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PLY TENSILE PROPERTIES OF BANANA STEM AND BANANA BUNCH FIBRES REINFORCED NATURAL RUBBER COMPOSITE

I.C. Ezema [e,a], **A.R.R. Menon**[b], **S.O. Edelugo**[c], **A.D. Omah** [f,a], **I.U Agbo**[d]

[a]Department of Metallurgical and Materials Engineering, University of Nigeria, Nsukka, Nigeria.
Emails: [e] *ikeezema@gmail.com*, [f] *dinobi2002@yahoo.com*
[b]National Institute for Interdisciplinary Science and Technology, (NIIST) CSIR Trivandrum, India.
Email: *drarrmenon@gmail.com*
[c]Department of Mechanical Engineering, University of Nigeria Nsukka. ***Email:*** *mcedeson@yahoo.com*
[d]Department of Pure & Industrial Chemistry,University of Nigeria, Nsukka ***Email:*** *iuagbo@yahoo.co.uk*

Abstract

Ply tensile properties of banana stem and banana bunch fibres reinforced natural rubber composite was studied. Banana stem and banana bunch stalk fibres were extracted, surface treated, uni-directionally matted and laminated with natural rubber latex. The result of the tensile loading in 0° fibre direction of the composite lamina (single ply) of 1.2mm thickness indicated a better performance of the banana stem fibres (BSF) than the banana bunch fibres (BBF). Natural rubber composite lamina reinforced with BSF which were treated with a mixture of NaOH and Na_2SO_3 had a superior tensile strength of 4.0 MPa and Young's modulus of 147.34MPa over the untreated BSF with tensile strength and Young's Modulus of 3.7MPa and 84.30MPa respectively. Both the treated and untreated BSF and BBF fibres exhibited better mechanical properties than the unreinforced natural rubber. The composite lamina exhibited anisotropic characteristics, having different tensile properties of 3.7MPa, 0.6MPa and 1.0 MPa corresponding to 0°, 45° and 90° loading directions with respect to the fibre direction. The micrographs of the composite surface after tensile test indicated a ductile failure of the material with appreciable plastic deformation.

Keywords: lamina, natural fibre, banana fibre, natural rubber, tensile properties, fracture surface, angle ply

1. Introduction

Most governments all over the world are now very conscious of their environment. Climate change and environmental hazards of non biodegradable products are with us. It is on this note that natural fibres are fast replacing synthetic fibres such as carbon, aramid and glass fibres in some semi-structural applications because of the higher cost and non-biodegradability of the latter and because natural fibres have high specific strength due to their low densities [1].

In the recent decade, research on natural fibres are on the increase, advancing even into the areas of structural applications either using the natural fibres alone or as a hybrid with synthetic ones because the former are biodegradable, of low density, renewable, cheap, easy to process and have promising mechanical properties [2-5]. Success stories have been told of how natural fibres from agro-plants and wastes have been made into semi-structural products for both domestic and industrial applications [6-8]. Numerous research have been done on kenaf, flax, hemp, sisal, jute, bamboo, pineapple and seed fibres such as rice husk and coir [9-11]. These natural fibres are readily available in abundance in most parts of the globe and can be easily recycled or burnt at the end of their life cycles, allowing energy recoveries and clean environment.

Literatures on the use of banana stem and/or banana bunch fibres are very limited. These fibres from banana are emerging materials for composite manufacture with high conversion rate from agro-waste to high economic value products. Banana fibres are available all year round and in most parts of the world. Maleque et al [12] studied pseudo banana fibre reinforced epoxy composite. Pothan et al [13] studied the dynamic mechanical properties of banana fibre reinforced with polyester resin. Prasad et al [14] found out that banana fibre reinforced with polyester have good tensile strength at 0.10 fibre volume fraction but with poor flexural properties. Kumar et al [15] reported that surface treatment of banana fibres resulted in a decrease in denier and diameter but an increase in density with improved mechanical properties.

The objective of this paper is to study the tensile and fracture surface behavours of banana stem (trunk) fibres and banana bunch (empty fruit) fibres reinforced lamina so as to establish their usefulness or otherwise as composite reinforcing materials.

2. Experimantal

2.1. Materials

Aerobically processed banana stem (BSF) and banana bunch fibres (BBF) were obtained from Process Engineering and Environmental Technology Division, National Institute for Interdisplinary Science and Technology,(NIIST)- Trivandrum, India. Natural rubber latex, NaOH, Na_2SO_3 and other additives for natural rubber modification were supplied by Polymer Section, NIIST, Trivandrum. Photographs of the raw BSF, raw BBF and extracted BSF samples are shown in Figure 1(a) through (c).

2.2. Fibre surface treatment

The retted banana stem and banana bunch fibres were chemically surface-treated with a mixture of 4% NaOH and 2% Na_2SO_3 for 24hours. These fibres were washed with water and dried under sun for 48 hours. The fibres were further dried in an oven at 60°C for 1 hour in order to remove traces of moisture

2.3. Matting of the fibres

Flat unidirectional arrangements of the fibres were made using natural rubber latex as the bonding agent. They were rolled to a thickness of 1.2mm and again dried in an oven at 80°C for 2 hours.

2.4. Composite manufacture

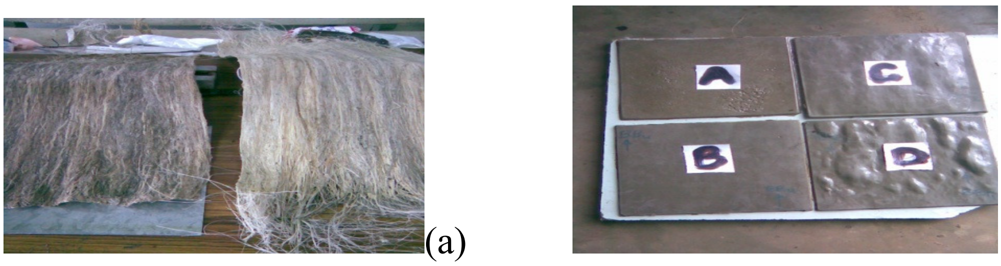
The natural rubber matrix was modified for use in lamination by mixing it with vulcanizing additives on a mixing mill for about 30 minutes and kept for 24 hours. Measured quantity of the modified rubber sheets were cut out and a lamina (ply) of the banana fibres was laid in between two rubber sheets and covered carefully with polyethylene terephthalate (PET) sheets. It was cured in a metallic flat plate mould by compression moulding on a hydraulic press (Model – INDUDYOG) for 5 minutes at 150°C and 115kg/cm^2 (11.28MPa) pressure. De-moulding was done at a very much lower temperature and allowed to cool off for 24 hours in open air. Figure 2(a) shows the photographs of unidirectionally matted treated and untreated banana stem fibre (BSFT and BSF) while Figure 2(b) shows the treated and untreated banana fibre reinforced natural rubber composite.

2.5. Tensile test

Tensile test specimens were prepared according to ASTM D-638. The detailed dimensions, gauge length and cross head speed can be found in ASTM D-638 [16]. The specimens with a gauge length of 50mm were tested on a tensile tester (Model – Hounsfield Tinus Olsen H5KS) at a cross head speed of 5mm/minute. Each specimen was loaded to failure. The force - extention curve was plotted automatically by the equipment software. The ultimate tensile strength and elastic modulus of the samples were thereafter determined from the plot. The test results were taken from the average of five tests.

a b c

Figure 1: (a) Raw BSF, (b) Raw BBF and (c) extracted BSF samples.



(a) (b)

Figure 2: (a) Treated and untreated BSF unidirectionally matted. (b) Natural rubber reinforced BSF.

Table 1: Tensile and Youngs modulus of treated and untreated BSF and BBF – natural rubber composites.

Sample code	**Surface treatment status**	**Ply angle (0)**	**Max Force (N)**	**UTS σ_{max} (MPa)**	**σ_f (MPa)**	**ε_{max} %**
BSF	Untreated	0°	20.8	3.7	1.4	42
		45°	6.20	0.6	0.3	33
		90°	7.8	1.0	0.2	228
	Treated	0°	42.3	4.0	1.5	26
		45°	0.6	1.2	0.4	21
		90°	2.0	0.2	0.2	83
BBF	Untreated	0°	8.3	3.2	1.1	43
		45°	7.66	0.7	1.1	262
		90°	1.0	2.2	1.0	543
	Treated	0°	46.2	5.0	1.7	38
		45°	10.5	1.1	1.0	551
		90°	14.4	1.4	1.1	722
NR	Unreinforced	Isotropic	24.0	3.3	2.6	3830

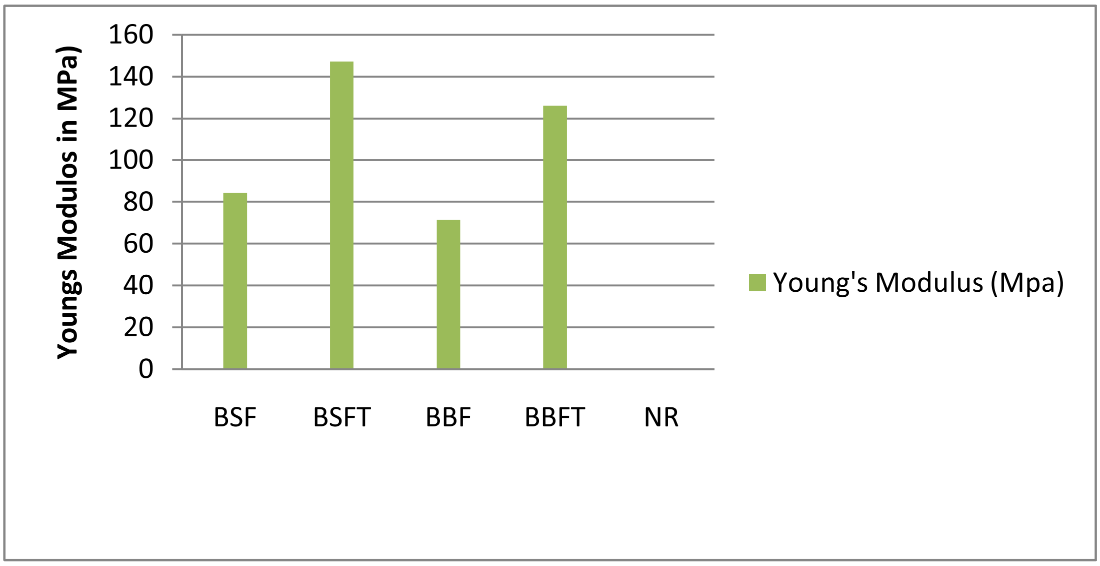


Figure 3: Youngs Modulus properties of untreated and treated banana stem, banana bunch and unreinforced natural rubber(NR) composites.

2.6. SEM

The fracture behaviour of the tensile specimens were observed using scanning electron microscope (Model – JOEL JSM-6100) after sputter coating the samples with gold for 45 seconds in a JOEL-JFC-1200 fine coater at a voltage of 12kV. Photographs were taken at various magnifications.

3. Results and Discussions

3.1. Tensile properties

Table 1 presents the tensile and Young's modulus of treated and untreated BSF and BBF reinforced natural rubber composite. From the table, the ultimate tensile strength of untreated banana stem fibre reinforced natural rubber composite have been found to be 3.7 MPa in the fibre loading direction while that of composite material reinforced with treated banana stem fibre (BSFT) was obtained as 4.0 MPa. The ultimate tensile strength of a lamina of untreated banana bunch fibre was found to be 3.2 MPa, whereas the treated banana bunch fibre (BBFT) was obtained to be 5.0 MPa which shows an improvement due to the surface treatment. The Young's modulus of the untreated and treated banana stem fibres were found to be 84.30 MPa and 147.34 MPa respectively while that of untreated and treated banana bunch fibre reinforced natural rubber composite were obtained to be 71.28 MPa and 126.07 MPa respectively, indicating a substantial improvement in the stiffness of the composite lamina due to the surface treatment.

Also from the table 1, it can be deduced that the strength of the composite is more in the fibre longitudinal direction of 0° than that in the transverse direction (90°) or any other angle of ply such as 45°. This corresponds to a value of 3.2 MPa, 0.2.2MPa and 0.7MPa respectively for composite produced from treated banana bunch fibres. This indicates that the composite exhibited anisotropic behaviour.

Again from table 1, the treated banana stem fibre (BSFT) & banana bunch fibre (BBFT) reinforced natural rubber composite showed better ultimate tensile strength than the unreinforced natural rubber which is an indication that the fibres bears the loads and the matrix holds the fibres together and aids in transmitting shear forces through the fibre-matrix interface. The Young's modulus values of the treated and untreated banana stem and banana bunch fibres are shown in Figure 3. From the figure, it can be seen that the Young's modulus values of 147.34 MPa and 126.7 MPa for the treated banana stem fibre (BSFT) and treated banana bunch fibres (BBFT) are superior to that of untreated banana stem fibre (BSF) and banana bunch fibre (BBF) coressponding to 84.30 MPa and 71.28 MPa respectively. Also, it can be deduced that the banana stem fibre has better stiffness property compared to that of banana bunch fibre.

Also from figure 3, it is very clear that the stiffness of the composite was enhanced by the addition of banana fibres as reinforcements and further by the surface treatment whereas that of the unreinforced natural rubber was too low to be useful in semi structural applications. The superiority of composites reinforced with treated fibres against those with untreated fibres shows that the treatment enhanced the interfacial bonding between the matrix and the fibres whereas untreated fibres may have had poor bonding with the matrix and hence lower tensile properties.

3.2. Fracture surface study

The fracture surfaces of the banana stem-natural rubber composite and banana bunch natural rubber composite are shown in Figures 4a and 4b respectively. It can be seen from the micrographs of the fractured surfaces after tensile tests that the fibre composite exhibits a ductile fracture with appreciable plastic deformation.

4. Conclusions

The following conclusions can be drawn from the present study

1. The tensile strength of the banana stem unidirectional fibre/natural rubber reinforced composite is higher than the unreinforced natural rubber.

2. Treatment of banana fibres with a mixture of Na_2SO_3 and NaOH further improved the tensile strength of the composite material.

3. The banana stem fibre reinforced natural rubber composite has better tensile properties than the banana bunch fibre reinforced natural rubber composite. This may be due to higher hemi-cellulose content of the banana bunch fibre than that of banana stem fibre.

4. The banana stem and banana bunch natural rubber composites exhibit ductile behaviour with appreciable plastic deformation.

5. The tensile properties of the composites were better in the longitudinal fibre direction than in transverse or any other direction.

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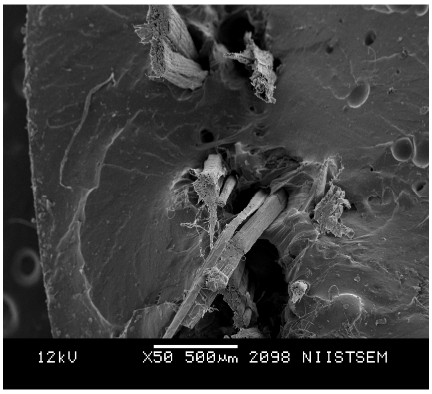

(a)

(b)

Figure 4: Micrographs of (a)BSF-NR Composite and (b) BBF-NR Composite.

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