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Effect of Alkali Treatment on Properties of Pineapple Leaf Fiber and Banana Fiber

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Abstract: Environmental consciousness and increasing awareness of green technology have stirred the entire gamut of industry to move toward new materials instead of using synthetic polymeric fibers. Natural fiber can be a good substitute as they are available in fibrous form at low cost. Banana fiber and pineapple leaf fiber are two abundantly available fibers in Bangladesh. The aim of the current research was to characterize banana fiber and pineapple leaf fiber. Both fibers were collected from local field and extracted manually. This work analyzed the structural and thermal properties of banana fiber and pineapple leaf fiber by Fourier transform infrared spectroscopy, scanning electron microscopy and thermogravimetric analysis. The effect of alkali treatment on the properties of fibers was also observed. Both fibers were modified by 5% NaOH alkali treatment. Morphological characterization showed debris at the surface of raw fiber. Treated fiber surface was cleaner than that of untreated fibers. Fourier analysis showed the presence of some characteristic functional groups available in cellulose, hemicellulose and lignin in both fibers. It indicated reduced hydrophilicity after chemical treatment for both fibers. Thermogravimetric analysis indicated higher level of thermal stability for treated fibers as compared the raw fibers.

Keywords: *Pineapple leaf fiber; Banana fiber; FTIR; SEM; TGA*

Introduction: Global warming is a major threat to mankind. To stop and to reverse the effect of global warming, there is a need to replace non-renewable, non-degradable and synthetic materials with renewable, biodegradable and natural material. The best way to bring about the change is to make the use of or find innovative uses for agricultural waste. Industries are widely using plant fibers for numerous applications from many resources. The most important property of natural fiber is biodegradability and noncarcinogenic. There are many plant fibers available which has potential to be applied in industries as raw materials such as pineapple, kenaf, coir, abaca, sisal, cotton, jute, bamboo, banana, Palmyra, talipot, hemp, and flex [1]. Natural fibers have some drawbacks too, such as the incompatibility between fibers and polymer matrices, tendency to form aggregates during processing and poor resistance to moisture that reduce the use of natural fibers as reinforcements in polymers. On the other hand, there are several physical or chemical modification technique methods of surface modifications, which improve fibers and polymer matrices compatibility reducing the hydrophilic characteristics. Frequently used treatments are bleaching, esterification, silane treatment, use of compatibilizer, plasma treatment, and acetylation and so on. Although natural fibers lag behind from the impressive properties of synthetic fiber, their eco-friendly nature has made them attractive. Thus, agro-industrial residues were studied in this work in order to compare their properties as fibers [1, 2]. Two agro fibers wastes were studied: pineapple leaf fiber and banana fiber. These wastes were chosen because they are abundantly available in Bangladesh. Banana fiber is a good replacement of synthetic fiber. It gives stiffness and strength to the matrix. Commercially pineapple fruits are very important and leaves are considered as waste materials of fruit which is being used for producing natural fibers. Pineapple (PALF) has tremendous mechanical properties and can be applied in making of reinforced polymer composites, low density polyethylene (LDPE)

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composites and biodegradable plastic composites [1]. The objective of current research was to characterize raw and chemically treated banana fiber and pineapple leaf fiber by finding out their structural and thermal properties. The properties of raw fibers were also compared with those of chemically treated ones.

Materials and Methods:

Materials: Pineapple fiber was extracted from Pineapple leaf and Banana fiber was extracted from pseudo stem sheath of plant. Banana plant trunk and pineapple crown were collected from local field. Both fibers were extracted manually. When extracted, the fibers contained moisture. So, they were dried after extraction. NaOH was also collected from local market.

Chemical Treatment: Alkali treatment of both fibers was carried out to enhance their compatibility with the polypropylene matrix. 5% NaOH solution was prepared by adding 5 gm NaOH to 100 ml water in a beaker. Fibers were then treated with 5% NaOH. In both cases same procedure was followed. Firstly the dried extracted fiber were drowned into the solution and stirred properly, so that all fibers were wet by the solution. Then the beaker containing the solution with fiber was heated at 70°C for about two and half hours. Then the fibers were washed at first with tap water. Then they were washed with distilled water. The fibers containing water were taken to the oven. After complete evaporation of moisture they were taken out from oven.

Fourier Transform Infrared Spectroscopy (FTIR): The infrared spectra of fiber were recorded on a Nicolet 380 spectrophotometer with co-addition of 32 scans. Powdered sample was taken for FTIR spectroscopy. Then potassiumbromide (KBr), which acts as a reagent, was mixed (KBr: sample = 100: 1) with them in a mortar pestle. The mixture was then taken in a dice of specific dimensions. The pellet was formed by pressing with a hand press machine and was placed on the sample holder. The IR spectrum obtained is presented in the Results and Discussion section.

Thermogravimetric Analysis (TGA): Thermogravimetric analysis was carried out for determining thermal stability of fibers. TGA method used was based on continuous measurement of weight on a sensitive balance (called a thermo balance) as sample temperature was increased in an inert atmosphere. In our study TGA was carried out in an universal V4.2 E instruments (TGA Q50 v6.4) at a temperature range of 25-500°C, with a constant heating rate of 10°C/min.

Scanning Electron Microscopy (SEM): Scanning electron microscopy (SEM) analyses the surfaces of materials, particles and fibers so that fine details can be measured and assessed via image analysis. Surface morphology of the raw and chemically treated fibers was observed under a scanning electron microscope (Philips XL 30). The fiber surface was initially made conductive by applying gold coating using a sputtering machine. The fiber was then taken inside SEM, vacuum was created and micrographs were taken.

Results and Discussion:

FTIR Spectroscopic Analysis of Pineapple and Banana Fiber: Cellulose, hemicelluloses and lignin, i.e., the main constituents of any lignocelluloses fiber, are composed of alkanes, esters, aromatics, ketones and alcohols with different oxygen-containing functional groups [3]. FTIR spectra of raw and treated banana fibers are shown in Figures 1 (a) and (b). The broad absorption band at 3409.5 cm^{-1} is attributed to stretching vibrations and other polymeric associations of hydroxyl groups. An overlapping of peaks is observed between 2853.1-2962.1 cm^{-1} that is assigned to C-H stretching vibration in CH_2 [4]. Another band is observed around 1705 cm^{-1} corresponding to non-cellulosic components (pectin, lignin and hemicelluloses). Bands around 1658.4 to 1626.6 cm^{-1} are for C=C stretch due to the presence of lignin [5, 6]. At 1261.2 cm^{-1} an intense peak is observed of C=O stretching vibration of acetyl group of lignin [5].

Overlapping peaks at 1096.3 and 1024.9 cm^{-1} can be attributed to C-O stretching of alcohol, ester or ether. On the other hand the sharp peak at 800.3 cm^{-1} can be assigned as =C-H bending vibration.

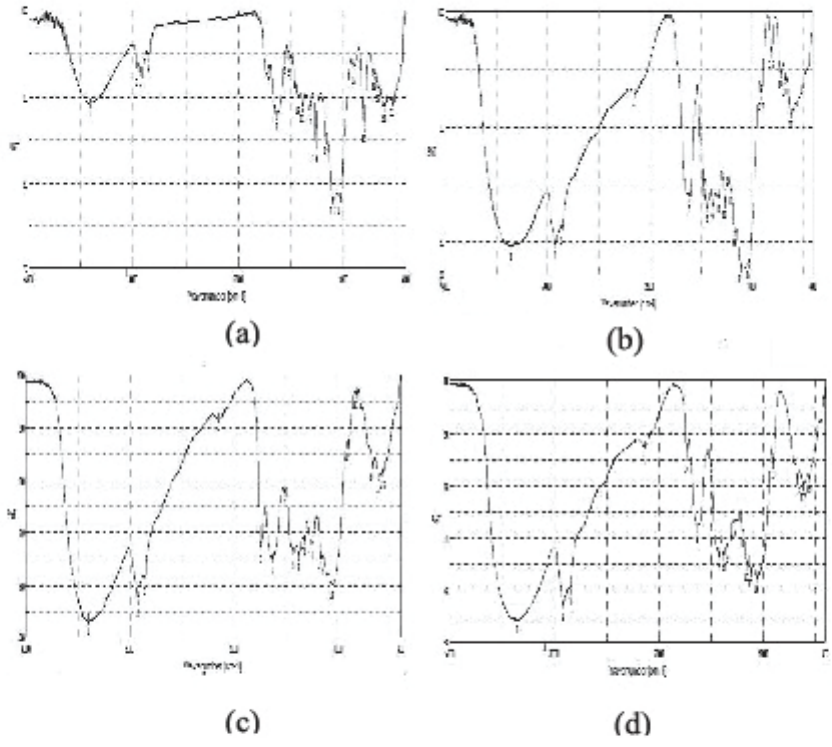
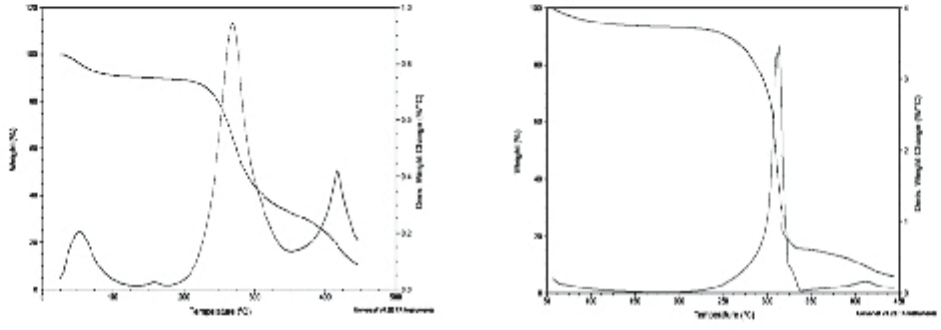


Fig. 1: FTIR spectrum of (a) raw banana fiber, (b) alkali treated banana fiber, (c) raw pineapple leaf fiber, (d) alkali treated pineapple leaf fiber.

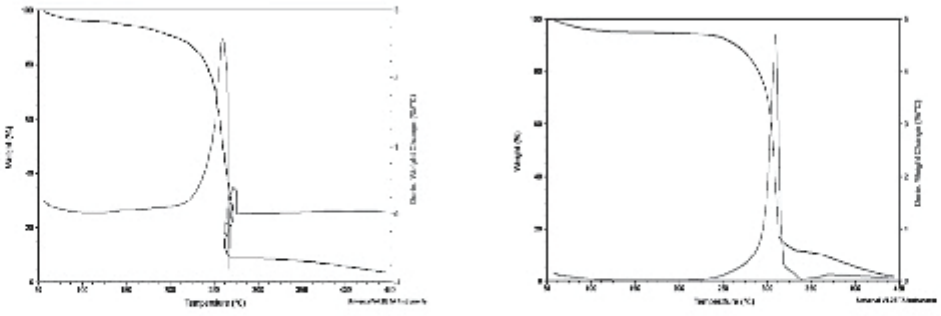
These peaks are generally observed in cellulose, hemicellulose and lignin present in natural fiber. This result demonstrates that the pseudostem banana fibers contain functional groups that allow interactions between metallic ions and the biosorbent [7]. For alkali treated banana fiber, all these characteristic peak intensities have shifted toward higher or lower wave number. It is observed that the absorption peak around 1705 cm^{-1}, corresponding to the carbonyl C=O stretching vibration of hemi-cellulose and other non-cellular components in the untreated fiber, is almost missing in the spectrum of the alkali treated fiber, indicating the elimination of hemi cellulose occurred by alkali treatment [8]. For pineapple leaf fiber, there is a broad absorption band at 3393.1cm^{-1} for O-H stretching of higher intensity than banana fiber. Bands around 2919.7-2852.2 cm^{-1} are attributed to C-H_n asymmetric stretching present mainly in cellulose, which was the major component of the lignocellulosic fibers. A peak at 1736.5 cm^{-1} is observed for un-conjugated stretching vibrations of the C=O of the carbonyl and acetyl groups in the xylan component of hemicellulose [9]. Peak at 1635.3 cm^{-1}can be attributed to alkene C=C stretching vibration. The bands at the region from 1000 to 1500 cm^{-1} are assigned to the aromatic region related to the lignin: the bands at 1428.0, 1380.7 and 1250.6 cm^{-1} are characteristic of C-H and C-O deformation, bending or stretching vibrations of many groups in lignin and other carbohydrate. Cellulose show bands characteristics at 1055.84 and 1160.9 cm^{-1} attributed to C-OR stretching and antisymetric bridge C-OR-C stretching of cellulose, respectively. The peak at 1321 cm^{1} is attributed to the O-H of alcohol groups and the band at 1428 cm^{-1} is assigned to aromatic skeletal vibrations associated to C-H in plane deformation of cellulose. The band at 899.6 cm^{-1} is attributed to CH deformation in the amorphous region of the cellulose [1, 9].

As a result of alkali treatment, characteristic peaks have shifted slightly in wave number. It is also observed that, the intensity of –OH group is reduced after alkali treatment, indicating that some of the –OH groups are reduced after alkali treatment. Intensity of peak for C=O of the carbonyl and acetyl groups of hemicellulose has decreased notably indicating removal of hemicellulose. Decreased intensities of other characteristic peaks also indicate decrease in hemicellulose and lignin.

Thermogravimetric Analysis of Pineapple and Banana Fiber: TGA is mainly used to characterize the decomposition and thermal stability of material. It examines the physico-chemical process occurring in the sample. TGA curve of Raw and alkali treated banana fiber is given in figures 2 (a) and 2 (b). DTG curve indicates higher thermal stability for treated NaOH banana fiber. Raw banana fiber is stable up to 225°C. NaOH treated banana fiber is stable up to 275°C. In DTG curve a first peak is observed which indicates heat of vaporization of water absorbed in the fiber. The peak is higher in raw banana fiber. The reason may be the presence of some low molecular weight compounds which are removed by alkali treatment [10]. So, in NaOH treated banana fiber lower peak is observed. A second peak is observed in raw Banana fiber which indicates hemicellulose degradation [11]. The peak is not observed in treated banana fiber indicating removal of hemicellulose during alkali treatment. The highest derivative weight% for cellulose degradation is observed for raw and treated banana fiber is 3.25% and 0.9% respectively. The fourth peak present in TGA curve indicates lignin degradation. This peak is higher for raw banana fiber indicating the presence of higher amount of lignin in raw banana fiber. As a result higher amount of residual char is observed in raw banana fiber. In figures 2 (c) and 2 (d), TGA curves of raw and treated pineapple leaf fiber are shown. From the two TGA curves, it is observed that thermal stability of heat treated fiber is higher than untreated fiber [12]. Untreated fiber is stable up to 225°C and treated fiber is stable up to 250°C. From the DTG curve some peaks are observed. Moisture content is low for both treated and untreated fiber. Highest peak for cellulose degradation is observed at 250°C and derivative weight change is 2.5% for untreated pineapple leaf fiber. Highest peak for cellulose degradation for NaOH treated fiber is observed at 300°C and derivative weight change is 4.75% [10]. A second peak is observed which indicates the lignin degradation and the peak is higher in untreated pineapple leaf fiber. This indicates higher value of lignin in untreated pineapple leaf fiber.



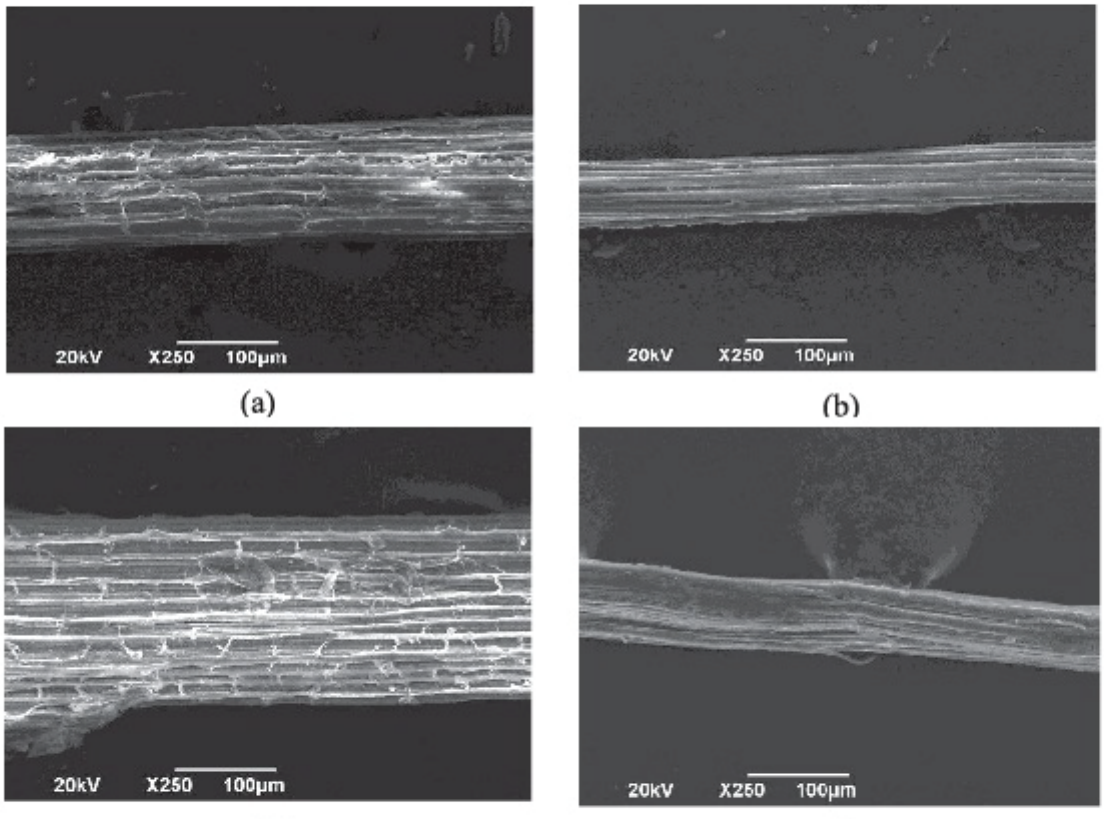
(a) (b)



(c) (d)

Fig. 2: TGA curves of (a) raw banana fiber, (b) alkali treated banana fiber, (c) raw pineapple leaf fiber, (d) alkali treated pineapple leaf fiber.

Scanning Electron Microscopic Analysis (SEM): From the SEM analysis it is observed that the surface of pineapple leaf fiber is rougher than banana fiber. The reason is that the cellulose content of pineapple leaf fiber is higher than banana fiber. And the hemicellulose and lignin contents of pineapple leaf fiber are lower than banana fiber. And both of these low hemicellulose and lignin contents make the pineapple leaf fiber surface rougher than banana fiber. Figures 3 (a) and 3 (c) show the raw banana fiber and raw pineapple leaf fiber respectively. Raw fibers have an irregular surface having variable roughness where the microfibrils appear to be parallel to the fiber's axis. The raw fibers have some impurities on their surfaces. Figures 3 (b) and 3 (d) show treated fibers. It may also be noticed that most impurities have been removed from the fiber's surface. Diameters of fibers have also decreased after alkali treatment [13-16].



(a) (b)

(c) (d)

Fig. 3: SEM micrographs of (a) raw banana fiber, (b) alkali treated banana fiber, (c) raw pineapple leaf fiber, (d) alkali treated pineapple leaf fiber.

Conclusions: Present research demonstrated that alkali treatment clearly affected structural and thermal properties of fibers obtained from pineapple leaf and seudostem sheath of banana plant. FTIR analysis indicated peaks generally observed in cellulose, hemicellulose and lignin present in natural fiber. Elimination of hemicellulose was observed in alkali treated banana fiber. Treated pineapple leaf fiber showed decreased –OH groups and decrease in hemicellulose and lignin. Thermogravimetric analysis indicated higher level of thermal stability for treated fibers as compared the raw fibers. SEM indicated presence of impurities in the irregular surface of untreated banana fiber and pineapple leaf fiber. Alkali treatment removed surface debris and resulted cleaner surfaces for both fibers.

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