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Alkali Treatment Influence on Characterization of Chicken Feather Fiber Reinforced Polymer Composites

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Abstract

Numerous investigations have been conducted recently to identify viable alternatives for synthetic fibers. Chicken feather fiber is regarded as an excellent alternative for synthetic fibers in bio-natural fiber composite. Due to the lack of standardized extraction methods, chicken feather fiber, a by-product of chicken production, is challenging to examine, treat, and post-process. The chicken feather fiber is remarkable class of fibers that has the potential to use in a variety of applications due to its relative abundance along with its suitable characteristics. This study suggests that the use of chicken feather fiber produces biodegradable and ecologically friendly mixtures that provide a solution to eliminating the majority of the solid waste generated by poultry farms. This paper gives a thorough examination of the composite, focusing on the mechanical, thermal, and water absorption characteristics of chicken feather fiber-reinforced polymer composites.

Keywords

Natural fibers, Chicken feather fiber, Water absorption, Mechanical properties

Introduction

Recent times a marked demand to utilization of natural fiber as reinforcement in composites as a replacement of synthetic fiber. Natural fibers have become essential due to their remarkable features such as being lightweight, environmentally friendly, non-abrasive, combustible, and biodegradable. Reinforcements such as glass fiber, carbon fiber, and numerous other reinforcing elements are used in traditional composites. Natural fibers such as kenaf, jute, hemp, flax, and bamboo, sisal, bagasse many others utilized as reinforcement in composites [1, 2]. Natural fiber-reinforced composite has the favour of being cost-effective, low-density, biodegradable, and easily recyclable, making them a viable alternative to synthetic fibers [3, 4]. Using natural fibers necessitates a thoroughgoing understanding of bonding surfaces and their chemical structure. Natural fibers composed of lignin, hemicellulose, cellulose, pectin, and wax. To strengthen the binding between the reinforcements and the matrix, the fiber surface can be altered using chemical techniques such as alkaline treatments. Many academics and researchers have worked on improving the fibers mechanical properties [5, 6].

The core drawbacks of using natural fiber are their indigent wettability of the composites, indigent matrix-fiber bonding, and higher moisture absorption properties. Chemical treatments are thought to be a better solution to enhance the bonding and increase the mechanical characteristics of the hydrophilic natural fibers and hydrophobic thermosets (resins/matrix). Pokhriyal et al. [7] worked on the effect of alkali treatment on *Himalayacalamus falconeri* culms and it improves the thermal stability and mechanical properties of the composites. Nagappan et al. [8] examined the alkali treated agricultural waste *Lagenaria siceraria* fiber reinforced composites by various fiber length and different weight percent of fibers with the compression mold technique. The composite reinforced alkali-treated fiber composites display superior mechanical characteristics compare to others. Bollino et al. [9] performed effect of alkali treatment with NaOH (Sodium hydroxide) on hemp fiber reinforced polymer composites and recommended that alkali treatment improves the composite performance. The impact of SiC nanoparticles on the characteristics of alkali-treated areca husk fiber/hybrid composites for marine and light weight applications was investigated by Mansingh et al. [10]. In light weight automotive and structural applications, Saravanakumar et al. [11] looked into the use of alkali treated *Moringa oleifera* fruit husk fiber/SiC nanoparticle composites.

Chicken feathers contains 90% protein and beta keratin. The chicken feather fiber must prevent cross-section space since it has a potent, resilient property. Using chicken feather fiber will save time while simultaneously encouraging the development of renewable fibers in an ecologically favourable environment. Chicken feather fibers have several different qualities, including good thermal conductivity, acoustic insulation, and low relative density. The poultry sector has generated a lot of trash made up of chicken feathers, which has to be managed properly. Additionally, because a large portion of poultry waste is dumped in landfills or burned due to the weak recyclable nature of chicken feathers, this contributes to environmental degradation [12, 13]. The utilization of chicken feathers as a reinforcement of the polymer composite can reduce environmental pollution.

In the present study, fiber-reinforced composites were prepared using chicken feathers and their mechanical and water absorption characteristics were tested. The fiber composition of the composite was mixed between 5 and 20 wt.% in 5 wt.% increments and the effects on mechanical properties and water absorption characteristics were evaluated. Chicken feather fibers were subjected to a 10% concentration of NaOH as an alkaline treatment to modify fiber surfaces and to improve bonding. Thermal degradation studies of chicken feather fiber reinforced epoxy resin composites in treated and untreated alkaline materials with 10% NaOH concentration were examined.

Materials and Methods

Materials

The present study used NaOH pellets as well as commercially obtainable epoxy (LY-5062) and hardener (HY-5062) from Sri Lakshmi Composites, Hyderabad (Telangana, India). Chicken feather fibers procured from local poultry farm in Kurnool City (Andhra Pradesh, India) and reclaimed as rachis. Figure 1 shows the collected chicken feathers and rachis.

Treatment of the fiber

Chicken feather fibers were placed in the glass tray containing solutions of 10% NaOH alkaline solution. To achieve the best results, the fibers submerged in solution around 5 h [14]. The excess NaOH solution that had coated the fiber layers was removed by thoroughly rinsing the fibers from the solution in water after they were removed from the tray. The purified water was used for final cleaning. To eliminate any remaining moisture content, the clean fibers were subsequently dried for four hours at 70 °C.

Fabrication of composite samples

A glass mold per the following measurements—160 mm x 160 mm x 3 mm—was developed to produce samples that complied with ASTM D 618, ASTM D 638, and ASTM D 4812 requirements. The prepared mold covered with wax; it served as a demolding tool to make it simple to remove the composite samples from the mold. The matrix required to make composite samples was created by combine the resin and hardener in 10:1 part by weight ratio. A mechanical stirrer is used to thoroughly combine the hardener (matrix) and epoxy for 10 min before the mixture is poured to the mold.

The hand lay-up technique is used to make composite samples. Fibers of chicken feathers in the mold were first coated with a small amount of matrix. Fibers were cautiously placed after pour a small quantity of matrix in the mold to prevent insufficient impregnation. Extra matrix expelled overhead the fibers. Utilizing a roller, the matrix was uniformly applied to each corner of the mold. The mold was then subjected to a 20 kg load for 24 h at room temperature to attain unvarying thickness and exclude any lingering matrix. To safeguard complete curing, composite laminates kept an hour in a hot air oven at 70 °C.

Preparation and testing procedure of samples

Tensile strength testing on chicken feather fibers treated with 10% NaOH and untreated epoxy composites was performed at the GPREC in Kurnool (Andhra Pradesh, India), utilizing the Instron 3369. The samples are 150 mm x 10 mm x 3 mm in size and were cut from laminate in compliance with ASTM D 638 standards. The studies were conducted at ambient temperature and 50% relative humidity with a crosshead speed of 10 mm/min. The composite materials were subjected to three-point bend (flexural) tests utilizing the same all-purpose testing device, the Instron 3369. The flexural investigations were done using ASTM D 618, the industry-recognized method for flexural properties. A span length of 50 mm and a crosshead speed of 5 mm/min were maintained for the test. IZOD impact tests were achieved using an IZOD impact analyzer in accordance with the recognized impact test protocol

Figure 1: (a) Chicken feather and **(b)** Chicken feather rachis.

(ASTM D 4812). 62.05 mm by 12.07 mm by 3.0 mm were the specimen dimensions for IZOD impact tests The energy in J was calculated using the fracture values acquired from the impact analyser.

The tensile strength, flexural strength, and IZOD impact test properties were tested for three samples of each specification and the average values were considered.

Water absorption

The water absorption properties of untreated and treated polymer composite laminates were determined using ASTM D-570-98 standards. The polymer composite specimen kept in single-use glasses filled with ordinary water to test the effectiveness of water absorption. Every 24 h, samples meticulously cleaned using tissue paper to eliminate any surface water before being weighed quickly with a digital precision scale. The percent of water absorption of polymer composite specimens are estimated by using equation 1.

$$\text{Percent of water absorption} = \frac{(P_t - P_o)}{P_o} \times 100 \quad (1)$$

Where P_o is the weight of polymer composite specimen (oven-dried weight) before being placed in water and P_t denotes the weight of the polymer composite specimen after it has been extracted from the water [15].

Thermogravimetric analysis

The thermogravimetric analysis (TGA) was done on untreated and treated 15 wt.% samples were tested at CENS Bangalore. A 2 gm of sample weight kept in an Al_2O_3 crucible and is heated to a temperature range of 30 °C to 800 °C at a rate of 10 °C/min in a nitrogen atmosphere.

Results and Discussion

This section covers the samples' mechanical, water absorption and TGA characteristics with varying reinforcement weight percentages from 5 to 20 for untreated and treated samples.

Tensile strength of the samples

Figure 2 displays the composite samples' tensile strengths and tensile modulus when reinforced with chicken feather fiber from 5 to 20 for untreated and treated samples. To learn the impact on tensile strength, the effects of varying reinforcement weight percentages from 5 to 20 for untreated and treated samples are examined. Tensile strength enhanced up to a fiber loading of 15 wt.%, according to the results, and then it started to decline, as seen in figure 2a. Other researchers also noted comparable outcomes [5, 16]. Alkali-treated specimens also had improved tensile characteristics than untreated composite specimens. This is because treated chicken feather fiber has a strong bond to matrix material due to alkali treatment removes hemicelluloses, lignin, and other substances from fiber facade. As a result, the matrix and reinforcement form a strong intermolecular bond. Together, the tensile strength and modulus of fiber-reinforced composites that have undergone alkali treatment with NaOH concentration are displayed. Inferred from the data the alkali treatment increases the tensile strength and ductility of the composites; better results were obtained with alkali treated 15 wt.% of reinforcement than with other weight percents. The maximum tensile strength and tensile modulus are 78.92 MPa and 5.82 GPa, respectively, for 10 % NaOH alkali treated 15 wt.% chicken feather fiber reinforcement polymer composites.

Flexural strength of the samples

Chicken feather fiber-reinforced polymer composite specimens bending characteristics are studied using a three-point bend (flexural) test. In essence, the sample's bending strength will depend on how shear and compression are grouped. The flexural strength is shown in figure 3 for various reinforcement weight percentage for untreated and treated specimens. The treated fiber specimen has a higher flexural strength than the untreated fiber specimen. Additionally, the flexural strength improved up to a weight of 15% of the chicken feather reinforcement, and afterwards increases in weight percentage were found to cause decreases in flexural strength. The reinforcement developed more brittleness as a result of the uneven load distribution among the reinforcement and matrix. Flexural strength is mainly determined by the bonding among the reinforcement and matrix. Lower flexural strength is a result of poor fiber/matrix bonding. The highest flexural strength and modulus are 255.94 MPa and 2.87 GPa, respectively, for 10 % NaOH alkali treated 15 wt.% chicken feather fiber reinforcement polymer composites.

Impact strength of the samples

Figure 4 displays the IZOD impact strength results for untreated and treated chicken feather fiber composites, as well as variations in reinforcement weight percentage. In epoxy matrix, it was discovered that increasing the weight of treated and untreated fibers up to 15 wt.% increased the impact strength of composite samples.

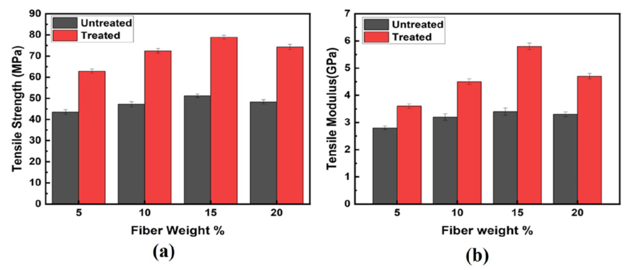

Figure 2: Effect of reinforcement wt.% for treated and untreated on **(a)** tensile strength and **(b)** tensile modulus.

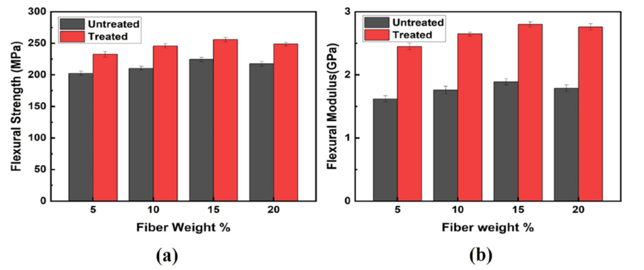

Figure 3: Effect of reinforcement wt.% for treated and untreated on **(a)** flexural strength and **(b)** flexural modulus.

The composite specimen of 15 wt.% had the maximum impact strength (84.3 J/m), against to all other polymer composite specimens. As shown in figure 4, the impact strength of the composites improved following alkali treatment for every weight percentage of reinforced fiber composites. By treating the fibers with alkali, the matrix and reinforcement have formed a strong bond with each other, which reduces fiber pull-out. This strong bonding among the reinforcement and matrix has been achieved by removing the soluble greasy nature from the fiber surface.

Water absorption test

The chicken feather fiber-reinforced composite specimens were submerged in a disposal glass filled with typical normal water at room temperature to measure its moisture content. After 24 h, the composite was taken out, wiped with tissue paper to remove any extra water droplets, and the sample's weight was recorded. Figure 5 displays the results as average values from three replicates. The alkali-treated polymer composite specimen had lower moisture contents than the untreated polymer composite specimens. Numerous researchers reported seeing comparable outcomes [17, 18]. The alkali treatment removes the hemicellulosic nature from the fiber, the percentage of composite samples that absorb water decreases. Fiber alteration enhances the bonding among the reinforcement and matrix, which lowers the voids in the composites and lowers the percentage of water absorption.

Thermogravimetric analysis

The justification for the use of bio-composites made from natural fiber-reinforced composites is that they have a low thermal stability. In order to study the thermal stability of manufactured samples with varying alkali treatments, TGA analysis was used. Figure 6 illustrates how TGA curves were used to examine the temperature degradation of composite specimen strengthened by chicken feather. Lignocellulose, which is present in natural fiber, is its primary component, so as a result, the decomposition occurred in two steps while thermal degradation befell in three steps. The initial weight loss of 10% occurred for alkali-treated fibers between 30 and 300 °C. It results from the elimination of pectin, hemicellulose, and the glycosidic connection of cellulose, which causes water to evaporate above the fibers in composite specimens. After this range of temperatures, the degradation accelerated as the temperature rose. At temperatures between 300 and 450 °C, the next stage saw a loss of weight about 65%. Later, the final stage saw a slower rate of lignin loss throughout entire temperature range, which is due to the presence of a complex structure with numerous aromatic rings. It was determined at the end of the study that chicken feather fiber-reinforce polymer composite thermally stable around 300 °C of temperature. Numerous researchers have reported similar findings for several natural fiber-reinforced composites [5, 6].

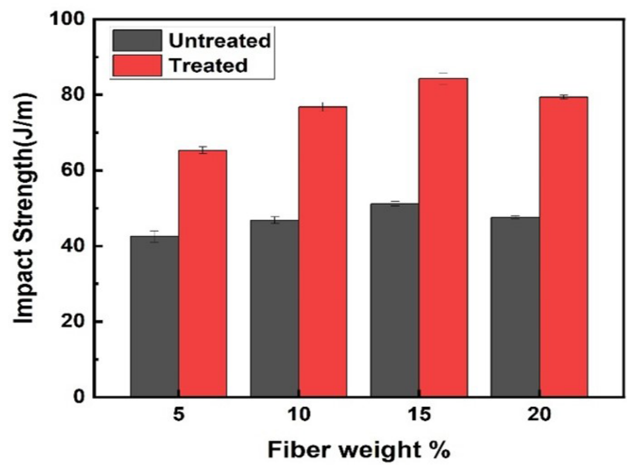

Figure 4: Effects of reinforcement wt.% for treated and untreated on the impact strength.

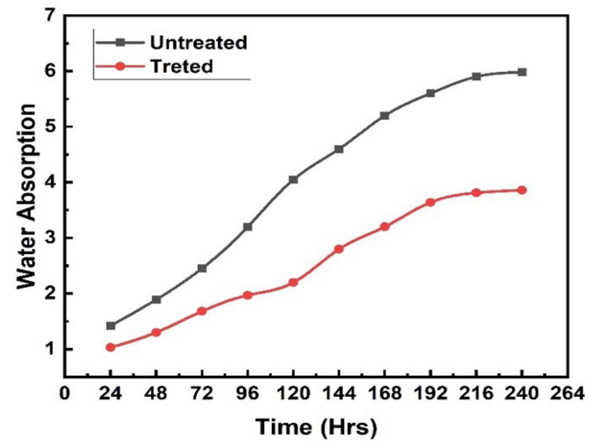

Figure 5: Effects of alkali treatment on water absorption for 15 wt.% chicken feather reinforcement polymer composites.

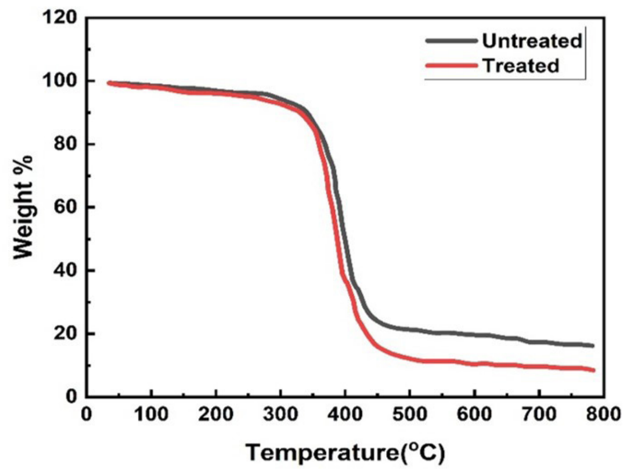

Figure 6: Effects of alkali treatment on thermal degradation for 15 wt.% chicken feather reinforcement polymer composites.

Conclusion

Hand lay-up method was applied to create the epoxy composites reinforced with chicken feather fibres. The reinforcement content in the composites increased the samples' mechanical characteristics, but after it exceeded 15%, the samples' mechanical characteristics deteriorated. The elimination of hemicellulose and lignin matter from the fiber because of fiber alkali treatment, it enhanced the samples' mechanical characteristics. Even fiber composite treated with NaOH reduces moisture absorption of composite. The elimination of the greasy character of the fibers due to alkali treatment improves the interfacial adhesion among the matrix and fiber. Both untreated and treated fiber-reinforce composite exhibit thermally stable around 300 °C, according to TGA analysis.

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Conflict of Interest

All authors declare that they have no conflicts of interest.

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