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Comparative Studies on the Mechanical Properties of some Selected Foreign and Indigenous Varieties Species of Kenaf

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ABSTRACT

The study investigated the strength characteristics of two foreign (Cuba 180, Talinum 2) and three locally available varieties of kenaf fibres (Ifeken DI 400, Ifeken 100 and Ifeken 400), with a view to providing insight to optimum conditions for the processing of the fibre into some products. It was observed that Talinum variety recorded the highest values for tensile strength and resistance to load deformation of 62.45×10^{-1}MPa and 6.3 N respectively while Ifeken 100 was observed to have given the lowest (23.62×10^{-1} and 2.4 N) values. Ifeken DI 400 exhibited the highest modulus of elasticity of 66.28×10^{7} while Ifeken 400 was observed to have the least modulus of elasticity of 17.42×10^{7}. Cuba 108 was observed to have the highest yield point with the value of 79.81×10^{-1} mm while Ifeken DI 400 had the least fibre extension with the value of 96.67×10^{-2} mm. Talinum 2 was also found to have absorbed the highest energy (0.029 J) before rupture with Ifeken 100 variety having the lowest value (0.099 J) for all the kenaf varieties compared. Analysis of variance revealed that the effect of kenaf variety on the fibre strength as well as performance was statistically significant ($P \leq 0.05$). The results of the study will be useful in guiding the utilisation of the materials as well serve as a precursor to the design of appropriate machines for further processing of the fibres to preserve the quality of the products.

1. INTRODUCTION

The current ban on the use of synthetic packaging materials in importation and exportation of agricultural produce has necessitated the exploration and use of natural fibres and as well as other eco-friendly alternatives in the production of packaging materials (Cruz-Romero and Kerry, 2008). According to Balogun *et al.* (2008), this development has led to the recent acceptance of kenaf as an industrial crop.

Kenaf has been described morphologically by Joshi *et al.* (2004) as a single, straight plant with an unbranched stem which consists of two parts namely the core and bark fibre and agronomically by Webber *et al.* (2002) as maturing between 3 to 4 months after planting. According to Dauda *et al.* (2014), the plant has been known to grow under a wide range of weather conditions, to a height of more than 3 m and a stem diameter of 1–5 cm. Studies have also shown that the moisture content of kenaf reduces after three months of maturity (Falana *et al*., 2019). According to Nimmo, (2002) up to 40% of kenaf stalk obtained is usable fibre, almost double that of jute, hemp or flax. This yield percentage makes the fibre more economical compared to that of other plants.

The origin of kenaf can be traced to Africa (Hamidon *et al.,* 2019); however, despite its location advantage and importance, Africa produces only 2.91% of the global production of kenaf (FAO, 2003). This trend may partly be attributed to the level of information on the crop as well as processing capacity.

In order to effectively mechanize the production process of kenaf in to packaging materials from both foreign and locally available varieties of kenaf it is important to know its inherent mechanical properties. Hence, the objective of this study was to determine and compare some mechanical properties of selected foreign and indigenous kenaf varieties with a view to providing valuable information which will aid the design and development of post-harvest processing equipment of the product.

2. MATERIALS AND METHODS

2.1. Selection of Test Materials

The varieties of kenaf fibres used for this study were planted in July 2019 at the kenaf research field of the Institute of Agricultural Research and Training, Ibadan, Nigeria and harvested after 12 weeks of planting. The harvested fibres were then soaked in water and allowed to rett for a period of 14 days after which the fibres were extracted and sundried. The obtained fibres were taken through a process known as carding in order to straighten them as well as remove portions that were not useful (Tao *et al.,* 1998; Lee *et al*., 2009)

2.2. Strength Characteristics

To determine the strength characteristics (tensile stress, tensile strain, Young's modulus, rupture load, and energy) of the kenaf stems, 60 samples each of Cuba 180, Ifeken DI 400, Ifeken 100, Ifeken 400 and Talinum 2 varieties were subjected to tests using a universal Instron testing machine (Plate 1). The force-deformation, rupture load, and energy of the samples were displayed on the monitor connected with the universal testing machine. Young's modulus was determined from the slope of the stress-strain curve.

2.3. Statistical Analysis

The obtained data sets were analysed by carrying out an analysis of variance test (ANOVA) at a 95% confidence interval ($P \leq 0.05$) using a Data Analysis Toolkit on Microsoft Excel Professional software (version 2016).

Plate 1: Universal Instron testing machine

3. RESULTS AND DISCUSSION

3.1. Maximum Applied Load

It was observed that the Talinum 2 variety was able to withstand the highest load value of 6.3 N (Figure 1) and this was followed by Ifeken DI 400 variety. The Ifeken 100 variety had the least resistance to load deformation as the maximum load before rupture was recorded at 2.4 N. This consequently makes the maximum tensile stress follow the same trend with Talinum 2 recording the highest stress level of 6.3 MPa and Ifeken 100 having the lowest value of 2.4 MPa (Figure 2) as expected of an ideal material and that any equipment design for handling these varieties especially in operations such as spinning and reeling should be such as can be adjusted to care for this peculiarity.

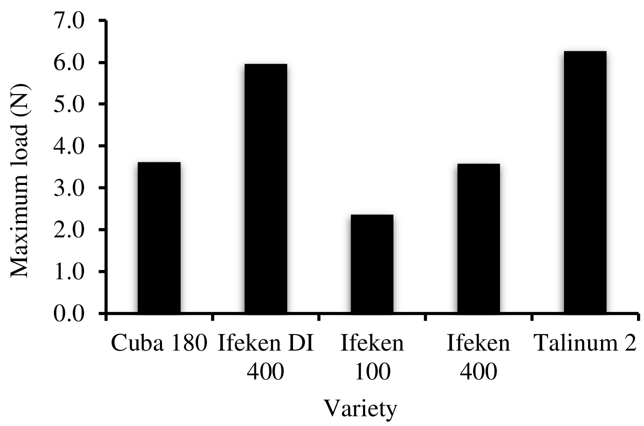

Figure 1: Comparison of maximum applied load

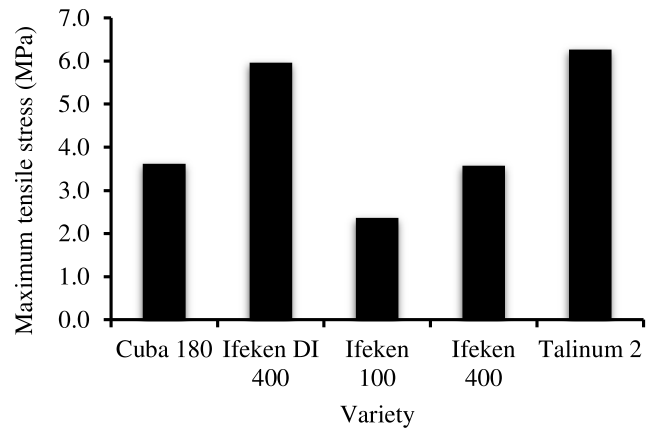

Figure 2: Comparison of maximum tensile stress

3.2. Maximum Tensile Strain

Comparison of the maximum values of tensile strain (Figure 3) for the varieties revealed that Ifeken 400 gave the largest relative elongation of 0.55 under the applied tensile force while Ifeken DI 400 exhibited the least maximum strain of 0.016 of fibre. This implies that the bonds holding Ifeken DI 400 are weaker compared to other varieties. According to Samad *et al.* (2002), when fibres are unstretched, the intermolecular chain formed by hydrogen bond is strong. However, at a certain level of load, the bond fails as the strain increases at the end of the Hookean region.

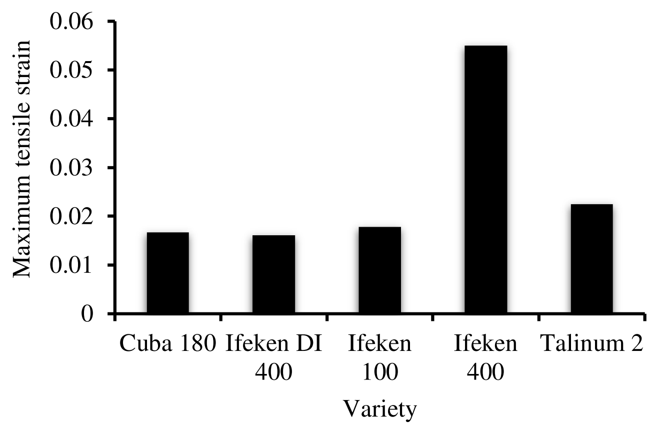

Figure 3: Comparison of maximum tensile strain

3.3. Extension

A comparison of the extension (Figure 4) shows that Talinum 2 had the lowest yield time of 10 seconds with a maximum extension of 2.5 mm while Ifeken 400 had the highest yield point at 35 seconds and an extension of 10.4 mm. Ifeken 100 was however observed to have not attained its yield point even after the 40 seconds test period. Although Talinum resisted higher load, it failed in a short time thereby showing almost no visco-elastic effect (Samad *et al.*, 2002). The lignin content might be responsible for this phenomenon. This is because the composition of lignin in the fibre may differ based on the variety (Millogo *et al.*, 2015).

Degradation of the fibre may also have occurred when exposed to adverse environmental conditions. Hence, the time of harvest may influence the strength of the kenaf fibre.

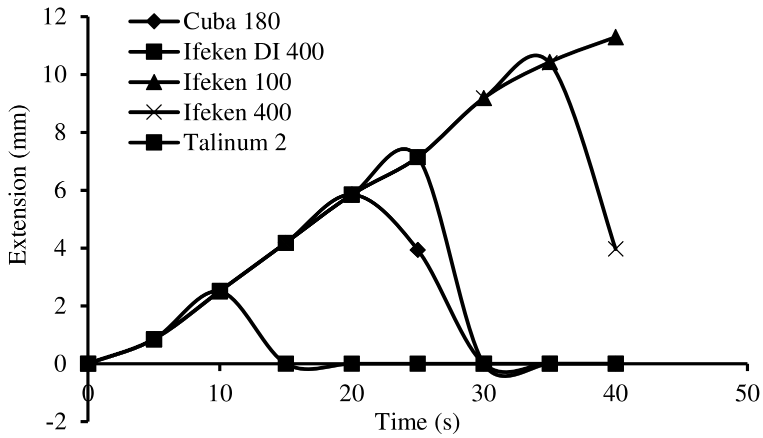

Figure 4: Comparison of extension at different times for the various fibre species

3.4. Maximum Energy Exerted on Fibre before Rupture

From Figure 5, it can be observed that the Ifeken 100 variety of kenaf gave the lowest (0.099 J) energy before rupture for the local varieties of kenaf while Ifeken DI 400 exhibited the highest (0.022 J) resistance to loading before rupture. However, for the foreign varieties Cuba 180 was observed to have the lowest resistance to rupture while Talinum 2 had a much higher value of 0.029 J. Overall it can be observed that the resistance of the Talinum 2 was far higher than all the local species of kenaf.

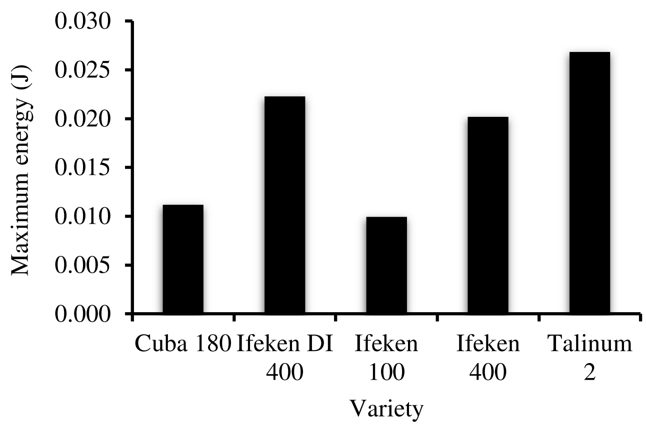

Figure 5: Maximum energy exerted on the fibres before rupture

3.5. Modulus of Elasticity

Comparison of the modulus of elasticity for the evaluated species as shown in Figure 6 revealed that the Ifeken DI 400 variety had the highest value thus indicating that the stress to strain ratio was highest (66.28 x 10^7 gf/tex) when compared with other species thus indicating that this specie was more stability under load conditions. Ifeken 400 was however observed to have the least value (17.42×10^7 gf/tex) for modulus of elasticity also inferring that the fibre condition was the least stable under load condition.

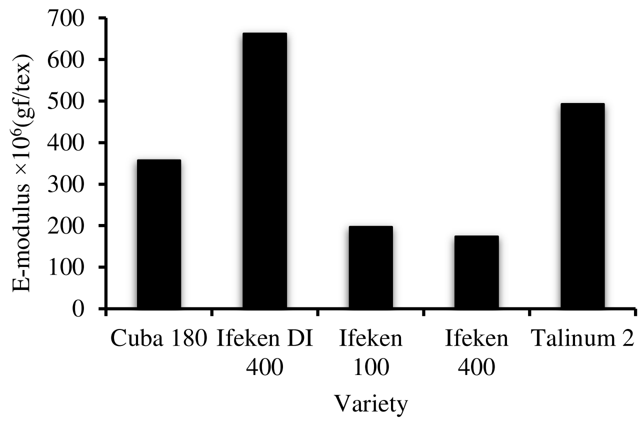

Figure 6: Modulus of elasticity for the various kenaf species

3.6. Statistical Analysis

Analysis of variance of the strength characteristics of the observed kenaf varieties (Table 1) revealed that the effect of kenaf variety on the fibre strength was statistically significant ($P \leq 0.05$). It was also observed that the effect of kenaf variety on the performance under different tests was also statistically significant ($P \leq 0.05$). There was also a statistically significant factor interaction from the result obtained. This invariably shows that the performance of kenaf fibres under test conditions is strongly dependent on the variety vis-à-vis the strength characteristics.

Table 1: Analysis of variance table for the strength of kenaf species

Source of variation	SS	df	MS	F	P-value
Kenaf variety	6.75×10^{16}	4	1.69×10^{16}	5.66	2.18×10^{-3}
Strength characteristics	1.14×10^{18}	4	2.84×10^{17}	95.44	9.17×10^{-15}
Interaction	2.7×10^{17}	16	1.69×10^{16}	5.66	6.42×10^{-5}
Within	7.45×10^{16}	25	2.98×10^{15}		
Total	1.55×10^{18}	49			

4. CONCLUSION

The study concludes that Ifeken DI 400 and Talinum 2 could be classified as exhibiting similar load as well as tensile strain characteristics in the higher range while Cuba 180 and Ifeken 400 were similar in the lower range category. This implies that indigenously developed Ifeken DI 400 could offer a viable replacement to foreign breeds in terms of mechanical properties and possibly durability in production line. Visco-elastic and lignin content were also observed to have considerable effects on rate of extension per unit time.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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