PHYSICO - MECHANICAL PROPERTIES OF CASTOR (recinus communis) PLANT FIBRE AND ITS UTILIZATION AS AN ENGINEERING MATERIAL

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ABSTRACT

In many communities, natural fibres and other waste materials from agricultural production are extracted without proper utilization due to inadequate knowledge of its engineering properties. This study is aimed at the extraction of fibre from SA -2 variety of castor plant at different stages of the plant growth with the view of evaluating some properties of the fibre relevant to its possible utilizations. The properties evaluated were physical and mechanical. ASTM (1997), TAPPI(1980) standard methods for the physical and material tensile testing machine (Cusson P5030) for mechanical properties were employed. The physical properties determined were moisture absorption (5.024%, 5.066% and 4.136%) and density (0.458gcm^{-3}, 0.684gcm^{-3}and 1.234gcm^{-3})at initial (4WAS),flowering(8-9WAS) and matured(16WAS) stage, respectively. The mechanical properties analysed were found to be (2.220kgf and 4.180kgf)breaking load, elongation at break (4.513mm and 6.65mm), stress (0.005kgf /mm^2 and 0.006kgf/mm^2), strain (0.056 and 0.066), modulus of elasticity (0.125kgf /mm^2 and 0.102kgf /mm^2) and the specific work at rupture(3.000kgf and 5.700kgf) at flowering(8-9WAS) and matured (16WAS) stages, respectively. The fibres were better when matured than any other stage but the fibres at all stages were recommended for various possible utilization in composite and engineering applications.

Keyword: castor fibre, moisture absorption, density, modulus of elasticity and specific work at rupture

1.1 INTRODUCTION

Castor plant is a glabrous annual or perennial shrub or a small tree growing to a height of 3-8m. Castor breeding has already reduced the plant from a tree(up to 10m tall) to a herb (of about 1.5m), with concomitant reduction in branching(Simmonds,1976). There are many varieties of both wild and cultivated castor, varying in plant height, colour of stem and seeds, bean size (William et al., 1989).Chhiddaet al.,(2006) reported that,SA – 2 castor variety, is a drought resistant and medium tall plant (180 – 200cm). Its seeds are dull white with brown mottling and small in size. This variety takes about 95 – 100 days to mature. Castor plant contains valuable resources that include oil, protein, carbohydrate, minerals and fibre among others. Hence, investigating on some physical and mechanical properties of SA – 2 variety of castor plant fibre will go a long way in identifying possibilities in its utilization at home and industry (as composites materials).

Physical properties such as size, shape surface area, volume, density porosity, colour and appearance are important in designing particular processing equipment or to determine the behaviour of properties for its handling (Sahay and Singh, 2001). Ability of fibre to absorp or de-absorb moisture should be considered when evaluating the stability of the fibre for various applications especially for textile, paper and composite (Narendra and Yang, 2005). Properties such as density and electrical conductivity among others are related to the composition and internal structure of a fibre (Narendra and Yang, 2005).Plant fibre have low density, so when used in the construction of car parts such as door panel and roof will lead to reduction in the amount of fuel consumed since it would require a little energy to propel a lighter object than a heavier object (Aguet al., 2012).

The mechanical properties of biomaterial explain the behaviour of the material under applied forces. Ogbonnaya and Bosede (2011) asserted that, knowledge of mechanical properties (properties that have to do with the behaviour of agricultural products under applied forces) such as stress, strain, hardness and compressive strength is vital to engineer's handling of agricultural products. Khurmi (2007) agreed that, every material is elastic in nature and that is why whenever some external system of forces acts on a body it undergoes some deformation. As the body undergoes deformation, it's molecules set up some resistance to deformation. This resistance per unit area to deformation is the stress. The degrees to which a structure deform or strain depend on the magnitude of an imposed stress (William, 1997). Most agricultural products are visco – elastic, they behave differently under static tensile or compressive force and under dynamic or repeated dynamic loads. It is important to note whether the product may be deformed by tensile or compressive force (Drambi, 2011). The behaviour of plant fibre proved to be soft and flexible, which make it difficult to ascertain its properties comprehensively.

2. MATERIALS AND METHODS

2.1 CROP VARIETY AND LOCATION

SA -2 variety of castor plant was cultivated in Yola and harvested during its initial (4WAS), flowering (8-9WAS) and matured (16-WAS) stages of growth. Natural fibres were extracted from the stem of the plant using water retting extraction process, giving the fibres of different lengths and diameters. The fibres were visually selected in order to verify the absence of defects before tests were conducted.

Fig 1. The extracted castor fibre

2.2 EXPERIMENTAL PROCEDURE

2.2.1 *Determination of Moisture Regain*

American society for testing and material (ASTM,1997) standard testing method for moisture regain was adopted to determine moisture absorption of castor fibre at initial, flowering and matured stages. Castor fibre sample was conditioned for 24hrs at 27 ± 2^{O}Cand the weight taken as (W_1). The conditioned fibre sample was oven dried at a temperature of 105^{O}C for 4hrs and the weight taken as (W_2). Moisture absorption percentage of the given sample was calculated according to the formula in equation 1 as reported by Brindha et al.,(2013).

$$\text{MoistureAbsorption\%} = \frac{W1-W2}{W1} X\ 100 \qquad 1$$

2.2.2 *Determination of the Fibre Density*

The density of castor plant fibre each at initial (4WAS), flowering (8-9WAS) and matured (16WAS) stages was determined by conditioning the fibre sample for 24hours at 65% relative humidity and at a temperature of 25^{O}C before carrying the test. Two grams(2g) of each sample was accurately weighed. Each weight was immersed in toluene in a calibrated glass tube (10ml measuring cylinder) and volume of toluene displaced was determined which equals the volume of castor fibre immersed. The density of the fibre sample was calculated from the formula below`.

$$\text{Density} = \frac{\text{Mass}}{\text{volme}} \text{ in g/cm}^3 \qquad 2$$

The method adopted was as described by Technical Association of pulp and paper industries (TAPPI, 1980).

2.3 ANALYSIS OF THE FIBRE ENGINEERING PROPERTIES

Engineering properties such as breaking load, elongation at break and specific work at rupture are those to be analysed using Material tensile testing machine. While parameters like tensile stress, tensile strain and modulus of elasticity are to be evaluated from the measured properties.

Castor fibre samples obtained at flowering and matured stages each of equal length of 100mm were prepared for tensile testing. Material tensile testing machine (Cusson P5030) model was used.The length of each fibre specimen was tightly secured on the spacer to prevent the specimen from slipping off during the tensile test. The tensile tester was actuated and the cross head was pulled upward so that the sample was stretched until breakage was observed. At this point, the cross – head stopped and the load and its corresponding elongation at breaking point were read directly from the monitor attached to the machine. Twenty five (25) replicates for each sample were carried out for these studies.

2.4 STATISTICAL ANALYSIS

Data collected was subjected to descriptive statistics and analysis of variance (ANOVA, P<0.01 and P<0.05) for each species separately using appropriate statistical software (SPSS) version 20.0 from which source of variation were drawn.

3. RESULTS AND DISCUSSIONS

The results of the study are presented in tables 1 and 2 and figures 2 and 3 below.

Table1. Measured fibre physical properties

Stages of the plant growth			
Parameter	Initial (4WAS) T_1	Flowering (8-9WAS) T_2	Matured (16WAS) T_3
Moisture absorption,%	5.024 ± 0.206	5.066 ± 0.482	4.136 ± 0.336
Density/cm^3	0.458 ± 0.044	0.684 ± 0.096	1.234 ± 0.039

WAS=Weeks after sowing, $T_{1=}$Treatment 1,T_2= Treatment 2 and T_3=Treatment 3

Moisture absorption of the fibre determined at different stages of the plant growth as shown in table 1, were found to be (5.024%, 5.066% and 4.136%) at initial (4WAS), flowering (8-9WAS) and matured (16WAS) stages, respectively. The values decreased by 18.360% from flowering (8-9WAS) to matured (16WAS) stages. ANOVA conducted revealed that, the values were highly significant difference at P<0.01level. Theresult also showed thatthis castor fibre absorbed low moisture and it will be good in composite application. Also, when compared with other plant fibre, it has been realised that they were lower than flax (Brindhaet al., 2013), jute (Debiprasadet al., 2012), sisal and cotton (Naveen et al., 2014). While density of the fibre evaluated were (0.458 gcm$^{-3,}$ 0.684 gcm^{-3} and 1.234 gcm^{-3}) at initial, flowering and matured stages, respectively. The values of the density increased by

80.42% from flowering (8-9WAS) to matured (16WAS) stage. Statistically, the values were significant at P<0.05level

Table 2. Measured fibre engineering properties

Parameters	Initial (4WAS)	Stages of the Plant growth Flowering (8 – 9 WAS)	Matured (16 WAS)
	T_1	T_2	T_3
Breaking Load (Kgf)	___	2.220 ± 0.665	4. 180 ± 2.355
Elongation at break (mm)	___	4.513 ± 2.517	6.653 ± 2.926
Tensile Stress (kgf/mm^2)	___	0.005 ± 0.001	0.006 ± 0.003
Tensile Strain	___	0.056 ± 0.021	0.066 ± 0.029
Modulus of elasticity (kgf/mm^2)	___	0.125	0.102
Specific work at ruptur (kgf)	___	3.000	5.700

Table 2. Summary result of mechanical analysis of castor plant fibres.

The load - elongation behaviour of the fibre at different stages of the parent's plant growth is shown in figures 2 and 3. The breaking load and breaking elongation curve for the fibre at flowering stage (8–9 WAS) as in figure 2, revealed that breaking elongation of the fibre sample increase sharply from 0.4 to 1.4mm and corresponds to increase in load from 1kgf to 1.6kgf. The point corresponding to 0.65mm is called the yield point. It may be noted that if load (kgf) on the specimen is removed then the increases in the length of the fibres specimen at that particular stage from 0.4 to 0.65mm will not disappear, but it will remain as a permanent set. The point of rupture of the fibre at that flowering (8-9WAS) stage occurred at 3kgf breaking load to a corresponding breaking elongation of 1mm. Even when the load increases beyond this point, the failure remain as it is since rupture has already occurred.

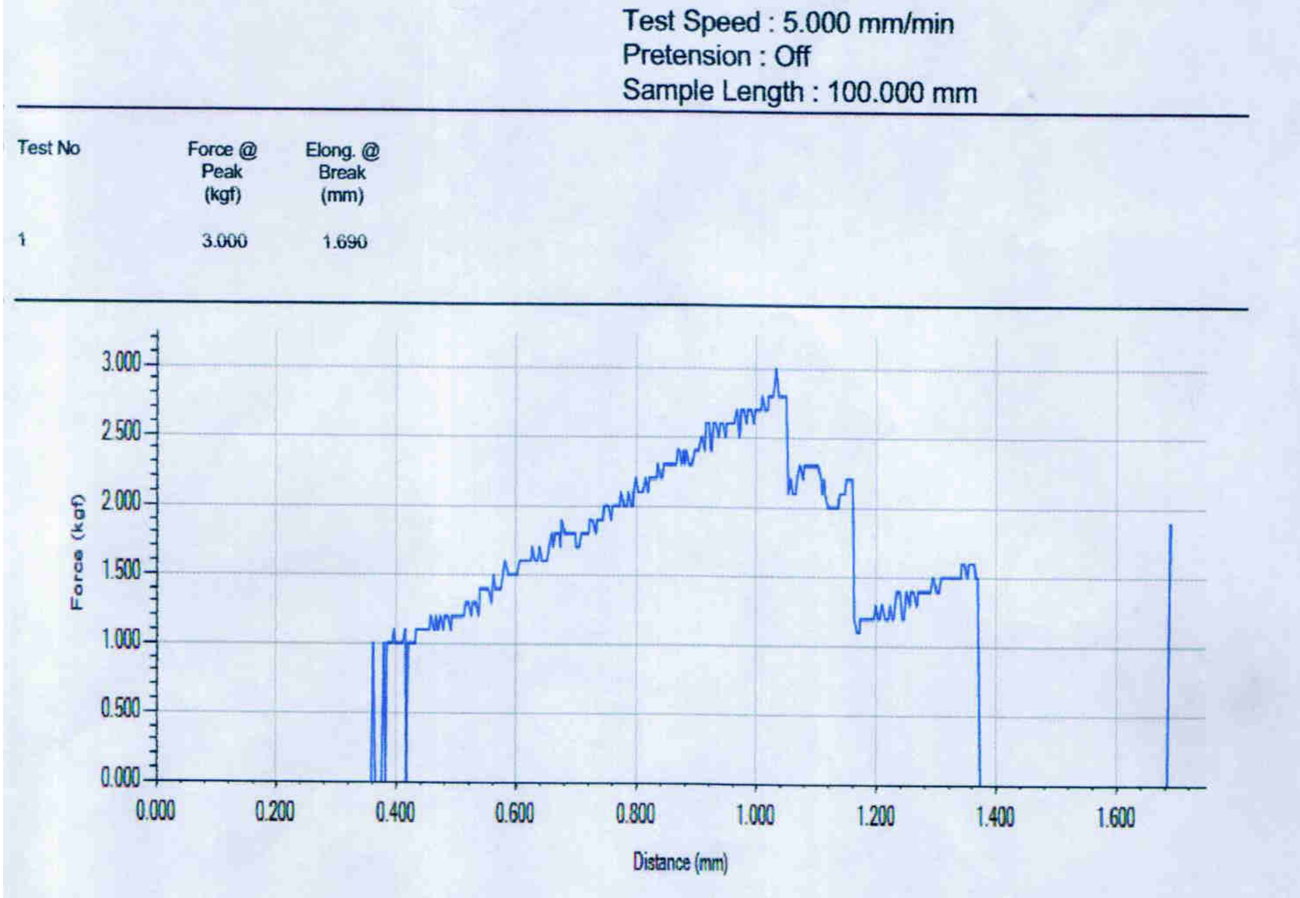

Fig 2. Load – elongation curve at flowering (8-9WAS) stage

Load – elongation behaviour of the fibre obtained at matured (16WAS) stage ispresented in figure 3, this figure showed proportional increase in breaking load with increase breaking elongation up to elastic point.

. The point at 3.5kgf where the curve deviates from the straight line is known as elastic point. This agrees with the result reported by (Shulka and Sharma, 1987). Beyond this point it formed another yield point precisely at 4.8kgf with increase in elongation to 6.2mm. Further increase in load from this point resulted to rupture of the fibre at 5.7 kgf corresponds to breaking elongation at 7.3mm.

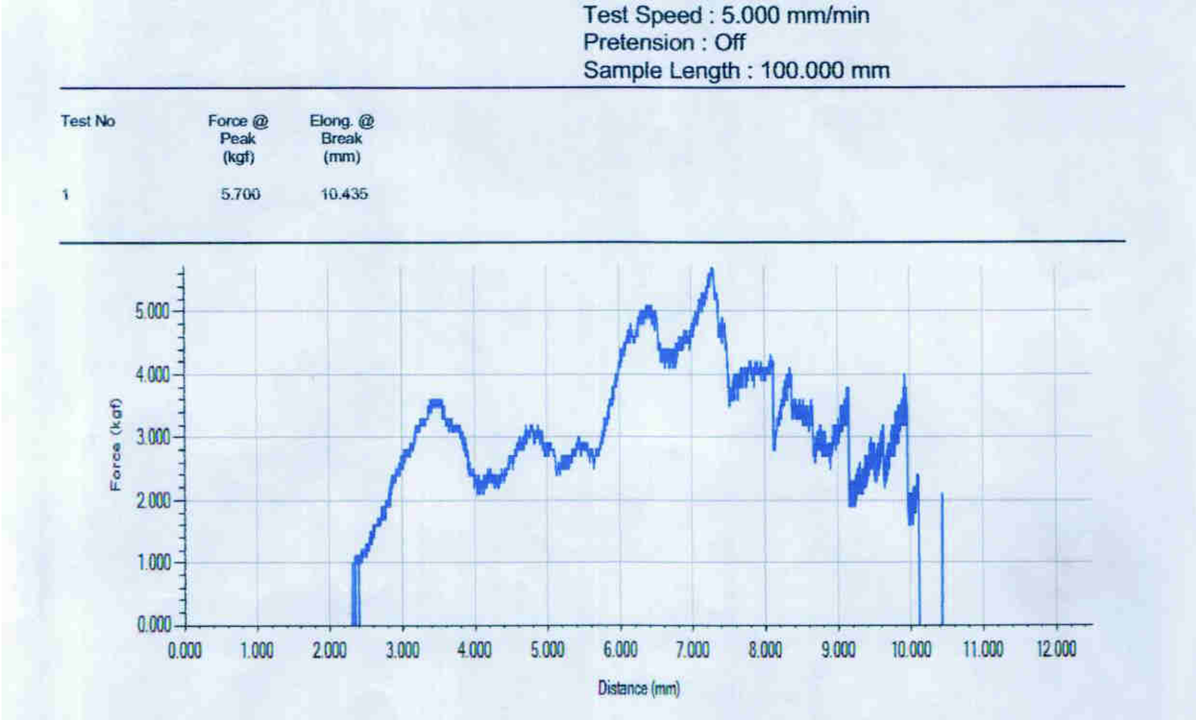

Fig 3. Load – elongation curve at matured (16WAS) stage

The mean values of stress – strain properties evaluated at flowering (8-9WAS) and matured (16WAS) stages were shown in table 2. Stress were found to be (0.005kgf/mm^2 and 0.006 kgf/mm^2) , Strain (0.056 and 0.066) and modulus of elasticity computed found to be (0.125 kgf/mm^2 and 0.102kgf/mm^2) at flowering (8-9WAS) and matured (16WAS) stages, respectively.

The result in Table 2, also revealed that tensile stress and tensile strain increases from flowering(8-9WAS) to matured (16WAS) stages, while the computed modulus of elasticity decrease from flowering to matured stage.

The modulus of elasticity of these fibre at all stages mentioned were greater than different varieties of Banana fibre of Poovan, Kadhali, Mondhan and Rasthali as reported by (Brindah, et al., 2012). Higher modulus of elasticity makes the fibre stiff and suitable for use in application such as composite and carpet materials as suggested by (Narendra and Yang, 2009).

4. CONCLUSION

SA-2 variety of castor plant fibre evaluated shows that at all stages of the plant growth, the fibres absorbed less moisture when compared with other plant fibres. The engineering properties analysed revealed that the values were higher at matured than flowering stage except modulus of elasticity that was higher at flowering than at matured stage. Hence, these fibres were better at matured than at flowering stage. On comparing these fibres properties with other plant fibres, the fibres can be effectively utilized in home and industrial applications especially in composites and carpet manufacture.

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