MECHANICAL PROPERTIES OF JUTE FIBER REINFORCED POLYPROPYLENE COMPOSITE: EFFECT OF CHEMICAL TREATMENT BY BENZENEDIAZONIUM SALT IN ALKALINE MEDIUM

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Raw jute fiber was treated with o-hydroxybenzenediazonium salt (o-HBDS) in alkaline media. Raw and modified jute fiber were used to prepare composites by mixing with polypropylene (PP) plastic in different weight fractions (20, 25, 30, and 35%) of jute fiber. The mechanical properties except elongation at break of o-HBDS-treated (in alkaline medium) jute fiber-PP composite were higher than those of PP alone, raw jute fiber-PP composites, and alkali-treated jute fiber-PP composites. The elongation at break of treated jute-PP composite decreased to a large extent as compared to that of PP. The increase of tensile strength, tensile modulus, flexural strength, flexural modulus, and Charpy impact strength were found to be exceptionally high (in some cases ~200%) as compared to those of literature values.

Keywords: Jute-PP composite; Chemically treated jute-PP composites; Jute fiber; Adhesion

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INTRODUCTION

The potentiality of natural fiber-plastic composites using wood, jute, sisal, coir, or hemp, etc., as reinforcing fiber in a thermosetting resin matrix has received considerable attention from scientists all over the world (Roe et al. 1985; Bisanda and Ansell 1991; Rout et al. 1999; Pothan et al. 1997; Parshad et al. 1983) for their excellent mechanical properties. Composites based on thermoplastic resins, are now becoming popular due to their processing advantages (Karmaker and Youngquist 1996; Wong et al. 2002). On the other hand, jute is an annually regenerative, biodegradable, lignocellulosic self-composite biopolymer bast fiber (Maldas et al. 1989). It is nonabrasive and has low density and high mechanical strength. It grows abundantly in tropical countries. Its production cost is comparatively low, and therefore there is particular interest in its use as a reinforcing agent in thermoplastic composites. Among different thermoplastics, polypropylene (PP) possesses outstanding properties such as low density, good flex life, sterilizability, good surface hardness, very good abrasion resistance, and excellent electrical properties (Rana et al. 1998). Various investigators have carried out research work on oxidized jute fiber-PP (Sultana et al. 2007), alkali-treated jute fiber-epoxy resin (Gassan and Bledzki 1999), cyanoethylated jute fiber-polyester resin (Shaha et al. 2000), jute fiber-RSUFC (resorcinol-urea-formaldehyde-casein) resin (Raval et al. 2005), jute fiber-polyester amide (Shaikh and Channiwala 2006) composite materials, etc. In the present investigation the mechanical properties (tensile strength, tensile modulus, flexural strength, flexural modulus, elongation at break and Charpy impact strength) of raw jute fiber-PP and o-HBDS-treated (in alkaline medium) jute fiber-PP composites of different compositions were studied.

EXPERIMENTAL

Materials

A commercial grade PP procured from the local market was used in this study. The reinforcing material jute fibers were collected from Bangladesh Jute Research Institute (BJRI), Dhaka, Bangladesh. The collected jute fibers were Tossa variety (Corchorus Olitorius).

Treatment of Raw Jute Fiber with o-Hydroxybenzenediazonium Salt in Alkaline Media

The middle parts of the jute fibers were used in this study and were chopped into lengths of approximately 3 mm. These were then treated as follows:

Small pieces of raw jute fiber (250 g) were manually cleaned, washed with distilled water, and then dried overnight at a temperature 105ºC in an oven. The dried jute fibers were taken in a 2.0 L glass beaker containing water, sodium hydroxide (to maintain pH = 8-9). These were then treated with o-hydroxybenzenediazonium chloride separately, taking 0.02 moles (3.04 g) of o-amino phenol, $NaNO_2$, and HCl in a beaker (Morrison and Boyd 1989). The treated fibers were washed with soap solution followed by distilled water.

Composite Fabrication

The raw and treated jute fibers were separately dried in an oven at 105^oC for 6 hours. Jute fibers were mixed thoroughly with PP in different weight fractions ranging from 20 to 35% based on fiber mass.

Composites were prepared by passing the mixtures through a single screw extruder machine. The processing temperature of extrusion was controlled at $160^o \pm 2°C$ and uniform pressure. The composites were delivered through a die of rod shape at a uniform rate. The prepared composites were cut into small pieces of 15-20 cm in length and dried in an oven at 105^oC.

Preparation of Samples by Injection Moulding

The dried granulated products were moulded into test specimens (tensile, flexural and Charpy impact test bars) by an injection-moulding machine at a moulding temperature of $160 \pm 2°C$. The lengths, width, and thickness of specimens for tensile test were 148 mm, 9.5 mm, and 4 mm, respectively. Dimensions of flexural test specimens were 79 mm length, 9.5 mm width, and 4 mm thickness. The specimen dimension for Charpy impact strength was 79 mm x 9.5mm x 4mm.

Physico-Mechanical Properties of Composite Materials

The mechanical properties such as tensile strength, elongation at break, flexural strength, and Charpy impact strength of composite materials were determined by performing the tensile test, flexural test, and Charpy impact test in a universal testing machine, model MSC-5/500, capacity 5KN, Ogawa Seiki C. Ltd. Japan. All these tests were conducted following ASTM D 638-01, ASTM D 790-00, and ASTM D 6110-97, respectively. Eight to ten specimens of each composite were tested, and the average values of five well matched specimens have been reported.

RESULTS AND DISCUSSION

The results on mechanical properties (such as tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus, and Charpy impact strength) of composites are presented in Figs. 1 through 5. It is observed from Fig. 1 that the tensile strength of raw jute fiber-PP composite was less than that of the polymer (PP) matrix. This may be due to the poor compatibility between hydrophilic raw jute fiber and hydrophobic PP. However, it was observed that the tensile strength of alkali-treated jute fiber-PP composites was slightly higher and the tensile strength of o-HBDS-treated in alkali medium jute fiber-PP composite was 50-60% higher than that of PP matrix. This indicates that the treatment of jute fiber with o-HBDS in alkali medium increased the compatibility between jute fiber and PP to a large extent. This may be due to coupling of o-HBDS with hydroxyl group of jute fiber, thereby reducing the hydrophilic nature of jute fiber. The treatment of jute fiber with o-HBDS may also increase the interfacial bonding between jute fiber and polymer matrix.

The results show that the effect of fiber loading (20-35%) on the tensile strength of the raw jute fiber-PP and alkali-treated jute fiber-PP composite was negligible.

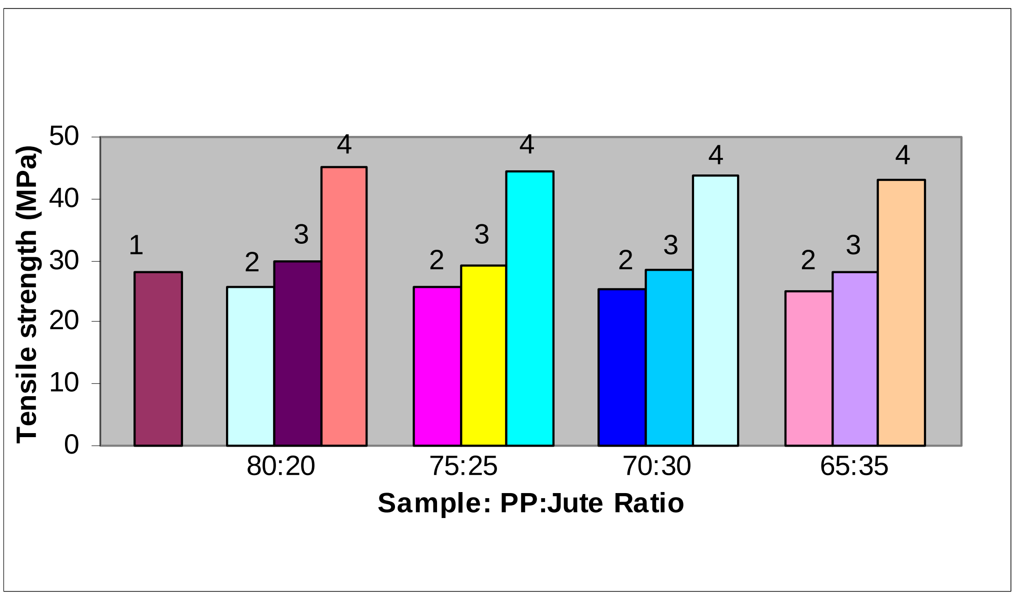

Fig. 1. Tensile strength of PP (1), raw jute fiber-PP (2), alkali-treated jute fiber-PP (3), and

o-HBDS (4) treated jute fiber-PP composites

It is observed from Fig. 2 that the tensile modulus values were approximately 75% higher in case of raw jute fiber-PP, 90% higher in case of alkali-treated, and 300-350% higher in the case of o-HBDS-treated (in alkali medium) jute fiber-PP composites than the PP matrix alone. The results also show that the effect of fiber loading (20%-35%) on tensile modulus of raw jute fiber-PP and treated jute fiber-PP composite was not appreciable.

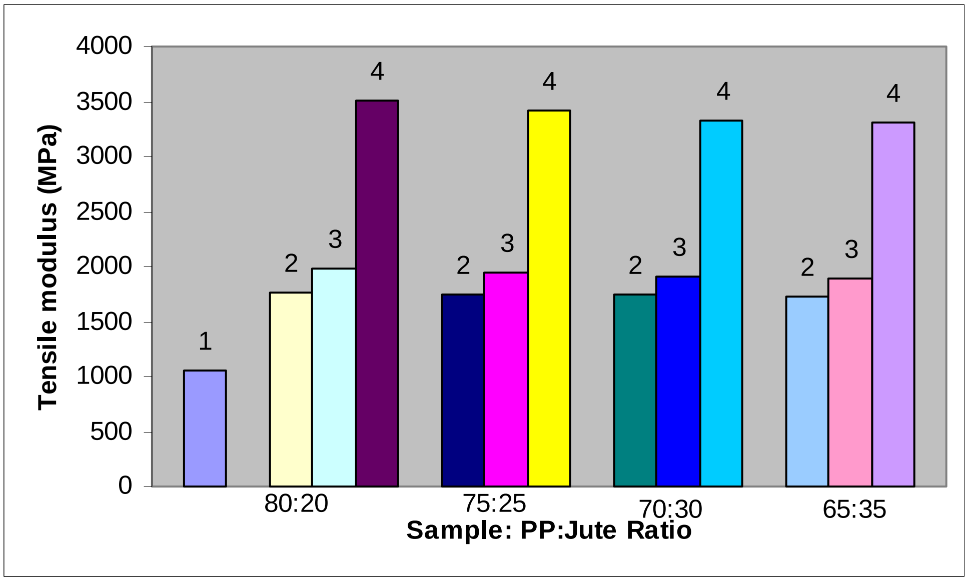

Fig. 2. Tensile modulus of PP (1), raw jute fiber-PP (2), alkali-treated jute fiber-PP (3), and o-HBDS-treated (4) jute fiber-PP composites

The results on elongation at break of treated jute fiber-PP composite are presented in Table 1. It is observed from the table that the jute fiber-PP composite had lower elongation at break than PP matrix. This may be due to the reinforcement of the polymer matrix with jute fiber. As a result, the deformation in length of all composites investigated in this study were decreased. It is also seen that the effect of treatment and fiber loading (20-35%) on the elongation at break of all these composites was almost negligible.

Table 1. Elongation at Break of PP, Raw Jute Fiber-PP, Alkali-Treated Jute Fiber-PP, and o-HBDS-Treated Jute Fiber-PP Composites

Sample:PP:Jute Ratio	Raw jute fiber-PP	Alkali-treated jute fiber-PP	o-HBDS-treated jute fiber-PP	PP only
80:20	1.36	1.51	1.48	15
75:25	1.33	1.50	1.46	
70:30	1.28	1.49	1.44	
65:35	1.22	1.48	1.41	

The results on flexural strength and flexural modulus are presented in Figs. 3 and 4, respectively. It is observed from the figures that the values of flexural strength and flexural modulus of all composites were significantly higher than those of the polymer matrix. The order of the increase of flexural strength and flexural modulus was: polymer (PP) matrix < jute fiber-PP composite < alkali-treated jute fiber-PP composite < o-HBDS-treated jute fiber-PP composite. This may be due to the initial reinforcement of PP matrix with jute fiber. The alkali-treated jute fiber might have created space (by washing out lignin, cellulose and hemicellulose) in jute fiber for incorporation of PP molecules. The o-HBDS treatment increased the extent of interfacial bonding between jute fiber and PP matrix. It is also observed from Fig. 3 that in the case of o-HBDS-treated jute fiber-PP composite the flexural strength decreased with the increase in fiber loading from 20 to 35%. This may be due to decrease in strength of interfacial bonding between jute fiber and PP with the increase in percentage of jute fiber.

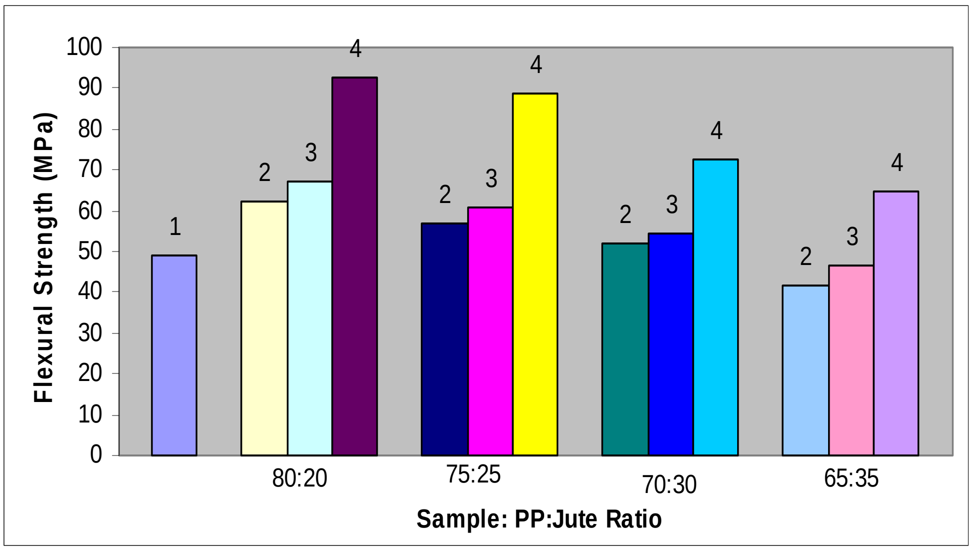

Fig. 3. Flexural strength of PP (1), raw jute fiber-PP (2), alkali-treated jute fiber-PP (3), and o-HBDS-treated (4) jute fiber-PP composites

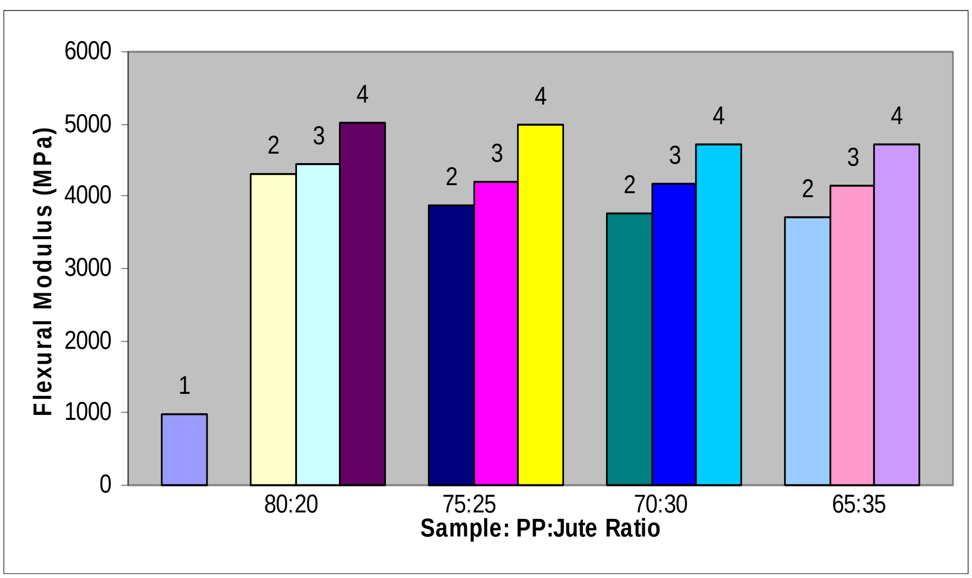

Fig. 4. Flexural modulus of PP (1), raw jute fiber-PP (2), alkali-treated jute fiber-PP (3), and

o-HBDS-treated (4) jute fiber-PP composites

The results on Charpy impact strength testing are presented in Fig. 6. It is also observed from the figure that values of Charpy impact strength of raw and alkali-treated jute fiber-PP composites were less than that of polymer matrix. However, the values of o-HBDS-treated (in alkaline medium) jute fiber-PP composites were higher (by approximately 200%) than that of PP matrix. The higher values of o-HBDS-treated jute fiber-PP composites may be due to better compatibility of o-HBDS-treated jute fiber with the PP matrix. As a result, a stronger force was required to pull out fiber from the composites. It is also observed from the Fig. 5 that the values of Charpy impact strength of the composites decreased with the increase of fiber loading. One of the factors of impact failure of a fiber-reinforced composite is fiber pull-out. With the increase of jute fiber loading the possibility of fiber pull-out of the composites increases. This may be the cause of decreasing Charpy impact strength with the increase of fiber loading in the composite.

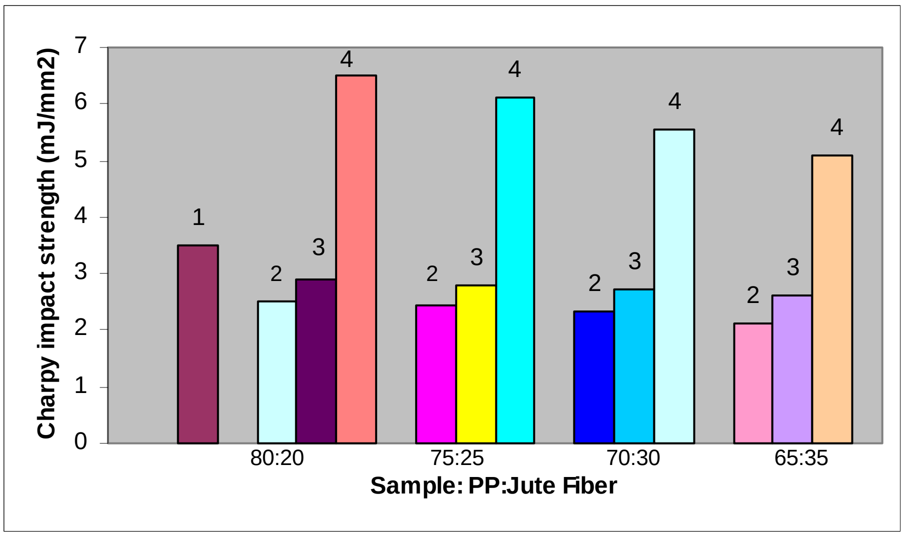

Fig. 5. Charpy impact strength of PP (1), raw jute fiber-PP (2), alkali-treated jute fiber-PP (3), and o-HBDS-treated (4) jute fiber-PP composites

CONCLUSIONS

1. The treatment of jute fiber with o-HBDS in alkaline medium improves the mechanical properties of jute-PP composite by almost 100-150 percent, compared to reported values (Sultana et al. 2007; Rahman et al. 2009; Das et al. 2002).
2. The tensile strength, tensile modulus, flexural strength, flexural modulus and Charpy impact strength of composites prepared by using o-HBDS-treated jute fiber with PP are higher in comparison to those of raw jute fiber-PP and alkali-treated jute fiber-PP composites.

3. With the increase of fiber loading the values of flexural strength and Charpy impact strength of composite material have been decreased. But the values of other mechanical properties remain almost the same.

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