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CHARACTERIZATION OF FIBER EXTRACTS FROM IMMATURE COCONUT HUSKS WASTE ALONG THE KENYAN COASTAL REGION

KOITUMET Joel Sabore[12], MWASIAGI Josphat Igadwa[1], GITHAIGA John[1]

[1]Moi University, School of Engineering, Department of Manufacturing, Industrial and Textile Engineering, P.O Box 3900-30100 Eldoret, Kenya, info@mu.ac.ke

[2]Technical University of Mombasa, School of Engineering and Technology, Department of Medical Engineering, P.O Box 90420-80100 Mombasa, Kenya, info@tum.ac.ke

Corresponding author: Koitumet, Joel Sabore, E-mail: jsabore@yahoo.com

***Abstract**: This paper presents a study on the characterization of fiber extracted from immature coconut husk waste that was collected along the costal region of Kenya. The husk wastes were naturally dried and fibers mechanically extracted. Fiber extracts were treated using 20% NaOH for 3 hours. The thermogravimetric analysis, Fourier transform infrared spectroscopy, and morphological analysis, using scanning electron microscopy of the fiber were investigated. From the results obtained, the alkali treatment of fiber extracted from immature coconut husks waste presented nearly minute changes in Fourier Transforms Infra-Red spectra for treated coir fibers. The thermal stability of the treated immature coconut fibers was improved after the alkali treatment because of the elimination of hemicellulose and lignin. Immature treated fibers display a minor peak centered at 100℃ as a result of water loss. The untreated fibers display two minor peaks centered at 100 ℃ and 295 ℃ due to moisture loss and hemicellulose decomposition respectively. The surface morphology of the untreated fibers reveals a fine and smooth surface where as that of treated fibers shows a rough and fine surface as a result of the removal of impurities. Treatment also decreases fiber diameter and results in a rougher surface. Fiber alkali treatment appeared to slightly enhance the properties of the fibers in comparison to the untreated fibers.*

***Key words:** characterization; coir fiber; extraction; surface morphology; FTIR; TGA*

1. INTRODUCTION

Coconut palms are abundantly grown in tropical nations, particularly along the coasts of Asia, Africa, and Latin America**.** Coconut (*Cocos nucifera L.*) belongs to the *Arecaceae* family (Palmae) and to the *Cocoideae* subfamily and has its origin in Southeast Asia [1]. It is one of the most economically significant crops in the tropics, used as a significant food source, thirst-quencher, medicine, fuel source, and material for construction. In Kenya, coconut trees are majorly grown for the production of coconut oil, wine, and wood as a construction material. Consumption of tender coconut water along the Kenyan coastal region has significantly increased over the years resulting to the generation of green husk wastes.

Mombasa town which is a tourist town leads in tender water consumption and green husk waste generation especially during holidays. One of the reasons for increased green husks waste generation perhaps is the higher economic return compared to cost of matured coconut fruit. The second evident reason is the considerably shorter harvesting time of immature coconut compared to matured which remains longer in the case of matured coconut. This increases the generation of byproducts as wastes majorly the husks which according to [2]; [3]; [4] correspond to approximately 85% of the fruit weight. The purpose of this work was to extract and characterize fibers from immature coconut husks waste along the Kenyan coastal region. Fourier transform infrared spectrophotometry, thermal gravimetric analysis and scanning electron microscopy (SEM) were used for the characterization of coir fiber for structural, thermal and morphology properties.

2. MATERIALS AND METHODS

Immature coconut husks were collected from Mama Ngina drive, Mombasa town CBD, Mtwapa and Kwale which are proximally located. The three locations were selected Firstly, because it is a representative of the four counties in the Kenyan coastal region with significant coconut farming according to the Agriculture and Food Authority (AFA) report of 2016. Secondly, Mombasa town is a converging zone for coconut tender water vendors, consumers as well as the suppliers from North and South coast regions. The samples were then dried in the sun for a period of three months. Coconut fibers extracted from immature coconut husk wastes were treated using 20% NaOH for 3 hours. There were two categories of samples with the following notations, IM_untreated for immature untreated coir fibers and IM_treated for immature treated coir fibers. The fibers were extracted using a mechanical decorticator.

3. CHARACTERIZATION OF COCONUT FIBERS

Raw and treated samples from both immature and matured coconut fibers were analyzed by infrared spectroscopy (FTIR) using JASCO FT/IR-6600 type with a wavelength range of 7,800 to 350cm^{-1}. TGA was performed using a PerkinElmer STA 6000 thermogravimetric analysis instrument, in a Nitrogen atmosphere, at a heating rate of 20°C/min from 25°C to 700°C to obtain derivative curves for the fibers. Surface morphologically was analyzed using TESCAN VEGA 3 scanning electron microscopy. Tensile strength was determined from the breaking load and elongation at break of single fiber performed using Electronic single fiber strength tester Model YG003E. The pulling force, speed, and gauge used were 100cN, 200mm/min, and 100mm respectively.

4. RESULTS AND DISCUSSION

4.1 FTIR Characterization

Figures 1 show characterization using FTIR spectrophotometer for raw untreated coir fiber and alkali-treated coir fibers extracted from immature coconut husk wastes. The notation used for immature coir fiber is IM_untreated and IM_treated for raw untreated and alkali-treated fibers respectively. The broadened bands at around 3300 cm^{-1} in both Fig 1 and 2 were observed in all spectra, indicating the presence of -OH groups in the structure which suggests OH stretching vibration from the cellulose and lignin structure of the fiber [5]; [6]; [7]. Figure shows bands at 1030 cm^{-1} and 1048 cm^{-1} for raw untreated and treated immature coir fibers and Figure 2 bands at 1024 cm^{-1} for both raw untreated and treated mature coir fibers. These peaks are attributed to the existence of C-O-C stretch, which arises from cellulosic characteristic peaks [8]. The peak in Figure 1 and 2 at around 1400 cm^{-1} in all spectra corresponds to the water absorption. The peaks were attributed to the stretching of hydrogen bonds and

bending of hydroxyl (OH) groups bound to the cellulose structure. According to [9], these results are an indication that the cellulose component was not removed during the chemical treatment carried out on the immature coconut fiber. [10], reported that the vibration at 2900 cm^{-1} to 2850 cm^{-1} shows the existence of –CH groups, where the lignin and waxes were eliminated after the different chemical treatments. The peaks at 1823 cm^{-1} for raw untreated fiber and 1786 cm^{-1} for treated fibers as shown in Figure 1 are distinctive of the carbonyl group found in coconut fiber. The respective peaks for raw and treated coir fibers are 1799 cm^{-1} and 1769 cm^{-1}. These peaks were attributed to C=O stretching of the ester linkage between the carboxylic groups of lignin and/or hemicellulose.

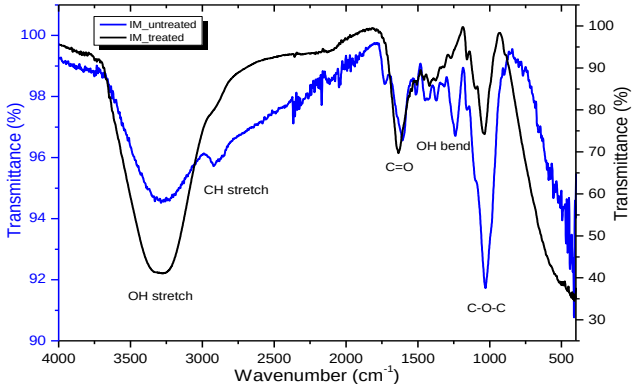

Fig 1. *Comparison of IM_untreated and IM_treated*

A decrease in the C=O peaks was observed following the chemical treatment. As reported by [11] the decrease was likely due to the partial removal of hemicellulose and lignin, confirming the efficacy of the treatment.

4.2 Thermal Gravimetric Analysis

Figures 2 and 3 show the TGA thermograms and DTGA curves for treated and untreated immature fibers respectively. The immature fibers both untreated and treated show initial degradation of 75 - 210℃ that is a result of loss of volatilities and moisture as shown in Figure 2. The treated fibers tend to have a high percentage loss of moisture due to the numerous OH groups in the cellulose structure that form hydrogen bonds with water. The untreated fiber displays the second degradation in the range 280 - 310℃ associated with hemicellulose decomposition. The third degradation appeared in the range 315 - 350℃, which is due to the decomposition of cellulose. In the immature treated fibers, there is an exothermic peak which is followed by second stage degradation between 280 - 350℃ associated with cellulose decomposition. Lignin decomposition occurs in the range of 250 - 450℃ because it is a stable constituent, therefore, not easily degraded [12]. The residual ash content was found to be 40 and 32% for immature untreated and treated fibers respectively as shown in figure 3. The treatment affected the removal of volatile, organic matter, hemicellulose, and lignin causing a decrease in the ash content [13]. The removal of the lignin and hemicellulose result in the exposure of the cellulose, which was easily decomposed.

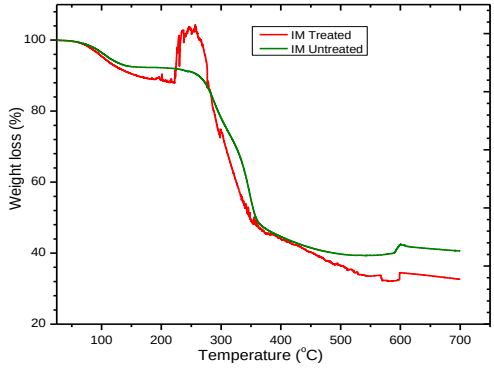

Fig. 2: *TGA thermograms*

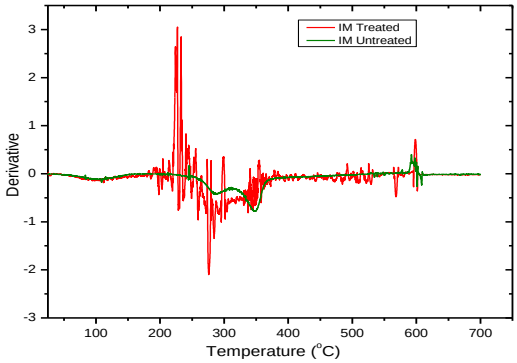

Fig. 3: *DTGA thermogram*

The thermal stability of the treated immature coconut fibers was improved after the alkali treatment because of the elimination of hemicellulose and lignin [14]. The DTGA thermograms of immature treated fibers in figure 3 display a minor peak centered at 100℃ as a result of water loss. There are many irregular endothermic and exothermic peaks due to cellulose and hemicellulose decomposition. The untreated display two minor peaks centered at 100 ℃ and 295 ℃ due to moisture loss and hemicellulose decomposition respectively. The major peak centered at 345℃ was attributed to cellulose decomposition [15].

4.3 Scanning Electron Microscopy analysis

The SEM micrographs of untreated and treated immature fibers are displayed in Figures 4 and 5 respectively. Figures 4b and c display the morphology of the untreated fibers with smooth surface unlike the rough surface displayed by alkali-treated fibers shown in Figures 5b and c. The untreated coconut fibers contain wax, lignin, cellulose, hemicellulose, and other impurities; therefore, a fine structure is observed in Figure 5c. The treated coconut fibers show the effect of the alkali treatment which disrupted the fine surface revealing rough surfaces. The cellulose surface was revealed. According to [18], alkali treatment yielded better interlocking sites and a large cellulose volume. The rough surface of the fiber after alkali treatment differs greatly from that of the untreated fibers. Elevated surface roughness of coconut fiber as a consequence of enhanced cellulose exposure [16]. The diameter of the untreated immature fibers decreased after alkali treatment. The treated fibers had a diameter ranging between 150 – 167 µm (Figure 2a) while that of untreated was 190 – 260 µm (Figure 1a).

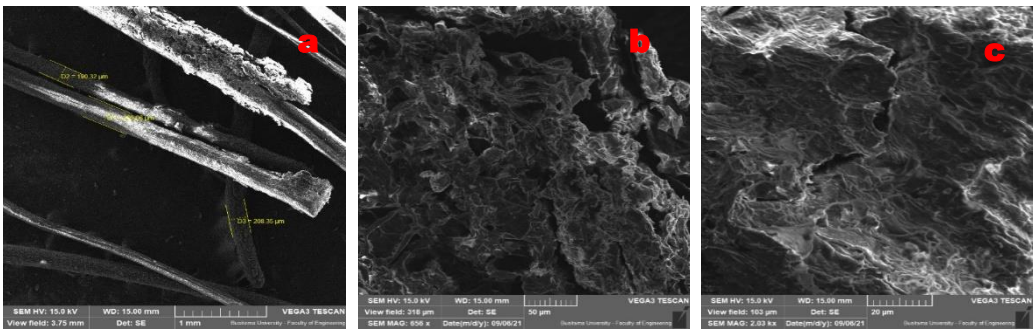

Fig. 4: *SEM micrographs of untreated immature coconut fibers*

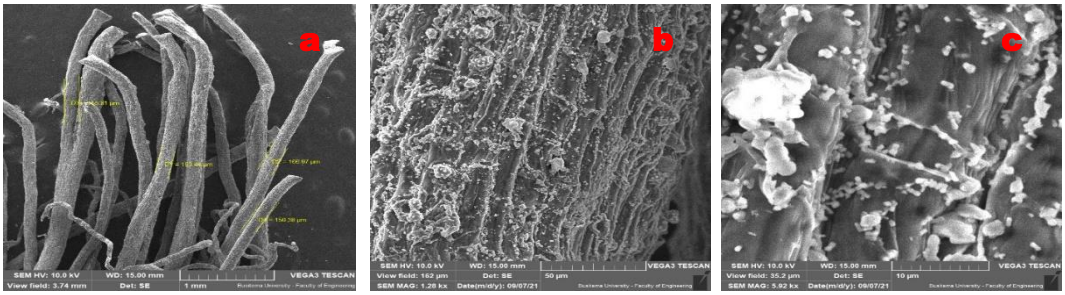

Fig. 5: *SEM micrographs of treated immature coconut fibers*

5. CONCLUSIONS

The alkali treatment of fiber extracted from immature coconut husks waste presented some little changes in FTIR spectra for treated coir fibers. The thermal stability of the treated immature coconut fibers was improved after the alkali treatment because of the elimination of hemicellulose and lignin. Immature treated fibers display a minor peak centered at 100℃ as a result of water loss as shown by DTGA thermograms in Figure 3. There are many irregular endothermic and exothermic peaks due to cellulose and hemicellulose decomposition. The untreated fibers display two minor peaks centered at 100 ℃ and 295 ℃ due to moisture loss and hemicellulose decomposition respectively. The major peak centered at 345℃ was attributed to cellulose decomposition. The surface morphology of the untreated fibers reveals a fine and smooth surface where as that of treated fibers shows a rough and fine surface as a result of the removal of impurities. Treatment also decreases fiber diameter and results in a rougher surface.

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Orcid

Joel Sabore Koitumet https://orcid.org/**0000-0001-5534-4714**

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