ASSESSMENT OF VARIATION IN THE FIBRE CHARACTERISTICS OF THE WOOD OF *VITEX DONIANA* SWEET AND ITS SUITABILITY FOR PAPER PRODUCTION.

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ABSTRACT

The study investigated the fibre characteristics and chemical composition of Vitex doniana towards determining its potentials for pulp and paper. Fibre dimensions are of great importance because of the strong correlation between it and the strength properties of wood and paper. Axial and radial examinations of fibre characteristics of naturally grown wood of Vitex doniana were investigated to determine its suitability for paper production. Wood slivers were prepared from slices, introduced into wash bottles containing equal volume (1:1) of glacial acetic acid and 30% hydrogen peroxide and investigated on a Rheichert Visopam microscope. Variations existed in the axial and radial direction of the wood. The mean values of fibre characteristics are: fibre length (1.48mm), fibre diameter (21.9µm), fibre lumen width (12.7µm) and fibre wall thickness of Vitex doniana was 4.9µ. The mean lignin, cellulose and extractive contents were 28.1%, 41.2% and 3.5% respectively. Based on the derived values: Slenderness ratio, flexibility coefficient and Runkel ratio, species of Vitex doniana were considered to be good paper making materials.

Key Words: Fibre dimensions, axial variation, radial variation, *Vitex doniana*, lesser known wood species.

INTRODUCTION

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. There is an alarming increase in the global paper making fibre consumption as the world paper consumption which was about 300 million Tons in 1996/1997 is expected to rise above 400 million (Hurter and Riccio, 1998). 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* Roxb 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). Gmelina is known to exhibit rapid growth rate which is highly advantageous for economic plantation management; has longer than average fibre length; Runkel ratio of less than 1, low basic density, low ash content and low chemical extractives (Dadswell *et al*., 1959; Dickman, 1975; Fuwape, 1991). Due to the suitability of the properties of Gmelina for paper production, plantations of Gmelina were established to produce raw materials for the paper mills. However, 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, fuelwood etc. (Evans, 1992) . Based on the established pulping attributes of Gmelina, it has become a reference point for workers who collect pulp and paper based data on tropical woody species. With the increasing demand of materials for paper making, increasing the range of raw materials is a central component of current efforts to increase fibre supply (Markets Initiative, 2007) . It has therefore become imperative to screen lesser known wood species for potential in papermaking. *Vitex doniana* is a medium-sized deciduous lesser known tree which is about 8-18 m high. It has a heavy rounded crown and a clear bole up to 5 m. The bark is rough, pale brown or greyish-white, rather smooth with narrow vertical fissures. The bases of old trees have oblong scales.

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 Runkel ratio) exhibit an important relationship with the mechanical strength of pulp and paper. According to Horn (1978), increase in raw materials fibre length enhances the tearing strength of hardwood pulps. Several investigations found that extensibility of the binding sites is a function of the fibre length (Horn 1974 and Wangaard,1973). Fibre characteristics vary extensively and to a large extent exhibit influences on bulk density, fibre strength and inter-fibre bonding (Dinwoodie, 2000). Since the papermaking 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, lignin and cellulose content of wood of *Vitex doniana* and estimate the suitability of the wood for paper production using various indices.

MATERIALS AND METHODS

Plant materials

Four trees of *Vitex doniana* were obtained from free area of Olokemeji Forest Reserve which is situated between Latitude 7º25´N to 7º39´ and Longitude 3º 44´ in Odeda Local Government Area, Ogun State, Nigeria. Bolts of 50cm long were marked and cross- cut at six different positions along the merchantable length of each of the trees. These were (50cm above the ground) at the base and at 10%, 30%, 50%, 70% and 90% of merchantable height. The bolts were labeled 'UP' and 'LP' representing the upper and lower portions of the test materials. The radial strips along the four directional planes of the surface of the bolts were created and partitioned into three zones based on the relative distance from the pith. Ring numbers 1-10 were categorized as corewood, 11-20 as middlewood and 21 – 30 as outerwood zone. The number of rings decreased vertically with corresponding increase in the width of rings which ensured effective partitioning of the wood into corewwood, middlewood and outerwood as carried out by Shupe *et al*, 1995.

Fibre Dimensions

The procedure of Franklin (1945) as reported by Oluwadare (2006) was adopted. Wood slivers were prepared from slices, introduced into wash bottles containing equal volume (1:1) of 10% glacial acetic acid and 30% hydrogen peroxide. The silvers were later boiled in the oven for 16 h at 105 ºC when they were bleached white and soft. The chemical mixture was decanted and macerated fibres washed in cold water and defibrised with glass beads to separate the fibres. The fibres were later aligned on a slide and measured at × 8 and × 10 magnification using Rheichert Visopam microscope. Bias of selecting only longer fibre was eliminated by using the procedure of Andrew and Prentis (1979). Twenty fibres were measured from each growth ring for fibre length (L), fibre diameter (D), Lumen width (d) and cell wall thickness (cw).

Derived values

From the fibre dimensions, three derived values were determined; slenderness ratio as fibre length / fibre diameter, flexibility coefficient as (fibre lumen diameter / fibre diameter) × 100 and Runkel ratio as (2 × fibre cell wall thickness)/ lumen diameter (Saikia *et al*.,1997; Ogbonnaya *et al*., 1997). The values were then compared to standards for those of softwoods and hardwoods and related to that of *Gmelina arborea* which is the reference material in determining the suitability of a material for pulp and paper making (PPM) (Anon, 1984 and Fuwape, 1991).

Chemical Composition

The axial and radial variation in the proportion of cellulose, lignin and extractive contents of wood of *Vitex doniana* were determined by the ASTM standard methods (ASTM, 1977).

RESULTS AND DISCUSSION

Fibre Dimensions

Variations existed in fibre dimensions both radially and axially (Table 1 and Table 2). Mean fibre length was 1. 48mm. An irregular pattern of variation was recorded axially while fibre length increased linearly from corewood to outerwood. *Vitex doniana* exhibit short fibre length since the mean fibre length was lower than 1.60mm as fibre below 1.60mm are classified as short while those above 1.60mm are said to be long (Metcalfe and Chalk 1983, Anon, 1984). In similar observation, Kpikpi and Olatunji (1990), Kpikpi (1992) and Uju Ugowoke (1997) reported fibre lengths of less than 1.60mm in some Nigerian hardwood species. Oluwadare (2007) recorded 0.65mm as fibre length of *Leucaena leucocephala*. Similar fibre length ranges of 1.50 to 2.9mm and 1.46 to 2.91mm were recorded for bamboos in Sudan and Thailand respectively (Khristova *et al* 2005 and Nitisoravut *et al,* 2007) . According to Oluwadare, (1998), these values are of acceptable range for hardwoods for paper making. The fibre diameter recorded a regular pattern both along and across the wood. It decreased from bottom to the top, probably due to a similar decrease in cell wall thickness.

This can be attributed to the fact that the cell wall growth is dependent on the accumulation of metabolism products (cellulose, hemicelluloses, lignin etc), which increases with maturity (Fahn, 1990; Vallet *et al*., 1996). In most cases, differences in fibre dimensions were not statistically significant both axially and radially. Mean fibre diameter was 21.9 µ and falls within the range recorded for coniferous and commercial pulp woods (Hammet *et al*, 2001, Ververis *et al* 2004). Mean lumen width and fibre wall thickness were 12.7 µm and 4.9 µm respectively.

Table 1: Axial variation in fibre characteristics

Tree (T)	Sampling Height (H)	Fibre Length (FL) (mm)	Fibre Diameter (FD) (µm)	Fibre Lumen Width (FLW) (µm)	Fibre Wall Thickness (FWL)(µm)
A	10.00%	1.64 ± 0.14	22.93 ± 2.00	12.80 ± 0.30	4.87 ± 1.46
	50.00%	1.48 ± 0.13	21.73 ± 2.33	11.97 ± 1.45	4.63 ± 1.66
	90.00%	1.43 ± 0.14	20.10 ± 0.89	13.13 ± 1.50	4.23 ± 1.72
	Butt	1.50 ± 0.20	23.70 ± 2.18	12.83 ± 1.88	5.30 ± 1.51
B	10.00%	1.52 ± 0.14	22.57 ± 2.05	12.57 ± 0.51	5.03 ± 1.46
	50.00%	1.41 ± 0.13	21.60 ± 2.79	11.67 ± 1.33	4.87 ± 1.70
	90.00%	1.36 ± 0.14	19.60 ± 0.89	13.03 ± 1.60	4.47 ± 1.78
	Butt	1.27 ± 0.15	23.30 ± 2.18	12.70 ± 1.83	5.40 ± 1.61
C	10.00%	1.52 ± 0.14	22.30 ± 1.81	12.83 ± 0.40	4.97 ± 1.66
	50.00%	1.46 ± 0.13	21.30 ± 2.54	12.00 ± 1.40	4.73 ± 1.81
	90.00%	1.41 ± 0.14	19.40 ± 0.89	13.20 ± 1.35	4.30 ± 1.87
	Butt	1.40 ± 0.20	23.03 ± 1.89	12.90 ± 1.83	5.40 ± 1.71
D	10.00%	1.62 ± 0.14	22.73 ± 2.15	13.07 ± 0.35	5.13 ± 1.46
	50.00%	1.45 ± 0.13	21.70 ± 2.88	12.20 ± 1.40	4.93 ± 1.66
	90.00%	1.40 ± 0.14	19.70 ± 0.89	13.53 ± 1.17	4.57 ± 1.72
	Butt	1.43 ± 0.25	23.57 ± 2.47	13.10 ± 1.83	5.50 ± 1.61

Table 2 : Radial Variation in fibre dimensions.

Tree (T)	Radial Position	Fibre Length (FL) (mm)	Fibre Diameter (FD) (µm)	Fibre Lumen Width (FLW)(µm)	Fibre Wall Thickness (FWL) (µm)
A	Corewood	1.35 ± 0.10	20.65 ± 1.20	13.73 ± 1.31	3.25 ± 0.55
	Middlewood	1.57 ± 0.14	21.55 ± 1.55	12.00 ± 1.32	4.63 ± 0.51
	Outerwood	1.62 ± 0.07	24.15 ± 2.17	12.33 ± 0.61	6.40 ± 0.36
B	Corewood	1.23 ± 0.11	20.23 ± 1.24	13.38 ± 1.59	3.40 ± 0.48
	Middlewood	1.45 ± 0.14	21.13 ± 1.59	11.90 ± 1.32	4.78 ± 0.48
	Outerwood	1.49 ± 0.07	23.95 ± 2.29	12.20 ± 0.65	6.65 ± 0.31
C	Corewood	1.29 ± 0.08	20.08 ± 1.29	13.65 ± 1.34	3.15 ± 0.55
	Middlewood	1.50 ± 0.11	21.00 ± 1.63	12.10 ± 1.32	4.75 ± 0.53
	Outerwood	1.56 ± 0.03	23.45 ± 2.10	12.45 ± 0.58	6.65 ± 0.40
D	Corewood	1.31 ± 0.12	20.30 ± 1.25	13.88 ± 1.31	3.50 ± 0.48
	Middlewood	1.52 ± 0.16	21.23 ± 1.59	12.30 ± 1.32	4.90 ± 0.43
	Outerwood	1.60 ± 0.08	24.25 ± 2.46	12.75 ± 0.48	6.70 ± 0.36

Derived Values

Runkel ratio is an important trait for pulp and paper properties in terms of conformity and pulp yield (Ohshima *et al.* 2005) The runkel ratio both across and along the wood varied. The extent to which the ratio is less than 1 is an indication of suitability of the wood for paper making. The lower this value, the thinner the fibre walls and the better are the fibres for paper making (Kpikpi and Olatunji 1990). Since all the values obtained along the wood are less than 1, good pulp and paper making resources could be obtained from the wood. The outerwood which recorded higher Runkel ratio though still within accepatable limit would produce porous papers (Iwenofu, 1979). Radially, high values of runkel ratio were obtained at the outerwood. The values of the runkel ratio is within the range of 0.99 recorded for *Anthonatha macrophylia* and *Dalium guinensis* (Ezeibekwe *et al.*

2009) but higher than those recorded for Gmelina (0.28) and Ficus spp (0.68) (Ogunkunle,2010). The potentials of *Vitex doniana* for paper making is further established by the results of its mean fibre flexibility coefficients both along and across the wood. The mean flexibility ratio compares favourably with what was reported for Leucocephala (0.63) (Oluwadare and Ashimiyu ,2007), 0.79 reported for Gmelina and the range of 0.63-0.79 for some Nigerian *Ficus species* (Ogunkunle and Oladele, 2008; Ogunkunle, 2010). The wood of *Vitex doniana* exhibited long bark fibres which have good derived values. Therefore, paper from midlewood and outerwood are expected to have increased mechanical strength and thus suitable for writing, printing, wrapping and packaging purposes (Saikia *et al*; 1997, Neto *et al*, 1996) . Core fibres on the other hand are shorter and thicker producing a poor slenderness ratio, which in turn reduces tearing resistance dramatically. This is partly because short and thick fibres do not produce good surface contact and fibre –to- fibre bonding (Ogbonnaya *et al*, 1997). The core fibres still has a good Runkel ratio which can complement the mechanical strength of the bark fibres (Khristova *et al*, 1998). It could be deduced that the entire wood of *Vitex doniana* could be harvested for pulping good quality and strength. Based on the values which compare favourably with known species, *Vitex, doniana* , a lesser known species can be said to be an alternative source of wood for paper making.

Table 3: Axial variation in Derived values.

Tree (T)	Sampling Height (H)	Slenderness Ratio	Flexibility Coefficient	Runkel Ratio
A	10.00%	71.5	55.8148	0.7605
	50.00%	68.1	55.0775	0.7741
	90.00%	71.1	65.3234	0.6448
	Butt	63.3	54.1350	0.8262
B	10.00%	67.4	55.7008	0.8008
	50.00%	65.3	54.0278	0.8341
	90.00%	69.4	66.4796	0.6856
	Butt	54.4	54.5064	0.8504
C	10.00%	68.2	57.5336	0.7743
	50.00%	68.5	56.3380	0.7888
	90.00%	72.7	68.0412	0.6515
	Butt	60.8	56.0066	0.8372
D	10.00%	71.3	57.4935	0.7855
	50.00%	66.8	56.2212	0.8087
	90.00%	71.1	68.6802	0.6751
	Butt	60.8	55.5862	0.8397
Pooled	10.00%	69.6	56.6357	0.7803
	50.00%	67.2	55.4161	0.8014
	90.00%	71.1	67.1311	0.6643
	Butt	59.8	55.0586	0.8384
		55-75	**55-70**	**0.4-0.7**

Table 4: Radial Variation in Derived Values

Tree (T)	Radial Position	Slenderness Ratio	Flexibility Coefficient	Runkel Ratio
A	Corewood	65.4	66.4891	0.4734
	Middlewood	72.8	55.6845	0.7708
	Outerwood	67.1	51.0559	1.0381
B	Corewood	60.8	66.1557	0.5082
	Middlewood	68.5	56.3314	0.8025
	Outerwood	62.2	50.9395	1.0902
C	Corewood	64.0	67.9950	0.4615
	Middlewood	71.6	57.6190	0.7851
	Outerwood	66.3	53.0917	1.0683
D	Corewood	64.3	68.3744	0.5043
	Middlewood	71.8	57.9505	0.7967
	Outerwood	66.0	52.5773	1.0510
Pooled	Corewood	63.6	67.2536	0.4869
	Middlewood	71.2	56.8964	0.7888
	Outerwood	65.4	51.9161	1.0619
Hardwoods		**55-75**	**55-70**	**0.4-0.7**

Chemical Properties of *Vitex doniana*

Table 5 shows the results of the three chemical properties of *Vitex doniana* that were analysed (cellulose, lignin and extractive content). Mean cellulose content was 41.2%. Vertically, cellulose content was minimum at 90% MH and increased steadily from the corewood to the middlewood and then decreased. This pattern of variation may be due to the masking effects of some other components of the wood. Cellulose content has a great impact on the end use of wood. Materials with cellulose content ranging from 34% and above are considered as promising for pulp and paper manufacture (Nieschlag *et al* 1960) and *Vitex doniana* with 41.2% exhibited potentials to generate moderately high pulp. Mean lignin content (28.1%) was also within satisfactory level (<30%). The lignin content decreased linearly from the butt to 90% MH. This pattern may be as a result of extent of development and maturation of the cells. This inference is based on the premise that wood maturation is higher at the lower portion of the wood than at the crown region. It follows that lignification which protects the structural integrity of the wood is more at the butt than at the crown region. The lignin content decreased linearly from the corewood to the outerwood. The value of lignin content indicates that milder conditions of pulping will be required to obtain a satisfactory Kappa number. This implies that bleaching will be at a faster rate and fewer chemicals will be utilized (Saika *et al*, 1997). Mean value for the extractive content of *Vitex doniana* was 3.5%. The variation in the extractive content in wood of *Vitex doniana* followed a similar pattern with the variation in the lignin content. Linear decrease observed in this study is common to most hardwoods (Anderson, 1961, Akpofure, 1992 and Ogunsanwo, 2006). There was no conspicuous demarcation between the sapwood and heartwood of *Vitex doniana*. Hence, there was no colour differentiation. However, with the high concentration of extractive content in the outerwood, it shows that the heartwood of *Vitex doniana* contained some active components which used up all the food materials in the region.

Table 5: Summary of values of chemical properties of wood of *Vitex doniana*

Wood Property	Tree	Mean ± S.E.	Radial Position	Mean ± S.E.	Sampling Height	Mean ± S.E.
Cellulose Content	A	40.608 ± 0.421[a]	Corewood	40.525 ± 0.365[a]	10%	42.033 ± 0.421[a]
	B	41.383 ± 0.421[a]	Middlewood	41.813 ± 0.365[b]	50%	43.217 ± 0.421[a]
	C	41.417 ± 0.421[a]	Outerwood	41.300 ± 0.365[ab]	90%	39.000 ± 0.421[b]
	D	41.442 ± 0.421[a]			Butt	40.600 ± 0.421[c]
Lignin Content	A	33.867 ± 0.779[a]	Corewood	29.925 ± 0.675[a]	10%	27.800 ± 0.779[a]
	B	31.342 ± 0.779[b]	Middlewood	28.125 ± 0.675[ab]	50%	27.158 ± 0.779[a]
	C	23.042 ± 0.779[c]	Outerwood	26.581 ± 0.675[b]	90%	25.617 ± 0.779[a]
	D	24.592 ± 0.779[c]			Butt	32.267 ± 0.779[b]
Extractive Content	A	4.152 ± 0.270[a]	Corewood	2.177 ± 0.234[a]	10%	4.100 ± 0.270[a]
	B	3.172 ± 0.270[b]	Middlewood	3.781 ± 0.234[b]	50%	3.097 ± 0.270[b]
	C	3.523 ± 0.270[ab]	Outerwood	4.914 ± 0.234[c]	90%	2.700 ± 0.270[b]
	D	3.650 ± 0.270[ab]			Butt	4.600 ± 0.270[a]

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