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Morphological Indices of the Fibres of *Terminalia catappa* Linn Wood for Pulp and Paper Production

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ABSTRACT

Fibre morphology is the study of individual fibres within a particular material with a resultant indication of its usefulness for many purposes. The study investigated the fibre morphology of *Terminalia catappa* wood, with a view to determine its suitability for paper making. Two trees were sourced from Kuola area of Apata, Ido Local Government of Oyo State. Samples obtained from base, middle and top of merchantable height and innerwood, middlewood and outerwood. Slivers were obtained from each zone, macerated in the same proportion of hydrogen peroxide and acetic acid at 80^{o}C. Twenty five whole fibres measured within every zonal area for morphological parameters such as diameter, lumen, length, wall thickness and derivatives such as Runkel ratio, flexibility and slenderness. Mean fibre length was 1.07mm, diameter, lumen and fibre wall thickness had 30.41µm, 20.61µm and 4.70µm respectively. Runkel ratio, flexibility and slenderness had 0.50, 67.77 and 35.19 respectively. Values obtained revealed the inherent potentials of *T. catappa* for paper production especially with Runkel ratio (<1) and the flexibility that is more than 50. Values obtained when compared with standard values and those of known paper making timber species like pine is favourable. Based on this study, it is recommended that *T. catappa* is suitable for pulp and paper.

Keyword: Characteristics, Coefficient of suppleness, Runkel ratio, Evaluation, Height

Introduction

Forest products are materials derivable in the forest for utilisation (Belcher, 2005). Wood, the most important forest product has versatile purposes which include wood fuel and construction among others. This phenomenon has lead to the global forests being depleted at an alarming rate. Martin (2011) reported that not less than 4 billion of the trees in the world are felled for the production of paper and allied products. FAO (2010) also estimated an annual forest loss of 7.3 million hectares to production of other items which include paper. Jochem *et al* (2021) reported a global production of not less than 409 and 196million metric tons respectively of paper and virgin pulp in 2018 meaning that the balance came from recovered paper. All over the world, the average quantity of paper and allied products consumed is increasing and has been estimated to be 2% per annum during the past decade (Hetemaki *et al.,* 2013). Globally, the most important wood using sector is the pulp and paper (Jochem *et al*., 2021).

Due to rising in demand of pulp globally, products from the forest should further be explored to increase supply. Forest concessions in the tropics contain different tree species but with wide knowledge gap on their characteristics and uses. However, considering holistic policies on forest management, adequate knowledge about these species should be sought. In an attempt to fill this gap, WWF (2020) opined that market for lesser known tree species (LKTS) must be developed by researching into adequate knowledge on the characteristics and uses of these often overlooked important species.

Terminalia catappa L., a Combretaceae is a large fast-growing deciduous or semi-evergreen lesser known tree species that originated from Asia. It is popularly referred to as almond (UTP, 2023 and Wikipedia, 2023). *T. catappa* is widely cultivated because of the shade it provides. Its fruits are edible while various parts of the tree are used for medicinal purposes (Wikipedia, 2023).

Coniferous softwood trees have fibres length ranging from about 0.5 to 1.5 millimetres which strengthens the paper while deciduous hardwood trees have fibre length ranging from about 2 to 4 millimetres which fill in the sheet and guarantees smoothness and opacity (Britannica, 2023). Paper properties are functions of the source where the sheet is formed and existing relationship between them which the paper structure also influenced greatly. Sampson (2009) opined that fibre characteristics and manufacturing procedures also affect paper structural variability.

With paucity of information on morphological parameters involving *T. catappa* and its pulping potentials, this research therefore evaluated the fibre morphology of *T. catappa,* a LKTS with a view to substituting and consequent utilization for pulp and paper making, thereby take pressure off well- known pulpwood species such as *Gmelina arborea* and *Pinus caribaea.*

Materials and Method

Two stands of *Terminalia catappa* averagely 17 years were obtained from Kuola area of Apata, Ido Local Government of Oyo State. Trees devoid of crookedness and knots, but straight boles were picked since randomisation could not be practised in a free area as the study site. Collection of test materials was done at base, middle and top of the merchantable heights while discs of 2.5cm thick were removed from every zonal area, the central portion was then partitioned into corewood, middlewood and outerwood. Thin wood slices removed from every zonal area macerated in same proportion of hydrogen peroxide and acetic acid for 2 hours at 80^{o}C (ASTM D 1413-61, 2007). They were rinsed in water and twenty five whole fibres were measured from each zone with a caliberated microscope taking into consideration the fibre parameters. Derivatives of fibre morphology indices were also evaluated according to Ververis et al., (2004); Oluwadare and Sotonnde, (2006) and Tutus et al., (2010).

$FT = \frac{FD-LW}{2}$..1

Derivatives of these dimensions were also evaluated thus:

$Runkel\ Ratio = \frac{2F}{LW}$............................2

$Coefficient\ of\ Suppleness = \frac{LW\times 100}{FD}$...........3

$Felting\ Power = \frac{FL}{FD}$. 4

Where,
FL= length (mm), FD= diameter (μm), LW= Lumen (μm) FT= cell thickness (μm).

Study materials were trees (2) sampled radially (3) and along the bole (3) hence a 2 x 3 x 3 factorial.

ANOVA was used to evaluate factors effect; DMRT to indicate significance of parameters evaluated.

Results and Discussion

Fibre morphology evaluated are revealed in Table 1 with fibre length having 1.07mm which decreased slightly from the base towards the tree merchantable height (1.10, 1.10 and 1.00mm). The result is in consonant with the report of Britannica (2023) for hardwood fibres.

San *et al* (2016) also recorded 0.91mm in their work on Green paulownias, which they claimed fell within the range stipulated for hardwoods. Ogunjobi *et al* (2014) reported mean value of 1.48mm on *Vitex doniana*, while 1.5 to 1.6mm was reported on *Ficus mucuso* by Adejoba and Onilude (2012). It should be noted that *Vitex doniana and Ficus mucuso* are uncommon timber species for paper production. Osadare (2001) earlier reported 1.86mm for *Pinus caribaea, a* prominent softwood for paper production. Fibre length increased from the pith towards the peripheral of the species, a pattern earlier reported by Ogunjobi *et al* (2014) and Ajala and Noah (2019) on *Vitex doniana* and *Aningeria robusta* respectively. The effect of radial position was significant on fibre length at 5% probability level (Table 2). The follow up test revealed that the corewood is quite different from both the middlewood and outerwood (Table 3). Low but positive correlation (0.32) was found between fibre length and diameter while strong but positively correlated (0.60) with lumen width.

This means the larger the lumen the greater the bonding, hence, increase in contact area for bonding and this will enhance strength properties of paper from such fibres. However, negative correlation (-0.15) was found between fibre length and wall thickness (Table 4). Fibre length for hardwood species ranged from 0.5 – 1.5mm (Britannica, 2023). The reported value (1.07mm) can be said to be appropriate for paper production.

Table 1: Summary of Results of *T. catappa* Morphology Evaluated

Morphology	Wood Position	Sampling Height			
		Base	Middle	Top	Mean
Length (mm)	Corewood	1.04	1.12	0.89	1.02
	Middlewood	1.15	1.00	1.00	1.05
	Outerwood	1.12	1.18	1.11	1.13
	Average	**1.10**	**1.10**	**1.00**	**1.07**
Diameter (µm)	Corewood	31.09	32.86	27.62	30.52
	Middlewood	29.73	30.22	30.55	30.16
	Outerwood	30.19	30.74	30.71	30.55
	Average	**30.34**	**31.27**	**29.63**	**30.41**
Lumen (µm)	Corewood	19.72	21.71	17.34	19.59
	Middlewood	20.21	21.30	21.81	21.11
	Outerwood	20.89	21.03	21.46	21.12
	Average	**20.27**	**21.34**	**20.20**	**20.61**
Wall Thickness (µm)	Corewood	5.68	5.58	3.23	4.83
	Middlewood	4.76	4.46	4.37	4.53
	Outerwood	4.65	4.86	4.60	4.71
	Average	**5.03**	**5.00**	**4.07**	**4.70**

Table 2: ANOVA for *Terminalia catappa* Fibre Morphology

SV	Df	Length	Diameter	Lumen	Thickness
Tree (Block)	1	2.34ns	1.05ns	1.76ns	2.95ns

Sampling Height (SH)	2	3.01ns	2.41ns	1.91ns	3.21
Radial Position (RP)	2	9.20*	6.87*	8.85*	3.25ns
SH*RP	4	2.23ns	2.74ns	2.69ns	2.60ns
Error	9				
Total	18				

*significant @ 5%

Table 3: Results of Follow up test on Morphology of *Terminalia catappa*

Morphology	Corewood	Middlewood	Outerwood
Fibre Length	1.02a	1.05b	1.13b
Fibre Diameter	30.52b	30.16a	30.56b
Lumen Width	19.59a	21.11b	21.13b

Mean with the same along the same column are not different from one another

Table 4: Correlation matrix of Fibre Dimensions of *Terminalia catappa*

	Length	*Diameter*	*Lumen*	*Cell Wall Thickness*
Length	1			
Diameter	0.32	1		
Lumen	0.66	-0.50	1	
Cell Wall Thickness	0.15	0.89	0.84	1
	ns	ns	ns	

ns- not significant @ 5%

The mean fibre diameter was 30.41µm (Table 1) and had a sinusoidal pattern along and across the bole of the species studied. Previous studies on *Ficus mucoso* by Adejoba and onilude (2012) reported 28.6µm while Noah *et al* (2015) reported 27.79µm on *Gerdenia ternifolia.* However, the pattern observed along the bole by the former was in line with this study but at variance with the latter. Age of trees used, environmental factors and geographical locations might have led to the observed variations in results. There is significant difference in the effect of radial position on the fibre diameter at 5% probability level (Table 2) but the follow up test showed that the corewood is significantly different from the middlewood and the outerwood (Table 3). Fibre diameter had a negative (-0.50) correlation with lumen width (Table 4). Lumen width was 20.61µm; it was inconsistent along the tree stem but increased slightly across it. Similar trend was noticed by Ajala and Noah (2019) with a mean of 16.14µm. The increase in lumen width reported in this study is in consonant with the findings of Adejoba and Onilude (2012). The observed variation could be function of age of trees, sampling intensity and environmental factor. Lumen width is significant at the radial position at 5% probability level (Table 2) but the fibres in the corewood are different from those of the middlewood and outerwood which have close values (Table 3). High and positive correlation was found between lumen width and fibre length (0.66) whereas it was negatively correlated with fibre diameter (-0.50) while high but negative correlation exists with lumen width and fibre wall thickness (-0.84).

Cell wall thickness was 4.70µm; it decreased with increasing sampling height but sinusoidal from the pith outwardly. In the radial direction, inconsistent variation was also observed, but this was at variance with *F. mucoso* where Adejoba and Onilude

(2012) discovered a decreasing trend from the pith backwards while Ajala and Noah (2019) reported a decreasing trend from the corewood outwardly in their work on *Aningeria robusta.* The variation could be traced to age of trees used, sampling intensity and environmental factor among others. A weak and low negative (-0.15) correlation exist between fibre thickness and length while strong and positive (0.89) exist between fibre wall thickness and diameter (Table 3). The relationship between wall thickness and diameter implies that fibre flexibility is increasing and this will result in good web formation and enhanced interfibre bonding, thereby leading to increase in strength properties. However, a strong but negative relationship exists between fibre wall thickness and lumen width (-0.84).

Ohshima *et al.* (2005) opined that for a good paper formation and high pulp yield the Runkel ratio should be less than 1. *T. catappa* had a Runkel ratio of 0.50 (<1) and also agreed with earlier findings by Ajala and Onilude, (2007); Oluwadare and Sotonnde, (2007) and Ajala and Noah (2019) on paper making.

The values reported for the study compare favourably well with species that have long being used for paper making (Table 5). Oluwadare and Sotonnde, (2007) disclosed that collapsibility and flexibility of fibres for web conformity depends on fibre wall thickness. This texture is reflective in the coefficient of suppleness and slenderness of *T. catappa* which are 67.77 and 35.19 respectively. Moreover, Ogbonnaya *et al.* (1992) and Noah *et al.,* (2015) noted that flexibility of =50 is vital and also improves paper strength.

Table 5: Mean Fibre Dimension of *Terminalia catappa* in Comparison with Popular Paper Species

Fibre Characteristics	*Terminalia catappa**	*Gmelina arborea***	*Pinus caribaea****
Fibre Length (mm)	1.07	1.24 - 1.38	2.4
Fibre Diameter (µm)	30.41	21.47 - 22.76	45 - 47
Lumen width (µm)	20.61	25.66 - 26. 19	36 - 37
Cell Thickness (µm)	4.70	2.43 – 2.91	4 - 6
Runkel Ratio	0.50	0.80 – 1.03	0.74 - 0.81
Coefficient of Suppleness (Flexibility)	67.77	NA	74.0 - 82.0
Felting Power (Slenderness)	35.19	57.75 – 60. 63	42 – 53

*Current Study, **Palmer *et al.* (1984), ***FAO (1975)

Conclusion and Recommendations

Values obtained for *T. catappa* are in agreement with standard values and known timber species for the production of paper though, inconsistent variation were noticed in all the parameters studied. Sampling along the bole was not significant at all but, across it was significant at 5% probability level for all the parameters tested except cell wall thickness. Taking a clue from the flexibility of 67.77 (> 50) and the Runkel ratio of 0.50 (< 1), *T. catappa* has satisfied the conditions required to make it suitable for pulping. However, the wood of *Taminalia catappa* should be subjected to convectional chemical pulping to ascertain its pulpability. Also, blending of its pulp with the likes of pine is recommended while establishment of its plantation will boost its utilization potential.

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