International Journal of Multidisciplinary Research and Growth Evaluation

International Journal of Multidisciplinary Research and Growth Evaluation
ISSN: 2582-7138
Received: 28-06-2020; Accepted: 30-07-2020
www.allmultidisciplinaryjournal.com
Volume 1; Issue 3; July-August 2020; Page No. 45-51

The effect of chemical treatment on mechanical properties of composites of unsaturated polyester resin with cow hair Fibre and chicken feather Fibre

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Abstract

The cow hair fibre (CHF)-unsaturated polyester resin reinforced composites and chicken feather fibre (CFF)-unsaturated polyester resin were prepared by hand-lay-up technique and the effect of chemical treatment on the mechanical properties was studied in this research. The chicken feather and cow hair fibres were collected from local poultries and leather manufacturing laboratory. This unusable animal waste were chosen for this research work to consider their reinforcement property and the reduction of environmental pollution. The animal fibres were washed and dried, cut and divided into two portions; one portion was treated with aqueous solution of NaOH while the other portion was untreated. The chemically treated and untreated both portions of fibres were then used to unsaturated polyester resin at 2, 5, 7, 10, 12 and 15 fibre loading respectively**.** The composites were characterized by tensile and bending properties, Fourier Transform Infrared (FTIR) spectroscopy, Scanning Electron Microscopy (SEM) and Thermo Gravimetric Analysis. Obtained all the results revealed best outcomes and significant enhancement in the properties of the composites with the optimum combination by 5 wt% treated cow hair fibre.

Keywords: cow hair, chicken feather, unsaturated polyester resin, methyl ethyl ketone peroxide, tensile properties and bending properties

Introduction

Unsaturated polyesters are extremely versatile in properties and applications and have been a popular thermoset used as the polymer matrix in composites. They are widely produced industrially as they possess many advantages compared to other thermosetting resins including room temperature cure capability, good mechanical properties and transparency. Curing of unsaturated polyester is due to a polymerization reaction that causes crosslinking among individual linear polymer chains. In contrast to other thermosetting resins, no by-product is formed during the curing reaction, hence resins can be moulded, cast and laminated at low pressures and temperatures. The reinforcement of polyesters with cellulosic fibres has been widely reported. Polyester–jute [1, 2], polyester–coir [3], polyester–straw [4] are some of the promising systems.

Unsaturated polyesters, usually strengthened by fibre-glass or ground mineral, are made into structural parts such as boat hulls, pipes, and countertops. Unsaturated polyesters are co-polyesters that is, polyesters prepared from a saturated dicarboxylic acid or its anhydride (usually phthalic anhydride) as well as an unsaturated dicarboxylic acid or anhydride (usually maleic anhydride). These two acid constituents are reacted with one or more dialcohols, such as ethylene glycol or propylene glycol, to produce the characteristic ester groups that link the precursor molecules together into long, chainlike, multiple-unit polyester moleicules. The maleicsanhydride units of this copolyester are unsaturated because they containcarbon-carbon double bonds that are capable of undergoing further polymerizationunder the proper conditions. These conditions are created when the copolyester is dissolved in a monomer such as styrene and the two are subjected to the action of free-radical initiators. The mixture, at this point usually poured into a mold, then copolymerizes rapidly to form a three-dimensional network structure that bonds well with fibres or other reinforcing materials [5]. Despite competition from new contemporary polymers, UPR continues to be an important plastic grade.

Applications of UPR are extensively seen in composite materials, wood paints, flat laminated panels, corrugated panels, ribbed panels, gel coat for boats, automotive and bathroom fixtures, colouring pastes, fillers, stucco, putties and chemical anchorings, self-extinguishing composite materials, quartz, marble and artificial cement [6]. Numerous approaches to progressively surmount these limitations utilizing varietiesof reinforcements from microfibres to nanotubes in the matrix of UPR are voluminously available in existing literature [7, 8, 9].

However, the use of natural fibres in composite materials has some drawbacks such as high moisture sorption, poor dimensional stability, low thermal resistance, isotropic fibre resistance and variability of composition [5]. The application of natural fibres as reinforcements in composite materials requires a strong adhesion between the fibre and the synthetic matrix [6, 7] because the macroscopic mechanical properties depend on the fibre–matrix interface. Physical and chemical treatments can be applied to optimize this interface and to promote adhesion [8]. For example, the fibres can be treated by reactive chemical coatings in order to induce chemical bonds between the matrix and the fibres [9, 10]. The tremendous volume of waste feather creates a serious solid waste problem in many countries [11, 12]. The feather fiber and quill are both made from keratin (about 90% by weight), which is an insoluble and highly durable protein found in hair, hoofs and horns of animals [13, 14]. Keratin consists of over 90 amino acids but largely made up of cystine, lysine, proline and serine [15, 16]. These amino acids tend to cross-link with one another by forming disulfide or hydrogen bonds resulting in fibers that are tough, strong, lightweight and with good thermal and insulating properties [14, 17]. A number of studies have shown that the intermolecular cross links in keratin can be broken to obtain a soluble fraction that can be processed into polymeric materials, such as packaging and mulching films [18, 19]. Fibers from chicken feathers are very small (5 microns in diameter) and have high surface area with excellent adsorbent properties [20]. Structure and mechanical properties of proteins have been discussed by Marc Andre Meyers et al. [21]. Tensile properties of various plant-based natural fibre reinforced polymer composites have been reviewed by H. Ku et al. [22]. Properties of plant and animal based natural fibre reinforced composites have been investigated by several authors [23, 24, 25, 26, 27].

The human hair have been reported by many authors and researchers to exhibit very good physical and mechanical properties, which in turn account for their intrinsic ability to undergo appreciable mechanical stressing and various types of chemical and thermal treatments without sustaining permanent damage. This unique behavior of hair has been attributed to the presence of structural proteins which are essentially keratin in the hair fibre [28]. Hair is a filamentous biomaterial consisting mainly of proteins especially keratin [29]. These keratins are scaffolding proteins which form a network of intermediate filaments in the cytoplasm of epithelial cells and their functional roles are to provide structural maintenance for cells and tissues, cell growth, hair cycling, wound repair and tissue remodeling [30]. The mechanical stresses of hair fibres is highly dependent on the stability of the structure of the cortical keratin [31]

Materials and Method

Materials

The materials utilized for this research work were done in Bangladesh. The chicken feather and the cow hair collected from commercial poultry farm and Leather Manufacturing Laboratories, Institute of Leather Engineering and Technology, Dhaka, Bangladesh respectively while the unsaturated polyester resin and MEKP were purchased from Hatkhola, Dhaka, the Cosmoplene Polyolefin Company Ltd.

Methods

Preparation of CFF-UPR and CHF-UPR Reinforced Composites

To prepare the composite, selected Chicken feathers (CFF) and Cow hairs (CHF) were washed with distilled water and detergent to remove different types of contaminants from the feather and hair surface . It was dried in sunlight for 12 hours and then in oven at 300 C for five days Then they were cut into average length of 5 mm (cutting machine, FRITSCH, Industriestr. 8, 55743 Idar-Oberstein, Germany) and divided into two portions. One portion of the cleaned samples was treated by using 0.25 M NaOH maintaining 50^0C temperature for 2 hours and dried in the oven at 60^0C for 5 hours and the other portion was kept untreated. The CFF-UPR and CHF-UPR reinforced composites were produced by hand-lay-up method by mixing together the fibre portions of 2%, 5%, 7%, 10%, 12% and 15% by weight with the matrix (UPR). It was kept in the fume hood at 25^0 C for 24 hours and prepared composites were then packaged in polythene bags.

Mechanical testing of composites

The tensile strength (TS), tensile modulus (TM), elongation at break (EB) and bending test of the composites were carried out by Testometric universal testing machine (M-500-30 KNCT) with an initial clamp separation of 20 mm and a cross head speed of 10 mm/min. The sample piece with dimensions of 60 mm×10 mm×1.6 mm was hooked on the grip and the test commenced. The samples were conditioned at 25^0 C and 50% relative humidity for 3 days before testing and all the tests were performed under the same conditions. All the test values were considered average of at least five samples.

Results and Discussion

Tensile properties

In figure 1, the tensile strength at peak of the control sample UPR, the CHF-UPR reinforced composites and CFF-UPR reinforced composites are compared. The control sample showed 18 N/mm^2 at the peak. The highest values for UTCHF, TCHF, UTCFF and TCFF were found 28.32673 N/mm^2, 32.24517 N/mm^2, 29.56210 N/mm^2 and 27.25678 N/mm^2 respectively. By comparing all the results, it was found that the highest tensile strength was observed for 5% TCHF-reinforced UPR composite and increased 79.14% than that of control sample. It was observed that treated and untreated both fibre loading gave the better results in comparison with the control sample. From the above discussion it was found chemical treatment of cow hair fibre at 5% loading showed very positive result.

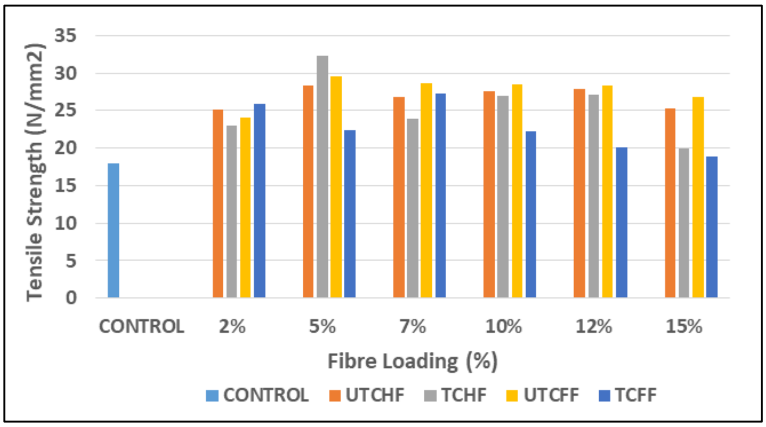


Fig 1: Variation of Tensile Strength peak of Control Sample, CFF-UPR and CHF-UPR composites

Fig. 2 represents the tensile modulus of the control sample UPR, CHF-UPR and CFF-UPR reinforced composites. These results showed that the tensile modulus at peak of the control sample was 650 N/mm^2. The 5% TCHF and 10% UTCFF reinforcement gave the best results with a value of 1138.54 1101.2405 N/mm^2 and increased 75.16% and 69.42% respctively. It was observed that the UTCFF reinforcement at 2-15 % fibre loading gave the better results in comparison with all the other animal fibre-UPR reinforced composites. It was observed that the reinforcement of CHF and CFF was improved by chemically treatment specially 5% TCHF loading.

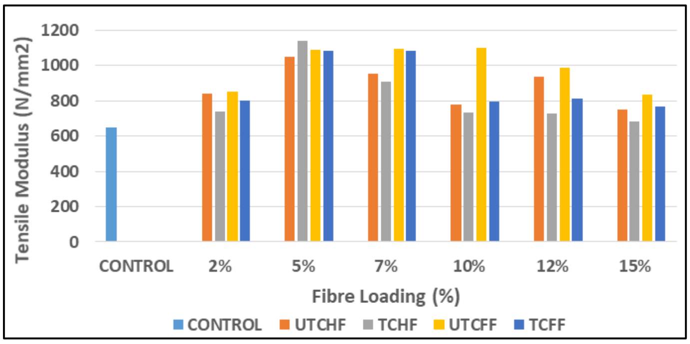


Fig 2: Variation of Tensile Modulus peak of Control Sample, CFF-UPR and CHF-UPR composites

In figure 3 the results for elongation at break of the control sample, CHF-UPR and CFF-UPR composites is showed. The value of elongation at break for the control sample was best in the tested results with a value of 5. 7% fibre loading of the TCHF reinforcement produced the best results compared to other reinforcement composites with a value of 2.878 which is 42.44% lower than the control sample.

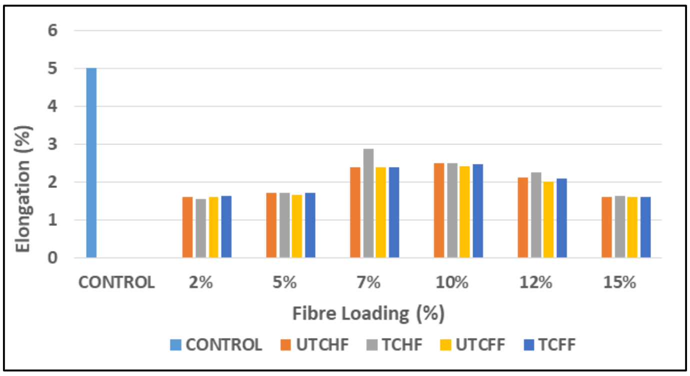


Fig 3: Variation of Elongation at Break peak of Control Sample, CFF-UPR and CHF-UPR composites

The results revealed that the effect of the chemical treatment on the 5% ands 7% cow hair fiber was more effective at tensile strength and elongation at break respectively but tensile modulus was not improved by chemically treatment.

Bending properties

The figure 4 indicated the results of bending strength of the control sample, CFF-UPR and CHF-UPR composites. The control sample showed 25 N/mm^2 bending strength. The best result was found for 5% fibre loading of TCHF reinforced composite with a value of 79.88 N/mm^2 and increased 219.52% and 5% UTCHF loading composite gave the value of 77.39 N/mm^2 which is better 2o9.58% than that of control sample. 5% of each animal fibres reinforcement showed best results compared to the other percentages used animal fibres.. This study showed that the bending strength was enhanced by chemically treatment of reinforcement materials. The fibre-matrix interface has a great impact on the overall mechanical properties of any fibre-reinforced polymeric composite.

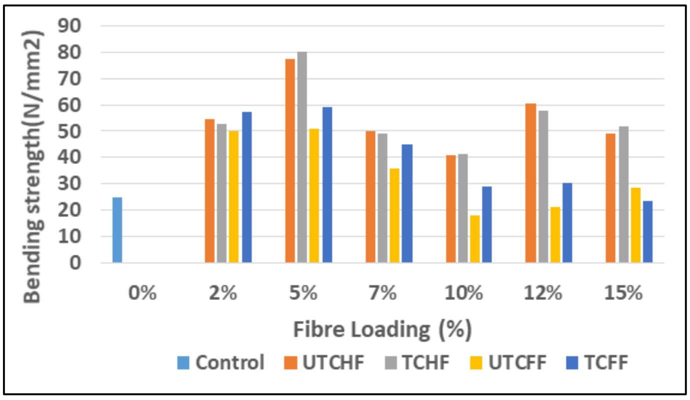


Fig 4: Variation of Bending Strength peak of Control Sample, CFF-UPR and CHF-UPR composites

Figure 5 represents the comparison of bending modulus in the control sample, CHF-UPR and CFF-UPR composites. Bending modulus for the control sample was 700 N/mm^2. The highest values were for both 5% UTCHF-UPR and TCHF-UPR composites. The best value was found for 5% TCHF loading and increased 529.94 % more than that of the control sample. Both UTCFF and TCFF reinforced composites showed less value than UTCHF and TCHF reinforced composites. The results showed that the treated cow hair fibre (UTCHF) and chicken feather fibre (UTCFF) reinforced composites gave the better bending modulus in all the fibre loading used than the control material

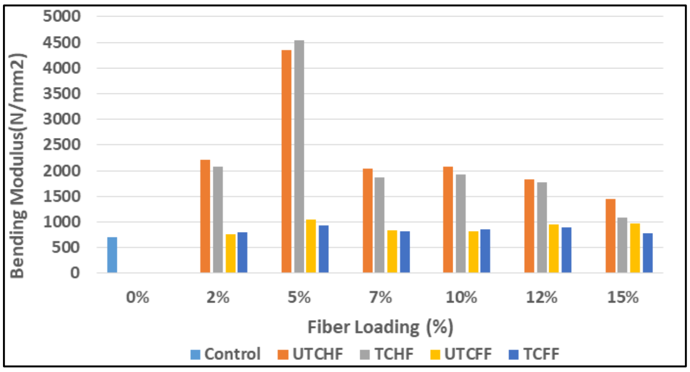
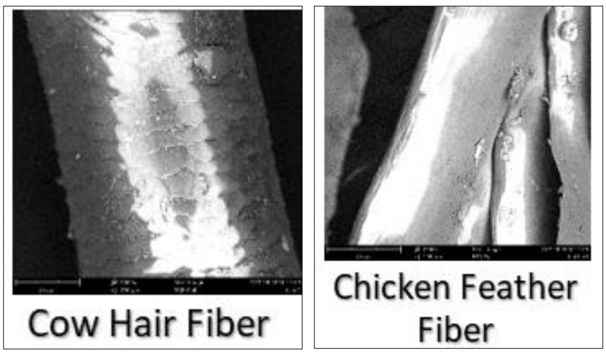
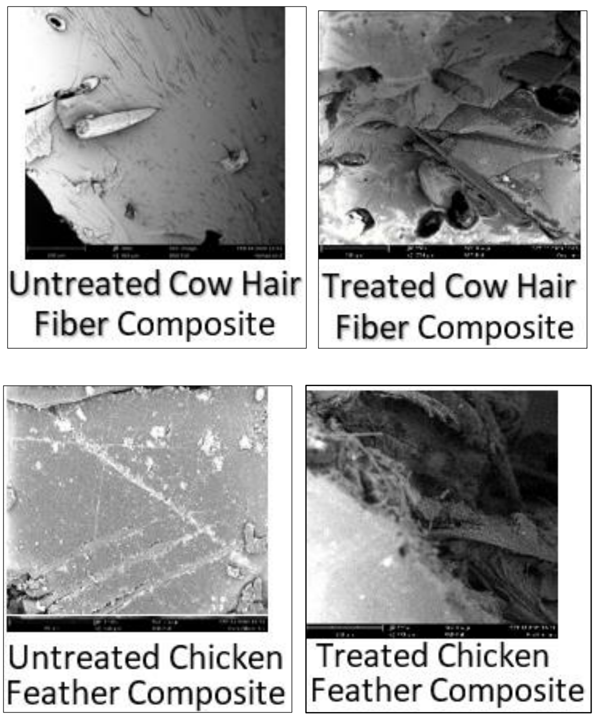


Fig 5: Variation of Bending Modulus peak of Control Sample, CFF-UPR and CHF-UPR composites

The results of this study have revealed that 5 % of fibre loading on the TCHF enhanced the flexural strength of the TCHF-reinforced UPR composite better than that of the UTCHF, TCFF, UTCFF and the control sample. This improvement in flexural strength is increased interfacial adhesion between the matrix and the fibre and it allows a more efficient transfer of stress between the fibre and the matrix. The overall performance of any fibre-reinforced polymer composite depends extensively on the fibre-matrix interface.

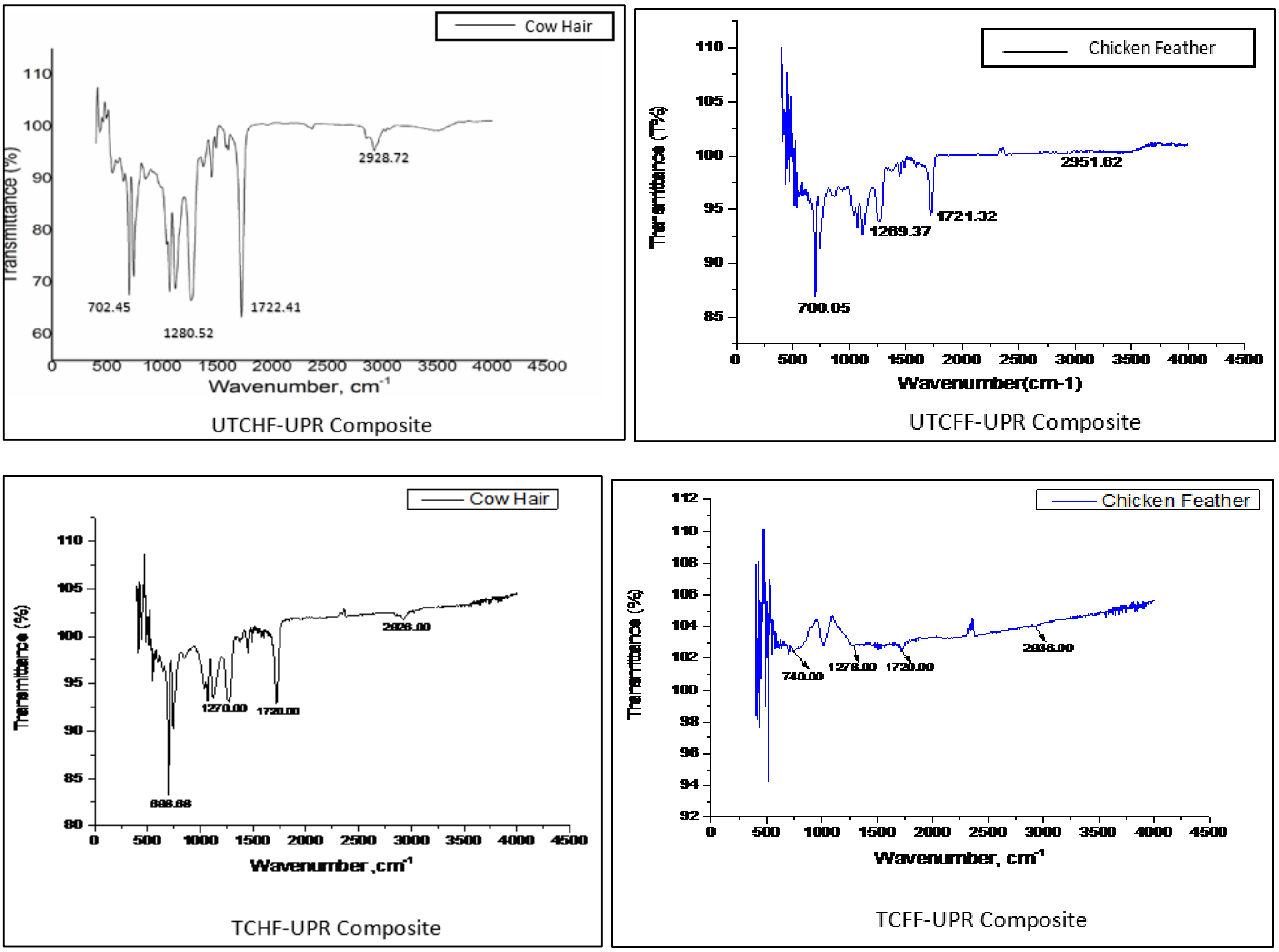
SEM Analysis





Interfacial properties of untreated and treated CFF-reinforced UPR composites and CHF-reinforced composites were analyzed by SEM. This analysis indicated that there is a considerable difference in the fiber-matrix interaction among the composites. Some gaps between fiber and matrix are clearly found for most of the composites which are responsible for the low mechanical properties.. This is clearly observed that the bonding between chicken feather and matrix is not so good. The SEM image of the fracture surface explains that the chicken feather pull-out is quite low in composites. Thus the mechanical properties increased in some extent. There was no void space in the prepared composites. The void space showing in the figures are for the fibre pullout from the matrix. There was good bonding between the fibre and matrix, which carries good evidence for the slightly better mechanical properties in composites.

FTIR Analysis



UTCHF-UPR Composite

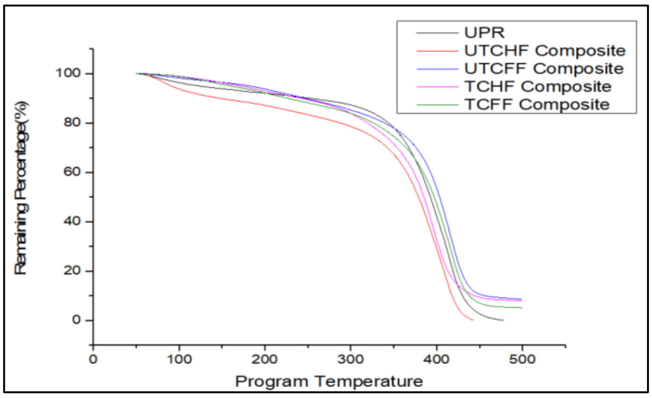
UTCFF-UPR Composite

TCHF-UPR Composite

TCFF-UPR Composite

Fourier Transform Infrared Spectroscopy was used to identify the functional group of the composite materials. The graphs for fibre- reinforced UPR Composites show a prominent peak at about 1720.00cm^{-1} for carbonyl (C=O) groups. C-O-C is a prominent feature in the spectrum appearing at about 1269.37cm^{-1} .A strong peak at 740.00 and another weak peak at 2929.72 cm^{1}- 2951.62cm^{-1} assign to =C-H out of plane bending and to –C-H stretching respectably. The FT-IR functional group analysis shows the same functional group in the same region in the IR spectra.For the presence of $–NH_2$ group, the peak appeared in the wavenumber of 2900 cm^{-1}. In the region of 1700 cm^{-1}, another peak was observed and this peak was for the presence of CH_3 and CH_2 groups (for sp^3 bending). In the region of 2800 cm^{-1} another peak was observed for CH group (for sp^3 stretching). In the region of 1575 cm^{-1}, another peak was observed and this peak was for the presence of CH_3, CH and CH_2 group (for sp3 bending). At 1690-1750 cm $^{-1}$ another peak was observed for the functional groups of C=O. For the presence of polymeric -OH groups very broad peaks appeared in the wavenumber of 3400 cm^{-1}. So there was no chemical bond between the feather fiber and UPR. The improved mechanical properties were due to the mechanical bond among t fibers and UPR.

TGA Analysis



Thermo-gravimetric analysis was carried out to analyze the thermal behavior of the prepared composite. The starting temperature was 50 °C and the final temperature was 490 °C. At 135 °C temperature, 90% of the control composite remained, and then a slight decrease was noticed up to 225 °C temperature. From 225 to 385 °C temperature, the composite showed a rapid decrease and the remaining percentage was formed 90 to 30%. From 385 °C to the final temperature, the composite showed a very high degradation. Comparing to the control composite, the fiber loading composites showed a very good temperature resistance up to 315 °C. The composites remain 99% at the temperature of 135 °C. Up to 315 °C temperature, the degradation rate was very slow and then rapid degradation was observed and continued to 450 °C. For the control sample, rapid degradation started at 207 °C, but for the composite it started at 385 °C with 84% remaining of each.

Conclusion

Cow hair and chicken feather is available and common in our country and it is waste material in leather industries and poultry farm. As a new source of materials the utilization of untreated and treated cow hair fibre and chicken feather fibre in the composite materials can be economic, eco-friendly and recyclable. These fibres may be used in the fabrication of eco-friendly composite products for diversified applications and thus synthetic fiber can easily be replaced with cow hair fiber. This was the case because the addition of these animal fibres to the matrix was able to improve the flexural response of the developed composite materials. The 5% was the best percentage for the treatment of cow hair fibre intended for the reinforcing phase of UPR was discovered. For engineering applications where high tensile strength and high ductility of unsaturated polyester resin are required, 5% cow hair fibre reinforced-UPR should be used instead of unreinforced UPR

Acknowledgement

The authors would like to give special thanks to Institute of Leather Engineering and Technology, University of Dhaka and IGCRT, BCSIR for providing required facilities for this research work.

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