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Characterization of Wood Cellular Structures of Five Lesser Used Wood Species Growing in Nigeria

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Abstract
The wood micro cellular structural constituents of five lesser used wood species in Nigeria among which are *Butyrospermum paradoxum, Albizia zygia, Lanea acida, Parkia felicoida* and *Isoberlina doka* are determined. Fibre cells accounts for 54% of the total wood micro cellular constituents of *B. paradoxum* while vessel, axial and ray parenchyma cells make up the rest of the wood micro structural constituents accounting for 11.3%, 11.98% and 22.27% respectively. The number of fibres at 2452 per mm^2 coupled with the high proportion of fibre cells at 54% indicates that the density of the wood species may likely be high. In *A. zygia* the volume fraction of fibres, vessels, axial and ray parenchyma are 36.1%, 7.83%, 23.2% and 32.87% respectively. The number of fibres per mm^3 is also high at 3,782. The result of the study on *L. acida* is slightly difference from the others. While the fibre constituent was 29.3%, the wood has no apparent axial parenchyma. The ray parenchyma cells make up 67% of the total wood micro constituents elements. The number of vessels per mm^3 is 10.01 while the number of fibre per mm^3 is 2370.5. In *P. felicioda* the percentage proportion of fibre cells is 39.1% while the volume fractions of vessels, axial and ray parenchyma cells are 4.60% 23.4% and 24.0% respectively. The number of vessels per mm^3 is 7.61 while that of fibre cells is 3288.6%. In *I. doka* , fibres proportion is 26.6%, while those of vessels, axial and ray parenchyma cells are 14.8%, 35% and 36% respectively. The result indicated that *B. paradoxum* could be a good candidate for structural application while various degrees of preservative treatment may have to be applied to the other wood species to increase their life in service.
Keywords: micro cellular, structural elements, point counts, breast height, ray and axial parenchyma, vessels.

1. Introduction

The forest estate in Nigeria has been exposed to unmitigated exploitation as a result of high demand for wood for industrial use and for export purposes. Prior to the ban on export of logs in 1976, the forests were gregariously exploited for economic wood species which were exported for foreign exchange generation. Since the placement of the ban, forest exploitation has not abated as the cream wood species are still being used by the local industries and are converted into components for export. In view of this, economic wood species have thinned out in Nigerian forests leading to increasing dependence on lesser used wood species as substitutes. These species were once neglected in favor of the economic tree species that were readily available.

The introduction of the lesser used species into the wood industry has impacted negatively on the acceptance of local wood products. According to Jayanelti (1998), Eastin *et. al.* (2003) and Barany *et. al.* (2003), where lesser used wood species are used as replacements of economic species, the products faces problems of acceptance in international markets. Thus, Coleman (1998), Barany *et. al.* (2003) and Eddowes (1980) considered lesser used species as important element of the forest of the future which deserve special attention in present day management decisions. For this to be achieved, Eddowes (1980) recommended the need to provide adequate data on the physical and mechanical properties of the wood species in all closed tropical forests.

A survey of literature revealed paucity of documented information on the wood cellular structures of *Butyrospermum paradoxum, Albizia zygia, Lannea acida, Parkia felicoida,* and *Isoberlina doka* that are finding their ways into the timber markets in the northern part of the country, including the Federal Capital Territory where a lot of construction works are ongoing. The wood cellular structures which include the proportions of fibres, vessel elements axial and ray parenchyma cells and their wall and lumen are very important determinants in the mechanical strength of wood species. As a biological material, these elements influence the multipurpose application of wood, making it imperative that a thorough knowledge of the wood micro structural properties should precede the selection or choice of wood species for specific end use. The present study is embarked on in this regard to evaluate the cellular structure of the sampled trees belonging to each of the five species in view of their increasing importance in the local wood industry.

2. Materials and Methods

2.1 Materials

The hardwood species utilized in the study comprised of *Butyrospermum paradoxum* Geartn F. (Aepper); *Isoberlina doka* Graib et. Stapf; *Lannea acida,* A. Rich; *Parkia felicoida* Keay and *Albizia zygia* (D. C), J. F. Macbr. The materials for the study were collected from tree species growing in the savanna area near Jebba in Kwara State (Latitude 9,3°N, Longitude 4.46°E) . The total annual rainfall within the area varied from 1000 to 1250 mm. The tree species were from uneven aged natural forest reserve. Five trees of each species were felled and disc samples, 7.5cm thick, were taken at breast height. The sampled discs were immediately wrapped in

plastic bags to prevent loss of moisture during transportation. The discs were stored in a cold room until required for further analysis.

2.2 Methods

Each disc was sanded with a mechanical sanding machine. The number of rings on each sanded disc was counted with the aid of a 10x magnification hand lens. The result was used to estimate the age of the trees. After this, the volume fractions of heartwood, sapwood and bark were completed on the entire discs of each sampled material using a 120 point circular grid. The test points were constructed by super imposing 15 concentric circles within the other on a tracing paper. The circles were divided into test points by constructing four diagonal lines that ran from one end of the circle to another. The number of points that fell on each feature of interest divided by total number of test point covered by the sample gave the volume fraction of each gross feature of interest.

Test block of one square centimeter each were obtained at the heartwood and sapwood zones of the sampled materials and used for the quantitative characterization of wood anatomical elements. The experimental design was such that two zones were designated on each disc from which test blocks were prepared. These were the heartwood and sapwood zones. The heartwood was taken at four rings from the pith and the sapwood four growth rings to the tree bark. Five trees per species, one disc per tree and two zones per tree samples were prepared making a total of fifty samples. Sample blocks were boiled in preparation for sectioning to produce transverse wood sections of about twenty micrometer thick. Sections were dehydrated in 95% ethanol, stained with safranin O and permanently mounted on slides for the microscopic analysis. The characterization exercise was to quantify the cellular micro structural features that make up the different wood species, namely: the proportion and dimension of cell types of the sampled wood. In this regard, a stereological measurement technique was used as described by Ifju (1983) and Onilude and Ifju (1988). This involved projecting the wood sections on the screen with a microscope and superimposing the image on a 16 point 60mm x 60mm grid square. The measurements were then carried out by counting. In counting, the grids were aligned parallel and perpendicular to the ray cells and the number of grid intersection points that fall on the following anatomical elements: fibres, vessels, axial parenchyma cells and ray cells were counted and tabulated to obtain the mean values for each parameter.

3. Results and Discussions

The average age, diameter and the heartwood, sapwood and bark proportions of the sampled species are shown in Table 1. The age of the sampled trees at breast height ranged from 24 to 34 years. The average age range of *B. paradoxum* is from 30-38 years, *A. zygia,* 31-37 years, *L. acida* 20-28 years *P. felicoida*, 22-27 years and *I. doka,* 15-31 years. The diameter at breast height ranged from 13.22cm in *L. acida* to 21.64cm in *P. felicoda*. The variations observed in the diameter of the different wood species is expected as wood properties are largely genetically determined (Zobel and Jett 1995) and can show great variations in width and height depending on site conditions and age (Huda *et. al.* 2012).

Consequently for optimum wood utilization, the age effects on wood properties must be determined, including the size and type distribution of cells (Pezlen 1994). The age of trees determines the maturity of wood cells and hence the usefulness for various applications. For example, some fast growing tropical tree species consist of juvenile wood only when they are harvested at young age (Zobel and Sprague 1998). Thus, the wood species utilized in this study are mature and can be used at industrial level. The variation observed in the age differences among species may also be due to the nature of the forest from which the samples were obtained. The Oke Awon forest reserve is a natural reserve that has been subjected to indiscriminate exploitation and exposed to annual dry season fires common to savanna and fringing forests in Nigeria.

Two patterns of heartwood, sapwood and bark proportions are observed in this study. Pattern 1 consists of species with no apparent heartwood. This was observed in *L. acida* and *P. felicoida.* In the two species, sapwood constitutes 88.94% and 92.18% of the volume fraction of heartwood, sapwood and bark respectively (Table 1). In pattern 2, the wood species were made up of different volumes of heartwood, sapwood and bark. Species in this category are *B. paradoxum* which consists of 30.52% heartwood, 56.32% sapwood and 13.3% bark; *A. zygia* which is made up of 49.19% heartwood, 40.04% sapwood and 10.77% bark and *I. doka,* which is made up of 26.4% heartwood, 62.8% sapwood and 10.8% bark. Heartwood differs from sapwood in chemical composition, density and some physical and technical properties. As observed in this study, it varies between and within species and has been related to growth rates, stand and individual biometric features, site condition sand genetic control as reviewed by Hills (1987), Bamber and Fukazawa (1985) and Taylor *et al.* (2002). Heartwood is impregnated with extractives which are responsible for its natural durability and for its usually darker colour. In practice, heartwood contents increase stem quality desirable for timber applications requiring durability and aesthetics, but disadvantageous for pulpwood (Pereira *et al*. 2003). Thus, species with heartwood constituents such as B. *paradoxum, A. zygia* and *I. doka* will be more useful in the sawmill, furniture and construction industries while *L. acida* and *P felicoida* could be good candidate raw materials for short fibre pulp production.

Tables 2 to 6 present the results of quantitative volume fractions of cellular structural composition of the sampled tree species. For each of the wood species, each of the four major cell types characterized was partitioned into lumen and cell wall components to give total fraction occupied by the particular cell type. As observed in Table 2, fibre cells alone accounted for 54% of the total wood volume of *B. paradoxum* while vessel, axial parenchyma and

ray cells make up the rest of the wood volume fractions accounting for 11.3%, 11.98% and 22.27% respectively. The ray density consists of only 3% lumen and 19.% wall component, indicating that this may have added to the density of the wood species. Also, the number of fibres at 2452 per mm^2 indicated a high quantity of fibres availability in the wood species. Table 3 presents the result of point count for cell types in *A. zygia.* The volume fraction of fibres, vessels, axial and ray parenchyma are 36.1%, 7.83%, 23.2% and 32.87% respectively, indicating that fibre cells made up more than a third of the wood micro constituents. The number of fibres per mm^3 is also high at 3,782.

The number of vessels per mm^3 is only 17.44 indicating a wood species with relatively high density and high mechanical properties (Woodcock *et. al*, 2000). The result of the study on *L. acida* presents a diversion from the others. While the fibre constituent is 29.3%, the wood has no apparent axial parenchyma, while the ray parenchyma constitutes 67% of the total wood micro constituents' proportion. The number of vessels per mm^3 is only 10.01, while the fibre per mm^3 is 2370.5 (Table 4). In Table 5, the percentage proportion of fibre cells in *P. felicioda* is shown as 39.1% while the volume fractions of vessels, axial and ray parenchyma cells respectively are 4.60%, 23.4% and 24.0%. The number of vessels per mm^3 is 7.61 and that of fibre cells, 3288.6% respectively. Table 6 shows that the proportion of fibres in *I. doka* is 26.6% while those of vessels, axial and ray parenchyma cells are 14.8%, 35% and 36% respectively.

Wood formation is a complex developmental process that includes differentiation of vascular cambial initials into various xylem tissues, cell elongation and secondary wall synthesis. As secondary wall forms, the fibres and vessels undergo massive thickening, thereby, significantly influencing wood quality. The high volume fractions of ray and axial parenchyma cells which are food storage cells in *A. zygia, L. acida, P. felicoida* and *I. doka* could have some implications on the industrial use of the wood species. Apart from constituting weakness spot areas within the solid wood, the cells contain food reserves for the tree. Thus, when found in large amount they are likely to make wood in service susceptible to biodegradation (Onilude and Audu 2002). In addition, wood species with high volume of vessels such as *I. doka* with 14% may result in mechanical weakness during load application while in service. However, wood species with high fibre proportions and cell wall fractions might mitigate potential mechanical weakening caused by high vessel proportion and high lumen area (Huda *et al.* 2012). As a result, wood species with high fibre and cell wall proportions such as *B. paradoxum* with fibre fraction content of 54% and fibre cell wall content of 19% is likely to have a high specific gravity as cell wall fraction is a good index to estimate specific gravity if the density of the cell wall material is known.

4. Conclusion

Base on the results of the present study, the wood cellular structures of the species characterized have shown that the sampled trees species posses comparable anatomical characteristics common to many tropical hardwoods. As wood is a biological material and wood microstuctural elements are genetically controlled, the wood species exhibited differences in their microstuctural constituents. *B. paradoxum* with 54% fibre proportion and 2452.44 fibres per mm^3 may be a good candidate species for structural applications. The vessel elements and axial and ray parenchyma constituents are relatively low, indicating durability in service. *A. zygia* with 36.1% fibre proportion may also be durable in service; however with 23.2% and 38.87% axial and ray parenchyma cells respectively, the wood may have to undergo preservative treatment to increase its durability as a result of likely attack by deteriorating agents. The high ray parenchyma cell constituent (67%) in *L. acida* necessitates that adequate preservative treatment be applied before deployment. The same is true for *P. felicoda* and *I. doka* respectively, as the axial and ray parenchyma cells are high. This study has provided data base on the volumetric composition of the cellular structures of *B paradoxum*, *A.zygia*, *L. acida P. felicoda* and *I. doka* which were hitherto nonexistent.

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Table 1: Means range and coefficient of variation of the age, diameter, heartwood, sapwood and bark proportions of five lesser used wood species

Species	Statistical parameters	Age (Years)	Diameter (cm)	Heartwood (%)	Sapwood (%)	Bark (%)
B. paradoxum						
	Mean	34.40	17.96	30.52	56.32	13.6
	Range	30-38	15.7-21.00	11.67-42.85	46.74-73.33	10.38-6.10
	CV	20	54	35.8	16.4	
A. zygia						
	Mean	32.6	14.28	49.19	40.04	10.77
	Range	31-37	13.0-16.30	33.33-55.55	30.43-54.17	8.6-12.5
	CV	6.8	4.1	16.53	20.53	15.6
L. acida	Mean	24.6	13.22	-	88.94	11.06
	Range	20-28	11.30-21.30	-	82.20-90.24	9.76-12.0
	CV	13.24	27.54	-	0.89	7.2
P. felicoida						
	Mean	25	21.64	-	92.18	7.82
	Range	22-27	15.5-29.5	-	89.61-96.15	3.84-10.38
	CV	12.4	23.60	-	2.45	28.90
	Range					
I. doka						
	Mean	28	15.54	26.40	62.8	10.80
	Range	15-31	13.0-22.0	11.76-32.20	57.62-76.47	5.88-11.11
	CV	38.45	21.27	20.45	11.63	30.91

CV =Coefficient of Variation

Table 2: Means and standard deviation of point counts for cell types of *B. paradoxum*

Cell types	Point Counts (%)		
	Lumen(%)	Wall(%)	Total
Vessels			
Mean	2.6	8.7	11.3
SD	0.03	0.07	0.13
Fibre			
Mean	35.0	19.0	54.0
SD	0.08	0.03	0.11
Axial parenchyma			
Mean	11.0	0.98	11.98
SD	0.05	0.02	0.20
Ray parenchyma			
Mean	3.0	19.9	22.72
SD	0.03	0.01	0.04
No of vessels/mm^3			
Mean	19.50		
SD	1.50		
No. of fibres/mm^3 per			
Mean	2452.44		
SD	42.16		

SD =Standard Deviation

Table 3: Means and standard deviation of point counts for cell types of *A. zygia*

Cell types	Point Counts (%)		
	Lumen(%)	Wall(%)	Total
Vessels			
Mean	4.7	3.13	7.83
SD	0.01	0.04	0.04
Fibre			
Mean	28.2	7.9	36.1
SD	0.02	0.03	0.11
Axial parenchyma			
Mean	14.0	9.2	23.2
SD	0.07	0.02	0.06
Ray parenchyma			
Mean	23.5	9.37	32.87
SD	0.03	0.03	0.11
No of vessels/mm^3			
Mean	17.44		
SD	0.72		
No. of fibres/mm^3 per			
Mean	3782		
SD	6.06		

SD =Standard Deviation

. Table 4: Means and standard deviation of point counts for cell types of *L. acida*

Cell types	Point Counts (%)		
	Lumen(%)	Wall(%)	Total
Vessels			
Mean	9.5	3.90	13.4
SD	0.03	0.03	0.03
Fibre			
Mean	20.3	9.30	29.6
SD	0.08	0.02	0.13
Axial parenchyma			
Mean	0.0	0.0	0.0
SD	0.0	0.0	0.0
Ray parenchyma			
Mean	46.0	11.0	67.0
SD	0.02	0.05	0.15
No of vessels/mm^3			
Mean	10.01		
SD	0.48		
No. of fibres/mm^3 per			
Mean	2370.45		
SD	34.87		

SD =Standard Deviation

Table 5: Means and standard deviation of point counts for cell types of *P. felicoida*

Cell types	Point Counts (%)		
	Lumen(%)	Wall(%)	Total
Vessels			
Mean	2.60	2.30	4.60
SD	0.03	0.03	0.03
Fibre			
Mean	26.0	0.10	39.1
SD	0.03	0.03	0.11
Axial parenchyma			
Mean	29.0	12.4	23.4
SD	0.06	0.08	0.09
Ray parenchyma			
Mean	13.0	11.0	24.0
SD	0.05	0.01	0.05
No of vessels/mm^3			
Mean	7.61		
SD	0.43		
No. of fibres/mm^3 per			
Mean	3288.6		
SD	10.89		

SD =Standard Deviation

Table 6: Means and standard deviation of point counts for cell types of *I. doka*

Cell types	Point Counts (%)		
	Lumen(%)	Wall(%)	Total
Vessels			
Mean	4.5	10.3	14.8
SD	0.03	0.22	0.10
Fibre			
Mean	21.9	4.7	26.6
SD	0.08	0.04	0.10
Axial parenchyma			
Mean	24.0	11.0	35.0
SD	0.07	0.03	0.08
Ray parenchyma			
Mean	12.6	11.0	23.6
SD	0.04	0.06	0.05
No of vessels/mm^3			
Mean	8.7		
SD	0.50		
No. of fibres/mm^3 per			
Mean	2629.58		
SD	128.49		

SD =Standard Deviation