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Research Paper

Effect of Alkaline Treatment on Tensile Properties of Raffia Palm Fibre

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The mechanical properties of raffia palm fibres treated with sodium hydroxide (NaOH) solution have been investigated in this study. Tensile properties (Tensile strength, Young modulus, elongation at break, tensile energy, tensile strain and yield strength) of the raffia palm fibres were tested under direct tension in a Universal Testing Machine at the crosshead speed of 5.00 mm/min. The raffia fibres were treated with 5 percent NaOH solution under ambient temperature for one hour. From the analysis of variance, alkaline treatment had significant ($P \leq 0.05$) effect on tensile strength, elongation at break, tensile energy and yield strength of the raffia fibre. The results indicated that the tensile properties of treated raffia fibre were better than raw raffia fibre. Based on the results, the tensile strength and Young modulus increased from 67.73 to 107.07 MPa and 1.261 to 1.406 GPa after the alkali treatment. The fibre elongation at break and tensile energy decreased from 6.38 to 5.25 mm and 0.103 to 0.033 Nm respectively. The results of this study are expected to be useful in the production of composite boards and textile industries.

Keywords: Raffia palm, Natural fibre, Tensile Properties, Alkaline treatment

INTRODUCTION

Raffia palms (*Raphia*) are a genus of about twenty species of palms native to tropical regions of Africa. The Raffia palm fibre is produced from the membrane on the underside of each individual frond, which is taken off to create a long thin fibre. Raffia fibres have many uses, especially textiles industries; also they are used in ropes, roof coverings and shoes production (Wikipedia, 2018; Tucker *et al*, 2010). Some unique properties of natural fibres include: low cost, biodegradability, recyclability, low density, good thermal properties, reduced tool wear, non-irritation to the skin, and enhanced energy recovery (Thakur *et al*., 2014). Researchers in the field of natural fibre reinforced plastics have revealed that their mechanical properties are comparable to those of glass fibre reinforced composites. Therefore, they are used to produce structural components of automotive industry such as panels, doors, roofs and covers (Huda *et al*., 2007; Cristaldi *et al*., 2010).

Natural fibres have a hydroxyl group due to cellulose and lignin, which is involved in hydrogen bonding within the cellulose, thereby reducing their strength and matrix adhesion. In addition to the hydroxyl group, natural fibres contain waxy and pectin substances which cap the reactive functional groups of the fibre and act as a hindrance to interlock with the matrix. Therefore, natural fibres need treatment to improve their composite strength, ageing and fibres matrix adhesion (Meyer, 1977; Edeerozey *et al*., 2007; Militky and Jabbar, 2015). Alkaline treatment is one of the chemical treatments of natural fibres to enhance their workability. The modification done by alkaline treatment is the disruption of the hydrogen bonding in the network structure, thereby increasing surface roughness. It also removes a certain amount of lignin, wax and oils covering the external surface of the fibre cell wall, depolymerizes cellulose and exposes the short length crystallites (Mohanty *et al*., 2001).

Several authours have investigated the influence of alkaline treatment on the mechanical properties of natural fibres. In a study carried out by Ray *et al.* (2001), the Young modulus and and the tenacity at break point of jute fibres increased by 12% and 46% after 4 hours of alkali treatment. Similarly, Gassan and Bledzki, (1999) reported an improvement of 120% and 150% in the tensile strength and modulus of jute yarns respectively treated with 25% NaOH solution for 20 min. Mwaikambo and Ansell, (2002) treated hemp, jute, sisal and kapok fibres with various NaOH concentrations and found that 6% was the optimum concentration in terms of cleaning the fibre bundle surfaces and retaining a high index of crystallinity. Though most researchers have showed significant interest on the treatment of natural fibres, there is no much literature on the effect of alkaline treatment on raffia palm frond fibres. Therefore, the objective of this research work was to evaluate tensile properties (Tensile strength, Young modulus, elongation at break, tensile energy, tensile strain and yield strength) of alkaline-treated raffia palm frond fibres compared with untreated raffia palm frond fibres.

MATERIALS AND METHODS

Sample preparation

The raffia palm fronds were obtained from the swamp forest of Isoko region of Delta State, Nigeria. Sodium hydroxide was obtained from chemical laboratory of the Department of Civil Engineering, Delta State Polytechnic, Ozoro, Nigeria. The fibres were separated from the underside of each individual raffia palm frond and air-dried for two days before the alkaline treatment.

Alkaline treatment

The extracted raffia palm fibres were soaked in a 5% NaOH solution at ambient temperature for 1 h. The fibres were then washed under running tap water for 10 min to wash away the NaOH solution from the fibres surfaces. Then the fibres were soaked in dilute tetraoxosulphate (VI) acid for 5 min (to neutralize any NaOH remaining in the fibres) and washed again with running tap water for 10 min. The fibres were then oven-dried at 50°C for 10 h. Thickness of the treated fibres sample ranged 0.027–0.032 mm.

Tensile test

The tensile test of the raffia palm fibres (treated and untreated) was performed according to ASTM C1557 (ASTM, 2008), with the aid of the Universal Testing Machine (Testometric model) equipped with a 50 N compression load cell and integrator. The tensile tests were done at the Material Testing Laboratory of the National Center for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria, at a test speed of 5.00 mm/min. During the test, each individual fibre was clamped to the tensile jaw of the machine, and subjected to tensile movement until the breaking point of the fibre (Figure 1). At the end of each test, the tensile properties (Tensile strength, Young modulus, elongation at break, tensile energy, tensile strain, and yield strength) of both the raw and treated single fibre were generated automatically by the microprocessor of the Universal Testing Machine. The experiment was conducted at room temperature.

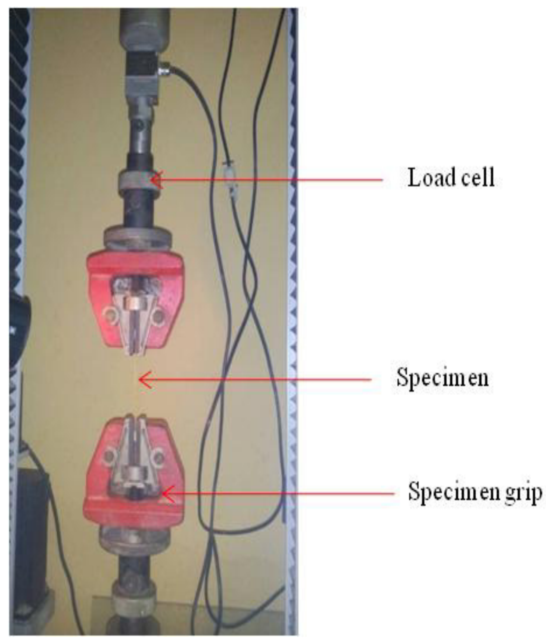

Figure 1. A raffia palm fibre undergoing tensile test.

Statistical analysis

The data obtained from this research were subjected to Analysis of variance using SPSS statistical software (version 20.0, SPSS Inc, Chicago, IL). The difference between mean values of parameters was investigated using Duncan's multiple range tests at 95% confidence level. All the experiments were conducted in ten replications and the average value recorded.

RESULTS AND DISCUSSION

The Analysis of Variance (ANOVA) results of tensile properties of the raw and treated raffia fibres are presented in (Table 1). From (Table 1), alkaline treatment

Table 1. ANOVA for response of tensile properties of treated raffia palm fibres.

Source of vibration	df	F	Sig
Tensile strength	1	8.002	0.030008*
Young Modulus	1	0.554	0.484639^{ns}
Elongation at break	1	9.102	0.023487*
Tensile energy	1	41.35	0.000669*
Tensile strain	1	4.612	0.075365^{ns}
Yield strength	1	11.98	0.013447*

* =Significant at P≤ 0.05, ns = non-significant, df = degree of freedom.

Table 2. Tensile properties of the raffia fibres.

Parameter	Treated	Untreated
Tensile strength (MPa)	107.07^{a}±11.51	67.73^{b}±19.17
Young modulus (GPa)	1.406^{a}±0.165	1.261^{a}±0.194
Elongation at break (mm)	5.25^{b}±0.70	6.38^{a}±0.28
Tensile energy (Nm)	0.103^{a}±0.007	0.033^{b}±0.014
Tensile strain (%)	5.25^{a}±0.695	6.11^{a}±0.415
Yield strength (MPa)	38.707^{a}±7.48	17.98^{b}±3.02

Values are mean ± Standard Deviation; Means with similar superscript in the same row did not differ significantly (p ≤ 0.05); MPa = Megapascal; GPa = Gigapascal.

had significant (P ≤ 0.05) effect on tensile strength, elongation at break, tensile energy and yield strength of the raffia fibre. The Young modulus and tensile strain of the raffia fibre were not significantly (P ≤ 0.05) influenced by the alkaline treatment. The mean values of the tensile properties of the raffia fibres are presented in (Table 2). From (Table 2), it was found that the alkaline treated raffia fibres had improved tensile properties compared to the raw raffia fibres. The results showed that treated fibres had higher tensile strength (107.07 MPa) compared to the untreated fibres (67.73 MPa). Mir *et al.* (2012) reported that the tensile strength and Young modulus of coir fiber increased from 50.4 to 84.8, and 3.69 to 3.83 GPa respectively, after alkaline treatment. During alkaline treatment, the interfibrillar region is likely to be less dense and less rigid making the fibrils rearrange themselves along the direction of tensile loading. When fibres were stretched, such arrangements among the fibrils resulted in better load sharing and hence higher stress development in the fibre (Joseph *et al*., 2003). From the experimental results, the tensile elongation (elongation at break) of the raffia fibre decreased by 17.71% after the treatment, while the tensile energy increased from 0.33 to 0.103 Nm, showing significant improvement. Cai *et al*. (2015) reported that the Young's modulus of the abaca fibres treated with 5% NaOH solution for 30 minutes was increased by 41%. The breaking strain of the jute fibres was reduced by 23% after 8 hours treatment (Ray *et al*., 2001). But Rodríguez and Vázquez (2006), reported that the tensile strength of jute fabrics decreased from 505 to 326 MPa, after NaOH (5 wt %) treatment for 24 h at room temperature. This could be probably due to the damage in the ultimate cells walls of the jute fibres caused by excessive extraction of lignin and hemicellulose, by the NaOH during the treatment. The mechanical properties of natural fiber such as elongation, ultimate breaking force, flexural properties, impact strength, suitability for processing, and crash behavior increases its demand for automobile components (Ahmad *et al.,* 2015). The improvement in tensile properties can be attributed to surface removal of amorphous constituents (lignins, pectins, hemicellulose and other impurities) as reported by (Bouatay *et al*., 2014; Bledzki *et al*., 2008).

Conclusion

In this study, raffia palm fibres were treated with NaOH solution, and their tensile properties determined with the Universal Testing Machine. From the tensile test results, there was general increment in the tensile properties of the raffia fibre treated with NaOH at ambient temperature for one hour. Based on the results obtained, the tensile strength and Young modulus of the treated fibre increased by 36.74 and 10.32%, while the tensile elongation decreased by 17.71%. Conclusively, it can be seen that NaOH had significant effectiveness in the cleaning process of the raffia palm fibre. The results of this study are expected to be useful in the production of composite and textile industries.

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