THE EFFECT OF ALKALI TREATMENT ON THE PROPERTIES OF NENDRAN BANANA FIBRE
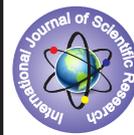
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ABSTRACT Alkalisation at room temperature was carried out with four concentrations of NaOH on banana fibres to study the degumming efficiency and fibre properties. Fibre characterization was done and properties such as linear density and tenacity were tested. SEM micrographs showed the fibre surface of the treated fibre to be rough thus indicating a possibility of cohesiveness between fibres for yarn spinning. FTIR spectrum and the increasing weight loss percentage proved the digestion of hemicelluloses and lignin at 3% NaOH concentration producing good degumming efficiency. Strength and linear density of the treated banana fibre decreased as the concentration of the alkali increased.

INTRODUCTION

The banana plant is the largest herbaceous flowering plant. The plants are normally tall and fairly sturdy, and are often mistaken for trees, but what appears to be a trunk is actually a "false stem" or pseudostem. After harvesting the fruit the pseudostem is discarded. Hence the stem forms a major waste material in large scale banana plantations and disposal of these stems is a real problem for the farmers (Das et al., 2010). It is estimated that 1.5 million tonnes of banana fibre could be extracted from 30 million tonnes of pseudostem waste produced annually each year across the country (Shivashankar et al., 2006). Commonly called as the Musa fibre, it is a natural lignocellulosic fibre which is a renewable and sustainable bioresource. Being a plant waste fibre, it has immense potential in the field of textiles, paper and composites.

Banana fibre exhibits high strength, good lustre, light weight and has good moisture absorption. Like other plant fibres, the banana fibre is composed mainly of cellulose. The non cellulosic components like lignin, pectin, wax and fats contribute the gummy material which makes the fibre stiff and less pliable. Degumming helps to remove this gummy matter to a certain extent but is accompanied by strength loss. The study was taken up to study the physical properties of the treated fibres and assess the efficiency of treatment with alkali.

MATERIAL AND METHODS

Fibre samples

The banana fibres of nendran variety were manually extracted for the study from Marthandam, KanyaKumari.

Alkali treatment

The fibre was treated with Sodium hydroxide at 4 different concentrations viz. 0.5%, 1%, 2% and 3% (w/v) at room temperature for 30 minutes with MLR 1:30. The fibres were washed in warm water 3-4 times and then neutralized with 0.1% (w/v) acetic acid for 2-3minutes. The treated fibres were washed thoroughly with distilled water 3-4 times and dried.

SEM

The morphology of the control and treated banana samples were observed using a Carl Zeiss scanning electron microscope (UK). The fibres were coated with gold palladium to make them conducive and scanned at a magnification of 500X and 10.00 KX to understand the surface topography.

FTIR

The banana fibre samples both control and treated were ground to a fine powder. The samples were passed through the spectrometer Thermo scientific, Znicolet 6700 at the wavelength of 4000 to 400 cm-1 to study its chemical property.

Linear density

The fibre fineness was tested using ASTM D 1059 Fibre bundles consisting of 100 fibres were cut to 5 cm length (L) with the help of a template and were weighed (W). Similarly the weight was recorded for total of 5 such sets. The linear density in tex was calculated with the following formula

$$Tex = 1000 \times W / L \times N$$

Where, N is the number of fibers in the specimen.

Tensile properties

The tensile properties were tested on Instron 3345 system at TIFAC CORE, Kumaraguru College of Technology, Coimbatore. Single fibre tests of control and treated fibres were carried out with 10 readings each. The guage length used was 65 mm with a crosshead speed of 100mm/min. The results and graphs were generated by the Instron approved computer system with Instron bluehill software.

RESULTS AND DISCUSSION

Structure and visual appearance

The banana fibres had high natural lustre and were off white in colour. Good quality banana fibre is off white, whereas, poor quality fibre is yellow in colour (Kulkarni, 1983; Batra and Subash, 2010). They are filament fibres with length varying from 90cm to 110cm. At random the fibres were measured for the diameter from optical observations under microscope and the average of ten readings were taken. The diameter measurements varied from 0.12 mm to 0.24 mm having thick and thin areas on individual fibre itself characteristic of natural fibres (Mukhopadhyay *et al.*, 2008).

When compared with the control fibres, it was noted that the independent sample t- test was found to be significant at 5% level in the case of diameter values for fibres treated with 3% NaOH (t cal = -6.191< t tab = 0.00 at 18 df)
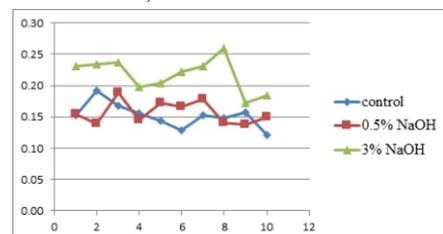

Fig. 1 Diameter of control and treated fibres at the lowest and highest concentration

Longitudinal view under the microscope shows cross markings which are more darker and prominent on the treated fibres.
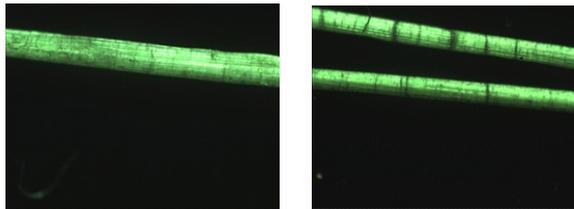
Plate 1 L.S. view of control banana fibre   **Plate 2** L.S. view of treated banana fibre(3% NaOH)

SEM Microscopy

In plate 3 fibres are seen arranged in a compact configuration and the alignment is parallel to the bundle axis. The control fibre shows the presence of non fibrous material in some regions as seen in the micrographs. This non fibrous matter encrusted on the banana fibres constitute mainly of hemicelluloses, lignin and pectin (Jayaprabha *et al.*, 2011). However the treated fibre has more rough surface and the non fibrous matter is seen but comparatively lesser, as treatment with alkali helps in the removal of hemicelluloses, lignin and pectin to a certain extent.
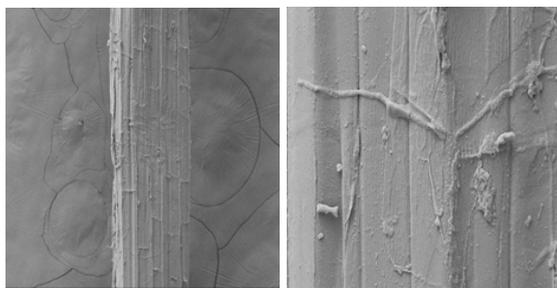

Plate 3 SEM image of control fibre

Plate 4 SEM image of alkali treated fibre at the 3% concentration

FTIR

The FTIR spectra of the control fibre and treated fibre (3% NaOH) are shown in Fig. 2 & 3. The broad band at 3334 cm^{-1} corresponds to the O-H stretching and the absorption peaks at 1422, 1158 and 1056 cm-1 features CH$_2$ deformation, C-O-C asymmetric and C-O-C symmetric stretching respectively. These were similar for both contol and treated fibre attributing the cellulose structure.

The vibration peak at 1729cm-1 in the control fibre is due to the C=O stretching of methylester and carboxylic acid in pectin or acetyl group in hemicelluloses. The most significant effect was seen with the disappearance of these peaks in the treated fibre, indicating that the alkalization process effectively broke the ester bond of the hemicelluloses and lignin and thus removed them (Sheng *et al.*, 2014). A strong band peak was seen at 897 cm-1 for control fibre and at 896 cm-1 for treated fibre at 3% concentration which is characteristic of the β-glucosidic bonds between glucose units.

Thus it can be concluded that treatment with alkali reduces the non cellulosic substances like lignin, hemicelluloses and pectin and retaining the cellulose I structure.
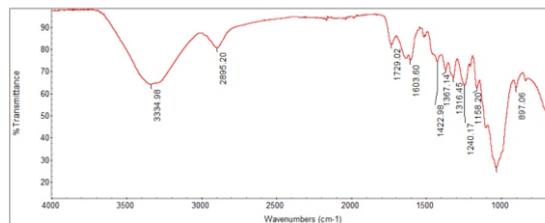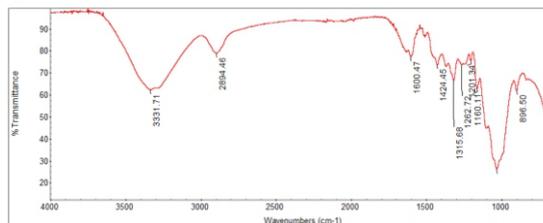

Figure 2 FTIR of control banana fibre

Figure 3 FTIR of banana fibre treated at 3% NaOH

Weight loss

The percentage weight loss of the treated banana fibre samples increased with an increase in concentration of the alkali. Similar trend was also seen in earlier studies (Temesgen and Sahu, 2014), (Balan *et al.*, 2011). As the non cellulosic materials are dissolved, there is an increase in cellulose content of the treated banana fibres.
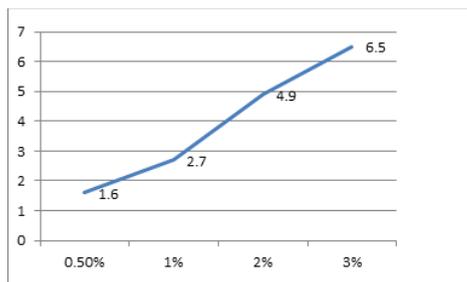

Fig. 4 Weight loss percentage of the alkali treated banana fibres

Linear density

The linear density of the fibres decreased after alkalization when compared with their control. This can be attributed to the fact that alkali treatment helps in the removal of hemicelluloses and lignin thereby losing their cementing capacity and making them finer (Dipa *et al.*, 2001) which has been also seen in the FTIR report. The results confined to those reported in earlier studies (Brindha *et al.*, 2012)
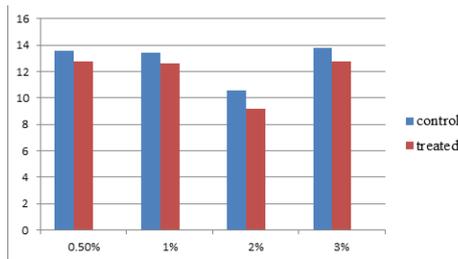

Fig. 5 Linear density of the control and treated banana fibre

Tensile properties

Sodium hydroxide is conventionally used to degum vegetable fibres to remove impurities and other gummy matter. Alkali treatment's main purpose is to disrupt hydrogen bonding in the network structure and remove some hemicellulose, lignin, wax and oils, thereby increasing surface roughness. This treatment influences fibre's mechanical behaviour, especially regarding strength (Li *et al.*, 2007). But the treatment is usually accompanied by loss in strength.

Alkali treatment caused strength loss which varied from 25% to 57%. As the concentration of NaOH increased, the tenacity showed a marked decrease (Balan *et al.*, 2011). When compared with the control fibre, the value of the t statistic was found significant at 5% level in the tenacity values at all concentrations except at concentration of 0.5%.

FIBRE	TENACITY (MPa)	CV (%)
Control	151	40.5
Treated fibre 0.5%	113	57.9
1%	98	39.3
2%	64	64.5
3%	65	38.3

Table 1 Single fibre tenacity of control and alkali treated banana fibres

CONCLUSION

1. Alkali treatment causes the fibre surface to be rough by partial removal of gummy matter. Rough surface can help the fibre in its spinability.

2. Hydrolysis of hemicelluloses and lignin were confirmed by FTIR.

3. Treated fibres are softer to touch and lustrous as compared with the untreated fibres.

4. Fibre fineness increases with increase in the concentration of the Sodium hydroxide but there is considerable loss of strength.

5. Due to its longer length, the fibre treated with 1% NaOH showing considerable strength and fineness can be used as a monofilament fibre yarn for weaving.

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