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EXAMINATION OF FIBRE CHARACTERISTICS OF *Aningeria robusta* WOOD AND ITS SUITABILITY FOR PAPER PRODUCTION

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Abstract:

Wood is versatile, inexhaustible and renewable. These made the wood an outstanding material used in different domain such as raw material for production of pulp, paper and fibre based products. In Nigeria, one of the problems in pulp and paper industry is inadequate supply of long fibre for paper production. Also, overexploitation of materials having desirable fibre characteristic was observed. Therefore, there is need to research into lesser known wood species so as to ascertain its suitability for paper making. This study presents the potential of Aningeria robusta wood as source for adequate fibres for paper making. Samples of 20x20x20mm were collected from the three trees of Aningeria robusta wood at different position; base (10%), middle (50%) and top (90%) along the merchantable height and prepared into slivers of 3mmx10mm for examination of the fibre characteristics. Thereafter, it was macerated and viewed under microscope. Further morphological indices were calculate accordingly. The mean fibre length, fibre diameter, lumen, cell wall thickness (CWT), slenderness, flexural ratio and runkel ratio were 1.55mm, 11.71µm, 8.78µm, 1.46, 132.12, and 75.07 respectively. Variation of indices along sampling heights were not significant except for CWT. A. robusta has shown good properties and could be added to already known wood species suitable for paper making.

Key words*: A. robusta; cell wall; fibre; paper; Runkel ratio; suitability.*

INTRODUCTION

Wood is a hard, fibrous tissue, which has been used for thousands of years for both domestic and industrial purposes. The composition of wood makes it to be an outstanding material; it is versatile, inexhaustible and renewable. These properties have made wood useful in various ways and forms. Over the decades, the demand for wood and wood products all over the world has continued to increase. (Hickey 2001). Wood has been one of the major basic raw materials for the production of pulp, paper and fibre based products since the beginning of the 19th century, Ogbogu (1996) stated that more than 50% of trees in Nigeria were utilized for construction of beams, purling (stitching, joining), flooring and paneling. A percentage which may have been exceeded. Meanwhile, Paper global consumption is estimated to be 400 million tons per year and expected to increase to 500 million tons by 2020 (Sharma *et al.* 2013).

In Nigeria, one of the problems in pulp and paper industry is inadequate supply of long fibre for paper production (Osadare 1995 and Oluwadare 2007). *Gmelina arborea* wood is the prime source of pulpwood in West Africa and Brazil due to its fair conformity with the qualities of an ideal pulpwood (Ademiluyi and Okeke 1979) and it has been highlighted to have a longer than average fibre length. Also, its plantation is highly advantageous to economic management (Dadswell *et al*. 1959; Dickman 1975; Fuwape 1991).

Fibers of selected softwoods and hardwoods have desirable fiber characteristics for pulp and paper production. Over exploitation of these woods for different purposes has resulted in continuous decline in their supply for pulp and paper production from natural forests (Ashori 2006). For instance, a greater percentage of the *Gmelina* established in Nigeria primarily for paper production have been lost to other economic purposes such as timber, plywood, veneer, fuel wood etc. (Evans 1992). Pressure on known suitable wood species for other economical uses has put pulp and paper production at a disadvantage. Therefore, there is need to promote lesser known wood species as potential resources for papermaking. However, before recommending any wood species for pulp production, the knowledge of the required fibre characteristics is necessary, as well as how its properties will affect its paper performance. Of the lesser-known species in Nigeria, *Aningeria robusta* is fast becoming popular due to its excellent performance in structural applications especially in roofing, and in recent times, door frames and furniture. *Aningeria robusta* belongs to the family Sapotaceae, a hardwood. It is referred to as ‘agengre’ in Cote d’Ivoire, ‘landosan’ in Nigeria and

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'osan' in Uganda (TRADA 1979 cited in Ajala and Ogunsanwo 2011), 'mukali' in Angola, 'mukangu' in Kenya (Chudnoff 1980 cited in Ajala and Ogunsanwo 2011) and 'asafonia' in Ghana (Okai 2003).

OBJECTIVE

The main objective of this study is to examine the fibre characteristics of *Anningeria robusta* wood, with a view of finding its suitability for paper production and additionally the corresponding morphological indices will be calculated.

MATERIALS AND METHOD

Fibre Measurement

The fibre measurements were conducted at Anatomy Laboratory in Forestry Research Institute of Nigeria, Ibadan in accordance with ASTM D1413-48 of 1983 and ASTM D 1413-61 (2007). Samples of 20x20x20mm were collected from the three trees of *Aningeria robusta* wood at various points starting with base (10%), middle (50%) and top (90%) along the merchantable height and prepared into slivers of 3mm x10mm. Maceration of the slivers was carried out using acetic acid and hydrogen peroxide (1:1) and placed in an oven for 2hours at a temperature of 100°C then the solution was vigorously agitated for individual fibres to be separated. The macerated fibres were randomly selected and dropped on a standard slide of 7.5cmx2.5cm using a procedure adopted by Dutt *et al.* (2012). All the characteristics like fibre length, fibre diameter, lumen diameter were viewed under a stage micrometer mounted on a Zeiss light microscope (Standard of 25 fibres) magnification of 80× in wet state. Twenty five (25) fibres were measured from each sample fibre. Thereafter, cell wall thickness was calculated using Eq. 1:

$$Cellwall\ thickness = \frac{Fibre\ diameter - Lumen\ diameter}{2}\ [\mu m] \quad (1)$$

Derived Morphological Indices

Four derived morphological indices (Eqs 2-4) of the fibre were calculated from the measured fibre dimensions based on method adopted by Saika *et al.* (1997); Ogbonnaya *et al.* (1997); Ververis *et al*. (2004); Oluwadare and Sotannde, (2006). These include:

$$Slenderness = \frac{Fibre\ length}{Fibre\ diameter} \quad (2)$$

$$Flexibility\ ratio = \frac{Lumen\ diameter}{Fibre\ diameter} \times \frac{100}{1}\ [\%] \quad (3)$$

$$Runkel\ ratio = \frac{2 \times cellwall\ thickness}{Lumen\ diameter} \quad (4)$$

The experiment was of 3 treatments (Top, Middle and Base) with 3 replicates laid in a completely randomized design, and significant difference was tested at 5% probability level. Descriptive statistic and analysis of variance was used. The mathematical model is thus:

$$Y_{ij} = \mu + T_i + E_{ij} \quad (5)$$

where: *Yij* = Observation;
μ = Mean;
Ti = Treatment (sampling height);
Eij = Error term.

RESULT AND DISCUSSION

The fibre characteristics (fibre length, fibre diameter, lumen diameter and cell wall thickness) of *Anningeria robusta* wood evaluated from base to top and within trees and its derived morphological indices was shown in Table 1 and 2 while Table 3 and 4 shows the analysis of variance done to the results obtained.

The longest fibre was obtained at the middle wood of tree 1 (2.044±0.49mm), and the shortest fibre was obtained at the middle wood of tree 2 (1.34±0.03mm). The pooled mean of fibre length for *A. robusta* obtained was (1.55±0.07mm), thus, greater than 1.29mm for *Gmelina arborea* as reported by Roger *et al.* (2007). According to Anon (1984), mean fibre length of 1.6mm or more are classified as long fibre. Therefore, fibre length of *A. robusta* was considered short owning to its pooled mean value lower than 1.6mm. In similar observation, Kpikpi (1992) reported fibre lengths of less than 1.60mm in some Nigerian hardwood species and Oluwadare (2007) recorded 0.65mm as fibre length of *Leucaena leucocephala*. It was stated by Kaila and Aittamaa (2006) that the length of fibre greatly affects the strength of pulp and the paper made from it. The advantage of a longer fibre for paper making is that it results in greater resistance of the paper to tearing (Oluwadare and Sotande 2007). Notwithstanding, Oluwadare (1998), opined that these results are still of acceptable range for hardwoods for paper making.

An irregular pattern of non-significant variation in fibre length was recorded axially. Which is contrary to Oluwadare and Egbewole (2008), reporting a fibre length significantly ($p<0.05$) decreasing from 2.64mm at the base to 2.36mm at top for *Sterculia setigera* Del**.**

Meanwhile, the fibre diameter recorded a regular pattern that was non-significant along the tree height. It decreased from bottom to the top. However, the widest fibre diameter was obtained at the base wood of tree 1 (12.64±0.63µm) while the shortest fibre diameter was obtained at the top wood of tree 2 (10.67±0.37µm), and the pooled mean was (11.71±0.21µm). This pattern observed in this study was similar with Ogunjobi *et al.* (2014) for wood of *Vitex doniana*. This may be attributed to growth in cell wall which was expected to be more in mature wood than in juvenile wood, as it is dependent on the accumulation of metabolism products (cellulose, hemicelluloses, lignin etc.), which increases with maturity (Fahn 1990).

The observed fibre diameter for *A. robusta* (11.71µm) was lower than *Ricinodendron heudelotii* wood (41.5µm) Ogunleye *et al.* (2017), 30.67µm for *G. arborea* (Roger *et al.* 2007), 36.09 and 34.25µm for *R. racemosa* and *R. harrisonii*, respectively (Emerhi 2012), 29.47µm for 20 years old Teak (Izekor and Fuwape 2011), 21.9µm for *Vitex doniana* (Ogunjobi *et al.* 2014) and 20.3µm for *T. scleroxylon* (Ogunsanwo 2000). Value obtained for *A.robusta* in this study didn't fall within the range recorded for coniferous and commercial pulp woods as reported by Ververis *et al.* (2004).

Similarly, lumen diameters observed was not significantly different at sampling height. However, the widest lumen diameter was obtained at the top wood of tree 3 (10.4±0.24µm) and the shortest lumen diameter recorded at the middle wood of tree 2 (6.67±0.40µm). There was an irregular pattern recorded axially which contradict Ogunleye *et al.* (2017) for *Ricinodendron heudelotii* wood. The pooled mean lumen diameter for *A. robusta* obtained was (8.78±0.38µm). Whereas, cell wall thickness was significant along sampling height while the mean cell wall thickness for *A. robusta* obtained was (1.46±0.17µm).

Lumen diameter has an effect on the pulping process. Larger lumen diameter gives better pulp beating because of the penetration of liquid into empty spaces of the fibres (Emerhi 2012). Value of lumen diameter obtained in this study was lower compared to *Ricinodendron heudelotii* wood (32.3 µm) (Ogunleye *et al.* 2017), 30.67µm for *G. arborea* (Roger *et al.* 2007), 15.60µm for 20 years old Teak (Izekor and Fuwape 2011) and 12.5µm for *T. scleroxylon* (Ogunsanwo 2000), and as such may not aid better pulp beating.

On the contrary, wood with thick cell walls tends to produce paper with a poor printing surface and poor burst strength as thick-walled cells do not bend easily and do not collapse upon pulping, which inhibits chemical bonding (Zobel and van Buijtenen 1989). Whereas, Thinner-walled cells collapse upon pulping, bond well together chemically, and produce a smoother paper surface (Malan 1991). Although, thicker cell wall gives a higher pulp yield and increase in tear resistance, however, thicker wall give coarse, bulky sheets (Joransen 1960). Biermann (1993) also reported that paper made from thick-walled cells resulted in low folding endurance. From the afore-mentioned, lower value recorded for cell wall thickness in this study was considered an advantage, it is by far the lowest value compared to *Ricinodendron heudelotii* wood (4.6µm) (Ogunleye *et al.* 2017), 4.02µm for *G. arborea* (Roger *et al.* 2007), 3.83µm for *G. arborea* (Ogunkunle 2010), 4.9µm for *Vitex doniana* (Ogunjobi *et al.* 2014). Therefore, top wood with the thinner cell wall is considered most suitable.

Morphological Indices

The slenderness ratio calculated for *A. robusta* in this research was 132.12, higher than *R. heudelotii* (35.85) (Ogunleye *et al.* 2017), 50.06 for *G. arborea* and 42.38 to 71.99 found for different Ficus species (Ogunkunle 2010). Along the sampling height, slenderness has an irregular pattern of variation. Ogunleye *et al.* (2017) reported that low slenderness ratio means production of weak paper; hence *A. robusta* wood will produce a stronger paper compared to species mentioned above. Since Ona *et al. (*2001) reported a positive correlation between the slenderness ratio and folding endurance, paper produced from *A. robusta* is expected to have a better folding endurance.

On the other hand, Runkel ratio is also an important trait for pulp and paper properties. Ogunjobi *et al.* (2014) reported that it plays an important role in terms of conformity and pulp yield. In addition, Ogunleye *et al.* (2017) reported that it is a measure of the suitability of fibre for paper production and that Runkel's ratio less than 1 are good for paper making because the fibres are more flexible, and will easily collapse to form a paper with large bonded area. Similarly, Ogunjobi *et al.* (2014) stated that the extent to which the ratio is less than 1 is an indication of suitability of the wood for paper making. Thus, *A.robusta* having a value of 0.35 is considered suitable for paper making. However, there was a non-significant irregular pattern of variation along sampling height.

Meanwhile, flexibility ratio is used to describe the strength properties of a paper, and as such determines the elasticity and degree of fibre bonding. Bektas *et al*. (1999) considered that flexibility ratio between 50% - 75% as good and 75% as excellent. Therefore, *A. robusta* having a mean of 75.07% suggests that it has a high fibre elasticity, and thus will produce a pulp of high strength. Flexibility ratio obtained in this research was higher than *G. arborea* (73%) (Ogunkunle 2010) and compared similarly with *R. heudelotii* (77%) (Ogunleye *et al.* 2017).

Table 1

Axial variation in fibre characteristics of Anningeria robusta wood

Sampling Height		TREE	FL(mm)	FD(μm)	LD(μm)	CWT(μm)
TOP		1	1.73±0.06	11.83±0.22	10.13±0.29	0.85±0.07
		2	1.37±0.03	10.67±0.37	8.16±0.49	1.26±0.08
		3	1.51±0.03	11.48±0.24	10.45±0.25	0.52±0.05
	MEAN		**1.54±0.10**	**11.33±0.34**	**9.58±0.71**	**0.88±0.21**
MIDDLE		1	2.04±0.49	12.21±0.41	8.43±0.52	1.89±0.12
		2	1.34±0.03	10.99±0.33	6.67±0.40	2.16±0.26
		3	1.52±0.05	12.43±0.58	9.60±0.61	1.42±0.28
	MEAN		**1.63±0.21**	**11.88±0.45**	**8.23±0.85**	**1.82±0.22**
BASE		1	1.44±0.16	12.64±0.63	9.12±0.62	1.76±0.02
		2	1.44±0.09	11.41±0.46	8.00±0.31	1.71±0.17
		3	1.54±0.06	11.73±0.31	8.59±0.30	1.57±0.13
	MEAN		**1.47±0.03**	**11.93±0.37**	**8.57±0.32**	**1.68±0.06**
	P. MEAN		**1.55±0.07**	**11.71±0.21**	**8.78±0.38**	**1.46±0.17**

FL – Fibre Length
FD – Fibre Diameter
LD – Lumen Diameter
CWT – Cell Wall Thickness
P. mean – Pooled mean

Table 2

Axial variation of derived morphological indices of Anningeria robusta wood

Sampling Height		TREE	Slenderness	Flexibility Ratio (%)	Runkel Ratio
TOP		1	146.49±6.45	85.63±1.23	0.17±0.02
		2	128.40±3.49	76.48±3.26	0.31±0.07
		3	131.53±3.81	91.03±0.81	0.10±0.01
	MEAN		**135±5.58**	**84.38±0.34**	**0.19±0.06**
MIDDLE		1	167.08±47.60	69.04±3.01	0.45±0.07
		2	121.93±5.17	60.69±4.2	0.65±0.10
		3	122.28±8.33	77.23±3.83	0.30±0.08
	MEAN		**137.10±14.99**	**69.00±4.77**	**0.47±0.10**
BASE		1	113.92±12.85	72.15±3.31	0.39±0.08
		2	126.21±9.74	70.11±2.27	0.43±0.05
		3	131.29±5.21	73.23±2.00	0.37±0.04
	MEAN		**123.81±5.15**	**71.83±0.91**	**0.40±0.01**
	P. MEAN		**132.12±5.28**	**75.07±0.21**	**0.35±0.05**

Table 3

ANOVA of Fibre variation for A.robusta wood

Source of Variation	*SS*	*df*	*MS*	*Ftab*	*Fcal*
FIBRE LENGTH					
Sampling height	0.04	2	0.02	5.14	0.36ns
Error	0.34	6	0.06		
Total	0.38	8			
FIBRE DIAMETER					
Sampling height	0.67	2	0.34	5.14	0.74ns
Error	2.73	6	0.45		
Total	3.40	8			
LUMEN DIAMETER					
Sampling height	3.86	2	1.93	5.14	1.72ns
Error	6.74	6	1.12		
Total	10.60	8			
CELL WALL THICKNESS					
Sampling height	0.90	2	0.45	5.14	6.35*
Error	0.42	6	0.07		
Total	1.32	8			

ns - not significant; * - significant at *Fcal* > *Ftab* (5% probability level).

Table 4

ANOVA morphological indices for A.robusta wood

Source of Variation	*SS*	*df*	*MS*	*Ftab*	*Fcal*
SLENDERNESS					
Sampling height	315.37	2	157.69	5.14	0.59ns
Error	1695.03	6	282.51		
Total	2010.40	8			
FLEXIBILITY RATIO					
Sampling height	402.54	2	201.27	5.14	4.83ns
Error	250.01	6	41.67		
Total	652.55	8			
RUNKEL RATIO					
Sampling height	0.12	2	0.06	5.14	4.20ns
Error	0.08	6	0.01		
Total	0.21	8			

ns - not significant

CONCLUSION

Based on the results obtained concerning fiber characteristics and morphological indices, the following conclusions can be drawn: the fibers of *A. robusta* had excellent characteristics, and as such can be used to complement the conventional choice of species used for paper making.

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