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IMPACT OF ALKALINE TREATMENT ON THE CONSTITUENTS, STRENGTH AND MORPHOLOGICAL CHARACTERISTICS OF BANANA FIBER

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Abstract

The readily availability of natural fibers have made them to be less expensive compared to the synthetic fibers. Hence, highest substitute for synthetic fibers in composites development today is natural fibers. In this research, banana fiber was extracted by dew retting and treated with alkaline for surface modification and possibly strengthening. Both treated and untreated fibers were tested with universal tensile testing machine and examined their surface morphology with scanning electron microscopy. The banana fiber's ultimate tensile strength (UTS) was assessed as a function of fiber diameter, test length and testing speed. It was observed from the results that chemical treatment improved the tensile strength of the fiber while surface morphology was noticed to be rough due to the removal of some fiber constituents. Hence, it was discovered that alkaline treatment improved the fiber condition, thus, making the fiber a suitable substitute for synthetic fibers in composite development.

Keywords: *alkaline treatment; surface morphology; natural fiber; banana fiber; composite materials.*

Introduction

The global interest towards sustainable materials has encouraged the use of agro-derivatives in applications that have hitherto been completely reliant on inorganic feedstock [1-3]. In recent times, more researches are being carried out to discover more agro-based fibers for the widespread development of natural fiber reinforced composites [4-5]. However, this trend has been limited by challenges in the compatibility of the matrix and the fiber which comprise the reinforcement phase. Fiber reinforced composites are a large class within this category of materials. Fiber reinforcement of materials from various lignocellulosic sources has been reported by numerous researchers [6-8].

Natural fibers provide safer and more sustainable alternatives to the synthetic fibers that have mainly been used in the development of composite materials in the early days. The Extension of studies into renewable resources based natural fibers has created newer methods that are more sustainable, safer and environmentally friendly and has also led to low-cost alternatives for artificial fibers[9]. Plants with parts that contain usable fibers are naturally grown in suitable environments throughout the world. Such fibers can be extracted from stems[10], leaves and fruits[8] of many commonly grown plants depending on which plant is most abundant in which area.

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Natural fibers like banana and coir have low densities and are of renewable resources. About 1.5 million acres of land in India are used for banana plantations which produces several tons of fibers annually [11]. Wood, sisal, hemp, coconut, cotton, kenaf, flax, jute, abaca, banana, bamboo, wheat straw and other fibrous materials are examples of natural fiber components. Lightweight, low-energy and environmental friendliness are a few benefits of natural fiber based composites. Natural fibers reduce weight and production energy requirements by 80% and 10%, respectively while the component costs 5% less than equivalent fiber-glass-reinforced components [12]. Banana fiber's mechanical characteristics were investigated where it was discovered that pulling out of microfibrils and ripping of cell walls cause the banana fiber intention to fail [13].

Natural fiber is one of the ecologically friendly materials that are being taken into consideration for the majority of applications due to their superior qualities when compared to synthetic fiber in terms of eco-relationship [14]. Utilizing materials that are waterproof, moderately strong and corrosion-resistant, natural fiber is used in the majority of technical components for the production of cars, aircraft, home appliances and packaging. Global industry researchers predicted that the global market for natural fibers would be worth $6.4 billion by 2022 and rise at a compound yearly growth rate of 10.2% from 2022 to 2026.

Chemical modifications are seen to be a viable option for altering the surface properties of fibers because they can both lessen natural fibers' water absorption and strengthen the interaction between fiber and matrix. Several researchers looked into chemical treatments for natural fibers [1-8]. The common chemical treatments are acetylated and alkaline treatments. When employed as reinforcement in thermoplastics and thermosets, alkaline treatment is one of the most popular treatments for natural fibers. The sodium hydroxide used in this investigation was selected due to its efficiency and low cost [15].

For uses in domestic goods, natural fibers like sisal, kenaf, palm, kenaf, banana, jute, and coir have been employed as reinforcement in polymer composites. At the moment, research into composite materials is focused on employing natural fibers rather than synthetic ones. When used as reinforcing fibers in matrices, natural fibers made from yearly renewable resources have a positive impact on the environment in terms of final disposal and raw material use. Because of their low density, superior mechanical performance, universal availability, and disposability, natural fibers provide an alternative to technical reinforcing fibers. Chemically altering the fiber surface can strengthen the bond between the fiber and matrix. The fiber surface can be cleaned, chemically modified, and given a rougher finish through chemical treatment.

This work was carried out to determine the suitability or otherwise, of banana fiber extracted by dew retting process. Another purpose is to assess the effects of chemical modification on the fiber strength and surface morphology of banana by employing some of the common treatments for natural fibers. Part of the reasons for this was due to the variation on natural fiber properties with respect to geographical location among many other natural phenomenal that usually influence the properties of natural fibers. These steps are intended to separate the technical fibers from the non-structural fiber constituents in the fiber bundles.

Materials and Methodology

Banana pseudo stem was collected from a farmland in Ikere Ekiti, Ekiti State, South-Western Nigeria after harvesting. Sodium hydroxide was bought from Pascal Scientific Store, Akure, Ondo State.

Dew Retting Process

Banana fiber was extracted by dew retting process in which the cut down stem was exposed to moisture and sunlight intermittently and continuously for 30 days. During the process, microorganisms were responsible for the separation of fibers from cortex and xylem naturally. The fibers were hand stripped, washed and sundried for 5 days.

Alkaline Treatment of the banana fibers

Parts of the extracted fibers were treated with sodium hydroxide solution. The fibers were treated by being soaked in a 2 M NaOH solution for 4 hours at 50 °C in electric oven. The fibers were washed with tap water and rinsed with distill water to achieve neutral status. The mercerized fibers were then dried in the sun within 3 days during the dry season.

Tensile Test of the Fiber

Tensile test was performed on both untreated and treated fibers in accordance with ASTM D 3822 utilizing general-purpose Instron testing equipment; model 3369 with a 25 N load cell full range. Fibers were assessed at a gauge length of 10 mm in their as-received state with displacement control and a crosshead speed of 1 mm/min.

Scanning electron microscopy

Scanning electron microscopy (SEM) was used to examine the morphology of the fiber surface both before and after treatment. Zeiss Gemini Scanning Electron Microscope (SEM) was used after gold coating the banana fibers for proper conductivity.

Results and Discussions

The Chemical Composition of Treated and Untreated Banana Fibers

Chemical characterizations of treated and untreated banana fibers were carried out to determine the cellulose, hemicelluloses, lignin, and ash content. Fig. 1 presents the quantitative analysis of the constituents of both treated and untreated fibers, respectively. Alkaline treatment of natural fibers with sodium hydroxide (NaOH) is widely used to change the cellulosic molecular structure. The treatment usually allows chemicals to penetrate the fibers thereby reducing the hydrophilic hydroxyl groups and increase the fibers moisture resistance property. It also removes a certain portion of hemicelluloses, lignin, pectin, and waxes. As can be seen in Fig. 1, the amount of cellulose present in the fiber is more compared to hemicellulose and lignin both in treated and untreated conditions. The fiber after treatment has about 48%, 22% and 20% of cellulose, hemicellulose and lignin, respectively. It was discovered that treated banana fiber has higher cellulose than untreated banana fiber which may be due to the influence of the chemical treatment. During chemical treatment of natural fibers, constituent like hemicelluloses was hydrolyzed by the action of alkaline solutions [4-5].

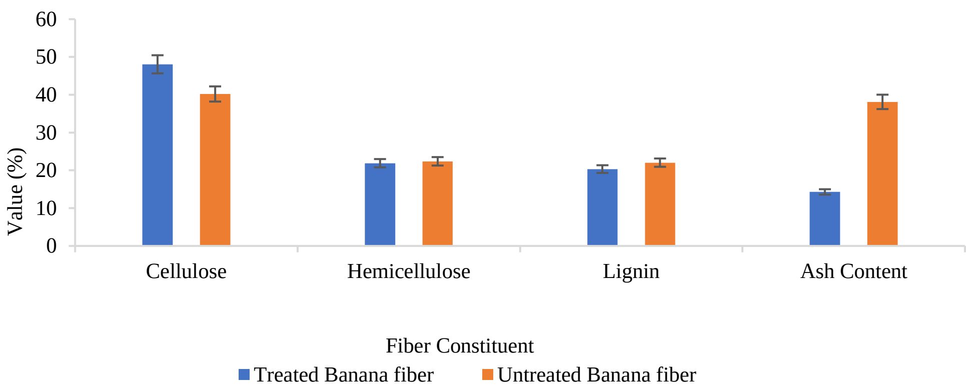


Fig. 1. Constituent of Untreated and Treated Banana Fibers.

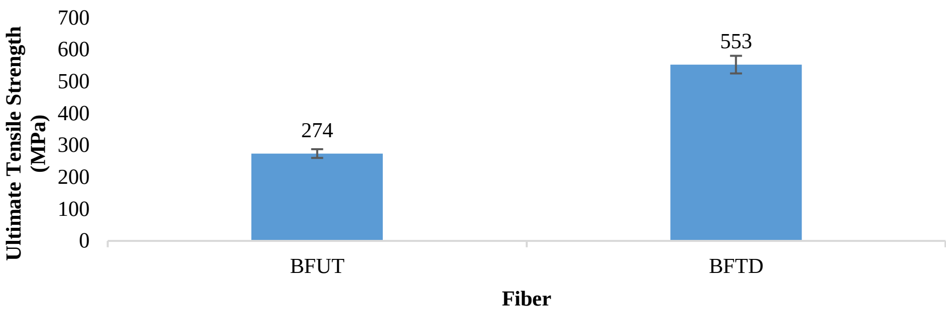
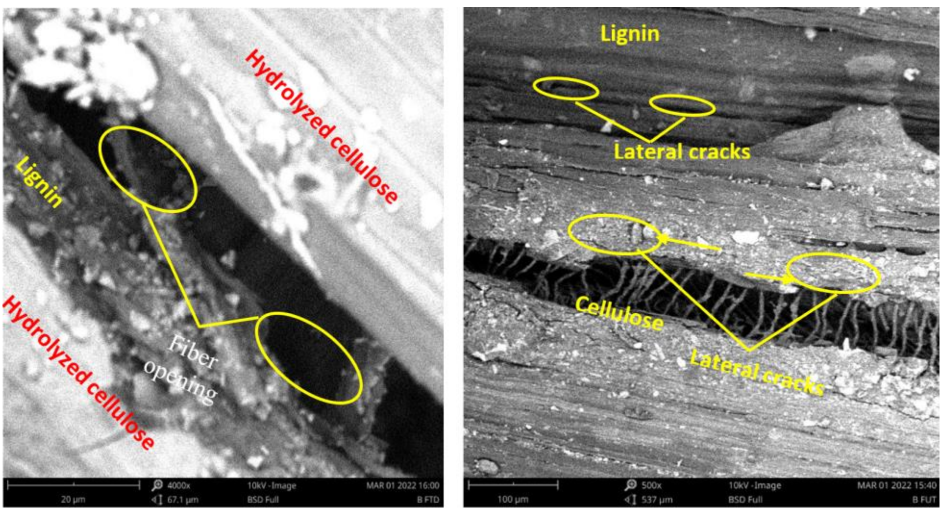


Fig. 2. Tensile Strength result of Untreated and Treated Banana Fibers.

Fig. 2 presents the ultimate tensile strength values obtained for the investigated natural fiber. It was observed that the alkali treated banana fiber (BFTD) possessed high tensile strength of 553 MPa compared to the untreated fiber with a value of 274 MPa. This can be attributed to the influence of treatment on the fiber as reported by previous researchers in their works on natural fibers [4-5, 15].

Scanning Electron Microscopy

Fig. 3 (a) illustrates how alkali treatment cleans the banana fiber surface from various artificial and natural contaminants with a rough surface. It has been discovered that alkali treatment causes a process known as fibrillation or fiber separation which results in the disintegration of the fiber composites' bundles into individual fibers. The surfaces after the alkali treatment exhibit a noticeable difference. Following alkali treatment, it was shown that surface contaminants were removed and the final cells were separated as a result of the elimination of the cementing elements, such as lignin and hemicellulose. The inter fibrillar region was expanded and the surface's texture was made rougher by the dissolving of waxy components. However, Fig. 3 (b) revealed the surface of the untreated fiber which was noticed to be smooth and covered in waxes and other impurities.



a) b)

Fig. 3. SEM image of (a) treated banana fiber (b) untreated banana fiber.

Conclusion

The effect of extraction process and chemical treatment on the constituents, mechanical properties and surface morphologies of natural fiber isolated from banana stem has been studied with respect to alkaline treatment and it was discovered that:

- Alkaline treatment altered the fiber constituents where all except cellulose were reduced in quantity after treatment. This treatment had an impact on the fiber's shape, crystallographic structures and macromolecular characteristics.
- Alkaline treatment improved the tensile strength of banana fiber due to increase in cellulose content compared to other constituents present in the fiber, hence, the fiber will function as a good reinforcement material for composite development.
- Surface morphology after treatment revealed increase in fiber roughness by significantly removing surface coverings. This feature will aid improved fiber-resin permeability and enhanced interfacial adhesion.
- Banana fiber can be effectively extracted using dew retting before alkaline treatment of the fiber.

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