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Vertical and Horizontal Cell Structural Appraisal of a 9-Year *Cedrela odorata* L. (*Miliaceae*) for Pulp and Paper Making

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ABSTRACT

Paper is a material of importance in human life and produced from wood. However, is not all wood that have the qualities to be used for paper production. This study assesses the suitability of a 9-year old *Cedrela odorata* wood in both vertical (bottom to top) and horizontal (sapwood to heartwood) directions for pulp and paper making. Specifically, we evaluated the variations in fibre dimensions and other derived technical requirements needed for wood to be used for paper production. Franklin's maceration process was adopted for the study. Collected data was subjected to statistical analysis using IBM Statistical Package for Social Sciences (SPSS) version 17.00. Mean fibre length was found to be short (i.e., ranged from 0.822 ± 0.142 mm – top heartwood to 1.142 ± 0.144 mm –base heartwood) which were all less than 1.6mm (1600µm). Runkel ratio was highest in top heartwood (0.26 ± 0.08); Flexibility Coefficient was highest in bottom sapwood (0.83 ± 0.05); and Slenderness Ratio was highest in bottom sapwood (49.18 ± 10.42). The derived fibre values were all within acceptable standard ranges for wood to be used for paper production: runkel ratio <1.0, Coefficient of Flexibility >75%, and slenderness ratio >33 indicating that the 9-year old *Cedrela odorata* hardwood in Ghana is a potential species to be used to produce pulp and paper of desired qualities, especially when it is mixed with other long fibre wood species. Thus, the 9-year fast grown *Cedrela* wood species is recommended for consideration among other known species for paper manufacturing in Ghana and elsewhere.

KEYWORDS: Ghana Paper; Wood fibres; Wood maceration; *Cedrela odorata*; Runkel ratio

INTRODUCTION

Wood products especially fibre is reported to be one major

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product recognized in the socio-economic development in forest-based industries across the world on account of their applications in the pulp and paper industries [1]. This recognition is also emphasized by the important role papers play in the lives of human beings in the areas of human and environmental sanitation, communication and Secretaryship, mother care, health care etc. However, in recent times, inadequate fibre has been identified as one of the major challenges facing the pulp and paper industries [2]. Though paper is made from wood, it is not all wood species that have the fibres which Conform to the desired qualities to be accepted for pulp and paper production.

For a wood species to be classified as a material for pulp and paper, its growth rate should be rapid for economical plantation management, the fibre it produces should be longer than average fibre length, the runkel ratio of the fibres should be less than 1, it should have low basic density, low ash content and low chemical extractives [3]. Thus, it is said that the quality of pulp and paper products is contingent on the morphology of the fibres and the chemical composition of the wood species [4]. Additional qualities of importance for considerations are that the species should have straight boles which aid debarking, and high fibre to non-fibrouis tissue ratio [5]. Thus, it is always important that more and more wood species are assessed in terms of the qualities expected of a potential pulpwood in order to recommend such species to augment the supply of fibre for the pulp and paper industry.

For some years now, *Cedrela odorata* species, a member here of the family *Meliaceae* has been planted in plantation forests in most regions of Ghana [6]. However, studies on the morphology (i.e., the anatomical cells characteristics) of the species in Ghana, especially in relation to vertical and horizontal variations and directed towards evaluation for paper production are either limited or unavailable. It is in this light that our present study focused on the variations in some anatomical characteristics of a 9-year *C. odorata*, at different vertical (bottom to top) and horizontal (sapwood to Heartwood) positions to ascertain the species' suitability for pulp and paper production.

EXPERIMENTAL PROCEDURE

Sampling site and Sampling

A total of five 9-year old *Cedrela odorata* trees were felled, extracted from Tano-Offin reserve, and processed. This reserve is the largest among four in the Atwima Mponua District of Ghana, and it has the following descriptions (Table 1).

Table 1: Description of site where samples of 9-yr. *Cedrela odorata* trees were extracted.

Vegetation	Temperature	Average Humidity	Average Precipitation	Geology
Semi-deciduous with diverse flora and fauna of different species (MOFA, 2020)	From 22.0°C to 31.1°C and averaging 27°C (MOFA, 2020; Forestry Commission, 2007)	Monthly = 80%	1700mm to 1850mm (March to May); 1000 – 1250 (August to November) though erratic and unpredictable (MOFA, 2020)	Elongated mountainous range (including Aya Bepo -Tributaries for Tano and offin rivers) with numerous steep slopes. Elevation is between 200m and 740m above sea level (MOFA, 2020; Birdlige International, 2011)

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The felled and extracted trees were conveyed in boules and processed to boards of varied dimensions and in accordance with their tree positions (Bottom sapwood, Bottom heartwood, Top sapwood, and Top heartwood). These boules were air-dried to 14±2%MC and finally prepared to dimensions of 2cm square. For each of the 5 *C. odorata* trees, eight samples were extracted (i.e., 2 top sapwood + 2 top heartwood + 2 bottom sapwood + 2 bottom heartwood) and made a total of Forty.

Matchstick sizes of each of the final samples were extracted for tissue maceration using Franklin's method where the samples were boiled for 5 minutes in concentrated Nitric acid (HNO3) to which a few crystals of potassium chlorate (KClO3) had been added. After teasing the macerates in glycerol, the fibre morphological measurements were taking (Figure 1) using Image J software (National Institute of Health, Bethesda, MD, USA).

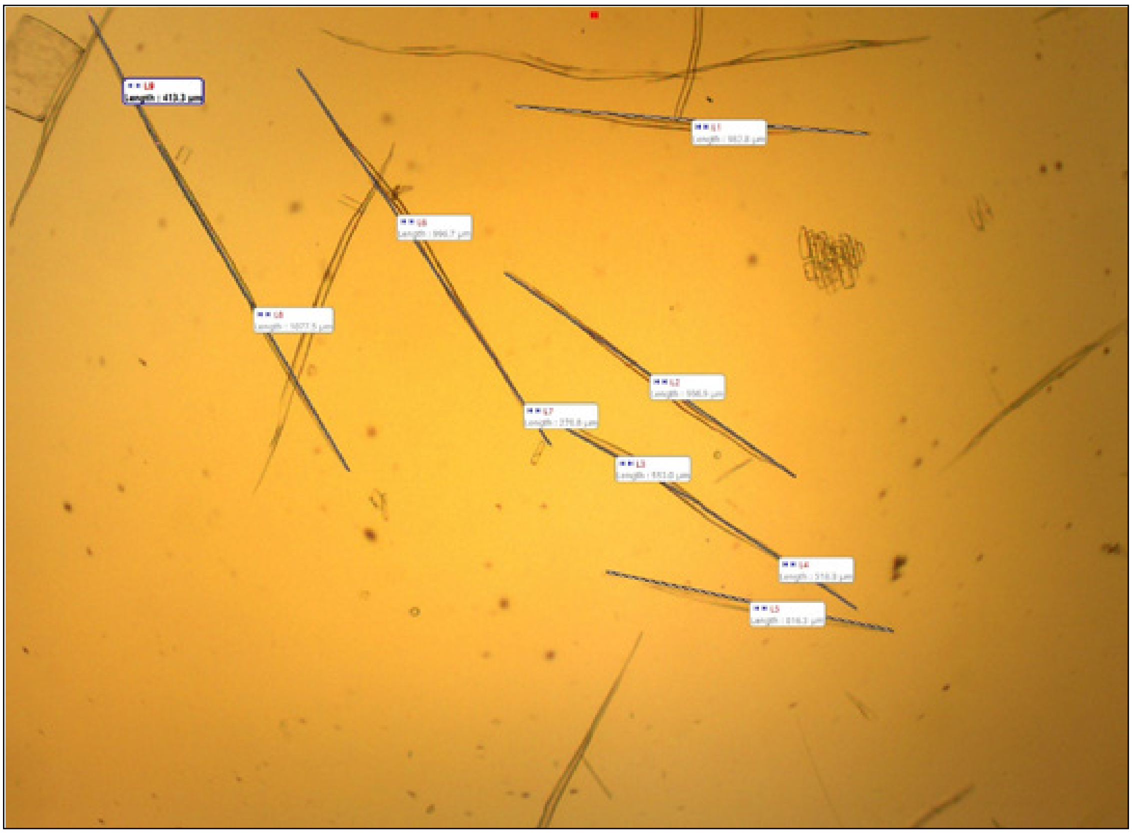

Figure 1: Picture showing the fibres and how fibre lengths were measured. Scale bar = 100µm.

The parameters measured in micrometers (µm) included the fibre lengh (FL), fibre diameter (FD), fibre cell wall thickness (FWT) and fibre lumen diameter (FLD). Also, the derived characteristics associated with pulp and paper properties were also estimated as expressed in the following standard relations (equations 1-3):

$$Runkel\ ratio\ (RR) = (2\ x\ FWT)/FL \quad \text{--------------------} \quad (1)$$

$$Flexibility\ Coefficient\ (FC) = FLD/FD \quad \text{----------------} \quad (2)$$

$$Slenderness\ Ratio\ (SR) = FL/FD \quad \text{-------------------------} \quad (3)$$

Where FL is the fibre length (µm); FWT is the fibre wall thickness (µm); FD is the fibre diameter (µm); and FLD is the fiber lumen diameter (µm).

STATISTICAL ANALYSIS

Data collected were subjected to Student's T-test (with SPSS 17.0) to ascertain whether or not there are significant differences between the obtained values (vertical and horizontal samples).

RESULTS AND DISCUSSIONS

Variations in Fibre Morphological Characteristics

At 5% significance level, indicate vertical (bottom to top) variations of fibre morphological characteristics were more significant (generally $P<0.01$) compared to horizontal (sapwood to heartwood) which appears dependent on cell type with irregular trend (Table 2).

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Table 2 : Descriptive Statistics and T-Test of Variations in Fibre morphological characteristics of 9 yr. *C. odorata*.

Fibre Morphological features		9 yrs Tree		T-Value	P-Value
		Bottom (SD)	Top (SD)		
Fibre length (µm)	SW	1138.54 (139.43)	1084.30 (189.66)	7.209	.000
	HW	1142.24 (144.52)	822.29 (142.32)	6.278	.000
	T-Value	-0.130 ns	7.813 ***		
Fibre diameter (µm)	SW	23.85(4.31)	27.31 (5.78)	-5.412	.000
	HW	24.83 (4.34)	21.53 (2.96)	-2.736	.007
	T-Value	-1.135 ns	6.288 ***		
Fibre lumen diameter (µm)	SW	19.85 (4.37)	22.25 (5.61)	-3.728	.000
	HW	19.97 (4.04)	21.53 (2.96)	-2.154	.034
	T-Value	-0.140 ns	5.434 ***		
Double fibre wall thickness (µm)	SW	4.00 (0.94)	5.06 (1.32)	4.030	.000
	HW	4.86 (1.50)	4.15 (1.05)	7.619	.000
	T-Value	-3.459 ***	3.853 ***		

Note: *** = P<0.01; ** = P<0.05; * = P<0.1 and ns = P>0.1). SW = Sapwood, and HW = Heartwood

The results show that whereas almost all fiber dimensions exhibited increases from sapwood to heartwood (horizontal variations) for bottom samples the opposite was the case for top samples. However, variations of the fiber dimensions from bottom to top (vertical variations) appear to have irregular pattern. These corroborate findings of *Anoop, et al.* [7] (2014) who observed similar trend. It is reported that, wood fibres of lengths above 1.6mm (1600.00 µm) are considered to be long fibres [8]. It could therefore be said from this present study that, *Cedrela odorata* has short fibres with fibre lengths ranging from 0.822 µm to 1.142 µm – Table 2).

Long fibres have been found to produce paper with higher tear resistance [8,9]. Therefore, *C. odorata* papers may have low resistance to tearing, but the short fibres also tend to produce fine sheet structured paper [10]. Hence, though *C. odorata* may not produce papers of high tensile strength but it will produce papers of fine structure. Findings also indicate that, some grades of printing and writing papers need a mixture of both short and long fibres together in order to yield good printability and opacity [2].

From the foregoing, at least, the *C. odorata* wood (short fibre wood) could be mixed with some other wood with long fibres so as to produce papers of a better improved qualities.

Variations in some Derived Values

Results indicated that, variations in both vertical and horizontal samples exhibited little significance (p<0.05) with horizontal samples at the top not showing any significant variations (p>0.1) in any derived value (Table 3).

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Table 3: Descriptive Statistics and T-Test of Variations in some derived values of 9 yr. *Cedrela odorata* (L.) fibres.

Parameter		9- years old *C. odorata*		T-Value	P-Value
		Bottom (SD)	Top (SD)		
Runkel ratio (RR)	Sapwood	0.21 (0.07)	0.24 (0.10)	-0.894	0.421
	Heartwood	0.25 (0.09)	0.26 (0.08)	-0.113	0.518
	T-Value	0.064 **	- 0.106 ns		
Flexibility coefficient (FC)	Sapwood	0.83 (0.05)	0.81 (0.06)	0.833	0.317
	Heartwood	0.80 (0.06)	0.79 (0.05)	0.321	0.430
	T-Value	0.148 **	0.238 ns		
Slenderness ratio (SR)	Sapwood	49.18 (10.42)	41.69 (12.83)	2.009	0.003
	Heartwood	47.19 (9.57)	38.98 (9.90)	4.398	0.002
	T-Value	0.994 ns	1.181 ns		

Note: *** = P<0.01; ** =P<0.05; * = P<0.1 and ns = P>0.1).

The current study found that; Runkel ratio (RR) ranged from 0.21 (Bottom sapwood) to 0.26 (Top Heartwood), Flexibility Coefficient ranged from 0.79 (Bottom Heartwood) to 0.83 (Bottom Sapwood), whereas Slenderness Ratio (SR) ranged from 38.98 (Top Heartwood) to 49.18 (Bottom Sapwood).

Generally, according to the standards, RR should be <1 and is considered most suitable for producing paper with desirable qualities. Fibres that have FC ranging from 0.50 to 0.75+ are also considered to be highly elastic. Such are the desired qualities of wood species suitable for paper making, especially paper of good tensile and bursting strengths [1,11]. SR should be >33 to be able to produce paper with acceptable qualities [12,13]. Hence, the SR range of 38 -49 for *C. odorata* (Table 3) is also a favourable indicator that the 9-yrs tree fibres are better materials to produce paper of good quality.

CONCLUSIONS AND RECOMMENDATIONS

From the foregoing analysis and discussions, we conclude and recommend that 9-year *C. odorata* wood species in Ghana is a potentially good material to produce paper of desired qualities. There appears to be varied consistencies in vertical (from bottom to top) and horizontal (from sapwood to heartwood) in fibre morphological differences in the 9-year old *Cedrela* wood. We however recommend further studies into the chemical consumption during cooking and other properties of the species for better informed decision on the 9-yr *C. odorata*, in terms of its use for commercial paper production in Ghana and elsewhere.

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