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Heartwood, Sapwood and Bark Proportions in Five Lesser Used Tropical Hardwood Species Growing in Nigeria.

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Abstract
The increasing scarcity of commonly used wood species has necessitated the use of lesser used wood species at industrial scale. However, for this to be possible, it is important that the properties if the lesser used wood species be investigated to elucidate their utilization potentials. The heartwood, sapwood and bark proportions of *Butyrospermum paradoxum, Albizia zygia, Lanea acida, Parkia felicoida* and *Isoberlina doka* were investigated. The proportions of heartwood, sapwood and bark proportions in *B. paradoxum* were 30.52%, 56.32% and 13.6% respectively. The proportions in *A. zygia* were 49.19%, 40.04% and 10.77% and in *I. doka* was 26.40%, 62.8 and 10.80% respectively. *L. acida* and *P. felicoida* doesn't have apparent heartwood. The proportions of sapwood and bark in the two species were 88.94% and 11.06% in *L. acida* and 92.18 and 7.82% in *P. felicoida.* *A. zygia* with the highest percentage of heartwood will be more durable in service, followed by *P. paradoxum* and *I. doka*. The deployment of *L. acida* and *P. felicoida* to service will require extensive preservative treatment using the full cell process, most especially, in situations where they will be in contact with the ground.
Keywords: sapwood, heartwood, bark, extractives, wood preservation

1.0 Introduction

The increasing scarcity of commonly used species in tropical forests has made in-depth research into utilization potentials of lesser used wood species inevitable in order to increase demand for their industrial products. Out of the 600 wood species that are available in tropical forests in Nigeria, less than 10% are used at industrial level. This coupled with high rate of deforestation and the increasing rate of downward movement of the desert conditions has seriously reduced wood availability in Nigeria. Thus, efforts have to be geared towards promoting the utilization of lesser used wood species as complimentary or substitute raw material in the industrial sector in Nigeria.

One of the major macroscopic elements of wood that determines its utilization potentials is the heartwood, sapwood and bark proportions. The heartwood is the wooden portion inside a tree where production of life cells has ceased or food reserve materials have been removed (Anonymous, 1983, Miller, 1999). The International Association of Wood Anatomists (IAWA) define heartwood as the inner layer of wood in the growing tree that has ceased to contain living cells and in which the reserve materials such as starch have been removed or converted into toxic substances generally refereed to as extractives (IAWA, 1964).

Heartwood, sapwood and bark proportions vary considerably between wood species. They define the volume of usable portion of wood, its durability and utilization potentials. The heartwood determines the durability of wood and its presence have been associated as a characteristic for high end products. It has properties that significantly influence the usefulness of wood. Notable among these is its resistance to deterioration by insects, marine borers and microorganisms (Taylor et al, 2002). Information on heartwood percentage in wood species promotes its acceptability by end users. In some species, heartwood may be distinguished from sapwood by a darker colour, lower permeability and increased decay resistance. Heartwood often has different moisture content than sapwood.

Sapwood is defined by IAWA (1964) as the portion of wood that contain living cells and reserve materials. It contains wood that is part of the transpiration stream of the tree and it generally has high moisture content. Its permeability is facilitated by unaspirated and unencrusted pits. It contains few toxic extractives and is generally susceptible to decay (Taylor, 2002). The primary role of sapwood in a tree is to conduct water from the root to the crown (Gartner, 1995). It also serves as a storage site for water, energy reserve materials such as starch (Hillis, 1987; Ryan, 1989) and as a site for living cells that can respond to injury through production of more tissues or defensive compounds (Boddy, 1992). Sapwood is also responsible for storage and synthesis of biochemicals (Wiedenhoeft and Miller, 2005)

The tree bark on the other hand protects the cambium and also retards the loss of water. It protects the tree from temperature extremes and intense sunlight. The bark is porous and helps the tree breathe and also protects it against disease organisms. While the bark proportions vary considerably between different species of tree, it also varies within species. Perez and Kanninen (2003) reported the bark proportion in *Tectona grandis* to vary between 14 and

37% of the total tree volume. Bark content estimation in tropical hardwoods is important in view of its present low economic value. Since tree volumes are normally sold without bark, volume projections must deduct portions lost on the bark. As a result, the heartwood as well the bark content are determinant quality characteristics that should be given proper attention in order to find linkages between management systems and their formation (Taylor et al, 2002).

There are only few studies on tropical species that concentrated on heartwood, sapwood and bark proportions. Most research studies on tropical hardwoods are directed at determining the physical, chemical and mechanical properties of wood species. As a result, this study was carried out to evaluate the proportion of heartwood, sapwood and bark proportions in five tropical lesser used wood species growing in Nigeria. The species include *Butyrospermum paradoxum, Albizia zygia, Lanea acida, Parkia felicoida* and *Isoberlina doka*. The primary objective of the study is to be able to predict performance of the various wood species in service and the type of preservation treatment they have undergo before deployment to service.

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^{o}N, Longitude 4.46^{o}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 they are required for 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 the above, 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 points covered by the sample gave the volume fraction of each gross feature of interest.

3. Results and discussions

The temperature and rainfall of the Oke Awon forest reserve where the trees were collected are shown in Table 1. The rainfall reaches its peak in July when the average temperature will be about 27^{o} C (Table 1).

The mean age of the wood species utilized in this study varied from 24.6 years in *P. felicoida* to 34.4 years in *B. paradoxum.* The age range of *B. paradoxum* samples varied from 30 to 38 years with a co-efficient of variation of 20 (Table 2). The mean age of the *A. zygia* samples utilized was 32.6 years while the age range of the wood samples varied between 31-37 years with a coefficient of variation of 6.8. The mean age of *L. acida* samples was 24.6 years. The age range was 20-28 years with a coefficient of variation of 13.24. In *P. felicoida* samples, the age range was 22-27 years with a mean of 25 years and a coefficient of variation of 25. *I. doka* samples have a mean age of 28 years and a wide age range of 15-31 years resulting in coefficient of variation of 38.45. The effect of age on heartwood formation has been reported. Taylor (2002) observed that sapwood and heartwood proportions vary considerably among and between species as a result of genetic, environment and tree age effects. Juvenile portion of trees contain mostly sapwood, indicating that heartwood is formed with increasing age of the tree. All the wood samples utilized in this study came from mature trees as the ages of the trees from which they were obtained were more than 20 years.

The means, ranges and coefficient of variation of the heartwood, sapwood and bark ratio of the five lesser used hardwood species are shown in Table 3. The proportions of heartwood, sapwood and bark percentage in *B. paradoxum* were 30.52%, 56.32% and 13.6% respectively (Table 3). The proportions in *A. zygia* were 49.19%, 40.04% and 10.77% and in *I. doka* was 26.40%, 62.8 and 10.80% respectively. *L. acida* and *P. felicoida* doesn't have apparent heartwood and the percentages of sapwood and bark in the two species were 88.94% and 11.06% in *L.*

acida and 92.18 and 7.82% in *P. felicoida* (Table 3). This type of occurrence was reported in *Sterculia setigera* wood by Ogunwusi (2002). This may be a good development with respect to water conduction in the tree. According to the pipe model (Shinoki et al, 1964) sufficient sapwood is required to supply foliage with water and the amount of foliage on a tree is often strongly correlated to the amount of sapwood (Berthier et al, 2001; Ryan, 1989; Dean and Long 1986; Whitehead, et al 1984). Sapwood also serves as a storage site for water and for energy reserve materials such as starch. However, sapwood influences wood utilization in a number of negative ways. It contains vessel elements, axial and ray parenchyma cells which assist in water transportation and in storage of nutrients. The fluids in sapwood are easily attacked by wood destroying agents during storage (Ogbogu, 1990; Onilude and Audu, 2002; Ogunwusi, 2013). The vessel elements may also serve as pathway for bacteria, fungi and virus infections in the wood leading to wood deterioration (Akachukwu, 1979).

B. paradoxum, A. zygia and *I. doka* contained various percentages of hardwood proportions. In *A. zygia*, the volume proportions of heartwood, sapwood and bark were 49.19%, 40.04% and 10.77% respectively. The proportion of heartwood in this species is high and may denote durability of the wood in service. In *B. paradoxum*, the proportion of heartwood, sapwood and bark were 30.52%, 56.2% and 13.6% respectively. While the species has a modicum proportion of heartwood the sapwood percentage is high at 56.32%. The same is true of *I. doka* with 24.6% heartwood, 62.8% sapwood and 10.80% bark. Thus, it is expected that *I. doka* and *B. paradoxum* may have to undergo adequate pretreatment before deployment.

The importance of heartwood in wood macrostructure is demonstrated by its mode of formation. Stewart (1966) observed that heartwood formation occurs as a response to build up of toxic products of metabolism. Death of the parenchyma cells in the heartwood may result in the buildup of the toxic products. These extractives are the most important factor determining the natural durability of wood (Bamber and Fukazawa, 1985; Hillis, 1987; Scheffer and Cowling, 1966). Durable wood from which extractives are removed becomes susceptible to decay (Scheffer and Cowling, 1966; Smith et al., 1989). Similarly, adding heartwood extractives to normally decay prone wood can render it decay resistant (Kamdem, 1994; Onuorah, 2001; Smith et al 1989). As a result, wood with high percentage of heartwood can be naturally durable compared with wood species with lesser percentage of heartwood. Heartwood is less attractive than sapwood for some pathogens as it lacks requisite nutrients. For example, starch is required for successful reproduction of *Lyctus* beetles that inhabits wood (Humphreys and Humphreys 1966). These insects rarely attack heartwood which is free of starch (Taylor et al, 2002). Sapstain and mould fungi feed on free sugars and starch in the sapwood and their penetration in the heartwood is limited by absence of carbohydrates. Thus lesser used wood species with higher percentage of heartwood compared to sapwood will find adequate use in both outdoor and indoor services

4. Conclusion.

The ratio of heartwood, sapwood and bark vary considerable in different wood species and these determine the durability and commercial value of various wood species. Heartwood is a very important component as it confers durability and marketability on wood species. While sapwood is important for water conduction and food storage, it is not durable, as it promotes the activities of wood destroying agents during storage and in service.

In the studied wood species, *A. zygia* with the highest percentage of heartwood will be more durable, followed by *P. paradoxum* and *I. doka*. The deployment of *L. acida* and *P. felicoida* to service will require extensive preservative treatment using the full cell process, most especially, in uses where they will be in contact with the ground.

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Table 1. Average annual climatic conditions of Oke Awon Forest Reserve

Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Rainfall (mm)	2.3	15.8	36.0	148.2	181.9	213.8	448.3	511.2	263.2	118.6	6.0	0
Relative Humidity	41.3	46.2	52.7	69.3	75.8	78	81.8	82	78.7	73.2	51.2	41.8
Temperature (°C)	24	28	32	33	32	29	27	26	28	31	29	26

Source: Momodu (1983)

Table 2: Means and ranges of the coefficient of variation of the age and diameter of the five indigenous wood species

Species	Statistical parameters	Age (Years)	Diameter (cm)
B. paradoxum			
	Mean	34.40	17.96
	Range	30-38	15.7-21.00
	CV	20	54
A. zygia			
	Mean	32.6	14.28
	Range	31-37	13.0-16.30
	CV	6.8	4.1
L. acida	Mean	24.6	13.22
	Range	20-28	11.30-21.30
	CV	13.24	27.54
P. felicoida			
	Mean	25	21.64
	Range	22-27	15.5-29.5
	CV	12.4	23.60
	Range		
I. doka			
	Mean	28	15.54
	Range	15-31	13.0-22.0
	CV	38.45	21.27

CV =Coefficient of Variation

Table 3: Means range and coefficient of variation of the heartwood, sapwood and bark proportions of the five indigenous wood species

Species	Statistical parameters	Heartwood (%)	Sapwood (%)	Bark (%)
B. paradoxum				
	Mean	30.52	56.32	13.6
	Range	11.67-42.85	46.74-73.33	10.38-16.10
	CV		35.8	16.4
A. zygia				
	Mean	49.19	40.04	10.77
	Range	33.33-55.55	30.43-54.17	8.6-12.5
	CV	16.53	20.53	15.6
L. acida	Mean	-	88.94	11.06
	Range	-	82.20-90.24	9.76-12.0
	CV	-	0.89	7.2
P. felicoida				
	Mean	-	92.18	7.82
	Range	-	89.61-96.15	3.84-10.38
	CV	-	2.45	28.90
I. doka				
	Mean	26.40	62.8	10.80
	Range	11.76-32.20	57.62-76.47	5.88-11.11
	CV	20.45	11.63	30.91

CV =Coefficient of Variation