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Physico-mechanical properties of coir fiber/LDPE composites: Effect of chemical treatment and compatibilizer

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Abstract−Coir fiber/low density polyethylene (LDPE) composites were fabricated with different fiber loading (10-30 wt%) using compression molding technique. A fiber loading of 20 wt% was found optimum, with maximum mechanical properties. Further, the effect of fiber treatment (alkali and acrylic acid) and compatibilizer (MA-g-LDPE) incorporation on the mechanical and water absorption properties of the LDPE composites were studied and compared. The results showed that MA-g-LDPE incorporation into untreated and treated fiber composites led to improved mechanical properties and water resistance compared with the same composite formulation without MA-g-LDPE. However, treated fiber composites with MA-g-LDPE showed lower mechanical properties than untreated fiber without MA-g-LDPE, due to the removal of hydroxyl groups from the hemicellulose and lignin region of the fiber and degradation of fibers by chemical attack. From SEM studies on the tensile fractured composite samples, a good relationship has been observed between the morphological and mechanical properties.

Keywords: Coir Fiber, LDPE Composites, MA-g-LDPE, Mechanical Properties, Water Absorption

INTRODUCTION

Natural fibers based thermoplastic composites have been gained significant research interest because of the recyclability and eco-friendly nature of the resultant composite products [1]. Natural fibers, such as kenaf, hemp, flax, sisal, banana and coir fibers, are widely distributed and easily accessible. Natural fibers based composites products offer acceptable mechanical properties with low density and low cost. These composite materials have gained importance in a number of applications, particularly as non-structural building materials and automotive components [2].

Coir fiber is a versatile lingo-cellulose fiber extricated from the coconut (Cocosnucifera) husk. Among other natural fibers, coir fiber has low cellulose and hemicellulose, high lignin content and high microfibrillar angle. As a result, coir fiber has lower tensile strength and Young's modulus, but higher elongation at break [3]. However, high lignin content makes coir fiber stiffer and tougher [4]. Owing to properties like hardwearing quality, toughness (not fragile like glass fiber), durability (moth-proof and resistant to microbial and fungi degradation), good acoustic resistance and non-toxic, coir fiber is remarkably accepted in many industrial applications [5].

The reinforcing efficiency of natural fiber based composites mainly depends on the fiber-matrix interface and stress transfer from the matrix to the fiber [6]. However, the inherent hydrophilic nature of lignocellulosic fibers and hydrophobic nature of thermoplastics result in weak interfacial bonding between them. Lignin, pectin and other impurities present within the coir fiber are considered harmful for its bonding with the polymer matrix [7]. To overcome these problems, two principal methods are used to improve adhesion between natural fiber and thermoplastic composites: chemical modification of fiber and the use of compatibilizer. Chemical treatment methods help to remove a certain amount of lignin, wax and oil from the surface of the fiber and expose more reactive sites on the fiber surface. This facilitates better bonding with thermoplastic matrix, and better mechanical properties of the composites can be achieved [8]. Whereas, compatibilizer is not only used to modify fiber surface, but also thermoplastic matrix, which facilitates better interfacial bonding and mechanical properties in the composites [9]. In this regard, a number of chemical surface modification methods have been introduced [10,11].

Alkali-treated coir fiber-polyester composites have been reported as having better properties than untreated fiber composites with fiber loading ranging from 10% to 30%. But, treated fiber composites exhibit a negative effect on the flexural properties [12,13]. Soaking time and alkali concentration play important roles in determining the mechanical properties of the composites [4,14]. Addition of maleic anhydride grafted polypropylene (MA-g-PP), a compatibilizer, improves the bonding between coir fiber and polypropylene [15,16]. Other treatments also showing a positive effect on coir fiber composite properties are silane, dodecane bromide, benzene diazonium salt, sodium periodate, p-aminophenol, stearic acid, m-isopropenyl-a-a-dimethylbenzyl isocyanate grafted polypropylene, etc. [6,17-20]. To improve interfacial bonding, flax fiber has been treated with alkali, silane, potassium permanganate, acrylic acid, and sodium chloride. Among these modification techniques, acrylic acid-treated fiber composites were found to be a relatively good method to improve mechanical properties of the both flax based HDPE and LLDPE composites [21]. Composites made with natural fiber and polyethylene, treated with polyethylene functionalized maleic anhydride

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(MA-g-PE) have been studied by many scientists who have obtained some interesting results. Sisal fiber-high density polyethylene (HDPE) composites, treated with MA-g-PE, exhibited higher stability than the individual components [22]. In another study, addition of MA-g-PE with jute/HDPE composites ensured better thermal stability than untreated composites [23].

From the above literature, it is found that the addition of compatibilizer (MA-g-PE) and acrylic acid treatment of fiber have a positive effect on the mechanical properties and thermal stability of the composite products. But there are very few studies available on these modification techniques. Thus, in this work untreated, alkali (NaOH) and acrylic acid treated short coir fiber-low density polyethylene (LDPE) composites with or without compatibilizer (maleic anhydride grafted LDPE, MA-g-LDPE) were fabricated and their influence on the mechanical, morphological and water absorption properties were investigated and compared. Incorporation of compatibilizer into the untreated coir fiber/LDPE composites led to improved mechanical properties and water resistance.

EXPERIMENTAL

1. Materials

The coir fiber, used as a reinforcing fiber, was collected from a local market and chopped to about 10 mm in length. It comprises of 43.44% cellulose, 45.84% lignin, 0.25% hemicellulose, 3% pectin, 5.6% ash, and 7.47% other constituents [24]. The thermoplastic low density polyethylene (LDPE), used as a matrix material, was procured from M/s Rapid Engineering Company Private Ltd., India in the form of powder. It had a melt flow index (MFI) of 34 g/10 min (2.16 kg at 230 °C) and density of 0.930-0.945 g/cm^3. The compatibilizer, LDPE functionalized with maleic anhydride (MA-g-LDPE, OPTIM-142® functionalized with 0.5-0.8% maleic anhydride) was procured from M/s Pluss Polymers Private Limited, India. Sodium hydroxide (NaOH) and acrylic acid used for the treatment of banana fiber were purchased from Merck, India and Loba Chemie, India, respectively.

2. Treatment of Coir Fiber

2-1. Alkali Treatment

Chopped coir fibers were first washed with water to remove impurities. After that, the coir fibers were soaked in 5% (w/v) NaOH solution, where the total solution was maintained 10 times the weight of the fibers. The fibers were kept in the solution for 72 h at ambient temperature [4,25]. After that, fibers were washed with tap water followed by distilled water until the last trace of alkali not removed or till the pH of the fibers observed approximately 7. Finally, they were air oven dried at 70 °C for 48 h to obtain alkali treated fibers.

2-2. Acrylic Acid Treatment

Alkali treated coir fiber were soaked in a 1% acrylic acid solution maintaining fiber/solution ratio of 10 : 1 (w/v) for 20 min [26]. Then, the fibers were washed thoroughly and air oven at 70 °C for 48 h to obtain acrylic acid treated fibers.

3. Fabrication of Composites

Before preparing composite samples, both coir fiber and LDPE were oven dried to avoid voids formation and poor fiber-matrix adhesion. Required amount of fiber and matrix for different weight fraction was weighed and taken in the beaker. Fiber and matrix were thoroughly mixed using mechanical stirrer and the mixture was arranged into a mold between two Teflon sheets for easy removal of the sample. Randomly oriented short coir fiber/LDPE composite sheets were prepared by placing the mold in the compression molding machine at around 180 °C temperature and 20 MPa pressure for 10 min. Then samples were removed after complete cooling at room temperature. Initially, untreated coir fiber/LDPE composites with different fiber loading (10, 15, 20, 25 and 30 wt%) were prepared, in order to find the optimum fiber-matrix ratio. Later untreated coir fiber composite with MA-g-PE and chemically treated coir fiber composites with or without MA-g-LDPE (3 wt% based on the total weight of the composite weight) were prepared with optimum fiber-matrix ratio.

4. Characterization

4-1. Fourier Transform-infrared (FTIR) Analysis

FTIR spectra of untreated and treated coir fiber samples were examined using FTIR spectrometer (Nicolet 6700 series). Potassium bromide (KBr) was used as reference substance. The samples were analyzed over the range of 4,000-600 cm^{-1} with a spectrum resolution of 4 cm^{-1}.

4-2. Mechanical Testing

A tensile test was conducted as per standard ASTM D3039 [27] using a universal testing machine (Instron Model 5982). The test was performed at a crosshead speed of 2 mm/min. Flexural strength tests were conducted according to the standard ASTM D790 [28] using the same testing machine as mentioned above and at the same crosshead speed. The test values were taken from the average of three specimens for each composition.

4-3. Scanning Electron Microscopy (SEM)

A scanning electron microscope (Model LEO-435VP) with an acceleration voltage of 0-30 kV was used for the morphological study of untreated, alkali treated and acrylic acid treated fibers surface. The fractured surface of composites after the tensile test was also studied to analyze the failure modes. For this purpose, prior to SEM analysis the samples were coated with a thin layer of gold.

4-4. Water Absorption

The water absorption of composite materials was conducted according to ASTM D570-98 standards [29]. Samples were oven dried at 50 °C until a constant weight was obtained. Then samples were dipped in distilled water. The samples were taken out after a constant interval of time, wiped with tissue paper, and weighed on a high precision balance. Water absorption capacity of the samples was calculated by the weight difference. The water absorption percentages were calculated by using following Eq. [30].

$$\text{Water absorption (\%)} = \frac{\text{weight of wet sample} - \text{weight of oven dry sample}}{\text{weight of oven dry sample}} \times 100$$

RESULTS AND DISCUSSION

1. Effect of the Chemical Treatments on the Coir Fibers

1-1. Infrared Spectroscopy Analysis

FTIR spectra of untreated, alkali treated, and acrylic acid treated coir fibers are shown in Fig. 1. The strong absorbance band observed in the region 3,600-3,100 cm^{-1} corresponds to the bonded

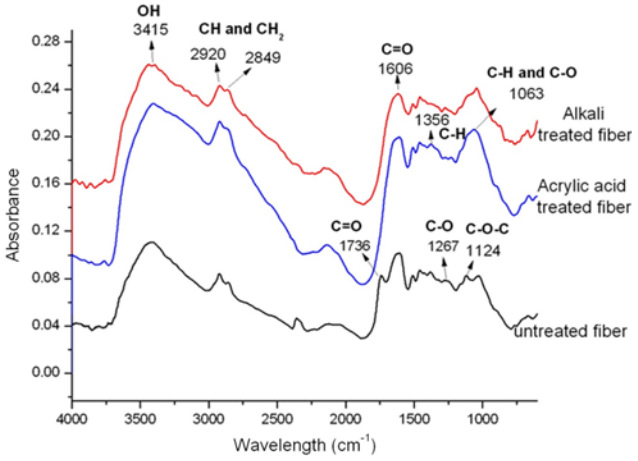

Fig. 1. FTIR spectra of the untreated, alkali treated and acrylic acid treated coir fibers.

O-H stretching vibration and hydroxyl group present in the cellulose and hemicellulose components [31]. The band near 3,415 cm^{-1} was observed to be reduced in alkali treated fiber due to removal of hemicellulose. However, the band increased again with acrylic acid treatment due to the hydroxyl group of the acrylic acid. The slightly stronger absorbance band at about 2,922 cm^{-1} and 2,854 cm^{-1} appeared for acrylic acid treated fiber corresponding to the introduction of -CH- and -CH$_2$- groups by the acrylic acid treatment. The absorbance band at 1,741.4 cm^{-1} corresponds to the C=O (carbonyl) of hemicellulose, pectin and wax is noticed for the untreated fibers, but this peak was no longer observed for the both alkali and acrylic acid treated fibers. The disappearance of the peak clearly indicates that the chemical treatment significantly removed the hemicellulose content, pectin and wax. The peak near 1,639 cm^{-1} for acrylic acid treated fiber was observed to be broader, indicating some ester group grafting on it. The band at 1,356 cm^{-1} corresponds to the -CH- of cellulose, and hemicellulose was noticed for untreated fiber, but almost disappeared for alkali treated fiber. The disappearance of the peak indicates that the alkali treatment removed part of hemicellulose components. However, the peak again appeared after the acrylic acid treatment corresponding to the ester bond formation by acrylic acid [32]. The change in the peak near 1,236.7 cm^{-1} is related to the C-O stretching acetyl group of lignin, indicating removal of lignin with the alkali and acrylic acid treatment. The band at 1,124 cm^{-1} is attributed to the C-O-C stretching of polysaccharide components of cellulose and shows significant reduction. This reduction is due to the degradation of cellulose components. The absorption peak at 1,063 cm^{-1} assigned to the C-O stretching of cellulose, hemicelluloses and lignin and C-O-C stretching of hemicellulose and cellulose is observed more prominent for acrylic acid tread fiber.

1-2. Morphology

Scanning electron micrographs (SEM) of the untreated, alkali treated and acrylic acid treated coir fiber are shown in Fig. 2(a)-(c). From the images, the morphology of the coir fiber was altered after the treatment. The untreated coir fiber surface (Fig. 2(a)) micro-

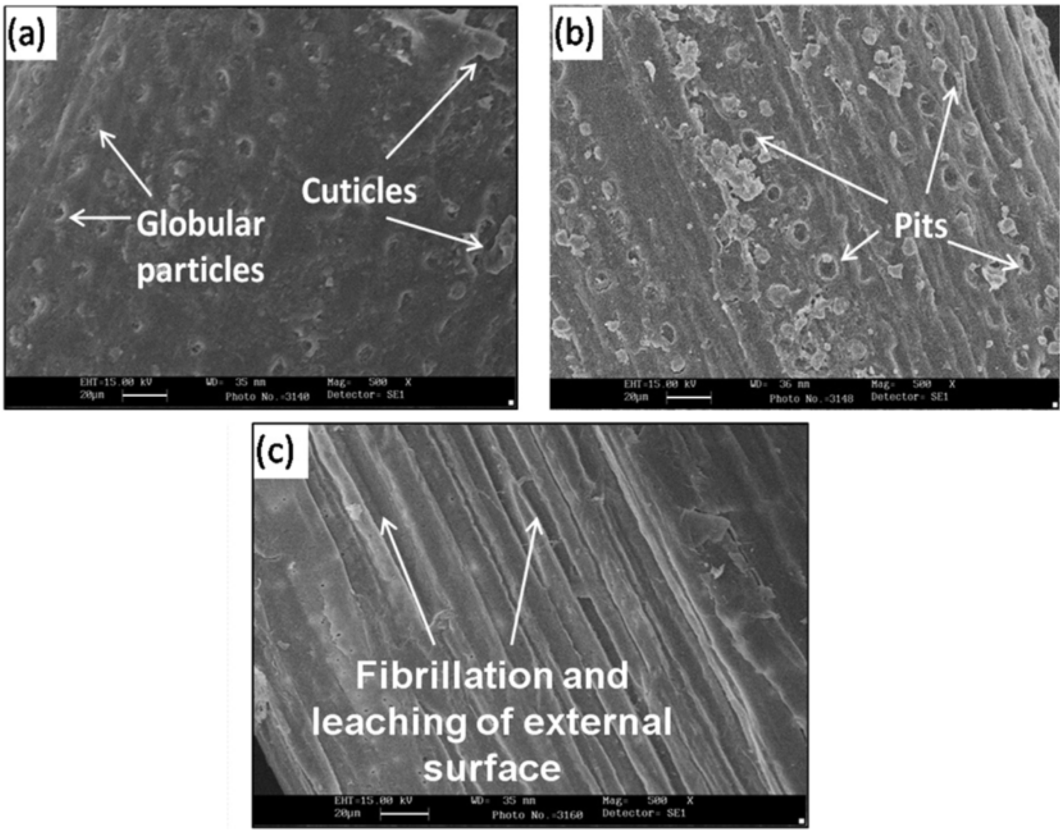

Fig. 2. SEM micrographs (a) Untreated coir fiber (b) Alkali treated coir fiber (c) Acrylic acid treated coir fiber.

graph shows a smooth surface due to the presence of fatty acid, waxy and globular particles. While, alkali treated coir fiber surface (Fig. 2(b)) micrograph appears to be rougher with number of pits corresponding to the removal of the fatty, waxy and globular particles and some part of hemicellulose and lignin. The acrylic acid treated coir fiber surface (Fig. 2(c)) micrograph shows exposed fibrils, attributed to the removal of external surface layer of the fiber by alkali and acrylic acid during the stage of treatment. These fibrillations may provide better interlocking with the polymer matrix.

2. Mechanical Properties

2-1. Effect of Fiber Loading

Influence of untreated coir fiber reinforced LDPE composites on the mechanical properties (tensile strength, flexural strength, Young's modulus and percent elongation at break) with respect to different fiber loading (10, 15, 20, 25 and 30 wt%) are illustrated in the Fig. 3-5.

The change in the tensile strength of LDPE composites with respect to untreated coir fibers loading at the different weight fraction is shown in Fig. 3. Addition of untreated coir fibers does not improve the tensile strength of LDPE matrix. This reduction in tensile strength was observed probably because of the inadequate stress transfer from the matrix to the fiber, which led to the insufficient interfacial adhesion. The composite at 10 wt% fiber loading showed a tensile strength of 8.99 MPa, which is 22% lesser value than that of LDPE matrix. However, there is an increase in the tensile strength at 15 wt% and 20 wt% fiber loading observed as compared with the composite at 10 wt% coir fiber loading. An approximately 22% increase and 5% decrease in tensile strength is observed for 20 wt% fiber loading in comparison with the composite at 10 wt% coir fiber loading and LDPE matrix, respectively. This improvement in tensile strength shows better stress transfer from the matrix to the fiber at 15 wt% and 20 wt% fiber loading compared to 10 wt% coir fiber loading composite. Beyond 20 wt% fiber loading a significant reduction in tensile strength of the composite is observed. Composite at 25 wt% fiber loading showed approximately 43% lower tensile strength than LDPE matrix. In the composite system, when the interaction between the fiber and matrix is reduced, the fiber-fiber interaction becomes dominant; as a consequence, stress transfer between the polymer matrix and the fiber will be reduced, resulting in poor tensile strength. Further, incorporation of 30 wt% of coir fiber increased the tensile strength by nearly 23% as compared with the composite at 25 wt% coir fiber loading. This is probably due to the homogeneous distribution of fiber throughout the composite, at higher fiber loading [33].

The flexural strength of the composites (Fig. 3) showed a similar trend as that of tensile strength of the composites. Incorporation of coir fiber does not improve the flexural strength of the composite. However, composite with fiber loading 15 wt% and 20 wt% showed flexural strength of 15.04 MPa and 19.05 MPa, which is approximately 31% and 66% improvement, respectively, in comparison with the 10 wt% coir fiber loading composite.

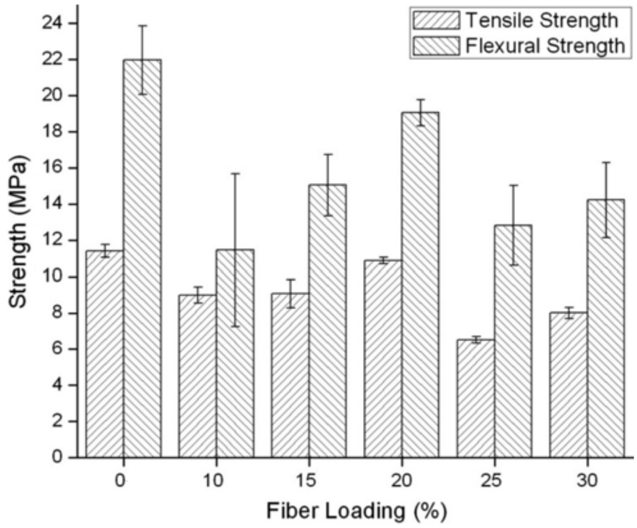

Fig. 3. Effect of different fiber loading on the tensile strength and flexural strength of untreated coir fiber/LDPE composites.

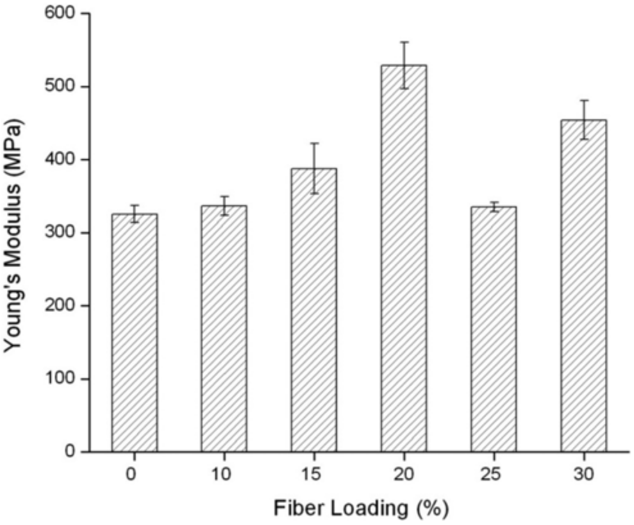

Fig. 4. Effect of different fiber loading on Young's modulus of untreated coir fiber/LDPE composites.

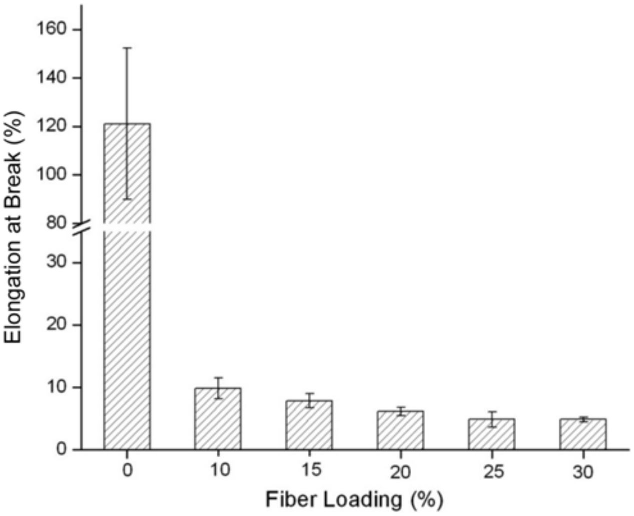

Fig. 5. Effect of different fiber loading on the elongation at break of untreated coir fiber/LDPE composites.

However, Young's modulus of the LDPE matrix (Fig. 4) exhibited a considerable increase with the incorporation of untreated coir fiber. This may be because the fibers have much higher modulus compared to the thermoplastic matrix. Composite with 20 wt% fiber loading shows Young's modulus of 528.9 MPa, which is approximately 62% improved value than that of LDPE matrix. The elongation at break for coir fiber reinforced LDPE composite (Fig. 5) shows a consistent decrease with increase in fiber loading. There is almost 96% decrease in the elongation at break observed that is from 121% of LDPE matrix to 4.8% when coir fiber content increases from 0 wt% to 30 wt%. The decrease in elongation at break may be because of the nature of natural fiber and polymer matrix. Natural fibers exhibit brittle behavior, whereas LDPE matrix provides ductility. Incorporation of coir fiber creates an obstacle to the mobility of LDPE segments. Thus, as the coir fiber loading increases, composites turn to be more brittle.

From this investigation, it is clear that the composite with 20 wt% untreated coir fiber loading exhibits optimum mechanical properties. Thus, composition with 20 wt% of the coir fiber loading has been retained for further study.

2-2. Effect of Modification

The mechanical properties of the untreated and chemically treated (alkali and acrylic acid) coir fiber (20 wt%) reinforced LDPE composites with or without compatibilizer (MA-g-LDPE) are illustrated in Figs. 6 to 8. For a clear understanding of the mechanical behavior, morphological behaviors of the tensile fractured surface of untreated and treated composites was also investigated by SEM micrographs (see Fig. 9(a)-(f)).

From the results, it is evident that the surface treatments to the coir fibers reduce the mechanical properties of the LDPE composites. In the case of alkali-treated fiber composites, a reduction of approximately 13%, 22% and 19% in tensile strength (Fig. 6), flexural strength (Fig. 6) and Young's modulus (Fig. 7), respectively, is observed in comparison to untreated fiber reinforced composites. However, these results are in contradiction to the results obtained by Nam et al. [4], who found mechanical properties of alkali-treated coir fiber reinforced with poly(butylene succinate) composites are significantly higher than that of untreated fibers. They used 5% NaOH solution for different soaking time (24 h, 48 h, 72 h and 96 h) and observed highest interfacial shear strength for 72 h. But in the present case, removal of fatty acid, waxy components, lignin, and hemicellulose from the coir fiber surface after the alkali treatment leads to the splitting of the fibers into the microfibrils [34]. Microfibrils are the cellulosic component of the fiber which provides strength to the fiber but are not compatible with the polymer (LDPE) matrix, resulting in poor fiber-matrix interfacial bonding. Another

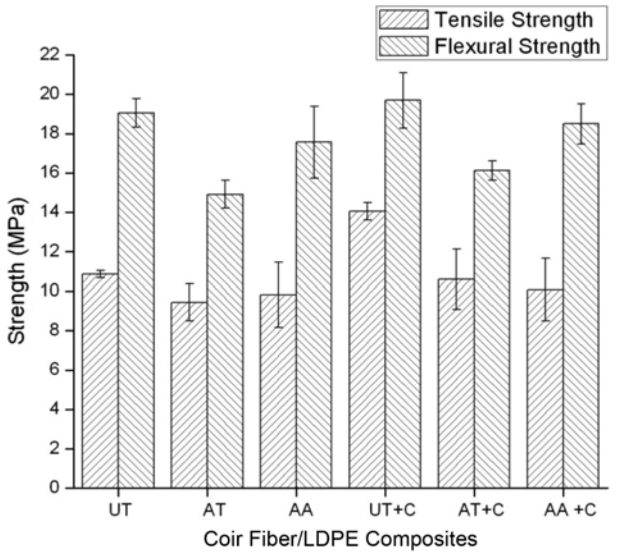

Fig. 6. Effect of different modifications techniques on the tensile strength and flexural strength of coir fiber/LDPE composites with 20 wt% coir fiber (UT: Untreated; AT: Alkali treated; AA: Acrylic acid treated; C: MA-g-LDPE).

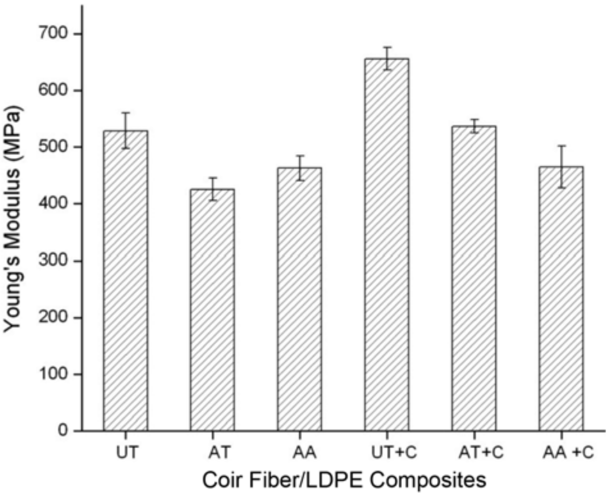

Fig. 7. Effect of different modifications techniques on Young's modulus of coir fiber/LDPE composites with 20 wt% coir fiber (UT: Untreated; AT: Alkali treated; AA: Acrylic acid treated; C: MA-g-LDPE).

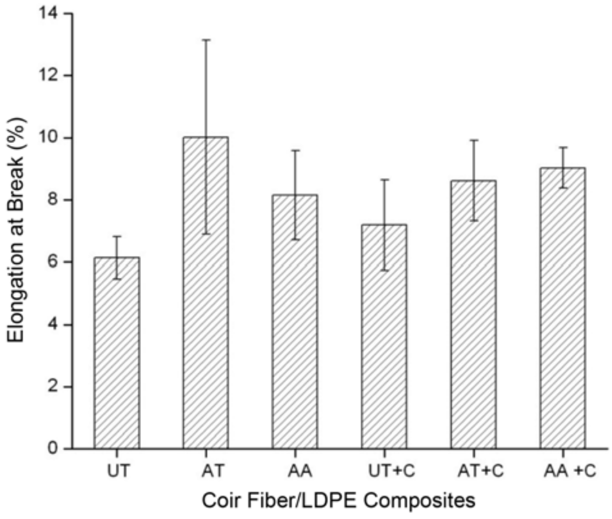

Fig. 8. Effect of different modifications techniques on the elongation at break of coir fiber/LDPE composites with 20 wt% coir fiber loading (UT: Untreated; AT: Alkali treated; AA: Acrylic acid treated; C: MA-g-LDPE).

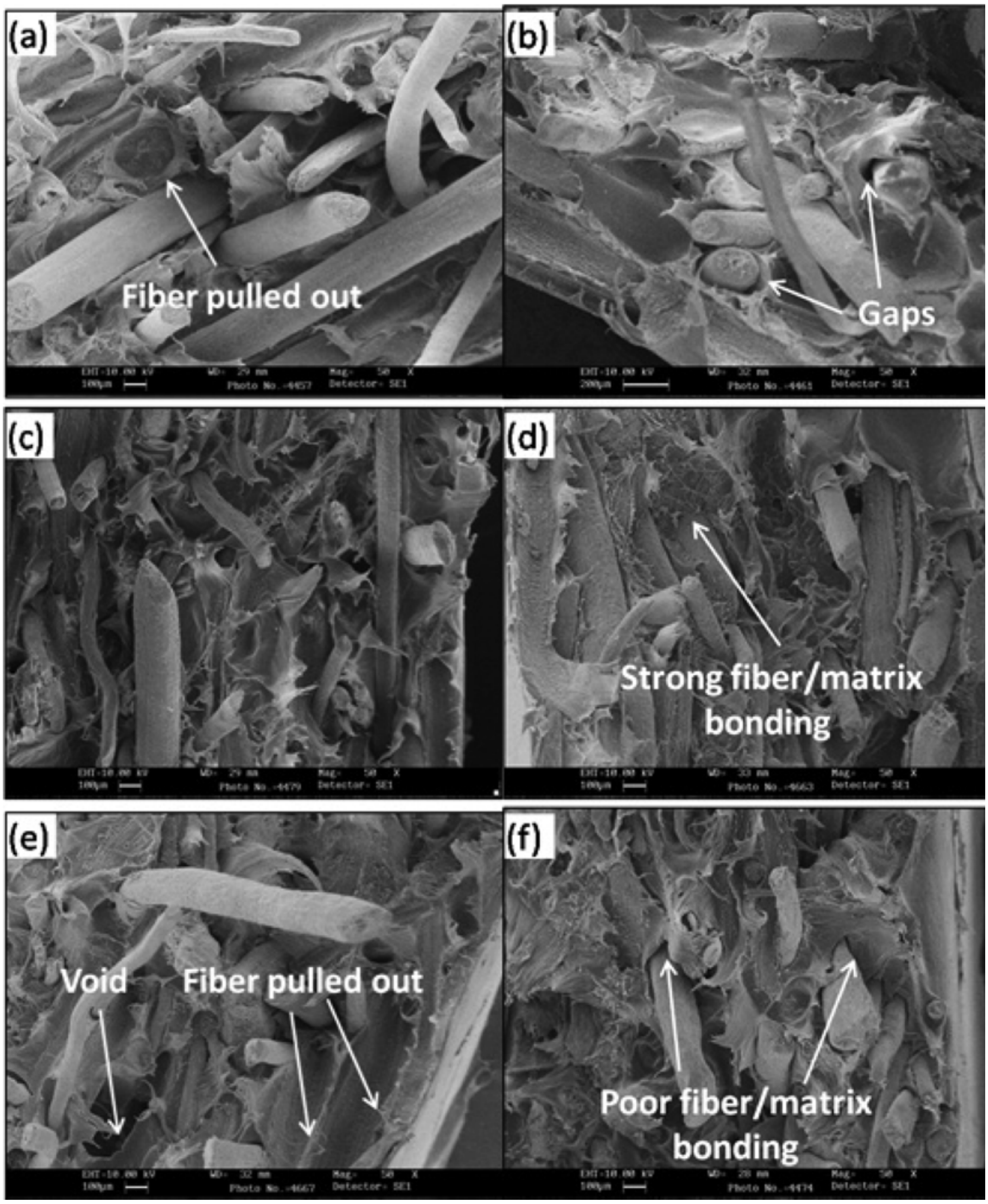

Fig. 9. SEM micrographs of tensile fracture surface of the 20 wt% coir fiber/LDPE composite: (a) Untreated (b) Alkali treated (c) Acrylic acid treated (d) Untreated+MA-g-LDPE (e) Alkali treated+MA-g-LDPE and (f) Acrylic acid+MA-g-LDPE.

reason may be the removal of lignin, fatty acid and waxy component form the coir fiber surface. The polymeric nature of lignin, fatty acid and waxy component made them bit compatible with the LDPE matrix [35-37]. As a result, untreated coir fiber/LDPE composites showed good mechanical properties. SEM images (Fig. 9(a) and (b)) support the above result; as in the case of alkali-treated fiber composites, fibers seem to have loosely bonded with the LDPE matrix as well as relatively larger pullout fibers, evidencing weak interfacial adhesion between the fiber and the matrix in comparison to untreated fiber composites.

On the other hand, acrylic acid-treated fiber composites show slightly higher mechanical properties than alkali-treated fiber composites, but are lower than those of untreated fiber composites. Acrylic acid generates strong ester linkage with the hydroxyl group of the fiber, making the fiber surface more hydrophobic [2]. As a result, fiber wetting and bonding with polymer matrix improved. The improved adhesion can be confirmed by SEM micrograph (Fig. 9(c)), which shows reduced gaps between the fiber and the LDPE matrix than that of alkali-treated fiber composites. But, acrylic acid treatment followed by alkali treatment led to the splitting of the fibers into finer filaments due to removal of external surface layer, resulting in degradation of the cellulose fibrils. This result was confirmed by the FTIR spectra and SEM micrographs of acrylic acid-treated fibers. Thus, in comparison to untreated fiber composites, bonding and wetting of fiber with the LDPE matrix may be improved, but chemical treatment has a lasting effect on the fiber and hence decreases the composite strength. However, compared to untreated fiber reinforced composites, a significant improvement in the elongation at break (Fig. 8) was noticed for the both alkali- and acrylic acid-treated fibers reinforced composites. This is because the treated fiber became more flexible due to the removal of impurities [7].

On the contrary, incorporation of MA-g-LDPE into untreated and treated coir fiber composites led to improved mechanical properties, compared to the same composite formulation without MA-g-LDPE. These results may be attributed to the improved interfacial adhesion provided by the MA-g-LDPE addition, which generates a strong covalent bond with the maleic anhydride groups and hydroxyl groups of fiber, whereas LDPE of MA-g-LDPE becomes compatible with LDPE, which lowers the surface energies of the fiber and increases its wettability and dispersion within the LDPE matrix [23]. However, treated fiber composites with MA-g-LDPE resulted in even lower mechanical properties than untreated fiber composites without MA-g-LDPE. The reduced mechanical properties may be probably because of the degradation of fibers by chemical attack, and the removal of hydroxyl groups from the hemicellulose and lignin region of the fiber. The lack of these hydroxyl groups leads to migration of excess MA-g-PE around the fibers, resulting in self-entanglement among themselves rather than the LDPE matrix causing slippage at the interface and generateing few micro-voids [22]. SEM micrograph depicted in Fig. 9(d) to (f) corroborates the mechanical findings. The incorporation of MA-g-LDPE reduced the gaps between the treated fiber and LDPE matrix, whereas no significant reduction in voids was observed. However, with the incorporation of MA-g-LDPE in untreated fiber composites, SEM micrograph shows significant reduction in voids formation and gaps between the fiber and the matrix. As a result, untreated fiber composites with MA-g-LDPE provide the best mechanical properties, which shows almost 30%, 24% and 4% higher tensile strength, Young's modulus and flexural strength, respectively, than those without MA-g-LDPE.

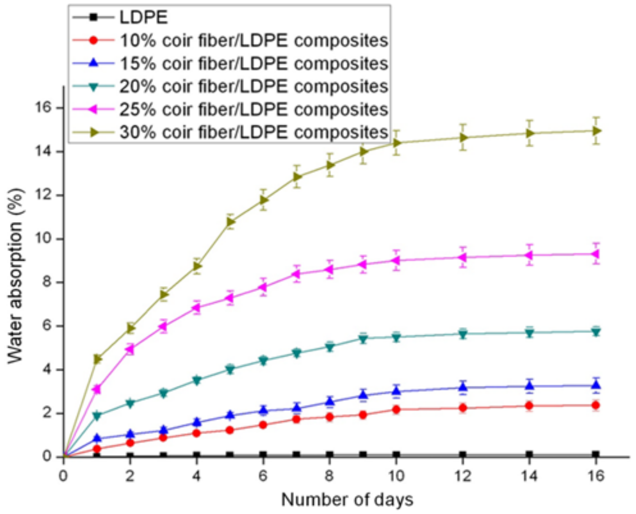

Fig. 10. Effect of different fiber loading on the water absorption behavior of untreated coir fiber/LDPE composites.

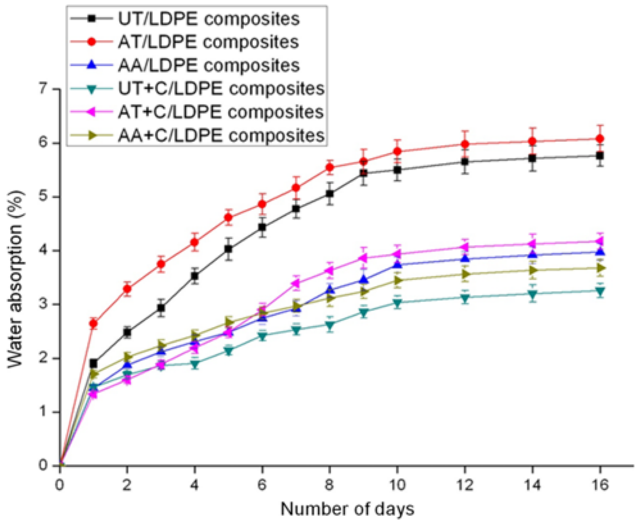

Fig. 11. Effect of different modifications techniques on the water absorption behavior of coir.

3. Water Absorption

The water absorption behavior of untreated and modified composites was studied and shown in Fig. 10-11. The effect of different untreated coir fiber loading on the water absorption behavior of the composites is shown in Fig. 10. It is evident that the water absorption capacity of the coir fiber/LDPE composites increases with increasing fiber loading from 10 wt% to 30 wt%. This behavior is attributed to the hydrophilic nature of the coir fiber. Coir fiber consists of cellulose structure that has free hydroxyl group, which creates a hydrogen bonding with the molecules. Another reason is the incompatibility of lingo-cellulosic fiber with the polymer matrix, which increases the number of micro voids formation in the composites [38].

The effect of different modification techniques on the moisture absorption behavior was studied (Fig. 11) for untreated and treated composites at 20 wt% fiber loading. From the graph it is evident that the water absorption for alkali-treated coir fiber composites is increased considerably compared to the untreated coir fiber composites. This increase in water absorption might be due to the exposed free hydroxyl group on the alkali treated coir fiber, which is attributed to the hydrophilic nature and poor wettability and adhesion between fiber and matrix. However, acrylic acid-treated coir fiber composites show a considerable reduction in water absorption, which is due to the replacement of hydroxyl groups by hydrophobic ester groups [39]. On the other hand, the incorporation of MA-g-LDPE reduced the water absorption significantly for untreated and treated coir fiber composites. These results can be ascribed to the reduction of the micro-voids, as the addition of MA-g-LDPE generated a strong covalent bond between the coir fiber and the LDPE matrix. The best result was obtained with the untreated coir fiber composite with the incorporation of MA-g-LDPE, which confirms better interlocking between untreated coir fiber and LDPE matrix.

CONCLUSIONS

Composites with a composition of 20 wt% untreated coir fiber were found to be optimum, with maximum mechanical properties. Furthermore, the influence of fiber treatment (alkali and acrylic acid) and compatibilizer (MA-g-LDPE) incorporation for 20 wt% coir fiber/LDPE composites on mechanical, morphological and water absorption behavior was investigated. Results show that composites made with treated fibers have negative effect on the mechanical properties than those of untreated fiber composites. The alkali treatment of the fiber removed part of cementing materials (hemicellulose and lignin) and impurities from the fibers surface, which led to the splitting of the fibers into microfibrils. These microfibrils are not compatible with the polymeric (LDPE) matrix resulting poor fiber-matrix interfacial bonding. Acrylic acid-treated fiber composites showed slightly higher mechanical properties than alkali-treated fiber composites, but are lower than those of untreated fiber composites. By acrylic acid treatment, though the fiber wetting and bonding with the polymer matrix improved by ester bond formation, the degradation of the cellulose fibrils led to reduced mechanical properties of the composites. The FTIR spectra and SEM micrographs of treated fibers also confirmed the removal of lignin, hemicelluloses, fatty and waxy components and degradation cellulose fibrils.

Incorporation of MA-g-LDPE into untreated and treated fiber composites led to improved mechanical properties and water resistance compared to the same composite formulation without MA-g-LDPE. But, maximum mechanical properties and water reduction were observed with composites made of untreated fibers, due to the strong fiber-matrix adhesion. The improved mechanical properties were confirmed by the SEM micrographs of the tensile fractured surface that showed a better compatibility between the untreated fibers and LDPE matrix with almost no void formation and to a great extent reduced the gaps between the fiber and matrix.

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