzene diazonium salt to increase their compatibility with the polypropylene matrix. Both raw and treated palm and coir fiber at five level of fiber loading (15, 20, 25, 30 and 35 wt.%) was utilized during composite manufacturing. Microstructural analysis and mechanical tests were conducted. Comparison has been made between the properties of the palm and coir fiber composites. Treated fiber reinforced specimens yielded better mechanical properties compared to the raw composites, while coir fiber composites had better mechanical properties than palm fiber ones. Based on fiber loading, 30% fiber reinforced composites had the optimum set of mechanical properties.

1. Introduction

Recently natural fibers have been receiving considerable attention as substitutes for synthetic fiber reinforcements such as glass in plastics due to their low cost, low density, acceptable specific strength, good thermal insulation properties, reduced tool wear, reduced thermal and respiratory irritation and renewable resources. However, natural fibers are generally hydrophilic and are inherently incompatible with hydrophobic thermoplastics such as polypropylene (PP). Major problem of using natural fibers with thermoplastics is the poor interfacial bonding between the fiber and thermoplastic. Compared to other natural fibers, palm (Jacob et al., 2004) and coir (Geethamma et al., 2005; Espert et al., 2004; Brahmakumar et al., 2005; Lovino et al., 2008) are quite new in reinforcing thermoplastics. Palm fibers are tough and are found to be a potential reinforcement in polymers. While coir fiber possesses high weather resistance due to higher lignin content. It also absorbs less water compared to other fibers due to lower cellulose content.

In this work, palm and coir fiber were used as the reinforcing material since they are abundant in nature and have minimal effect on the environment because of their biodegradable properties (Jacob et al., 2004; Geethamma et al., 2005; Espert et al., 2004; Brahmakumar et al., 2005; Lovino et al., 2008). Both fibers were chemically treated with benzene diazonium salt to increase their compatibility with the PP matrix. Thus, the aim of this study is to manufacture composites from raw and treated palm and coir fibers and PP and subsequently characterize those using microstructural analysis and mechanical testing. Comparison between physico-mechanical properties of the palm and coir fiber reinforced PP composites is also presented. Finally, the effect of the fiber loading on the mechanical properties and morphology of the palm and coir fiber reinforced PP are also reported.

2. Methods

2.1. Materials

The thermoplastic polymer polypropylene (PP), used as matrix material, was supplied by the Polyolefine Company Private Limited, Singapore in the form of homopolymer pellets. It had specific gravity of 0.90–0.91, melting temperatures of 165–171 °C and crystallinity of 82%. Both the palm and coir were collected from rural areas of Bangladesh. The coir comprises of 43.44% cellulose, 45.84% lignin, 0.25% hemicellulose, 3% pectin, 5.6% ash and 7.47% others (Shukala and Roshan, 2005), while the palm had 49.6% cellulose, 18% hemicellulose, 21.2% lignin, 17.8% pentosan and 2% ash (Khalil et al., 2007). Chemicals used in this study to treat palm and coir were HCl (Merck, Germany), $NaNO_2$ (Merck, Germany), $C_6H_5NH_2$ (Merck, Germany) and NaOH (Merck, India).

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2.2. Treatment of palm and coir fiber

Benzene diazonium salt was synthesized by the standard diazotization method (Ismail et al., 2002). Dried fibrous material (palm and coir) of 500 g were kept in a benzene diazonium salt solution (5 °C) containing 1000 ml 5% NaOH for 10 min. Fibers were then taken out, washed with soap solution followed by water and finally dried in open air.

2.3. Fabrication of composites and test specimens

Dried palm and coir of approximate length of 3 mm (at 15, 20, 25, 30 and 35 wt.%) were mixed thoroughly with PP granules separately in order to prepare the composites in a single screw extruder machine. The extruded composites were cut into 15–20 cm long small pieces. All the pieces were then crushed into smaller granules (0.5 mm) using a grinding machine (Model FFC-23, Machinery Company Limited, India). The dried granulates were molded according to DIN EN ISO 572-2 Type 1A and DIN EN ISO 179, Type 1 using the injection molding machine to prepare tensile and flexural test specimens.

2.4. Microstructural analysis

The infrared spectra of the raw and treated palm and coir were recorded on a Nicolet 380 Spectrophotometer, while the interfacial bonding between the palm and coir fiber and PP matrix in manufactured bio-composites were examined using a Scanning Electron Microscope (Philips XL 30).

2.5. Mechanical testing

Tensile, flexural, charpy impact, hardness and water absorption tests were carried out according to ASTM Standard. For each test and type of composite, ten specimens were tested and the average values are reported. Tensile tests were conducted according to ASTM D 638-01, 2002 using a Universal Testing Machine (Model: MSC-5/500, Agawn Seiki Company Limited, Japan) at a crosshead speed of 10 mm/min. Static flexural tests were carried out according to ASTM D 790-00, 2002 using the same Testing Machine mentioned above at same crosshead speed. Dynamic charpy impact tests were conducted according to ASTM D 6110-97, 2002 using a Universal Impact Testing Machine. The hardness of the composites was measured using a Rockwell Hardness Testing Machine according to ASTM D785-98, 2002. Cold water absorption tests were conducted according to ASTM D 570-99, 2002.

3. Results and discussion

3.1. Structural analysis

In order to improve mechanical properties of the composites, both palm and coir was chemically treated using benzene diazonium salt. The hydroxyl group in the raw palm/coir is responsible for high water absorption and weak interfacial bond between the fiber and PP matrix. The chemical treatment converts hydroxyl groups into diazo group and results in azo product, 2,6-diazo cellulose. The FT–IR spectroscopic analysis of the raw palm, treated palm, raw coir and treated coir confirm this phenomenon. There are some structural differences between palm and coir due to their difference in chemical composition. Therefore, their structural behaviour is quite similar, but not totally same. The IR spectra of both treated palm and coir clearly show the presence of characteristic band of NO group in the region of 1500–1650 cm^{-1} and C–O stretching at the region of 1300–1000 cm^{-1}. In addition, IR spectra of treated palm and coir had an absorption band of N=N stretching near 1400 and 1454.6 cm^{-1}, respectively. Again the IR spectra of both the raw palm and coir show the absorption band at the region near 1732 cm^{-1}. This absorption band may be due to carboxyl group of acetylester in cellulose and carboxyl aldehyde in lignin (Matuana et al., 2001).

3.2. Tensile properties

The tensile strength of the raw and treated palm and coir fiber reinforced PP bio-composites at different fiber loading is shown in Fig. 1. For the raw fiber reinforced composites, the tensile strength decreased with fiber loading (Yang et al., 2004, 2006, 2007; Lou et al., 2007; Jamil et al., 2006). As the fiber load increased, the weak interfacial area between the fiber and matrix increased, which consequently decreased the tensile strength. In order to increase the compatibility of the palm and coir fiber with PP matrix, raw fibers were chemically treated with benzene diazonium salt. This consequently increased the tensile strength of the 15% fiber loaded treated composites compared to the PP matrix itself. These results suggest that stress is expected to transfer from the matrix to the fiber, indicating a better interfacial bonding with a consequent improvement in the mechanical properties. The tensile strength of the chemically treated composites decreased with fiber loading due to the same reason mentioned above. Again the tensile strength of the raw and treated coir fiber reinforced PP composites was higher than those of the raw and treated palm composites respectively due to the lower cellulose content of the coir fiber compared to the palm. The Young's modulus increased with fiber loading and chemical treatment. The Young's modulus found for the raw and treated coir fiber composites was higher than those of the raw and treated palm fiber reinforced PP composites respectively due to the same reason mentioned above.

3.3. Flexural properties

Flexural strength of the raw and treated palm and coir fiber reinforced bio-composites at different fiber loading are shown in Fig. 2. The flexural strength increased with fiber loading (Rana et al., 2003) however there was a decrement from 30% to 35% fiber loaded composites (Fig. 2) for both fibers. Again the flexural modulus also increased with fiber loading (Lou et al., 2007; Rana et al., 2003). Since both palm and coir fibers are high modulus material, higher fiber concentration demands higher stress for the same deformation. Increased fiber–matrix adhesion provides increased stress transfer between them. However, the increase of fiber loading from 30 to 35 wt.% decreased the fiber/matrix adhesion, result-

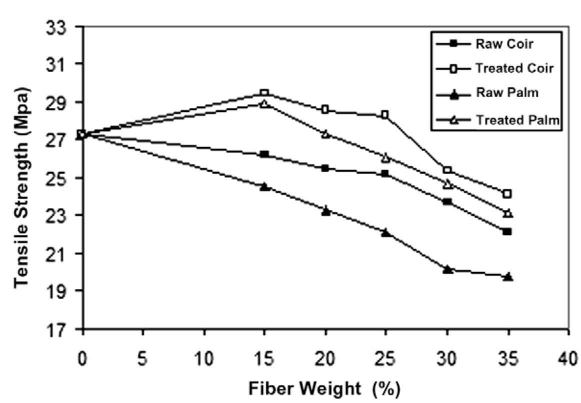

Fig. 1. Variation of tensile strength at different fiber loading.