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Mechanical Properties of Varieties of Kenaf *(Hibiscus Cannnabinus)* Stem

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Keywords: *kenaf, moisture content, mechanical properties.*

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MECHANICALPROPERTIESOFVARIETIESOFKENAFHIBISCUSCANNNABINUSSTEM

Strictly as per the compliance and regulations of:

Mechanical Properties of Varieties of Kenaf *(Hibiscus Cannnabinus)* Stem

Raji, Abdul Ganiy Olayinka [α] & Aremu, David Olufemi [σ]

Abstract- Due to the diversity in the use of kenaf, its processing and production, there is need to determine some mechanical properties of the kenaf stem so as to get a suitable database for design and mechanical features of the equipment and facilities for processing kenaf stem. This study was designed to investigate the effect of moisture content (mc) on mechanical properties of kenaf stems. Five common varieties of kenaf in Nigeria were identified and selected (Ife Ken 400, Ife ken D1 400, NHC 25 v 31, NHC 1 v 37 and Kuba 108). Samples were stored at room temperature for five weeks and moisture loss was monitored. Samples from each variety were cut into 30mm were prepared and placed horizontally between the crosshead of the Instron Testing Machine (Model 3369, 100KN, USA) to determine the mechanical properties (load at maximum tensile stress, tensile strain at maximum tensile stress, energy at maximum tensile stress and tensile stress at break) at 2mm/min. The data were subjected to statistical analysis. Highest load at maximum tensile stress of 714.90 at 21% mc and the least load at maximum tensile stress of 406.44 at 18% mc were obtained respectively for Ife Ken D1 400 and Ife Ken 400. Highest energy at maximum tensile stress (2.6466) was obtained for Kuba 108 while Ife Ken 400 has the least energy at maximum tensile stress (0.7865). Ife Ken D1 400 has the highest tensile stress at break (22.336) while Ife Ken 400 has the least Tensile Stress at break (8.567). Moisture content had significant effect on the mechanical properties of the kenaf stem. The study established that the kenaf stem is harder and may be difficult to crush for extraction of fibre at higher moisture content.

Keywords: kenaf, moisture content, mechanical properties.

I. General Background

Kenaf (*Hibiscus cannabinus*) is an annual crop which is high in fiber yield (Bakhtari *et* al., 2011; Mazumder *et al*., 2005). Kenaf's ability to fix CO_2 has expanded its global consciousness as a natural source of cellulose fiber (Hossain *et al*., 2011; Lam *et al*., 2003). Its carbon dioxide assimilation capability, water purification ability and fast growing characteristics have invigorated several nations to consider kenaf as an alternative source of natural fibre (Kobayashi *et al*., 2013; Dauda *et al*., 2013).

It is cultivated for its fiber in India, Bangladesh, United States of America, Indonesia, South Africa, Malaysia, Viet Nam, Thailand, parts of Africa and to a small extent in South Eastern Europe. The stems produce two types of fibers. A coarser fiber in the outer layer (bast fiber) and a finer fiber in the core. It matures in 100 to 200 days. Kenaf was grown in Egypt over 300 years ago. The kenaf leaves were consumed in human and animal diet, the bast fiber was used for bags, cordage and the sails for Egyptian boats. This crop was not introduced into southern Europe until the early 1900s. Today, principal farming areas are China, India and it is also grown in many other countries such as US, Mexico and West Africa. The main uses of kenaf fiber have been rope, twine, coarse cloth similar to that made from jute and paper (Zakiah *et al*., 2011). Uses of kenaf fiber include engineered wood, insulation, clothing-grade cloth, soil-less potting mixes, animal bedding, packing material and material that absorbs oil and liquid. It is also useful as cut bast fiber for blending with resins for plastic composites, as a drilling fluid loss preventative for oil drilling muds, for seeded hydro mulch for erosion control. It can be made into various types of environmental mats, such as seeded grass mats for instant lawns and moldable mats for manufactured parts and containers (Amel *et al*., 2013). Kenaf seed yields vegetable oil used for cosmetics, industrial lubricants, biofuel production and also important for reducing cholesterol and heart diseases (Zakiah *et al*., 2011). It can also be used for making papers. The fibers are produced mostly for textiles, gunny sacks and to a certain extent, paper. New uses for kenaf have recently been developed for different industrial applications. Products range from bio composites, paper, textiles and cattle feed and absorbing agents (Dauda *et al*., 2013).

The kenaf stem is divided into two separate parts, the bark or bast containing relatively long fibers and the stem containing short fibers, called core. The ratio of the core to bast is 65:35% of the whole stem weight. The plant grows on various types of soil but is best grown during the rainy season for good yields. Yields of kenaf range from 8 – 12 metric tons of dry stem per hectare. Mechanized operation from seeding to harvesting is required for large scale cultivation. Fiber production can be processed through mechanical and water retting (separation) where steams are soaked in ponds. Traditional growers of kenaf are China, Indonesia, Myanmar, Thailand and the United States of America. Post-harvest handling of kenaf stems requires processing machines like decorticators, driers,

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pelletizers, milling machines etc, the efficiency and design of these machines is dependent of the engineering properties of the stem which include the mechanical properties. The mechanical properties of a material describe how it will react to application of physical forces; some materials will deforms or flow, solids will deform liquid and gas will flow. Mechanical properties are determined through series of standardized mechanical tests resulting from the structure, physical state and rheology. They can be subdivided into two groups; structural and geometrical properties and strength properties. Structural and geometrical properties include mass, volume, area-related properties (density, shrinkage and porosity) and morphological properties (surface area, roundness and sphericity) (Mohsenin, 1986)

Due to the diversity in the use of kenaf, its processing and production, there is need to determine some mechanical properties of the kenaf stem so as to get a suitable database for design and mechanical features of the equipment and facilities of processing kenaf stem. Thus, this study was carried out to determine the effect of moisture content and time on some mechanical properties of kenaf stem such as tensile strength, young modulus and tensile strain.

II. Methodology

a) Sample Collection and Preparation

Five varieties of kenaf stems (Ife Ken 400, Ife ken D1 400, NHC 25 v 31, NHC 1 v 37 and Kuba 108) were obtained from kenaf farm of the Institute of Agricultural Research & Training (IAR&T), Ibadan, Nigeria and the Teaching and Research farm of the Obafemi Awolowo University, Moor Plantation, Odo-Ona, Apata, Ibadan, Nigeria. The samples were kept at room temperature for five weeks to determine the loss in weight with time on the mechanical properties of the kenaf stems. Samples were tested at every week of storage for strength properties. The moisture content at each period of testing was determined and linked with the period of test.

b) Moisture Content Determination

During each week of test, samples were taken from each variety and cut into 30mm length. The samples were weighed and placed in the oven at 103±°C to dry to a constant weight. At the end of 24 hours, the samples were removed from the oven and cooled for ten minutes and reweighed. The moisture content of the stems was then obtained using Equation 1.

$$\text{Mc} = \frac{Ww - Wd}{Ww} \times 100 \qquad (1)$$

Where: Mc is the Moisture content (%) of material, W_w is the Wet weight of the sample, and W_d is the weight of the sample after drying.

c) Determination of Mechanical Properties

The experiments were conducted at Federal College of Agriculture, Ibadan and Obafemi Awolowo University (O.A.U) laboratories. Five samples from each of the five varieties (thus making 25 samples) were cut into 30mm and were placed horizontally between the crosshead of the Instron Testing Machine (Model 3369, 100KN, USA), at 2 mm/minute (Plate 1). The machine was connected through a data logger to a computer system where the force deformation curve and data were observed as the experiment progressed. This procedure was repeated every two weeks to investigate the effect of moisture (due to loss of weight) on the mechanical properties of kenaf stems. The parameter recorded are load at maximum tensile stress, tensile strain at maximum tensile stress, energy at maximum tensile stress and tensile stress at break.

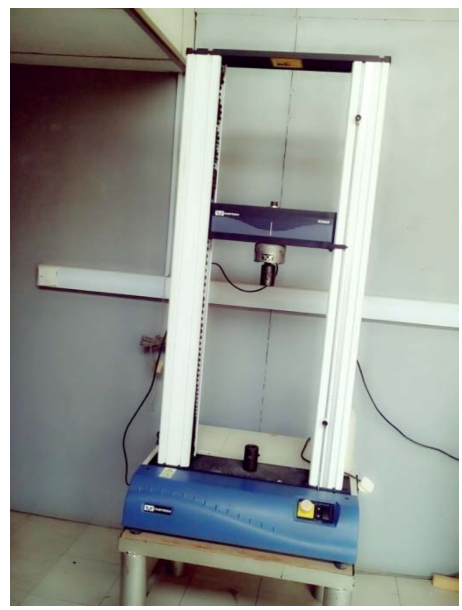

Plate 1: Instron Testing Machine

d) Statistical Analysis

Analysis of variance (ANOVA) of two factors complete randomized design (CRD) was used to evaluate the effect and significance level of moisture content on the mechanical properties of kenaf stem used for the experiment at alpha (α) = 0.05. The effect of moisture content on mechanical properties of kenaf stem were statistically analyzed using Duncan's Multiple Range Test (DMRT) at $P < 0.05$

III. Results and Discussion

The percentage moisture content of the samples at each period of storage for the five varieties is presented in Table 1.

Table 1: Percent Moisture Content of Kenaf Samples at five weeks of Storage

Time	Moisture Content (wb %)				
	Ife Ken 400	Ife Ken D1 400	NHC 25 v 31	NHC 1 v 37	Kuba 108
Week 1	69	38	20	60	52
Week 2	43	34	18	55	45
Week 3	31	30	15	48	40
Week 4	20	23	12	40	36
Week 5	18	21	10	32	28

The mechanical strength (load at maximum tensile stress, tensile strain at maximum tensile stress, Energy at maximum tensile stress and tensile stress at break) of the kenaf stems was investigated at each week of storage is presented in Tables 2 – 3.

It was observed that variety 3 (NHC 25 v 31) has the highest value of Load at Maximum tensile stress of 895.08935N, while variety 2 (Ife Ken D1 400) has the highest Tensile Strain at Maximum Tensile Stress of 0.25667mm/mm. The Load at Maximum Tensile Stress increases every two weeks while Tensile Strain at Maximum Tensile Stress varies every two weeks, this findings are similar to report of Ghahraei *et al*. (2011). The mechanical properties of the varieties of the kenaf stem of the weeks shows that variety 5 (Kuba 108) has the highest Energy at Maximum Tensile Stress of 4.51469 J while variety 2 (Ife Ken D1 400) has the highest Tensile Stress at Break of 26. 38957MPa. Energy at Maximum Tensile Stress increases at week 4 while Tensile Stress at Break varies every two weeks (Ghahraei *et al*., 2011).

a) Load at Maximum Tensile Stress

The ANOVA table for load at maximum tensile stress for the five kenaf varieties is presented in Table 4. It was observed that there is high significant difference at 5% level of probability by Analysis of Variance (ANOVA) of each level of MC(Variety) of the mechanical properties. The result of Duncan Multiple Range Test (DMRT) as shown in Table 10 shows that Variety 2 (Ife Ken D1 400) has the highest Load at Maximum Tensile Stress of 714.90a while Variety 1 (Ife Ken 400) has the least Load at Maximum Tensile Stress of 406.44b.

Table 2: Load and Tensile Strain at Maximum Tensile Stress of Kenaf Stems

Time	Load at Maximum Tensile Stress (N)					Tensile Strain at Maximum Tensile Stress (mm/mm)				
	Ife Ken 400	Ife Ken D1 400	NHC 25 v 31	NHC 1 v 37	Kuba 108	Ife Ken 400	Ife Ken d1 400	NHC 25 v 31	NHC 1 v 37	Kuba 108
Week 1	380.15618	609.14613	719.07828	357.07821	340.31765	0.03500	0.10973	0.04686	0.05086	0.05130
Week 2	633.50109	612.58785	618.69042	732.01834	460.40463	0.13320	0.25667	0.02300	0.03646	0.05224
Week 3	365.71051	726.28495	764.11598	512.67929	437.34626	0.12593	0.09653	0.02892	0.10213	0.05332
Week 4	430.70995	733.61161	730.58575	547.72875	472.78725	0.05813	0.11920	0.13559	0.05109	0.06262
Week 5	222.11501	892.86456	895.08935	621.29735	554.11480	0.03260	0.07547	0.03646	0.04686	0.06372

Table 3: Energy at Maximum Tensile Stress and Tensile Stress at Break of Kenaf Stems

Time	Energy at Maximum Tensile Stress (J)					Tensile Stress at Break (MPa)				
	Ife Ken 400	Ife Ken D1 400	NHC 25 v 31	NHC 1 v 37	Kuba 108	Ife Ken 400	Ife Ken D1 400	NHC 25 v 31	NHC 1 v 37	Kuba 108
Week 1	0.23025	1.27989	2.02156	1.82156	0.28145	3.37843	15.47069	13.18491	10.18491	12.87201
Week 2	1.76856	2.67480	2.01103	1.42347	2.32186	20.60159	20.80127	20.30988	16.60978	18.15281
Week 3	1.41212	1.29628	1.03497	1.54637	2.36985	12.83085	26.38957	24.31447	20.55336	10.82148
Week 4	0.41088	1.95499	1.05190	0.30732	4.51469	1.82691	23.38528	23.10068	7.216086	20.92310
Week 5	0.11081	1.05170	1.07169	3.02131	1.98634	4.19574	25.63396	25.36029	18.14472	15.88175

Table 4: Analysis of Variance (Load at Maximum Tensile Stress)

Source	Type III Sum of Squares	Df	Mean Square	F	Pr > F	Remarks
Variety	1819438.686	4	454859.672	4.39	0.0026	Significant (S)
MC (Variety)	1324304.665	20	66215.233	0.64	0.8744	Not Significant (Ns)
Error	10371946.38	100	103719.46			
Corrected Total	13515689.73	124				

MC (Variety) means moisture content nested into variety

Ns: Not significant at Pr > 0.05

S: Significant at Pr > 0.05

b) Tensile Strain at Maximum Tensile Stress

The ANOVA table for tensile strain at maximum tensile stress for the five kenaf varieties is presented in Table 5. It was observed that that there is no significant difference at 5% level of probability by Analysis of Variance (ANOVA) of each level of Variety of the mechanical properties. The result of Duncan Multiple Range Test (DMRT) as shown in table 10 shows that Variety 5 (Kuba 108) has the highest Tensile Strain at Maximum Tensile Stress of 1522.7a while Variety 1 (Ife Ken 400), Variety 2 (Ife Ken D1 400), Variety 3 (NHC 25 v 31) and Variety 4 (NHC 1 v 37) has the least Tensile Strain at Maximum Tensile Stress 0f 0.1a.

Table 5: Analysis of Variance (Tensile Strain at Maximum Tensile Stress)

Source	Type III Sum of Squares	Df	Mean Square	F	Pr > F	Remarks
Variety	46369147.1	4	11592286.8	1.00	0.4113	Not Significant (Ns)
MC (Variety)	231854236.1	20	11592711.8	1.00	0.4692	Not Significant (Ns)
Error	1159274299	100	11592743			
Corrected Total	1437497682	124				

MC (Variety) means moisture content nested into variety

Ns: Not significant at Pr > 0.05

c) Energy at Maximum Tensile Stress

The ANOVA table for energy at maximum tensile stress for the five kenaf varieties is presented in Table 6, it was observed that there is high significant difference at 5% level of probability by Analysis of Variance (ANOVA) of each level of Variety of the mechanical properties. The result of Duncan Multiple Range Test (DMRT) as shown in table 10 shows that Variety 5 (Kuba 108) has the highest Energy at Maximum Tensile Stress of 2.6466a while Variety 1 (Ife Ken 400) has the least Energy at Maximum Tensile Stress of 0.7865b.

Table 6: Analysis of Variance (Energy at Maximum Tensile Stress)

Source	Type III Sum of Squares	Df	Mean Square	F	Pr > F	Remarks
Variety	43.38261425	4	10.84565356	3.23	0.0155	Significant (S)
MC (Variety)	72.33586725	20	3.61679336	1.08	0.3860	Not Significant (Ns)

MC (Variety) means moisture content is nested into variety

Ns: Not significant at Pr > 0.05

S: Significant at Pr > 0.05

d) Tensile Stress at Break

The ANOVA table for tensile stress at break for the five kenaf varieties is presented in Table 4, high significant difference was observed at 5% level of probability by Analysis of Variance (ANOVA) of each level of Variety of the mechanical properties. The result of Duncan Multiple Range Test (DMRT) as presented in Table 7 shows that Variety 2 (Ife Ken D1 400) has the highest Tensile Stress at break of 22.336a while Variety 1 (Ife Ken 400) has the least Tensile Stress at break of 8.567b. The mean effect of the mechanical properties of kenaf stem is presented in Table 8.

Table 7: Analysis of Variance (Tensile Stress at Break)

Source	Type III Sum of Squares	Df	Mean Square	F	Pr > F	Remarks
Variety	2938.926280	4	734.731570	5.06	0.0009	Significant (S)
MC (Variety)	3508.516857	20	175.425843	1.21	0.2633	Not Significant (Ns)
Error	14512.27943	100	145.12279			
Corrected Total	20959.72257	124				

MC (Variety) means moisture content is nested into variety

Ns: Not significant at Pr > 0.05

S: Significant at Pr > 0.05

Table 8: Mean Effect of Varieties on Mechanical Properties

Variety	Load at Maximum Tensile Stress	Tensile Strain at Maximum Tensile Stress	Energy at Maximum Tensile Stress	Tensile Stress at Break
Ife Ken 400	406.44b	0.1a	0.7865b	8.567b
Ife Ken D1 400	714.90a	0.1a	1.67060ab	22.336a
NHC 25 v 31	677.30a	0.1a	1.7371ab	20.644a
NHC 1 v 37	557.39ab	0.1a	1.6468ab	15.095ab
Kuba 108	452.98b	1522.7a	2.6466a	15.283ab

Mean with same letter in a column are not significantly different at Pr > 0.05 by Duncan Multiple Range Test (DMRT)

IV. Conclusion

The effect of moisture content on some mechanical properties of different varieties kenaf stem was investigated; it can be deduced the higher the moisture content, the higher the load at maximum tensile strength, energy at maximum tensile stress and the tensile stress at break however, there was a decrease when these properties gets to the breaking point.

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