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MORPHOLOGICAL PROPERTIES OF HURA CREPITANS L. (EUPHORBIACEAE) AS PROSPECTIVE RESOURCE FOR PULP AND PAPERMAKING

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ABSTRACT

Hura crepitans L. (Euphorbiaceae) is a tropic tree species that was investigated for pulp and paper characteristics in this study. The diameters of five (5) different stands of *Hura crepitans* trees were first determined using diameter tape. Wood slivers were obtained from sapwood of the trees parallel to grain and at three (3) different positions along the axis, at the base (5%), middle (50%) and top (90%). The wood slivers were macerated in a mixture of equal volumes of glacial acetic acid and hydrogen peroxide at between 80 -100 degrees Celsius for 2 hours. Macerated fibres were washed and used to prepare microscopic slides where 15 fibres were measured per slide. Data recorded was subjected to One-way Analysis of Variance (ANOVA) based on Completely Randomized Design (CRD). Results show that both the primary fibre characteristics and derived characteristics were significantly different at $p<0.05$? The mean fibre characteristics ranged as follows, Fibre lengths (0.87-1.16 mm), Fibre diameter (18.84 - 24.44 µm), Lumen width (9.92-16.89 µm) and Cell wall thickness (3.93-4.60 µm). The derived mean fibre characteristics ranged as follows; Runkel ratio (0.36-0.78), Elasticity coefficient (44.20-67.91%), Rigidity coefficient (15.98-27.82 %) and Slenderness ratio (0.44-0.80). This result implies that *Hura crepitans* has short fibres with high flexibility, which can collapse easily and form a fully bonded paper and is therefore recommended for pulp and paper production.

Keywords: Wood slivers, Macerated fibres, Glacial acetic acid, Pulp and Paper.

INTRODUCTION

The basic raw material for pulp and paper production since the advent of paper manufacture is wood (Oluwadare and Ashimiyu, 2007). The exploitation of trees for pulp wood production has caused a tremendous decline in the plantation stock and is heading towards alarming proportions especially with increase in population and pulp wood end uses. It is estimated that the world paper consumption which was about 300 million tons in 1996/1997 is expected to rise above the One million tons in the next century (Osadare, 1995, Hurter and Riccio, 1998; and Oluwadare and Ashimiyu, 2007). The increasing demand for pulp and paper due to increasing population has initiated the need to increase the search for range of raw materials so as to increase fibre supply. This implies screening lesser known wood species for their pulp potentials (Market Initiatives, 2007). The analysis of fibre characteristics such as fibre length, fibre diameter lumen width, cell wall thickness and their derived values (slenderness ratio, flexibility coefficient and Runker ratio) exhibit an important relationship with the mechanical strength of pulp and paper (Tembe *et al.,* 2020 and Ekhuemelo *et al.,* 2020). Fibre characteristics vary extensively and to large extent exhibit influences on bulk density, fibre strength and inter-fibre bonding (Dinwoodie, 2000). *Hura crepitans* L. commonly called Sandbox tree belongs to a family Euphorbiaceae and it is a fast-growing, semi-deciduous tree that has a heavy bole and limbs that are covered in spines (Barwick, 2004). The wood of *H. crepitans* has a moderately high blunting effect. It takes stain well; nailing and screwing are poor to satisfactorily; gluing is correct. This species is used for all-purpose carpentry, interior construction, boxes, crates, veneers and plywood, furniture and joinery. It is traditionally used to make dugout canoes (Barwick, 2004).

Since the paper making characteristic of any given pulp is a function of the chemical and fibre properties of the plant, this study is therefore aimed at examining the fibre dimensions and the derived characteristics of *H. crepitans* and estimate the suitability of its wood for pulp and paper production.

MATERIALS AND METHODS

Study area

The study was conducted at the Federal University of Agriculture, Makurdi (FUAM), Benue State. Benue State falls within the coordinate 7º 47' and 10º 00' East, 6º 25' and 8º 8' North. Benue State experiences two distinct seasons (Obiora *et al.,* 2015). The rainy season lasts from April to October with annual rainfall of 1000-1500 mm. The dry season begins in November and ends in March. The temperature fluctuates between 23-37 ºC in the year.

Sample collection

Five (5) trees of *Hura crepitans* from the Federal University of Agriculture Makurdi (FUAM) campus were selected for this study. The diameter of each tree was first taken using the diameter tape. Wood slivers parallel to grain were collected at the base, middle and top positions corresponding to 5%, 50% and 90% respectively on each to form the tree replicates.

Determination of fibre characteristics

Fibre characteristics determination was carried out at the Forest

Research Institute of Nigeria (FRIN) Ibadan. The microscopy was performed in accordance with the ASTM D1030-95(2007) and ASTM D 1413-61 (2007). Wood slivers were macerated in equal volumes of Glacial acetic acid and Hydrogen penxide (1:1) under heat at about 100ºc for 2 hours. The resultant solution was agitated in other to separate it into individual fibres and washed. The clean fibres were mounted on microscopic slides and stained using Naphthalene, the stained fibres were mounted on a Zeiss light microscope (Standard 25) under 80x1, where 15 random fibres were measured on each slide, following the approach by Jorge (1999), Tembe *et al*. (2010; 2020) to keep error below 5% for the 95% confidence level. The fibre characteristics measured included Fibre length (FL), Fibre Diameter (FD) Lumen Width (LW), and Cell Wall Thickness (CWT). From these, derived fibre characteristics were calculated as follows; Felting rate (slenderness) = fibre length ÷ fibre diameter

i. Elasticity coefficient (%) = fibre length ÷ fibre diameter x 10
ii. Rigidity coefficient = cell wall thickness ÷ fibre diameter x 100
iii. Runkel ratio = Cell wall thickness x 2 ÷ lumen diameter
iv. F factor (%) = Fibre length ÷ cell wall thickness x 100
v. Wall fraction = (2 × wall thickness)/ fiber width
vi. Luce's shape factor = (fibre diameter ^{2} – lumen diameter ^{2})÷(fibre diameter ^{2} + lumen diameter ^{2})

Data collected was subjected to one-way analysis of variance (ANOVA) to test for significant differences. Duncan's Multiple Range Test (DRMT, 1955) was used to compare significant means. The experimental design used was Completely Randomized Design.

RESULTS

Table 1 shows the Analysis of variance Result (ANOVA) for fibre length, fibre diameter, lumen width and cell wall thickness of five trees of *H. crepitans* with different DBH. The result shows that there were significant differences between the mean fibre lengths of the five trees. The mean fibre lengths ranged between 1.16 and 0.87 mm. The ANOVA result for fibre diameter (Table 1) show significant difference among the means of the five trees of *H. crepitans*. The mean fibre diameter ranged from 24.44 to 18.84 µm. Mean values of Lumen width of the five trees were also significant at $p<0.05$ and ranged between 16.89 and 9.92 µm. The cell wall thicknesses of the fibres were not significant with the means ranging from 4.60 and 3.93 µm. Fibre diameter was highest (24.44±8.11 µm) in T4 and lowest (18.84±8.26 µm) in T2. Lumen width was least (9.92±9.03µm) in T2 and highest (16.89±7.96 µm) in T4. Similarly, Cell wall thickness is highest (4.60±1.55 µm) in T2 and least (3.93±1.05 µm) in T4.

Table 1: Fibre morphology of different diameter at breadth height of *H. crepitans*

Number of Tree	DBH (m)	Fibre Length	Fibre Diameter	Lumen Width	Cell Wall Thickness
		Mean±Sdv	Mean±Sdv	Mean±Sdv	Mean±Sdv
T1	0.621	1.00±0.00^{b}	23.20±7.19^{bc}	15.16±7.02^{bc}	4.16±1.00^{ab}
T2	0.478	1.16±0.42^{c}	18.84±8.26^{a}	9.92±9.03^{a}	4.60±1.55^{b}
T3	0.430	0.98±.15^{ab}	20.29±6.03^{ab}	12.38±5.46^{ab}	4.11±1.05^{ab}
T4	0.398	0.93±.25^{ab}	24.44±8.11^{c}	16.89±7.96^{c}	3.93±1.05^{a}
T5	0.183	087±.34^{a}	20.69±6.05^{ab}	12.31±5.82^{ab}	4.29±0.90^{ab}

^{abc}*: Means with different superscripts along same row shows significant differences (P<0.05)*
T1, T2, T3, T4 &T5: Tree stands, DBH: Diameter at Breast Height, Sdv: Standard deviation

Table 2 shows the mean values of derived indices of the five trees of *H. crepitans*. The result shows that there were significant differences among all the derived fibre indices except for Runkel ratio were no significance ($p>0.05$) difference existed. Wall coverage ration ranged between 0.42 and 0.00. Runkel ratio is between 0.78 and 0.36; Elasticity coefficient mean values ranged between 44.20 and 67.91%; Rigidity coefficient from 27.82 - 15.98 % and values of slenderness between 0.71 and 0.49%. Also, means of Luce's shape (LSF) factor ranged from 0.58 to 0.27; F factor from 26.16 - 19.96 while solid factor ranged from 488.84 to 261.48, respectively.

Table 3 presents classification of elasticity coefficient of *H. crepitans* mean values. The result indicates that fibres of *H. crepitans* are elastic fibres, short with good Runkel ratio value.

Table 2: Derived Indices of *H. crepitans* (from different locations in Benue State

Number of Tree	DBH (m)	Wall coverage ratio	Runkel Ratio	Elasticity Coefficient (%)	Rigidity Coefficient (%)	Slenderness ratio (%)	Luce's Shape Factor	F factor	Solid Factor (SF)
		Mean±Sdv	Mean±Sdv	Mean±Sdv	Mean±Sdv	Mean±Sdv	Mean±Sdv	Mean±Sdv	Mean±Sdv
T1	0.621	0.04±0.21[a]	0.51±0.63 [a]	63.76±13.04[bc]	18.11±6.58 [ab]	0.71±0.46[b]	0.36±0.48 [a b]	20.64±7.86	427.67±226.03[bc]
T2	0.478	0.42±0.50[b]	0.78±4.69 [a]	44.20±29.08[a]	27.82±14.57 [c]	0.44±0.50[a]	0.58±0.50 [c]	26.16±9.20[c]	261.48±198.62 [a]
T3	0.430	0.07±0.25[a]	0.67±0.56 [a]	59.42±13.16 [b]	20.22±6.68 [b]	0.51±0.51[a]	0.53±0.51[bc]	23.22±21.77 [bc]	359.73±173.70 [b]
T4	0.398	0.00±0.00[a]	0.36±0.48 [a]	67.91±12.27 [c]	15.98±6.23 [a]	0.80±0.41[b]	0.27±0.45 [a]	19.96±8.32 [ab]	488.84±250.11[c]
T5	0.183	0.02±0.15[a]	0.69±0.51 [a]	58.29±11.46 [b]	20.91±5.72 [b]	0.49±0.51[a]	0.53±0.51[bc]	16.71±6.75[a]	450.93±177.57[c]
	Total	**0.12±0.32**	**0.60±0.60**	**58.40±19.20**	**20.77±9.64**	**0.59±0.49**	**0.46±0.50**	**21.44±12.39**	**394.77±220.96**

Key: abc: Means with different superscripts along same row shows significant differences ($P<0.05$),
T1, T2, T2, T3, T4 and T4: Tree stands, Diameter at Breast Height, Sdv: Standard deviation

Table 3: Description and Suitability of *H. crepitans* for pulp and paper production

Number of Tree	DBH (m)	Fibre length (mm)	Fibre class	Runkel ratio	Ranking	Elasticity Coefficient (%)	Types of fibres
T1	0.621	1.00	Short	0.51	Good	63.76	Elastic
T2	0.478	1.16	Short	0.78	Good	44.20	Elastic
T3	0.430	0.98	Short	0.67	Good	59.42	Elastic
T4	0.398	0.93	Short	0.36	Good	67.91	Elastic
T5	0.183	0.87	Short	0.69	Good	58.29	Elastic

Key: High elastic fibres > 75; Elastic fibres 50 to 75; Rigid fibres 30 – 50; High rigid fibres < 30;
T1, 2, 3, 4 &5 = Tree stands, DBH: Diameter at Breast Height, Sdv: Standard deviation

DISCUSSION

Fibre morphology of stands of *Hura crepitans*

Fibre Lengths

The mean value of fibre length in this study shows that T_2 had the highest mean of 1.16 mm while T_5 had the lowest mean of 0.87mm. Fibres from the study are all short which may be attributed to genetic composition as well as shorter agronomic features (Tembe, *et al*, 2010). The fibre length values are lower than 1.65 -2.57mm reported by Izekor and Fuwape (2011) for 25-years-old Teak in Eastern Nigeria and 1.57m for 42-year-old *Hevea brazidensis* reported by (Tembe *et al*., 2010).

Fibres below 1.60 mm are classified as short while those above 1.60 mm in length are said to be long fibres (Mexcalfe and Chalk, 1983, Anon 1984) Ogunkule and Oladele (2008) reported a fibre length of less than 1.60mm for Ficus species. Oluwadare (2007) recorded 0.65mm as fibre length for *L. levcocephala.* Long fibres are preferred for the manufacture of paper because they give a more open and less uniform sheet structure (Oluwadre and Ashimyu, 2007). Short fibres lack formation of good surface content and fibre- fibre bonding (Ogbonnaya *et al*., 1992). Ademiluyi and Okeke, (1979) reported that the longer the fibre, the higher the tear resistance and the better the quality of paper produced. In which aspect does the findings of Okeke, (1979) applicable to your work? Please specify.

Fibre Diameter

From the result obtained among the five trees of *Hura crepitans*, T_4 has the highest value of 24.44 mean value of fibre diameter and T_2 has the lowest with 18.84. These values are above the ranged of (14.0-16.9 μm). *Gmelina arborea* was found to have fibre diameter of (18.5-27.5μm) by Rogue and Fo, (2007). Increase in fibre diameter was reported to be associated with molecular and increase in cell wall during the tree growing process (Plomion *et al.,* 2001; Roguel *et al*., 2007).

Lumen width

The mean lumen width in this study ranges between 16.89 and 9.92 μm. The mean values are within the range of 2.47 - 4.49 μm reported by (Awuku, 1994) for some indigenous hard wood species in the tropical rainforest ecosystem Generally, variation in lumen width could be attributed to the increase in cell size and physiological development of the wood as the tree grows in girth. Rogue *et al.* (2007) reported a positive relationship in Lumen width and cambium age in their study. Fibre Lumen width affects the beating of pulp in the sense that the larger the fibre lumen width, the higher will be the beating of pulp due to the penetration of liquids into vascular spaces of the fibres (Paschium and de Zeeuww, 1980). The mean values recorded for fibre lumen width of the five stands of *Hura crepitans* in this study implies that the species will be very good during beating up of pulp.

Cell wall thickness

The results reveal that T_2 had the highest 4.60 μm of cell wall thickness and T4 had the lowest 3.29 μm. The results are within the range of 1.94-4.99um reported by Ogunkunle (2010) for Ficus species and 5.00-10.00mm reported for pine by Pulp and Paper Resources and Information, (PPRI, 2011); and 3.96 μm reported by Adeniyi *et al.* (2013) for *Ficus exasperate* but lower than 2.82 μm for *Gmelina arborea* reported by Ogunkunle (2010).

Derived Fibre Morpological Indices of Hura Crepitans (UAM)

Runkel Ratio

Runkel ratio of wood is one property that has been recognized as important trait for pulp and paper properties (Ohshima *et al*., 2005). It is related to paper conformity and pulp yield. Runkel ratio obtained in the study shows that the means of the five stands of *Hura crepitans* are below 1. This may be attributed to genetic factors or agronomic as earlier stated. Bektas *et al*. (1999) stated that higher Runkel ratio gives lower paper strength properties especially lower burst, tear and tensile indexes. This was corroborated by Oluwudare and Egbewole, (2008) who stated that Punkel ratio is closely associated with cell wall thickness and it influence paper strength properties. Runkel ratio should be < I for wood with good quality for pulp production (Kpikpi, 1992). Runkel ratio determines the suitability of a cellulosic material for pulp and paper production. *Hura crepitan* is a suitable raw material for pulp and paper production since it's have Runkel ratio is < I. Runkel ratio is directly affected by cell wall thickness, and not really by lumen diameter (Ona *et al.,* 2001). It is also related to paper conformity, pulp yield and fibre density. High Runkel ratio fibres produce bulkier paper than fibres with low Runkel ratio.

Elasticity Coefficient

Elasticity coefficient is another important criterion for evaluating fibre quality. Elasticity coefficient (flexibility ratio) are classified into four groups of fibres (Bektas *et al.,* 1991) as high elastic fibres having elasticity coefficient greater than 75; elastic fibres with elasticity ratio 50-75; rigid fibres having elasticity ratio less than 30-50 and highly rigid fibres < 30. Going by this classification, elasticity coefficient of *H. crepitans* in this study is within the elastic fibres. As elastic fibres do have efficient elasticity, they are suitable for paper production (Akgul and Tozkiogu, 2009). Elastic fibres can be stretched making it a suitable raw material for paper making in other to get high resistance.

Rigidity coefficient

The values of rigidity coefficient obtained in this study, ranged from (18.11 - 20.91%) for all the five stands of *Hura crepitans*. These mean values are lower than those reported by (Hus *et al.,* 1975) for juvenile beach wood (22.95 %) and 27.66 % for Eucalyptus. High rate of rigidity coefficient affects tensile, tear, burst and double fold resistance of paper negatively (Hus *et al.,* 1975). This implies that these samples are suitable raw materials for pulp and papermaking due to lower rigidity coefficient which will not affect tensile, tear, burst and double fold paper negatively.

Slenderness

One of the criterion that control the suitability of wood material for paper production is slenderness also called feting power calculated by comparing length to diameter of wood fibres (Akgul, 2009), felting power is an important factor which has positive effect on strength, tea, burst, breaking off, double folding resistance according to physical test result of the paper. Felting power required for good paper is between 70 – 90 % for soft woods and 40 – 60 % for hardwoods. The values of felting rate or slenderness obtained in this study ranged from (0.41-0.80) % for all the five stands of *H. crepitans.* Generally, the acceptable value of slenderness for pulp and paper making is more than 33 (xu *et al,* 2006)

Luce's Shape factor

The values of Luce's shape factor of all the five trees of *H. crepitans* ranged from (0.27 - 0.58). Luce's Shape factor is an important fibre index and derived from fibre diameter and lumen diameter. It is directly related to paper sheet density (Sharm *et al*, 2013). Luce's shape factor was found to be related to paper sheet density and could be significantly corrected to breaking length of paper (Ona *et al*., 2001). Similar to Runkel ratio, the trend to variation of Luce's shape factor might be associated with that of wall thickness, because both the fibre diameter and lumen were used to obtain the cross sectional fibre wall area in the equation for Luce's shape factor (Luce 1970). Luce's shape factors for the study conducted by Ogunknle (2010) on *Gmelina arborea*, Ficus mucuso, *Ficus exasprata* were 0.29, 0.25 and 0.16. Ojo (2013) reported Luce's shape factor for *Gmelina arborea, Afzelia african* and *Detarium senegalensis* as 0.2, 0.47, and 0.73 respectively. The results reported by Oluwadare and sotannde (2007) on *Leucaena lencocephala* gave its Luce's shape factor 0.41- unit?.

F Factor

F Factor (%) was found to be related to paper sheet density and could be significantly corrected to breaking length of paper (Ona *et al.*, 2001). The value of F ratio obtained in this study ranged from 16.71-26.16% for all the five trees of *Hura crepitans* F factor for beech Juvenile wood was found as 140.38% for the black pine Juvenile wood (Akgul, 2009), in related studies of hardwoods F factor was found to be 235.92 % for *Populous tremula* (Kar, 2005). It therefore, implies that all the five stands of *Hura crepitans* are not similar to the five juvenile wood and black pine juvenile woods.

Solid Factor

The value of solid factor of the five trees of *H. crepitans* ranged between 261.48-488.84 which is above the range of the value computed from the data reported by other researchers. Ojo (2013) gave solid factor for *Gmelina arborea, Afzelia africana* and *Detarium senegalensis* as 1.5×10^{-4}, 1.0×10^{-4} and 4.1×10^{-4}, respectively. The result reopened by Oluwadere and Sotannde (2007) on L*evcaena lencocephala* gave its solid factor for the study conducted by Ogunkunle (2010) on *Gmelina arborea, Ficus mucuso, Ficus exasperata* were 4.4×10^{-4}, 2.1×10^{-4} and 1.5×10^{-4}. Solid factor was found to be related to paper sheet density and could be significant corrected to breaking length of paper (Ona *et al.,* 2001).

CONCLUSION

This study shows that fibres of *Hura crepitans* are elastic and this will enhance the tensile strength, bursting properties and influence the number of inter-fibre bonds because more flexible fibres have more inter fibre contacts. The study also revealed that *Hura crepitans* fibre are short, and can be used for kraft paper production.

RECOMMENDATIONS

Fibre morphological characteristics of *Hura crepitans* suit pulp and paper production, however blending with long fibre materials will further improve the properties and better paper quality.

Hura crepitans species with Runkel ratio <1(0.36-0.78) is recommended for paper production.

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