Assessment of Density and Anatomical Properties of Nigerian Grown *Cocos nucifera* Wood

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ABSTRACT

The knowledge of density and anatomical features of wood is required to understand its morphology prior to its use in order to recommend appropriate treatments and application. Anatomy of coconut wood with its density was investigated in this study. Methods used include sectioning and fibre characterization both along and across the stem of the tree. The mean results obtained for the Fibre Length, Fibre Diameter, Lumen Width and Vessel Diameter were 1.49mm, 0.030mm, 0.02mm, and 0.27mm in that order. Its density was found to vary along the stem. The basic density distribution of Cocos nucifera showed that the middle portion has the highest density of 1107.85kg/m3, followed closely by the base portion with 1052.67 kg/m3 while the top portion recorded the least density of 1003.79 kg/m3. Both the density and anatomical results showed a comparable value which make it a suitable alternative for timber.

Key words: Anatomy, Cell lumen, Density, Fibre length, Vascular bundles

INTRODUCTION

Cocos nucifera L (Coconut) is referred to as tree of life because of its great importance to mankind. The tree can be used for several purposes and can be made into various commercial and industrial products (Arancon, 1997; Sukanya *et. al.*, 2014). *C. nucifera* wood, with its unique features, is a worthy potential renewable resource for timber and a good substitute for hard wood species in structural application such as trusses, walls, joists, doors, window frames and jalousies (Arancon, 1997; Taufikkurahman, 1998).

The tree belongs to the palm plants family; Arecaceae, whose members are mostly found in the tropical regions but some in subtropical or semi-arid regions such as date palms (Arancon, 1997). *C. nucifera* is grown in more than ninety-three (93) countries of the tropics with world annual production was estimated to be 62.45 million tons of nuts per year (FAOSTAT, 2015). Great potentials exist for increasing coconut production and productivity in Nigeria (Uwubanmwen *et. al.*, 2011). The coconut trees is not indigenous to Nigeria (Plate 1) but they are found to grow well in places with a mean annual temperature range from 25°C - 28°C and an annual rainfall of 200mm. The increase in the diameter of a palm species such as coconut tree is as a result of cell division and cell enlargement in the parenchymatous ground tissue as well as the enlargement of vascular bundles which makes the diameter increase limitedly (Jones, 1995). The depletion of most of the important hardwood species such as *Melicia eselsa, Nauclea diderichii, Mansonia altissima, Triplochyton sckroxy, Chodea milini, Khaya species, Afzelia species* and *Lophira alata* as a result of overexploitation has now led to the ardent campaign that non–conventional wood species such as coconut tree could be sort as alternative for timber production. The study therefore focused on the assessment of the density and anatomical properties of the Nigeria grown coconut wood in order to determine its morphological properties.

MATERIALS AND METHODS

Study Locations
The samples of this species were collected from its Plantation at Bolorunduro, a rural settlement in Akure North Local Government Area, Ondo State, Nigeria. The soil of the area is classified as a sandy clay soil according to USDA textural classification of soil (Soil Survey Staff, 1999). The soil is moderately well supplied with organic matter and nutrients. Moisture holding capacity is moderately good (Fasinmirin and Konyeha, 2009). The samples conversion and density determination aspect of the research was conducted at the Federal University of Technology, Akure, Nigeria located on latitude 7º14'N and longitude 5º08'E. Akure has a land area of about 2,303 sq. km and is situated in the western upland area within the

humid region of Nigeria and with a general elevation of between 300 -700 meters above mean sea level. (Fasinmirin and Konyeha, 2009). The anatomical test was carried at the Forestry Research Institute of Nigeria, Jericho Hill, Ibadan. at the anatomical section.

Plate 1: Coconut Plantation at Bolorunduro, Akure North, Nigeria

Sample Collection

Samples for this research were obtained from two coconut trees that were 65 years of age with heights 15.7 and 18meters respectively and divided into three equal billets at 25%, 50% and 75% along the stem. Test samples were collected across the stem position (outer, inner and core) and along the stem height position (Bottom, Middle and Top).

Samples Preparation

Determination of Wood density

Samples of 20 x 20 x 60 mm were cut from the two selected senile coconut wood both along (bottom, middle and top) and across (Outer and Inner) as specified by ASTM D2395-14 to determine the density of the wood. The mass, height, length and width of the samples were obtained to compute the Density of the wood with the use of standardized formula;

$$\text{Density (kg/mm}^3) = \left[\frac{M}{V}\right]$$

Anatomical Characterisation
Maceration

For this test samples, 20 x 20 x 20 mm were collected from the two senile coconut wood both from along (Bottom, middle and top) and across (outer, inner and core) of the stem height. The strands collected from each sample were macerated. The microscopy was performed in accordance with the ASTM D1413-48 of 1983 and ASTM D1413-61 procedure of 2007. Each sample was later sectioned on a sliding microtome to 20 micrometre thickness and the vessel diameter was measured under the microscope.

Experimental Design

The experiment was laid out as a Randomized Complete Block Design (RCBD) using samples from two (2) trees T_1 and T_2 collected at three (3) different point along their longitudinal axis (Bottom, Middle and Top) and across the longitudinal axis (Outer, Inner and Core). Each experiment was replicated six (6) times. The Data generated were analysed using Statistical package for Social Science (SPSS) version 23. Data on the anatomical properties were analysed with descriptive statistics. Analysis of Variance (ANOVA) was carried out to assess if they are significant differences between the various stem heights and lateral positions at 95% confidence interval and New Duncan Multiple Range Test (DMRT) was adopted for mean separation where significant differences occur.

RESULTS AND DISCUSSION

Basic Density

The distribution of the basic density of *Cocos nucifera* (**Figure 1**) showed that the middle portion of the stem height had the highest density (1107.85kg/m³). This is followed closely by the base portion with a density of 1052.67 kg/m³ while the top portion had the lowest density (1003.79 kg/m³). This is not in consonance with the work of Owoyemi *et. al.,* (2015) that basic density of Borassus *aethiopum* stem ranged from 514.71 kg/m³ at the top core portion to 620.00 kg/m3 at bottom dermal portion, which may be as a result of lower age trees used in their study. But Izekor *et. al.,* (2010) reported that wood density increased with increase in age as reflected in this study with coconut wood that is 65 years old. The outer portion of the wood has higher density values than the inner with higher concentration of vascular bundles. The high production of early wood near the crown contributes significantly to the low wood density at the top. It was also observed that the density decreased from the outer part to the inner portion. This was corroborated with the work carried out by Arancon (1997) on different species of coconut wood obtained from Asian and Pacific Coconut Community, from his result classified coconut wood into three density groups as follows, High density wood (outer) 600kg/m³ and above, medium density wood (inner) 400kg/m³ to

599kg/m³, and low-density wood (core), below 400kh/m³, except for the base portion where the density increased from the outer to inner part. This may be as a result of the age of the trees. Owoyemi *et. al.,* (2013) reported that wood with density of 600-800kg/m³ can be classified as high density, Therefore, *C. nucifera* wood could be classified of high density and could be considered for applications where high density wood is required (Arancon, 1997). There was no significant difference in the densities from the different stem heights and lateral positions as shown by the results of the Analysis of Variance (Table 1).

Table 1: ANOVA Table for basic density of Coconut Wood obtained from different stem height and lateral positions

Sources of variation	Sum of Squares	df	Mean Square	F	P	Sig.
Stem Height Position	65054.07	2	32527.03	1.786	0.184	Ns
Lateral Position	24283.51	1	24283.51	1.333	0.257	Ns
Error	582806.04	32	18212.69			
Total	**672143.61**	**35**				

Table 2: ANOVA Table for Anatomical properties of Coconut Wood obtained from the different stem height and lateral positions

VARIABLE	Sources of Variation	Sum of Squares	Df	Mean Square	F	P	Sig.
FIBRE LENGTH (mm)	**Stem Height Position**	9.297	2	4.648	18.076	0	*
	Lateral Position	4.095	2	2.047	7.962	0.001	*
	Error	33.429	130	0.257			
	Total	**46.821**	**134**				
FIBRE DIAMETER (mm)	**Stem Height Position**	0	2	0	5.389	0.006	*
	Lateral Position	4.449×10^{-5}	2	2.224×10^{-5}	1.08	0.343	ns
	Error	0.003	130	2.059×10^{-5}			
	Total	**0.003**	**134**				
LUMEN WIDTH (mm)	**Stem Height Position**	6.187×10^{-6}	2	3.094×10^{-6}	0.121	0.887	ns
	Lateral Position	1.665×10^{-6}	2	8.327×10^{-7}	0.032	0.968	ns
	Error	0.003	130	2.565×10^{-5}			
	Total	**0.003**	**134**				
VESSEL DIAMETER (mm)	**Stem Height Position**	0.009	2	0.004	6.405	0.002	*
	Lateral Position	0.102	2	0.051	73.115	0	*
	Error	0.122	175	0.001			
	Total	**0.232**	**179**				

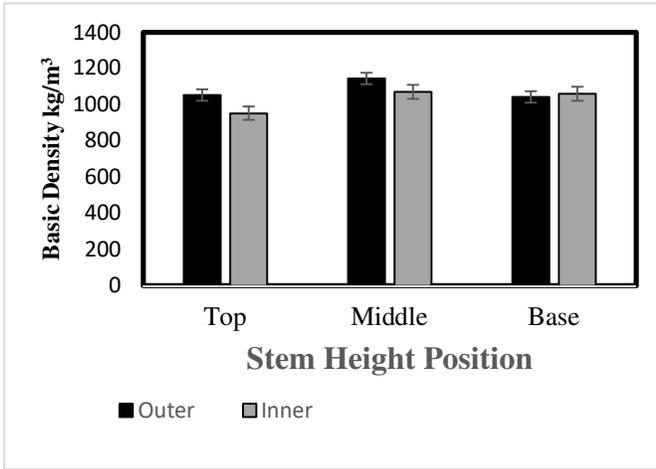* = Values less than 0.05 are significant, ns = Not significant

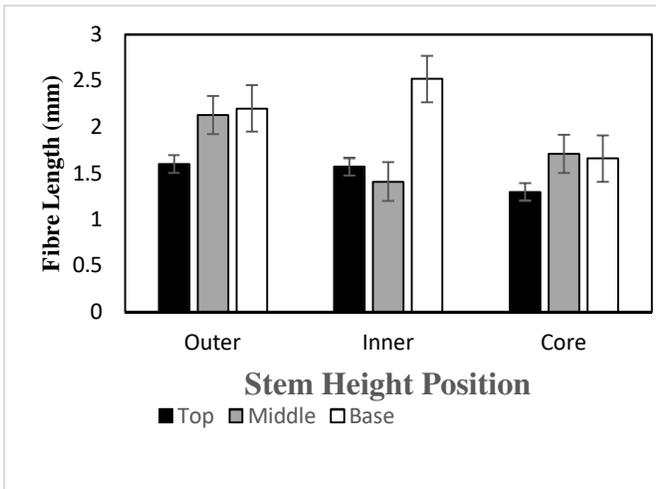**Figure 1:** Basic Density of *Cocos nucifera*

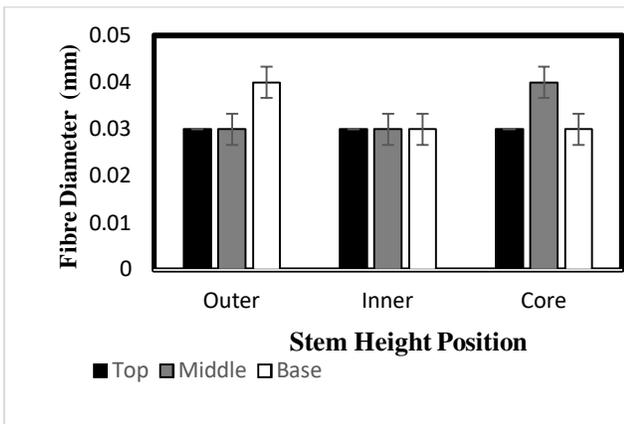**Figure 2:** Fibre length distribution of *C. nucifera*

Figure 3: Fibre diameter distribution of *C. nucifera*

Anatomical Properties

The fibre length of *Cocos nucifera* decreased along the stem height from the base to the top (**Figure 2**). The values ranged from 2.13 to 1.49mm which was higher than some hardwood species. Richter and Dallwitz (2000) reported an average fibre length of 0.8 to 1.65mm for *Polyalthia longifolia.* Fathi (2014) also reported the fiber length of 2.04mm for oil palm wood while Abdul Wasim (2007) reported 0.78 to1.3 mm length for *Melia azedarach* fibers. Fibre length of Coconut wood did not seem to follow any definite pattern with respect to the lateral positions of the three stem height positions. This contradicts the works of Jorge *et. al*., (2000); Miranda *et. al*. (2001); Miranda and Pereira (2002) reported that the fibre length, in most trees, increases from piths to the maximum level and after reaching the maximum frequency, it stays in balance and then decreases gradually. The results of this study showed that coconut wood can be classified categories as long fibre wood with its fibre length ranging from 1.49 to 2.13mm. The density properties make it an acceptable wood in wood and paper industries. Walker and Butterfield, (1996) reported that the minimum fibre length of 2 mm is necessary to produce acceptable Kraft pulp and a reduction in lignin content will lead to a considerable savings during the production of bleached Kraft pulp. The results of the One Way Analyses of Variance (ANOVA) for anatomical properties of Coconut wood (Table 2) showed that the fibre length obtained from the different stem height and lateral positions are significantly different from each other.

Fibre diameter distribution along the stem height from the base to the top, did not follow any linear pattern (Figure 3), which contradicts the work of Fathi (2014) on Oil palm. He noted that fiber diameter gradually decreased from the butt end to the top of the trunk. It was observed that Coconut palm, Date palm, and Oil palm are anatomically related (Fathi, 2014). The average diameter of the fiber of this present study (30 µm) is close to the findings of other studies, it is less than those found in Softwood (35µm) and higher than those in hardwood (25µm) (Razak *et. al.,* 2012). The comparison between the fiber diameters of this study showed that the fiber diameter (30 µm) was more than that of *Eucalyptus spp* (15.5 - 16.3µm) and less than that of *Gigantochloa scortechinii (*23-37µm) (Latif, 1995). It was also observed that coconut did not follow any definite pattern with respect to the lateral positions of the three stem height positions. This trend might have been as a result of age which was shown through the wood sectioning that there is no variation in the anatomical features of the wood. The ANOVA results for the comparison of the (Table 2) fibre diameters from the different stem heights are significantly different while samples obtained at the lateral positions are not.

Table 3: Mean Lumen Width of Coconut wood from the Different Stem Height and Lateral Positions

STEM HEIGHT POSITION	LATERAL POSITION	LUMEN WIDTH (mm)	AVERAGE
TOP	OUTER	0.02±0.00[a]	
	INNER	0.02±0.00[a]	0.02±0.01[a]
	CORE	0.02±0.01[a]	
MIDDLE	OUTER	0.02±0.00[a]	
	INNER	0.02±0.00[a]	0.02±0.00[a]
	CORE	0.02±0.00[a]	
BASE	OUTER	0.02±0.01[a]	
	INNER	0.02±0.00[a]	0.02±0.00[a]
	CORE	0.02±0.00[a]	

Values are means±SD; Values in the same column for each stem height position with the same superscript are not significantly different from each other

The values of the Lumen width (**Table 3**) obtained are approximately the same with respect to the wood obtained from the stem height and lateral positions of the Coconut tree. Which contradicts the report of Fathi (2014); Khozirah *et. al.,* (1991) who reported that lumen width decreases from the outer zone to the pith and a little change in cell wall thickness is observed with stem height. As a comparison, the fiber lumen width of Coconut wood is 2.0 μm which was lesser than that of *G. scortechinii* and *Eucalyptus spp* which were 4.3 μm and 3.29-3.86 μm respectively (Viane *et. al.*, 2009). The Analysis of Variance for the anatomical properties (**Table 2**) showed that lumen width obtained from the different stem heights and lateral positions are not significantly different from each other with respect to their lumen width.
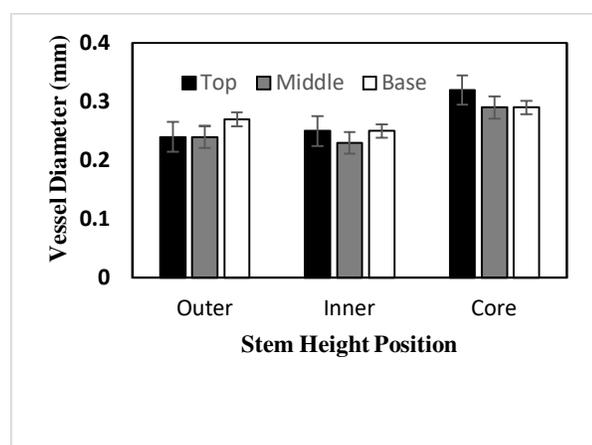

Figure 4: Vessel diameter distribution of *C. nucifera*

Figure 4 shows the vessel diameter of the Coconut wood obtained from the different stem heights and lateral positions. There are significant differences in vessel diameters along the stem height and as well as in the lateral

positions. The vessel diameter distribution along the stem height from the base to the top did not follow any linear pattern. It also did not follow any definite pattern with respect to the lateral positions of the three stem height positions. In a study on radial variation of anatomical characteristics in plantation grown *Pericopsis mooniana*, the vessel diameter of wood at the bark side were higher than those at the pith (Ishiguri *et. al.,* 2011). Similar trend of increasing anatomical properties from inner wood to outer wood was also observed in *Tectona grandis* (Izekor *et. al.,* 2010). This trend might have been as a result of age which was also confirmed through the wood sectioning result that showed no variation in the anatomical features of the wood. The ANOVA for the comparison of the anatomical properties (**Table 2**) shows that there is significant difference ($P < 0.05$) between the vessel diameter of the wood from the different stem heights of top, middle and base positions. Also, there is significant difference (i.e. $P < 0.05$) between the vessel diameter of wood obtained laterally across the stem, i.e. the outer, inner and core positions.

Wood Sectioning

It was observed from this study that there was no variation in the sections of the wood samples from across and along the wood as shown in Plate 2, and the vascular bundles are scattered among the parenchymatous tissues. The axial parenchyma cells are both paratrachea (mostly vasicentric) and apotrachea.

Parthasarathy and Klotz (1976) in their studies showed that the secondary walls of *C. nucifera* in old fiber usually display a characteristic multi-layered structure. Likewise, it was observed that the vessels are distributed among axial parenchyma, sometimes in clusters of two to three, or solitary as show in Plate 2 and 3. Intervascular pits are slit-like and opposite. This agreed with the work of Corley and Tinker (2003) who described the structure of vascular bundles within the trunk as not straight. The vessels of this tree are mostly higher than 200 microns.

CONCLUSION

This study has shown that coconut wood has the potential to fill the gap created by the decline in timber species by providing alternate material for construction, instead of the destruction of senile coconut plantations by burning, they could be sold as timber material to provide additional income to coconut farmers. The density variation from outer to inner also suggests that canting method should be adopted during conversion to isolate the lower density inner core. The morphology of the fibres showed significant differences between portion and position in terms of length, diameter and lumen size. However, the wood should be treated with water or oil borne preservatives to prolong the serviceable live. An awareness of the usability of senile

coconut wood is required to prevent the present practice of burning old stands.

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