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Axial and Radial Variations in Wood Density and Moisture Of The Trunk of *Afzelia africana* Sm. ex Pers.

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***Abstract**:Variations in the wood density (kg/m^3) and moisture content (%) of the trunk of a fully grown specie of Afzelia africana were assessed along the radial and axial axes following recommended standard procedures. The average wood density of the trunk of the specie was assessed to be 697.34 ± 0.20 (Base), 690.78 ± 0.10 (Middle) and 740.15 ± 0.40 (Top) while the average moisture content was assessed to be 55.38 ± 0.40 (Base), 56.57 ± 0.20 (Middle) and 65.25 ± 0.10 (Top) along the axial axes respectively. There were no significant variations ($P \leq 0.05$) in both the wood density and percentage moisture between the base and the middle of the trunk. However, significant variations ($P \leq 0.05$) existed in the wood density and the percentage moisture content of this specie between the middle and top portions of the trunk. Consequently, both the wood density and percentage moisture of the trunk were high (i.e. > 540kg/m^3 and > 30% respectively.) and increased with the height of the tree. On the other hand, the wood density decreased from the core to the outer portions of the trunk both at the the base, middle and top positions. This meant that the wood density decreased as the plant increased in girth. The reverse was the case for percentage moisture content which increased significantly ($P \leq 0.05$) with the girth of the trunk. The high wood density and high moisture revealed about this specie in this present assessment were tapped as base line for proposing the possible end uses of the trunk of this specie.*
Key words: wood density, moisture content, axial, radial, variations, height, end uses.

I. Introduction

According to Panshin and Dezeeuw (1980) wood density is the mass per unit volume (g/cm^3) at some specific condition. It is an important indicator of the mechanical properties of woods (Otoide, 2013) The moisture content of wood is defined as the weight of water in wood given as a percentage of oven dry weight. In most species, the moisture content of sapwood is higher than that of heartwood (Winandy, 1994).

Afzelia africana Sm. ex pers is a tropical evergreen tree plant which belongs to the family, Fabaceae. It is an excellent wood for use in pleasure-crafts, especially for keels, stems and panels, for bridges, as well as interior fittings. The wood is also valued for journey and panelling, parquet floors, doors, frames, stairs, furniture and sporting goods. It has been used traditionally for building of canoes, mortars, masks, and drums. The wood is also used as firewood and for charcoal production (Chudnoff, 1980; ATIBI, 1986 and Gerard and Louppe, 2011).

According to Gill *et. al.* (1983)the need to thoroughly investigate the basic structure of plants from the tropics has been stressed by Metcalfe (1972). To the author's knowledge, this demand has not received the much expected attention. In the recent time, many researchers are primarily concerned with the phytochemical and medicinal values of tropical plants with little interest in the study of the structure of the cells and tissues that serve as the framework for the biochemical and medicinal properties of plants. However, in responds to the above demand the author and his collaborators have studied the physical properties (wood density and percentage moisture), tissues and cells in some tropical tree plant species as reported in Otoide *et. al.*,(2012), Otoide (2013), Otoide and Kayode (2013) and Otoide (2014)

This present assessment is another demonstration of the author's interest in examining the basic wood structure and physical properties (wood density and moisture) of tree plants in the tropics for the purposes of providing additional and more recent information about them and confirming their end uses.

II. Materials And Methods

Collection of Materials

A fully grown tree of *Afzelia africana* which could be of about 40 years old was felled at the diameter at chest height (1.3meters above ground level), from Igbo oluwa quarters in Iworoko village, Ekiti State, Nigeria. The log was thereafter taken to the Department of Wood Technology and Utilization (WT&U) of the Forest Research Institute of Nigeria (FRIN), Ibadan, Nigeria for identification and assessment of physical properties (wood density and moisture)

III. Experimental Procedures

The procedures used in this assessment strictly followed Otoide *et. al.*,(2012). The bole length of the felled tree was measured with the aid of a measuring tape from the level of chest height, to the crown and the value was 1.10meters. Thereafter, transverse disc of 20cm thick axially was cut from the base, middle and the top of the trunk. A total of three transverse discs was cut out of the entire trunk. Each of the discs was divided longitudinally into two semi-circular hemispheres with the line of division passing through the pith. One of the two semi-circular hemispheres was tagged as the Northern hemisphere and the other one, the Southern hemisphere. Only the Northern semi-circular hemispheres were used for the whole of the experiments while the Southern semi-circular hemispheres were discarded. The base, middle and the top semi-circular hemispheres were further divided into three regions, with the lines of division parallel to the equator, which passes through the centre of the pith. These three regions were labelled as:

- CORE (C),
- MIDDLE (M) and
- OUTER (O).

Five blocks of the dimension, 2cm x 2cm x 2cm and another five blocks of the dimension, 2cm x 2cm x 6cm cut out of the core, middle and outer blocks earlier extracted from the three semi-circular hemispheres, each of which was cut out from the base, middle and the top of the trunk. On the base disc, five replicate extracts, each from the core, middle and the outer regions of the semi-circular hemisphere were cut out, making a total of 15 blocks of the dimension, 2cm x 2cm x 2cm and also a total of 15 blocks of the dimension, 2cm x 2cm x 6cm. A total of 30 blocks were extracted separately from the Base, Middle and the Top of the log. Ground total of 90 blocks of wood pellets was extracted from the whole of the tree trunk. All the 90 blocks of wood pellets were used for the whole of the experiments involved in the assessment.

IV. Determination of Wood Density.

Determination of wood density was according to Okoegwale and Gill (1991). Each of the freshly cut blocks of the dimension 2cm x 2cm x 6cm was initially weighed using sensitive Balance and the value was recorded as the wet weight (Ws) The wet weighed blocks were oven dried at the interval of 2 hours with the aid of an electric oven machine and the new weight was measured as the oven-dry weight (Wo). From these measurement, the density of the wood (D) was determined as:

$$D = \frac{1}{\frac{Ws-Wo}{Wo} + \frac{1}{1.53}}$$

Where D=Wood density
Ws=Wet-weight of specimen
Wo=oven-dry weight of specimen
1/1.53=Reciprocal of the density of wood substance.

V. Determination Of Percentage Moisture Content

Determination of percentage moisture content was according to Otoide *et. al.*, (2012). Each of the freshly cut blocks of dimension, 2cm x 2cm x 2cm was initially weighed, using sensitive balance and the value was recorded as the wet weight (Wu). The wet weighted blocks were then, oven dried at intervals of 2 hours with the aid of an electric oven machine. At the various intervals of this process, the blocks were reweighed to achieve a new type of weight. This was repeated until a constant weight, known as the oven dry weight (Wo), was measured and recorded. The formula:

$$\%Mc = \frac{(Wu-Wo)}{Wu} \times \frac{100\%}{1}$$

Where:
%Mc = Percentage moisture content (%)
Wu = Wet weight of wood (g)
Wo = Oven dry weight (g),
was used to determine the percentage moisture content.

Experimental Design

The Experimental Design adopted for this work is a two Factorial in a Complete Randomized Design (C.R.D) with different replications of the test Samples.

Factor A: The longitudinal direction (Base, Middle and Top) of the trunk.

Factor B: The radial directions, where the sample sticks were collected (The Core, Middle and Outer) region of the trunk.

Statistical Analysis

Analysis of Variance (ANOVA) was conducted to test the relative importance of various sources of variation on the Density (kg/m^3) and percentage moisture of the trunk. The main effects considered were differences along the longitudinal (i.e. Axial) and Radial Positions. The Follow up test was conducted, using Duncan Multiple Range Test (D.M.R.T). This was done to know the significant difference between the two Means at $P \leq 0.05$.

The mathematical Model for the two Factors factorial experiment is given as:

Yij = u + Ai + Bj + (AB)ij + Eij

Where:

μ = General mean of individual observation;

Ai = Effect of Factor A;

Bj = Effect of Factor B;

(AB)ij = Effect of interaction between Factor A and B;

Eij = Effect of interaction Error term.

VI. Results And Discussion

Results obtained from this assessment have been summarised in Tables 1 and 2.

Along the axial axes of the trunk, i.e. from the base, middle and top, the average wood densities were 697.34 ± 0.2, 690.78 ± 0.1 and 740.15 ± 0.4 respectively. Whereas, they were 729.20 ± 0.1, 726.49 ± 0.2 and 636.35 ± 0.1 for the base, along the radial axes of the trunk respectively. In the same vein, the middle of the trunk had average wood densities of 803.08 ± 0.3, 704.78 ± 0.1 and 564.49 ± 0.2 for the core, middle and outer regions respectively. Similarly, the top of the trunk had averages of 823.43 ± 0.2, 743.37 ± 0.1 and 653.65 ± 0.3 as wood densities for the core, middle and outer portions respectively.

The average moisture content (%) of the base, middle and top positions of the trunk were 55.38 ± 0.4, 56.57 ± 0.02 and 65.25 ± 0.1 respectively. Furthermore, along the radial direction of the base, the average moisture contents of the trunk were 44.19 ± 0.3, 52.78 ± 0.1 and 69.17 ± 0.2 for the core, middle and outer portions respectively. Whereas, the middle portion of the trunk showed 45.58 ± 0.4, 54.72 ± 0.2 and 69.43 ± 0.3 as moisture of the core, middle and outer regions respectively. Still, the upper region (Top) of the trunk had averages of 45.94 ± 0.1, 55.28 ± 0.2 and 94.53 ± 0.1 for the core, middle and outer portions respectively.

This present assessment revealed variations in density along the axial and radial axes of the trunk (Table 1). These variations were not significantly different (at $P \leq 0.05$) from each other at the base and the middle portions of the trunk. However, the wood density of the top portion of the trunk was different significantly ($P \leq 0.05$) from those of the base and middle (Table 1). This showed that the wood density of this plant increased with its height. This discovery does not however support the previous reports of Panshin and Dezeeuw (1980) that density decreases more or less uniformly from base to top.

On the other hand, the average density of the trunk of this species varied along the radial axes. The outer portion varied significantly from the core and middle of the trunk both at the base, middle and top regions (Table 1). More so, variations occurred between the core and middle portions along the radial axes at the middle and top regions of the trunk. And this was significant. Conversely, insignificant variations ($P \leq 0.05$) occurred at the base of the trunk of this species from the core to the middle.

The moisture content of the trunk of this taxon, on the other hand, did not vary significantly ($P \leq 0.05$) from the top to the middle along the axial axes but varied significantly at the top of the trunk which signified that the wood moisture of this specie increased with increase in its height. (Table 2)

In the same vein, significant variations occurred in the average moisture content of the trunk of this taxon from the core, through the middle to the outer portions at both the base, middle and top regions meaning that the moisture composition of the wood of this specie increases as the trunk increases in size.

The average moisture of the trunk of this woody plant is above the commonly accepted average (being between 55% and 65%) (Table 2). The trunk at this present condition, would need to be subjected to drying in order to reduce the moisture content to 30% so as to reduce its susceptibility to fungi infections and to enhance its end use assurance. On the other hand, the density of the trunk of this specie is high (between 697.34kg/m^3 to 740.15kg/m^3). In this state, it is said to be heavy.

In conclusion, the trunk of this specie is recommended for construction of high quality furniture, canoe, roofing of houses and flooring. It could also be recommended for wood carvings such as mortars and poles.

Table 1: Variations in Wood Density along the Axial and Radial Axes Of The Trunk of *Afzelia africana*

AXIAL POSITION	RADIAL POSITION	AVERAGE DENSITY IN THE RADIAL AXES KG/M^3	AVERAGE DENSITY IN AXIAL AXES KG/M^3
Base	Core	$729.20^a \pm 0.10$	$697.34^a \pm 0.20$
	Middle	$726.49^a \pm 0.20$	
	Outer	$636.35^b \pm 0.10$	
Middle	Core	$803.08^a \pm 0.30$	$690.78^a \pm 0.10$
	Middle	$704.78^b \pm 0.10$	
	Outer	$564.49^c \pm 0.20$	
Top	Core	$823.43^a \pm 0.20$	
	Middle	$743.37^b \pm 0.10$	$740.15^b \pm 0.40$
	Outer	$653.65^c \pm 0.30$	

Means with the same letter in each column are not significantly different at P≤ 0.05.

TABLE 2: VARIATION IN PERCENTAGE MOISTURE CONTENT ALONG THE AXIAL AND RADIAL AXES OF THE TRUNK OF *AFZELIA AFRICANA*.

AXIAL POSITION	RADIAL POSTION	AVERAGE MOISTURE CONTENT IN THE RADIAL AXES (%)	AVERAGE MOISTURE CONTENT IN THE AXIAL AXES (%)
Base	Core	$44.19^a \pm 0.30$	$55.38^a \pm 0.40$
	Middle	$52.78^b \pm 0.10$	
	Outer	$69.17^c \pm 0.20$	
Middle	Core	$45.58^a \pm 0.40$	
	Middle	$54.72^b \pm 0.20$	$56.57^a \pm 0.20$
	Outer	$69.43^c \pm 0.30$	
Top	Core	$45.94^a \pm 0.10$	$65.25^b \pm 0.10$
	Middle	$55.28^b \pm 0.20$	
	Outer	$94.53^c \pm 0.10$	

Means with same letter in each column are not significantly different at P≤ 0.05

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