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Variations in Axial and Ray Parenchyma Cells in Ten Hardwood Species Growing in Nigeria

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Summary
The optimal industrial utilisation of lesser used wood species globally require knowledge of the wood properties of the various species. One of the important properties of wood is the percentage composition of parenchyma cells. The distribution of axial and ray parenchyma cells of most of the indigenous hardwood species growing in Nigeria have not been studied. This study centered on the distribution of axial and ray parenchyma cells of ten indigenous hardwood species in Nigeria. The mean lumen diameter vary from 11.0% in *Anogeissus leiocarpus* to 32.9% in *Sterculia setigera*. The mean cell wall constituent of the axial parenchyma cells of the studied species also vary from 1.60% in *Daniella oliverii* to 12.5% in *Mitragna inermis*. The total axial parenchyma element of the wood species vary from 16.3% in *Parinarium kerstingii* to 45.4% in *Sterculia setigera*. The ray parenchyma cells also vary within the species. The mean lumen content varies from 7.0% in *Anogeissus leiocarpus* to 15.8% in *Daniella oliverii*. The mean wall percentage of axial parenchyma cells also varies from 3.17% in *Sterculia setigera* to 15.29% in *Anogeissus leiocarpus*. The total axial parenchyma in the studied species vary from 12.37% in *Sterculia setigera* to 30% in *Parinarium kerstingii*. The total parenchyma cells in all species vary from 41.6% in *Prosopis africana* to 59.32% in *Detarium senegalense*. Available information in literature showed that the higher the percentage of parenchyma cells the lower the quality of the wood species for pulp and paper production as parenchyma cells does not contribute significantly to strength development during pulp and paper making. In most cases, the parenchyma cells dissolve in the pulping chemicals. Thus, species such as *Mitragyna inermis, Prosopis africana, Parinarium kerstingii* and *Anogeissus leiocarpus* may perform better as wood for pulp and paper production on the basis of their low total parenchyma cell constituents. This may be due to the trade-off between higher fibre lumen constituents and parenchyma cells. This assumption may also be true for structural applications as parenchyma cells also influence wood density.
Keywords: Axial parenchyma, ray parenchyma, hardwood, lumen, wall

Introduction
The tropical forests in Nigeria have witnessed significant reduction in the availability of economic wood species. The exploitation of economic wood resources of Nigeria for export commenced in Nigeria in 1872 (Aribisala, 1993; RMRDC, 1991). This was complemented by the clearing of forests for housing, infrastructure and agricultural development in the 1960's to 1980's. More recently, several studies (Aribisala, 1993; Olorunnisola, 2000; RMRDC, 2009; Ogunsanwo, 2010; Ogunwusi, 2012) indicated that the overexploitation of the economic wood species have impacted negatively on capacity utilization in the national forest industries. Most of the industries, especially the sawmill and furniture subsectors are now forced to utilize lesser wood species, leading to considerable expansion in the number of wood species currently found in plank markets across the country. Where lesser known wood species are used as replacements for economic wood species, the products face acceptance problems in the global market (Jayanelti, 1998; Eastin *et al,* 2003; Barany *et al,* 2003). Research studies (Coleman, 198l; Barany *et al,* 2003; RMRDC, 2013) indicated that information on species availability, natural durability, physical properties, working quality and the range of application which are of utmost importance to manufacturers are lacking for most of the lesser used wood species. Hence, efforts at promoting their utilization will not be successful without well documented, readily available, concrete information on their wood properties (Arowosoge, 2010).

In view of the above, it has become mandatory that systematic studies be carried out on wood quality parameters of lesser used wood species in the country. The fibre length and density of some of the lesser used hardwoods have been reported (Ogunwusi, 2012; Onilude *et al,* 1989; Ogunwusi, 2012 b; Ogunwusi, 1991). However, the properties of the parenchymatous cells of most of the wood species have not been adequately reported in literature despite their importance as foundations of the plant body since all cells produced from the meristems and regions of regenerations go through stages of development when they possess characteristics similar to parenchyma cells (Morris *et al*, 2016). In general, the parenchyma cells have twin primary cell walls and were the first eukaryotic cells to have evolved (Stewart, 1983). The cells resemble the undifferentiated cells produced by division of meristematic cells (Simpson, 2006). They vary in shape from elongate to isodiametric, although they can also be square or rectangular as found frequently in the parenchyma of secondary xylem and phloem (Panshin and De Zeew, 1980). Parenchyma cells are alive at maturity and have the ability to differentiate (totipotency), which is particularly important during injury (Heplax and Newcomb, 1963; Wargo, 1977; Shigo, 1984).

In most angiosperms, parenchyma cells are found in every organ. The properties of a group of parenchyma cells and the density of the packaging arrangements largely dictate how effective they will be as a whole, rather than just at individual level (Niklas, 1992). Knowing the amount of parenchyma cells in secondary xylem of woody plants together with their spatial distribution across a range of plant species, growth forms and climates are very valuable bases for evaluating the function of living cells and how they contribute to overall plant physiology. In addition, the proportion of wood elements affects wood properties. The proportion of vessels, fibre and parenchyma cells have significant effect on the suitability of wood for several applications (Ogunwusi, 1991; Panshin and De Zeew, 1980; Akachukwu, 1979). Akachukwu (1979) in a review of some wood quality parameters of hardwoods reported that increase in proportions of vessel elements may lead to decrease in wood density and increase in number of weak points along the surface of the wood. The weak points may serve as pathway for bacteria, fungi and fungi infections, leading to wood deterioration (Akachukwu, 1979). Also, Amidon (1975) observed that while parenchyma cells provide pathways for preservatives during treatment, the proportion of vessels and parenchyma cells have negative correlations with pulp yield and strength properties of paper. Mottet (1963) also observed that an increase in proportion of parenchyma cells would cause reduction in the linsil, burst and tear strength as well as folding endurance of paper. This is attributable to the thin walls of the axial and ray parenchyma cells (Panshin and De Zeew, 1980). The proportion and variation of axial and ray parenchyma cells of most non-economic wood species growing in Nigeria have not been reported in literature. Consequently, there is a dearth of information on the pattern of distribution of parenchyma in most of the non-economic hardwood species growing in Nigeria and their influence on the utilization potentials of the wood species. In this study, the proportions of lumen and wall of axial and ray parenchyma cells of ten indigenous species were studied to determine the percentages of each element and the total parenchyma cell in the various wood species in order to determine their utilization potentials.

Materials and Methods

Materials

The hardwood species utilized in this study comprised of *Anogeissus leiocarpus* (D. C), Guel and Perr*; Prosopis africana* (Taub), *Pterocarpus erinaceous, Mitragna inermis, Detarium senegalense, Afzelia africana, Acacia nilotica, Anogeissus leiocarpus, Daniella oliverii* and *Sterculia setigera*. The materials were collected from tree species growing in the savanna area near Jebba in Kwara State (Latitude 9.3^{0}N, Longitude 4.46^{0}E). The total annual rainfall within the area varied from 1000 to 1250mm. The tree species were uneven aged, growing in natural forest reserve with ages ranging from 18 to 60 as deducted from ring counts from samples taken at breast height. 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.

Methods

Test blocks of one square centimetre each were obtained at the sapwood and heartwood zones of the sampled materials. The specimens were boiled in water until they were fully saturated. The saturated blocks were firmly mounted on the clamp of a laboratory microtome, with the rays parallel to the direction of movement of the microtome knive and both the microtome knive and the samples flooded with 70% alcohol. Transverse sections, about 20µm thick were cut from the samples and dropped in a petri dish containing 2% safranin solution for about 5 minutes. The sections were then thoroughly washed in running water and several grades of alcohol ranging from 10 to 95% concentrations. The sections were cleared in xylene before being mounted on glass slides using Canada balsam. The mounted slides were allowed to dry for 2 days at room temperature. They were then stored in a wooden slide box pending subsequent stereological measurements. The stereological counting of the structural elements was carried out by using the quantitative method described by Ifju (1983).

Result and Discussion

The result of the percentage composition of axial and radial parenchyma cells in the ten species are presented in Table 1. The table shows the average lumen diameter to vary from 11.0% in *Anogeissus leiocarpus* to 32.9% in *Sterculia setigera*. The mean cell wall constituent of the species also varies from 1.60% in *Daniella oliverii* to 12.5% in *Mitragyna inermis*. The total axial parenchyma constituent of the wood species varies from 16.3% in *Parinarium kerstingii* to 45.4% in *Sterculia setigera*.

The ray parenchyma cells also vary within the species. The lumen percentage (%) varies from 7.0% in *Anogeissus leiocarpus* to 15.8% in *Daniella oliverii*. The mean wall percentages of axial parenchyma cells also vary from 3.17% in *Sterculia setigera* to 15.29% in *Anogeissus leicarpus*. In all, the total axial parenchyma in the studied species varied from 12.37% in *Sterculia setigera* to 30% in *Parinarium kerstingii*. The total parenchyma cells in all the species is also shown in Table 1. The table shows total parenchyma to vary from 41.6% in *Prosopis africana* to 59.32% in *Detarium senegalense*. This results is within the range reported for angiosperms by several authors. Total parenchyma in *Adenia spinosa, Adania stylosa* and *Adania venerate* have have been reported to constitute 98%, 96% and 92% of the wood elements respectively.

As wood is a complex tissue in which the three cell types perform different functions, their relative proportions would influence the different properties of wood (Zieminska *et al,*2103). One of the important wood structural properties is wood density. As wood density is mainly driven by density of wood outside vessel lumens rather than vessel lumen fraction, it is mainly influenced by the wall and lumen fractions (Zieminska *et al*, 2013). A juxtaposition of the percentage parenchyma cells and density of the individual wood species investigated indicated that there may be a correlation between total parenchyma and density. Table 2 shows the total parenchyma cells in each of the species and the density of the species.

The species with the lowest parenchyma cells, *Prosopis africana* has a density of 656kg/m^3. The density of the species with the highest parenchyma cells such as *Detarium senegalense* is lower. The density of *Detarium senegalense* is 556kg/m^3. *Steculia setigera,* with a percentage parenchyma cell of 59.32% has a density of 260 kg/m^3. On a general note, the higher the percentage of parenchyma cells in the studied wood species, the lower the density. This indicated that total parenchyma have influence on wood density. Depending on the end use, it can be surmised that the higher the percentage of parenchyma cells the lower the quality of the wood species for pulp and paper production as parenchyma cells does not contribute significantly to strength development during pulp and paper making. In most cases, the parenchyma cells dissolve in the pulping chemicals. Thus, species such as *Mitragna inermis, Prosopis africana, Parinarium kerstingii* and *Anogeissus leiocarpus* may perform better as wood for pulp and paper production on the basis of their lower total parenchyma cell contents. This may be due to the trade-off between higher fibre lumen constituents. This assumption may also be true for structural applications

Conclusions

Axial and Ray parenchyma cell vary considerably between the studied species. As parenchyma cells are storage organs and does not influence strength development in wood, the wood species with the high percentage parenchyma cell may not be very useful for structural application both in term of strength and durability. In addition, wood species with high parenchyma cells may not produce high yield of pulp.

This study has shown the possible industrial utilization potentials of the different wood species studied.

Table 1: Percentage of Axial and Ray Parenchyma Cells in Ten Underutilized Hardwood Species Growing in Nigeria

S/N	Species	Statistical Parameter	AXIAL PARENCHYMA Lumen %	Wall %	Total %	RAY PARENCHYMA Lumen %	Wall %	Total %	% Total Parenchyma
1.	*Acacia nilotica*	Average	11.8	5.5	17.3	11.8	9.3	21.1	48.4
		Standard deviation	0.03	0.01	0.04	0.04	0.06	1.00	
2.	*Mitragna inermis*	Average	15.8	12.5	28.3	13.4	8.0	21.3	49.6
		Standard deviation	0.04	0.04	0.04	0.01	0.01	0.03	
3.	*Prosopis Africana*	Average	17.0	5.3	22.3	18.3	6.3	24.6	41.6
		Standard deviation	0.01	0.00	0.06	0.05	0.00	0.08	
4.	*Steculia setigera*	Average	32.9	12.5	45.4	9.2	3.1	12.3	57.7
		Standard deviation	0.05	0.07	0.12	0.09	0.05	0.08	
5.	*Pterocarpus erinaceus*	Average	16.0	11.8	27.8	15.6	11.8	27.4	55.2
		Standard deviation	1.0	0.06	0.09	0.09	0.06	0.08	
6.	*Detarium senegalense*	Average	24.3	6.3	30.6	22.1	6.62	28.72	59.32
		Standard deviation	0.03	0.03	0.09	0.08	0.05	0.09	
7.	*Afzelia Africana*	Average	23.6	6.3	29.9	12.6	14.2	26.8	56.7
		Standard deviation	0.08	0.05	0.11	0.03	0.11	0.08	
8.	*Parinarim kerstingii*	Average	12.5	3.80	16.3	15.9	14.1	30.0	46.3
		Standard deviation	0.04	0.03	0.05	0.10	0.05	0.09	
9.	*Anogeissus leiocarpus*	Average	11.0	12.4	23.4	7.0	15.1	22.1	45.5
		Standard deviation	0.06	0.08	0.09	0.07	0.07	0.09	
10.	*Daniella oliverii*	Average	22.9	1.60	24.5	15.8	6.8	22.6	47.1
		Standard deviation	0.10	0.02	0.10	0.13	0.07	0.12	

Table 2: Density and Total Parenchyma Contents of Ten Underutilized Hardwood Species Growing in Nigeria

S/N	Species	% Total Parenchyma	*Density (kg/m^3)
1.	*Acacia nilotica*	48.4	493
2.	*Mitragna inermis*	49.6	568
3.	*Prosopis africana*	41.6	656
4.	*Steculia setigera*	57.7	260
5.	*Pterocarpus erinaceus*	55.2	600
6.	*Detarium senegalense*	59.32	556
7.	*Afzelia africana*	56.7	550
8.	*Parinarius kerstingii*	46.3	619
9.	*Anogeissus leicarpus*	45.5	696
10.	*Daniella oliverii*	47.1	397

* Source: Ogunwusi (1991)

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