



Physical and Mechanical Properties of Kenaf (*Hibiscus cannabinus* L.) Stems at Varying Moisture Contents

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Author's contribution

Author SAF designed the study, wrote the protocol, managed the analysis of the study and literature searches and wrote the manuscript.

Article Information

DOI: 10.9734/AJB2T/2020/v6i330081

Editor(s):

- (1) Dr. Md. Shaheed Reza, Bangladesh Agricultural University, Bangladesh.
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Complete Peer review History: <http://www.sdiarticle4.com/review-history/57175>

Original Research Article

Received 13 April 2020
Accepted 19 June 2020
Published 06 October 2020

ABSTRACT

The physical and mechanical properties of Nigerian variety Kenaf stems Ibadan Local were studied. Plant height was ranged from 224 cm to 327 cm and maximum stem diameter was ranged from 15 mm to 50 mm. The mechanical properties revealed that maximum cutting force and shearing energy were 1778.62 N and 10.20 J, respectively for 37% moisture content while it was 742.67 N and 3.74 J for 77% moisture content. The Young's modulus ranged from 60.04 – 266.80 MPa. The greater shearing energy was obtained at the base of the stem.

Keywords: Kenaf stems; moisture content; bast fibre; core fibre; decorticating; retting.

1. INTRODUCTION

Kenaf (*Hibiscus canabinnus* L.) which belongs to the *Malvaceae* family is believed to have

originated and first been domesticated and used in Northern part of Africa [1]. It has been cultivated since around 6,000 BC for food and fibre. It is known as mesta in India and Bengal,

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as stockroot in South Africa, as *java jute* in Indonesia and as *ambari* in Taiwan, [2] but in Nigeria, it is known as *Rama* in Hausa and *ida orisha* in Yoruba language [3]. It is a valuable warm season annual fibre crop closely related to cotton (*Gossypium hirsutum* L.) and okra (*Abelmoschus esculentus* L.) and is widely grown today in the US, Bangladesh, Thailand, Australia, Indonesia, Southeast Europe, Malaysia, Brazil and Africa [4]. The useful Kenaf plant components include the stalks/stems, leaves, flowers, and seeds. Depending on the component under discussion it may contain such useful substances as bast (phloem tissues) and core (xylem tissues) fibers, proteins, and essential oils [5]. It is used as cordage crop to produce sackcloth, rope, fishing nets and twine for over six millennia [6]. Its water purification ability, carbon dioxide assimilation capability and fast growing characteristics have made several nations of the world to consider Kenaf as an alternate source of natural fibre [7].

In Nigeria, the process of separating the bast fibre from its core is still being done manually on a large scale by our farmers with the use of knives to strip off the outer part of the plant stem that is the bast. Others have adopted steam explosion, retting and chemical treatment methods. These methods are laborious, time consuming and have resulted in drudgery while some health hazards have been attributed to the use of some of these methods by farmers, especially chemical treatment. The use of mechanical method will be less energy consuming, faster, requires much lesser space and will not pose any health hazard to the farmers with a high quality end product.

In this study, the kenaf plant was grown on a deep, friable, well drained sandy loam soil with humus at the Department of Agricultural & Bioresources Engineering, Federal University of Technology, Minna research plot (9.53° N, 6.45° N). Understanding the crops composition and the determination of its physical and mechanical properties are essential requirements which are key in the design and fabrication of indigenous Kenaf decorticating machine using locally available materials for easy maintenance and would be affordable by farmers and as a result will encourage them to go into large-scale farming of this fiber crop. In this regard, this study was carried out to determine the physical and mechanical properties of Nigerian Kenaf stem variety Ibadan local.

2. MATERIALS AND METHODS

2.1 Sample Preparation

Kenaf (*Hibiscus canabinnus* L.) seedlings of the Nigerian variety known as Ibadan local were collected from the Institute of Agricultural Research and Training, Ibadan on 5th May, 2017. The land size was 50 ft x 50 ft which was cleared manually with the use of hoes and cutlasses while major stones, stumps and debris were removed from the site. The sample seed gotten from the Institute of Agricultural Research and Training, Ibadan, Nigeria was planted on 10th May, 2017 on seed bed of 15 cm high and interplant spacing of 30 cm. First and second weeding were carried out on the site on the 4th and 8th week respectively. Collection of samples on the site was done on 10th August, 2017 (90 days old).

2.2 Physical Properties Determination

The following properties of Kenaf plant were determined; Stem length and stem diameter. The stem diameter was measured with a Vernier caliper while a tape rule was used to measure the length of the stems. The determination of the moisture content was done by oven dry method at 104°C for 24 hours while all measurements were taken accordingly in the Crop Processing laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna at room temperature [8].

2.3 Mechanical Properties Determination

The Nigerian Variety Kenaf stems known as Ibadan local was randomly selected and cut from the plot site located at 9.5836°N, 6.5463°E, Federal University of Technology Minna, were used for this experiment. The freshly harvested Kenaf stems were manually sampled while others were kept in the cold room of the Crop Processing Laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, to monitor its moisture contents. The sample stems were cut close to the ground. The cut stems were divided into three samples. As soon as the targeted moisture contents were reached, the samples were tested. Moisture content (Mc) and diameter (D) of the stems were recorded. The diameter was measured using a Vernier caliper (precision 0.010 mm). The moisture content was determined by oven dry method at 104°C for 24 hours [9]. Towards the top of the plant, the Kenaf

stems diameter decreased. Hence it was equally divided into three major parts; as top (upper), intermediate (middle) and basal (lower) [10]. In order to determine the maximum cutting force (N), Compressive Stress (MPa), Young's modulus (MPa), maximum energy (J) and stem area (mm^2), blade with 22.5° edge angle was fixed on the universal Instron Testing Machine cross head at the Farm Power Laboratory, Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria. The stem was positioned on the counter shear support and was cut at a speed of 500 mm/mm. The data was transmitted to the Instron Computer system. Three reading were taken each for moisture contents at 77%, 57% and 37% in order to verify the effects of moisture content on the cutting properties. Average simple mean was tabulated in the data.

3. RESULTS AND DISCUSSION

3.1 Physical Properties

100 samples of the Kenaf stem were randomly selected from the test plot and measured accordingly. The results obtained showed that the maximum value of the stem length was 3.27 m while the minimum value of the stem length was 2.24 m. The maximum diameter recorded was 50 mm while the minimum diameter was 15 mm.

3.2 Mechanical Properties

The experiments were carried out at three moisture content levels of 37%, 57% and 77% w.b. and at three levels up the stem which are the basal, intermediate and top levels. At the different moisture contents studied, the values of the compressive stress were within the ranges of 3.25 – 10.26 MPa, 4.39 – 11.72 MPa, and 2.23 – 9.72 MPa, for the top (upper), intermediate and basal (lower) levels in the stem, respectively. The

maximum cutting force and shearing energy were 1778.62 N and 10.20 J, respectively, for 37% moisture content while it was 742.67 N and 3.74 J for 77% moisture content. The Young's modulus ranged from 60.04 – 266.80 MPa. It was observed that the greater shearing energy was obtained at the lowest level in the stem which could possibly be as a result of the accumulation of more mature fibre at the lower part of the stem which is the oldest part of the plant at lower region of the Kenaf which has relatively highest content of lignin. The result also showed that at higher moisture content of the stem, the force required to cut the stem was lower at an average of 595.87 N which increased with a decrease in moisture content to an average of 1634.98 N. This could be attributed to the decrease in density difference between the stem levels at lower moisture contents.

The maximum cutting force and cutting energy varied with cross sectional area as could be seen in Tables 2, 3 and 4 indicating the significance of cross sectional area on the parameters studied. This is similar to results reported by [10]. The results similarly indicated that increase in the moisture content of stalk leads to a decrease in Young's modulus, shearing force and the shearing energy. The shearing energy decreased with decrease in stem diameter along the stem towards the upper regions, this is similar to results obtained from studies conducted by [11,12] on kenaf and alfalfa stems. This may be due to the viscous damping effect of moisture.

Table 1. Kenaf stems physical properties average values

Stem property	Range	Average
Stem Length (m)	2.24 – 3.27	2.76
Stem Diameter (mm)	15 – 50	32.5
Stubble Height (cm)	10 -15	12.50
Moisture Content (%)	77	77

Table 2. Some Kenaf mechanical properties at 77% moisture content

	Stem diameter (mm)	Maximum force (N)	Compressive stress (MPa)	Young's modulus (MPa)	Maximum energy (J)	Stem area (mm^2)
1	15.89	572.62	3.25	45.82	3.24	186.95
2	15.69	742.67	4.39	130.56	3.74	180.91
3	15.46	371.51	2.23	3.73	1.64	176.55
Mean	15.68	562.27	3.29	60.04	2.87	181.47

Table 3. Some Kenaf mechanical properties at 57% moisture content

	Stem diameter (mm)	Maximum force (N)	Compressive stress (MPa)	Young's modulus (MPa)	Maximum energy (J)	Stem area (mm ²)
1	14.14	215.94	5.42	115.59	0.73	137.82
2	15.81	1367.14	9.13	261.41	7.29	171.48
3	13.72	204.54	1.97	37.51	1.11	124.14
Mean	14.56	595.87	5.50	138.17	3.04	114.48

Table 4. Some Kenaf mechanical properties at 37% moisture content

	Stem diameter (mm)	Maximum force (N)	Compressive stress (MPa)	Young's modulus (MPa)	Maximum energy (J)	Stem area (mm ²)
1	16.68	1778.62	10.26	414.94	8.14	194.67
2	15.96	1726.33	11.72	262.66	10.20	171.61
3	15.45	1399.99	9.72	122.79	8.63	143.99
Mean	16.03	1634.98	10.56	266.80	8.99	170.09

The results obtained are similar to results reported by [13,14,15]. It similarly indicated that increase in the moisture content of stalk led to a decrease in Young's Modulus, shearing energy and shearing force. The shearing energy also decreased with decrease in stem diameter along the stem towards the upper regions, this is similar to studies conducted by [16,17] on alfalfa stems.

4. CONCLUSION

The cutting characteristics of Kenaf stems at different levels 37%, 57% and 77% revealed that the greater shearing energy was obtained at the basal (lower) level of the stem. At higher moisture content of the stem, the force required to cut the stem was lower. These are vital information necessary for the design and fabrication of kenaf decorticating machine.

ACKNOWLEDGEMENTS

The author acknowledges the support of the staff of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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