SHORT COMMUNICATION

ALKALINE SURFACE MODIFICATION OF BANANA STEM FIBRES

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ABSTRACT

One of the important issues in producing composite materials with natural fibres is the modification of the surface of the fibres to enhance adhesion and interfacial bonding with polymer matrix. In this report, the effect of alkalization on the mechanical properties, thermal stability and surface morphology of banana stem fibres is examined. The results show that treatment with sodium hydroxide modified the surface of the fibre, attenuating IR absorption intensities at 1733cm^{-1} corresponding to reduction of C=O groups, at 1514cm^{-1} and between 3000 and 2850cm^{-1} associated with reduction/removal of low molecular weight constituents of the fibres. It was found that alkali-treatment improved both tensile and flexural strengths, and the thermal stability of the fibres.

INTRODUCTION

Polymer matrix composites are made by embedding fibres such as carbon, aramid or glass in a polymer matrix[1]. Carbon fibres have remarkable properties with tensile strength of 3.2 GP_a and a tensile modulus of 230 GP_a[2]. The high stiffness and strength of this material makes it ideal for many applications in the defense and aerospace industries and in civilian applications. The disadvantages of carbon fibres are their high cost and brittle nature. Glass fibres are the most widely used fibres for general reinforcement of polymers and while not as strong as carbon fibres, glass produces desirable properties in composites such as cost. Because of increasing environmental consciousness and demands of legislative authorities, there is a paradigm shift towards designing materials that are compatible with the environment[3].

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The use of natural fibres as replacement for synthetic fibres has thus received considerable research attention. Although carbon fibres remain superior to natural fibres in high-end applications, natural fibres have comparable properties to glass fibres in high volume applications[4]. Natural fibres are complex in structure, whose characteristic properties vary considerably[5], and depend on whether the fibres are taken from plant stem or leaves, quality of plant location, the age of the plant, etc[6,7]. Depending on their origin, natural fibres may be grouped into leaf (e.g. sisal, pineapple leaf), bast (flax, hemp, jute), seed (cotton), fruit (coconut coir). Natural fibres are lignocellulosic, consisting of helically wound cellulosic microfibrils in an amorphous matrix of lignin and hemicellulose. Lignocellulosic materials are the most abundant renewable biomaterial of photosynthesis, with annual production estimated at 2.0×10^{11} tons (compared to 1.5×10^{8} tons of synthetic polymers)[8] and are widely distributed in the biosphere in the form of

trees (wood), plants and crops[3]. The mechanical properties of natural fibres (biofibres) are dominated by the cellulose content and microfibril angle. A high cellulose content and low microfibril angle are desirable properties in a fibre to be used in polymer composites[3].

The properties of fibre-reinforced composites depend on many factors such as fibre-matrix adhesion, volume fraction of fibre, fibre aspect ratio, fibre orientation as well as stress transfer efficiency of interphase[9, 10]. The potential strength and toughness of natural fibres have not yet been fully exploited because of poor chemical compatibility between hydrophilic fibre and the more hydrophobic polymer matrix. Owing to the presence of –OH and polar substituents on natural fibres, moisture regain is high leading to poor interfacial bonding with high hydrophobic polymer matrix. This situation demands proper strategy to obtain better mechanical properties through fibre surface modification.

In this report, the effect of alkalization on the mechanical properties, thermal stability and surface morphology of banana fibres is examined.

EXPERIMENTAL

Materials: The banana fibres used in this study were obtained locally, washed with detergent solution and rinsed thoroughly with deionised water and dried at 50^{o}C.

Surface modification of fibres: The fibres were steeped in 5% (w/v) NaOH solution for 24h, rinsed with 1% acetic acid solution, followed by deionised water until the washing was neutral to litmus, and then dried at 50^{o}C.

Fibre characterization

FTIR spectroscopy, Perkin Elmer PC/600, was used for analysing the variations of fibre chemical composition before and after treatment with alkali.

Tensile testing of untreated and treated sisal fibre samples was carried out using a Universal Testing Machine (UTM) H5KS at a cross-head speed of 2.0mm/min and a guage length of 50mm following the ASTM-D-638 method.

Thermal stability of the untreated and treated fibres was carried out by dynamic (non-isothermal) thermogravimetric analysis under nitrogen at a heating rate of 10^{o}C/min.

Scanning electron micrographs of the untreated and treated sisal fibres were examined to analyse the surface morphology of the fibres.

RESULTS AND DISCUSSION

FTIR spectra of untreated and alkali-treated banana fibres are shown in Fig. 1. The characteristic absorption bands are given in Table 1. The hydrophyllic nature of the fibres is reflected in the broad absorption band at 3418cm^{-1} which is ascribed to phenolic –OH in the lignin and –OH group of the cellulose[12]. The absorption peak at about 2912cm^{-1} is due to C-H stretching vibration of the cellulose and hemicellulose of the fibres[13].

The absorption band at 1733cm^{-1} is ascribed to the stretching vibrations of the carbonyl group[14]. While the band at 1639cm^{-1} is attributed to the α-keto carbonyl in the cellulose structure. The absorption bands between 1457 - 1318cm^{-1} are associated with -CH in plane deformation while the band in the region 1248-1059cm^{-1} involves the C-O stretching vibrations of the aliphatic primary and secondary alcohols in the cellulose, hemicullose and lignin[13]. The most significant effect introduced by the alkali treatment is associated with the attenuation of vibrations around 1733cm^{-1} which corresponds to the reduction of C=O groups.

Table 1: FTIR absorption bands of untreated and alkalized banana fibres

	Wave number (cm^{-1})	
	UBF	**TBF**
OH bonds stretching in cellulose and lignin	3418	3400
C-H stretching vibrations	2917	2902
C-H deformation of cellulose and lignin	1460	1465
C=O of non-conjugated ketone in hemicellulose	1733	
C=O of hemicellulose	1626	1639
C=C stretching vibration	1503	1503
C-O-C asymmetric glucose rings and xylane groups of hemicellulose	1157	1163
C-H stretching of β glycosidic linkage	849	894

UBF = untreated banana fibre; TBF = alkali-treated banana fibre

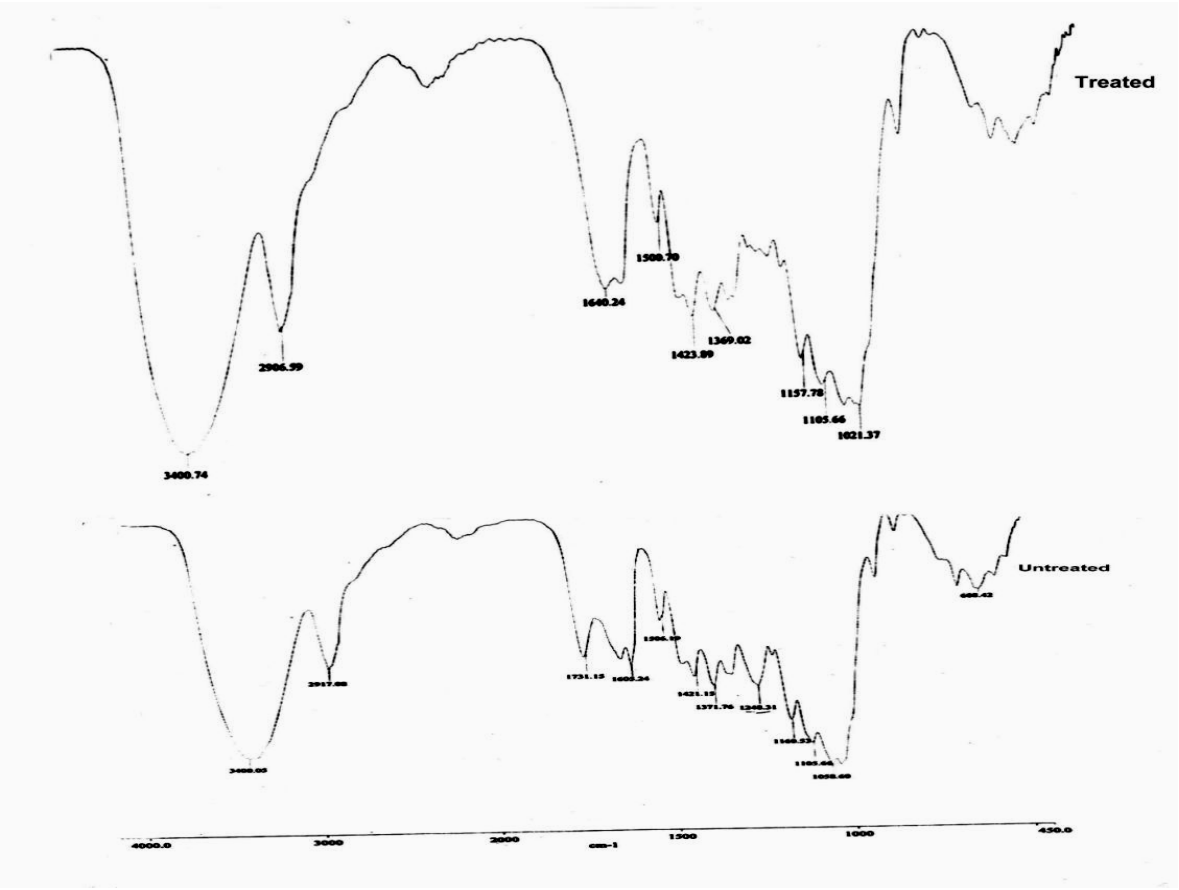

Fig. 1: FTIR spetra of untreated, UBF, and alkali-treated, TBF banana stem fibre

However, as noted by previous workers[15,16], the slight intensity decrease of the band around 1514cm^{-1} suggests that some lignin can be removed by treatment with alkali. Vibrations in the region between 3000 and 2850cm^{-1} associated with C-H stretching of lignin, hemicellulose and cellulose decrease slightly upon alkalization[17].

Tensile mechanical properties

The tensile mechanical properties of untreated and alkalized banana fibres are given in Table 2 in comparison with other fibres. The results show that alkali treatment generally improved the mechanical properties of the fibres. The treatment of biofibres with alkali is associated with leaching of alkali-soluble waxes, oils and pectins from the fibres and leads to microfibrilation[18]. It is thought that this process accounts for the observed enhanced tensile properties of biofibres treated with alkali.

Thermal stability

Fig. 2 shows the thermograms of untreated and alkali-treated banana fibres. Thermogravimetric analysis by dynamic assay provides information related to the regions of weight loss in fibres. Three distinct temperatures regions are observed in thermograms. The first region (100 – 120^{o}C) is associated with moisture desorption.

Both untreated and treated fibres showed moisture losses in amounts between 3 and 7wt%, however the treated fibre showed less important decrease of these values. This behaviour is related to the reduction in the hydrophilic tendency of treated fibres which is associated with reduction of hemicellulose components such as xylane[19]. These results are in agreement with previous work[20]. The second and third regions occurred at 250 and 480^{o}C respectively and are associated with the decomposition of fibre constituents[20]. For the manufacture of composites with suitable matrix it is important to know the degradation of mechanical properties when fibres are exposed to composite processing temperature (180 – 200^{o}C) for a period of time.

Table 2: Effect of alkalization on tensile mechanical properties of banana fibres

Sample	Elongation at yield (%)	Tensile strength MP_a
UBF	1.61 ± 1.17	255.3 ± 110.1
TBF	1.98 ± 1.14	749.2 ± 221.1
Coconut coir	1.50 – 4.0[a]	131 – 175
Flax	2.7 – 3.2[a]	345 – 1100
E-glass	2.5[a]	2000 – 3500
Carbon	1.4 – 1.8[a]	4000

UBF = Untreated banana fibre
TBF (banana fibre treated with 5% (w/v) NaOH for 24h
a = elongation at break (%)

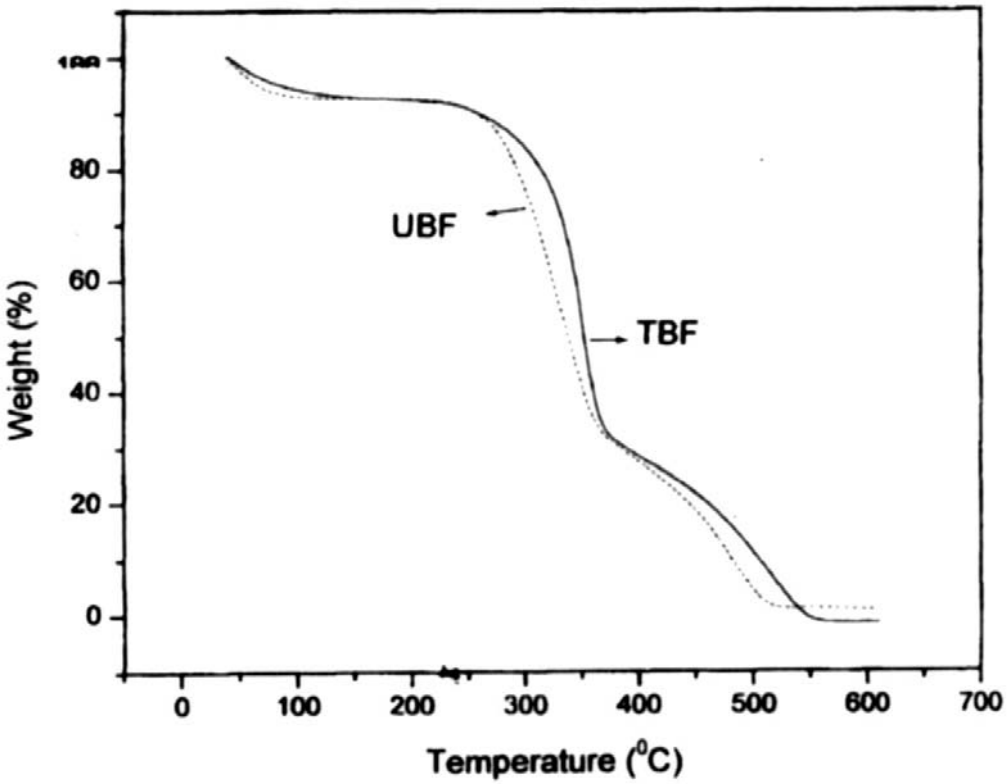

Fig. 2: Thermograms of untreated, UBF, and alkali-treated, TBF, banana stem fibres

Table 3 summarises the thermal behaviour of untreated (UBF) and treated (TBF) banana fibres. The results indicate that both untreated and treated sisal fibres are stable to heat within the composite processing temperature range. Maximum degradation temperatures of the treated fibres are higher than observed for the untreated fibre. These results indicate an increase in thermal stability associated with fibre surface treatment, which is explained in terms of reduction in the lower molecular weight and more heat labile constituents of the fibres.

Surface morphology

The surface morphology of the untreated and treated sisal fibres are shown in Fig. 3. It can be seen that the fibres comprise of bundles of individual cells held together by lignin. The micrograph of the untreated fibres (Fig. 3a) shows surface irregularities which are less discernable in the micrograph of treated fibres (Fig. 3b). The cleaner surface of the treated fibres is usually associated with the partial dissolution in alkali of hemicellulose, pectin, etc[21] resulting in a more hydrophobic surface.

CONCLUSION

We have treated banana fibres with 5wt% NaOH solution and examined the effect of alkalization on the mechanical properties, thermal stability and surface morphology of the fibres. It has been shown that alkali-treatment of the biofibres generally enhanced the reinforcement potentials of the fibres. Biofibres from other locally available sources like agricultural crop residues are being investigated for potential application in the fabrication of composites.

Table 3: Thermal behaviour of untreated and alkalized banana fibre T_i and T_m are initial and maximum decomposition temperatures.

Specimen	Temperatures at which various extents of decomposition were attained (^oC)				Residue at 600^{o}C (%)
	T_i	$T_{10(\%)}$	$T_{50(\%)}$	T_m	
UBF	234	256	338	517	4.4
TBF	232	257	352	555	11.2
TJF	250	266	358	431	< 0.5
TSF	244	294	362	587	17.5

UBF = untreated banana fibre
TBF = treated banana fibre
TJF = treated jute fibre
TSF = treated sisal fibre

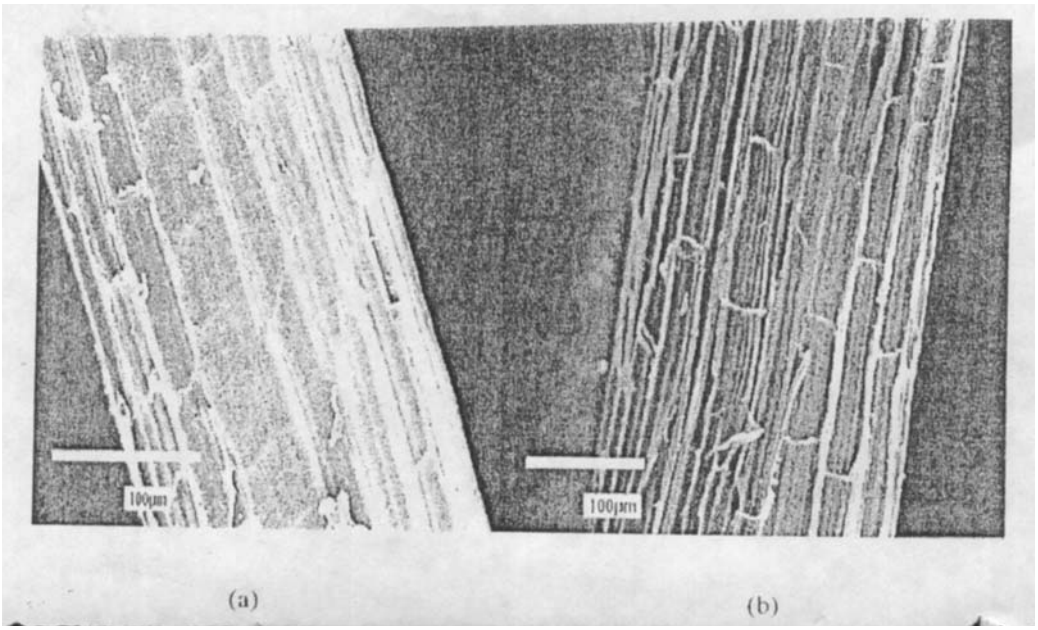

Fig. 3: SEM of untreated (a) and alkali-treated (b) banana fibres

ACKNOWLEDGEMENTS

The authors acknowledge the Postgraduate Fellowship granted IOB jointly by the Third World Academy of Sciences (TWAS), Trieste, Italy and the Council of Scientific and Industrial Research (CSIR) India. This work was carried out in the laboratories of the Regional Research Laboratory, CSIR Trivandrum, India; while IOB was on study leave from the Rubber Research Institute of Nigeria, Iyanomon, Benin City

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Received: 19/09/2006
Accepted:13/12/2006