DOI 10.18551/rjoas.2022-02.13

ASSESSMENT ON ANATOMICAL AND PHYSICO-MECHANICAL PROPERTIES OF GROWN NEWBOULDIA LAEVIS (P. BEAUV.) AND ANINGERIA ROBUSTA (AUBREV. AND PELLEGR.) IN NIGERIA FOR UTILIZATION POTENTIALS

Ogunleye Mercy Bolade
Department of Forestry and Wood Technology, Federal University of Technology, Akure,
Ondo State, Nigeria

Aina Kehinde Sesan, **Adeniyi I. Michael**
Department of Forest Products Development and Utilization, Forestry Research Institute
of Nigeria, Ibadan, Oyo State, Nigeria

*E mail: sesan2003toy@gmail.com
ORCID: 0000-0002-5342-9746

ABSTRACT

Nigerian grown *Newbouldia laevis* and *Aningeria robusta* were investigated in this study. The densities of the wood at the green condition and 12% moisture content were assessed. The other properties such as modulus of rupture, modulus of elasticity, compression, shear, impact bending, fibre diameter, cell wall thickness, fibre length, lumen width, Runkel ratio, flexibility, wall fraction, felting power and wall rigidity were determined. The results show that densities at the green and 12% MC for *Newbouldia laevis* and *Aningeria robusta* falls between the ranges of 0.49 to 0.69 g/cm^3 and 0.49 to 0.55 g/cm^3. The mechanical properties for the wood species range from 3177.22 to 8425.37 Nmm^{-2}, 59.09 to 86.27 Nmm^{-2}, 25.96 to 39.49 Nm, 16.05 to 38.96 Nmm^{-2} and 5.72 to 10.89 N/mm^{-2} for modulus of elasticity, modulus of rupture, compression, torsion and shear strength. The anatomical properties for the wood species range from 0.90 to 1.28 mm, 17.36 to 25.57 mm, 10.70 to 16.94 m, 3.63 to 4.31, 0.61 to 1.25, 0.35 to 25.95, 0.58 to 18.43, 0.05 to 4.27 and 0.18 to 0.97 for fibre length, fibre diameter, lumen width, cell wall thickness, Runkel ratio, wall fraction, flexibility, felting power and wall rigidity. Significant differences exist in the main factor (specie, wood portion and stem portion) for anatomical properties, compression and shear strength. The outcome of properties found in *Newbouldia laevis* was similar to other species like *Mansonia altissima* and *Gmelina arborea* while *Aningeria robusta* displayed the same properties with species like *Tectona grandis* and *Pinus palula*. This study revealed the properties of grown wood species and their purposes for utilization potentials when compared with other highly used wood species. The findings show that *Newbouldia laevis* and *Aningeria robusta* can be used for construction, general carpentry, decorative veneer, flooring and musical instruments.

KEY WORDS

Newbouldia laevis, Aningeria robusta, anatomical properties, physical properties, Nigeria, veneer, species.

Wood is the widely used engineering material in the world that is found to be the most commonly used raw material for building till today (Anaduaka et al., 2013). In the world today, about 109 metric tons of wood are used annually for building construction and it is relatively high when compared to the consumption rate of iron and steel. The high demand for wood is attributed to the strength and aesthetic figures displayed; it has a low cost per ton 1/60th with high specific strength (stiffness and toughness) than steel. Since wood is known to be a renewable resource, it's a good material resource derived from the environmental perspective and its production requires low energy input. Over the past decades, the world's managed fast-growing forests have been increasingly degraded due to total dependence on wood and that was associated with a significant decline in quality (Adjei-Sakyi et al., 2000). It has now been noted that forest is now characterized by younger age; smaller stem diameter, larger taper, larger knots, higher juvenile wood content, and different wood characteristics (Emerhi et al., 2012). The changes noted in wood quality have triggered a chain reaction that has a profound impact on wood processing, end-product quality, and marketing (Garces Sotillos et al., 1995). An attempt to increase managed forests in Nigeria was achieved through the propagation of exotic wood species in the tropical region. Many researchers have worked on propagation and silvicultural practices of many temperate wood species while information on utilization potentials in relation to the properties is still limited. Among these wood species is *Coffea canephora*, which is popularly known as Aningeria robusta and belongs to the family of *Sapotaceae*, a hardwood. This species was first discovered in Africa, in the former Belgian Congo in the 1800s, and indigenous to Uganda. It is referred to as 'osan' in Uganda 'agengre' in Cote d'Ivoire, and 'landosan' in Nigeria (Ogunleye et al., 2017). 'mukali' in Angola, 'mukangu' in Kenya (Ajala and Ogunsanwo, 2011).'asafonia' in Ghana (Okai et al.,2003). Currently, it is grown in Central Africa with several useful characteristics such as high tolerance to leaf rust pathogen, white stem borer, and nematode invasion, and has the potential to give consistent yields. Due to these properties displayed, the cost of *Aninigeria robusta* cultivation is relatively low. On the other hand, the negative attributes of the wood species are the inability to endure long drought conditions, late cropping, late stabilization of yields, and also slightly inferior quality. This plant has many medicinal properties and is widely valued in Africa (Okai et al., 2003).

Another fast-growing evergreen shrub tree found in tropical forests is *Newbouldia laevis*. *Newbouldia laevis* (ogilisi) is a tropical plant belonging to the family of Bignoniaceae. It is among the most useful plants in Africa and grows up to 10 m in height with cauliflorous habit. It only reaches a height of 3 - 8 meters in the west, but can attain the height of 20 meters in the east, The bole can be up to 90 cm in diameter but usually less. The tree has a range of local medicinal uses which is gathered from the wild. It is often grown as a living hedge to mark boundaries, as ornamental, and also valued for its flowers (Anaduaka et al., 2014). It is an ever-greenish plant with a height of approximately 7–8 m high in West Africa and can grow up to 20 m in Nigeria. The plant has the characteristics of shiny dark green leaves with large purple flowers, different African countries have different names for *Newbouldia laevis* e.g Togo call it lifui, Ghana call it sesemasa, Hausa call it Aduruku, Igbo call it ogilisi or ògírìsì, Senegal call it gimgid, Gambia call it kallihi, Yoruba call it Akoko, Guinea call it canhom, Urhobo call it Ogiriki, Sierra Leone call it Sherbro, Mali call it kinkin, Edo state call it íkhímì, Tiv call it Kontor, while the Ibibio call it itömö. *Newbouldia laevis* is usually grown as an ornamental tree and planted by cuttings. It is a very popular plant in the African continent and is highly valuable due to its numerous immense benefits to the human race. Some parts of Nigeria commonly regard this tree as the tree of fertility or the tree of life. The wood is pale brown, durable, evenly textured, and hard and it tends to remain alive for a long time even after cutting it. This makes it viable for usage as posts, woodworks, yam stakes, house posts, firewood, and bridges. *Newbouldia laevis* has different symbols and meanings to different countries for example; some villages in Ivory Coast and Gabon plant the tree near the tombs to act as a protective talisman. The Ibibio and Efik people of Nigeria regard the tree as a symbol of their deities thus they tend to place it in sacred places. The Igbo part of Nigeria refers to the Newbouldia laevis (ogilisi) tree as a sacred tree usually planted in front of the chief’s house (Ersan et al. 2008).

However, the main function of a plant as a tree is to provide mechanical support. The sizes of fibre cell walls from wood species range from thin-walled to thick-walled fibre depending on location (Garces Sotillos et al., 1995). The physical properties of plants are the quantitative characteristics of wood and their behavior to external influences other than applied forces which are highly needed for utilization (Akerele et al., 2011). Information regarding the properties of *Newbouldia laevis* and *Aningeria robusta* in relation to utilization in Nigeria is still limited. These plants are fast-growing evergreen shrub in Nigeria and it is fast becoming popular in the household for fencing. As these wood species are fast becoming popular, all their properties are yet to be known for utilization purposes.

MATERIALS AND METHODS OF RESEARCH

Three stands of *Newbouldia laevis* (Akoko) and *Aningeria robusta* (Ladosan) of age ranged of 20 to 22 years were felled at 1.3 m above breast height in accordance with (FPL, 2010) from Research plot at Onigambari forest reserve located on latitude 70^{o} 25′ and $70^{o}55'$ N and longitude 30^{o} 53′ and $30^{o}9'$E within the low land semi-deciduous forest belt of Nigeria and covers a total land area of 17,984 ha. The felled stumps were transported to Wood Workshop Laboratory for conversion at the Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria, Ibadan, and Oyo State. The trees stem was converted into three sections namely base, middle and top portion respectively (Figure 1). Experimental samples were derived from the wood at a distance of 0.3 m to 2 m from the bark of the wood to the pith of the wood in each stem portion as illustrated in Figure 1. An experimental specimen for each test was cut into specific dimensions in accordance with (FPL, 2010). After dimensioning into specific sizes, the specimens were oven-dried at 65 ± 5^{o}C to attain 12% moisture content. Prior to testing, all specimens were preserved in desiccators to prevent gain or loss in moisture.

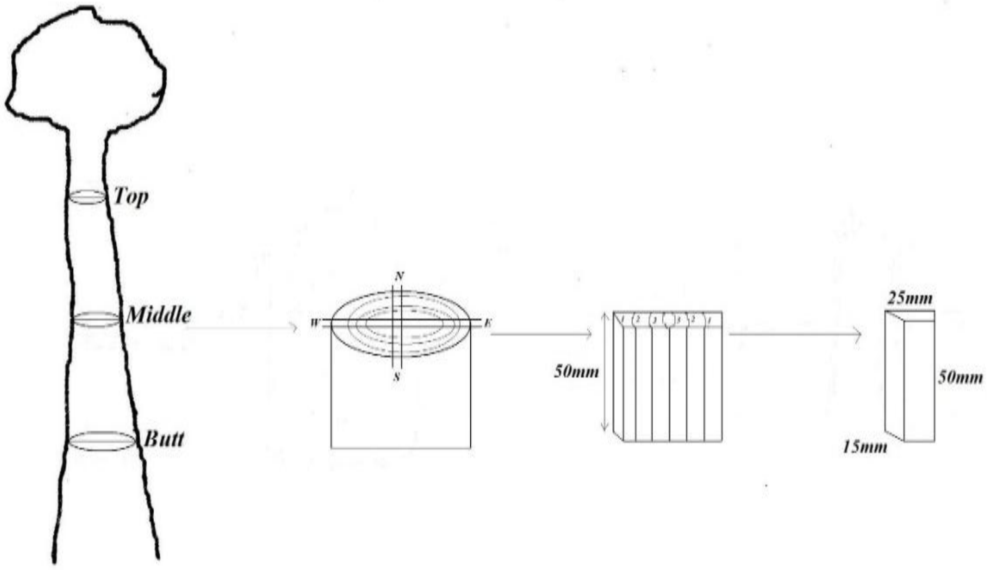

Figure 1 – Schematic diagram showing specimen extraction

Density is the mass per unit volume; it is a good indicator concerning the resistance of wood and the amount of cell wall substance. The value of density depends on many endogenous and exogenous factors such as the rate of growth as well as cellulose and lignin content. There is thus a strong correlation between density, specific gravity, and mechanical properties (FPL, 2010). In this study, density was determined under two factors: density at green and density at oven-dried conditions at a temperature of 20 ± 1°C and relative humidity of 65 ± 3% to calculate the density at both factors, the equation is below was used:

$$\rho N = mN \frac{mN}{vN} \qquad (1)$$

Where: ρN = density in g/cm^3 ; mN= mass in g and vN = volume in cm^3.

The mechanical properties are used to describe the wood strength and the ability of the wood to resist applied or external forces (Record, 2004). The final use of the wood is dependent on these properties. The specimens derived from each wood species that is free of defects under controlled conditions of (65 ± 3% RH and 20 ± 1°C) were subjected to these tests; modulus of elasticity, modulus of rupture, compression strength, and impact bending strength at 12% moisture content. The strength, modulus resistance, shear, and compressibility of the wood species were derived using a standard Universal Testing Machine of model WDW-50 (Jinan Hensgrand Instrument Co., Ltd, Jinan, China) of 50 kN load cell at a crosshead speed of 2.8 mm/min in accordance with ASTM D 790. The ability of the wood species to resist shock (Torsion) was determined through the use of the Hatt-Turner Impact testing machine. The test specimen was supported over a span of 240 mm on a supporting radius of 15 mm, spring restricted yokes were filled to arrest rebounded. This was then subjected to a repeated blow from a weight of 1.5 kg at increasing height was recorded in meters as the height of maximum hammer drops. The specimens were placed in such a way that rings are parallel to the direction of the hammer drops. Impact bending test was calculated using the equation:

$$a = W/A \qquad (2)$$

Where: a = Impact bending strength (J/mm), W = work done by the load (J), A = Area of the samples (mm^2).

A non-destructive method of wood sampling extraction using an increment borer was adopted for fibre characteristics (von Arx, *et al.,* 2016). 6 wood samples were derived from each species for laboratory investigations. Samples of 1cm x 1cm x 1cm were sectioned into 20 µm thin using sliding microtome, stained in Safranin and dehydrated in different concentrations of ethanol. The clearing was done using vegetable oil (Adeniyi *et al*., 2014) while sections were mounted on slides and covered with a coverslip. The maceration of slivers of 1cm x 2 mm x 2 mm was done at ratio 1:1 of ethanoic acid and hydrogen peroxide in accordance with (Oluwadare and Ashimiyu, 2007). 20 macerated fibers were randomly selected and measured using stage micrometer under Zeiss light microscope at 80x in accordance with ASTM D 1030-95 (2007) and ASTM D 1413-61 (2007). The micrographs of each wood section were obtained while nomenclature and cell sizes were determined following microscopic terminology for hardwood identification (IAWA Committee 1989).

The methods adopted for analysis and presentation of data in this study include descriptive analysis, analysis of variance and microscopic features. The statistical analysis was based on 2 by 2 by 3 factorial experiments in a completely randomized design which wood specie, wood portion, and stem portion are the main factors. The separations of means were done using Duncan's Multiple Range Test [DMRT] at a 5% level of probability. These were done to know the differences between the means and to choose the best variables combination. SPSS (Statistical Package for the Social Sciences) version 20.0 package was employed for the analysis.

RESULTS AND DISCUSSION

The physical, mechanical and anatomical properties investigated in this study for *Newbouldia laevis* and *Aninigeria robusta* are presented in Tables 1-2 and Figures 2-3.

The mean values obtained for densities are presented in Table 1. The densities at green condition, after oven-dried, and after water immersion test at 24 hours were presented in Table 1. As presented in Table 1, the values obtained varies for *Aninigeria robusta* and *Newbouldia laevis*, the values range from 0.61 to 0.80 g/cm3 and 0.49 to 0.69 g/cm3 at green; and 0.57 to 0.69 g/cm3 and 0.49 to 0.55 g/cm3 at 12% moisture content. The density of *Aninigeria robusta* decreased by 16% while that of *Newbouldia laevis* decreased by 26% after drying. It shows that moisture extraction in the cell wall through the lumen is faster in *Newbouldia laevis* than in *Aninigeria robusta*. This reaction can be attributed to the nature of the cell wall and lumen diameter found in wood species. Swelling and shrinkage of wood mostly occur within the thickness of the cell wall which resulted in changes of cell diameter (Okai 2003). The cell of *Aninigeria robusta* was found to be medium walled and falls within the cell wall thickness of 3.33 mm to 4.02 mm while *Newbouldia laevis* was found to be thin to medium walled cells with a cell wall thickness of 3.63 mm to 4.21 mm (Table 1, Plates 1 and 2). It has also been found that cell lumen plays a very important role in the movement of moisture along and across the stem portion of wood (Adeniyi et al., 2014). The lumen found in wood species imparts void space in the bulk volume of wood which determines the density of particular species (Emerhi 2012). The void space found in wood varies from species to species. Previous studies reported that If not for lumen found in wood, all woods would have gotten a density of about 1.5 x density of water (FPL 2010). As illustrated in Figures 3 and 4, the micrographs show that lumen diameters found in *Aningeria robusta* were thinner and lesser while the lumen found in *Newbouldia laevis* were wider and numerous. This implies that the movement of water through the lumen of *Newbouldia laevis* would be faster than the *Aningeria robusta* which has a thinner lumen diameter. The movement of water in wood species affects the service life of wood products, from cell to cell and through the pit to pit (FPL 2010). Previous studies show that conduction in wood occurs through the pits and also allows water to propagate for centimeters into the wood board end, thus greatly increasing the amount of water taken up by the wood board (Emerhi 2012).

Table 1 – Mean values for the properties

Properties	Factors	*Newbouldia laevis*		*Aninigeria robusta*	
		Sapwood	Heartwood	Sapwood	Heartwood
Green density	Top	0.63± 0.03	0.61 ± 0.01	0.57 ± 0.02	0.63 ± 0.02
	Middle	0.69 ± 0.01	0.69 ± 0.00	0.64 ± 0.01	0.63 ± 0.02
	Base	0.80 ± 0.04	0.77 ± 0.10	0.69 ± 0.01	0.66 ± 0.01
Density @ 12% MC	Top	0.53± 0.01	0.49 ± 0.01	0.49 ± 0.01	0.52 ± 0.02
	Middle	0.55± 0.03	0.55 ± 0.01	0.53 ± 0.01	0.54 ± 0.01
	Base	0.69 ±0.06	0.65 ± 0.08	0.54 ± 0.00	0.55 ± 0.01
Rupture (MOE) Nmm^{-2}	Top	7447.74 ± 948.57	6956.08±2567.71	4652.91± 1623.10	5628.48± 446.12
	Middle	3177.22±645.84	5898.86±68.96	5045.73±5933.46	6305.49±5436.85
	Base	8425.37 ± 470.93	4068.96±1623.10	5933.46±741.77	5436.85±336.90
Strength (MOR) Nmm^{-2}	Top	84.80±3.,71	86.62±10.97	73.75±3.71	69.07±0.19
	Middle	87.26±12.37	81.75±9.90	87.29±12.37	78.03±0.13
	Base	64.56±1.08	79.89±6.33	59.09±2.20	70.05±6.36
Compression (Nmm^{-2})	Top	37.23± 0.03	39.49±0.91	31.63±0.05	31.25±0.06
	Middle	32.67±0.03	38.78± 0.93	34.66±0.87	33.86±1.00
	Base	25.96±0.06	29.53±0.57	27.97±0.26	32.31±0.36
Torsion (Nm)	Top	16.74± 2.382	24.31±4.29	30.47±0.95	18.53±2.38
	Middle	36.42± 9.79	26.63±1.90	22.39±0.91	22.39±0.81
	Base	38.96±6.66	34.54±13.02	17.37±3.36	16.06±4.32
Shear (Nmm^{-2})	Top	10.48±0.25	6.70±0.05	9.50±0.02	7.45±0.05
	Middle	6.21± 0.03	10.70±0.05	5.72 ±0.02	6.21± 0.03
	Base	8.22 ± 0.30	10.89±0.11	8.22±0.02	6.21±0.03
Fibre length	Top	1.12±0.00	1.17±0.04	0.90±0.04	1.11±.00
	Middle	1.11±0.00	1.12± 0.00	1.14± 0.02	1.10± .01
	Base	1.28±0.03	1.04±0.01	1.05±0.03	1.05±.03
Fibre diameter	Top	21.54±0.02	25.57±2.94	17.36±0.43	22.81±0.04
	Middle	21.40±0.18	23.07±0.24	22.03±0.16	21.85±0.65
	Base	19.29±1.63	21.50±0.11	20.19±0.38	19.13±1.85
Lumen width	Top	13.74±0.02	16.94±2.29	10.70±0.90	14.76±0.03
	Middle	13.63±0.15	14.97±0.19	14.12±0.14	14.02±0.50
	Base	12.02±0.10	13.67±0.10	12.70±0.21	11.62±1.64
Cell wall thickness	Top	3.90±0.00	4.31±0.32	3.33±0.23	4.02±0.00
	Middle	3.88±0.01	4.05±0.02	3.95±0.01	3.91±0.07
	Base	3.63±0.51	3.92±0.01	3.75±0.08	3.75±0.25
Runkel ratio	Top	1.25 ±0.05	0.69 ± 0.12	0.61 ± 0.13	0.94 ± 0.05
	Middle	1.00 ± 0.16	0.94 ± 0.06	1.22 ± 0.09	0.92 ± 0.06
	Base	1.01 ± 0.51	0.73 ± 0.07	1.13 ± 0.07	0.83 ± 0.07
Wall fraction	Top	25.95 ± 2.21	0.39 ± 0.04	0.35 ± 0.03	18.10 ± 2.06
	Middle	16.15 ±13.66	17.14± 2.37	23.66 ± 1.41	16.50 ± 0.44
	Base	0.42 ± 0.03	6.68 ± 10.88	21.76 ± 0.90	0.42 ± 0.02
Flexibility	Top	18.43± 1.63	0.62 ± 0.04	0.65 ± 0.03	10.17 ± 2.14
	Middle	10.58 ± 8.71	10.84 ± 2.22	15.41± 0.93	9.95 ± 0.35
	Base	0.59 ± 0.03	4.28 ± 6.36	13.22 ± 0.62	0.58 ± 0.02
Felting power	Top	3.76 ± 0.36	0.06 ± 0.00	0.05 ± 0.01	3.96 ± 0.10
	Middle	2.82 ± 2.42	3.15 ± 0.34	4.13 ± 0.26	3.28 ± 0.39
	Base	0.07 ± 0.01	1.31 ± 2.17	4.27 ± 0.14	0.05 ± 0.00
Wall rigidity	Top	0.47 ± 0.06	0.20 ± 0.02	0.18 ± 0.02	0.97 ± 0.18
	Middle	0.49 ± 0.24	0.66 ± 0.10	0.61 ± 0.02	0.73 ± 0.12
	Base	0.21 ± 0.02	0.37 ± 0.29	0.73 ± 0.01	0.21 ± 0.01

This reaction explains the movement of water across the stem portion of the wood. Meanwhile, for service application of wood at 12% moisture content found that densities values obtained for sapwood and heartwood of *Newbouldia laevis* ranged from 0.53 to 0.69 g/cm3 and 0.49 to 0.65 g/cm3 while that of Aninigeria robusta ranged from 0.49 to 0.54 g/cm3 and 0.52 to 0.55 g/cm3 (Table 1). This study revealed that densities of *Newbouldia laevis* decrease by 20% while that of *Aninigeria robusta* decrease by 16% across the stem portion from sapwood to heartwood. The percentage values imply that densities of wood species vary across the stem portion of the wood. As presented in Table 2, only wood portion and species were significant differences at 5% level of probability for densities at the green and 12% moisture content.

The results of mechanical properties are presented in Table 1. The mechanical properties values obtained in this study for the selected wood species ranged from 3177.22 to 8425.37 Nmm^{-2}, 59.09 to 86.27 Nmm^{-2}, 25.96 to 39.49 Nm, 16.05 to 38.96 Nmm^{-2}, 5.72 to 10.89 N/mm^{-2} for rupture, strength, compression, torsion, and shear strength respectively. The values obtained in this study agree with the previous study of (Arowosoge et al., 2011). Meanwhile, the mechanical values obtained for *Newbouldia laevis* along and across the stem portions of the wood ranged from 3177.22 to 8425.37 Nmm^{-2}, 64.56 to 87.26 Nmm^{-2}, 25.96 to 39.49 Nmm^{-2}, 16.73 to 38.96 Nmm^{-2}, and 6.21 to 10.89 Nm for rupture, strength, compression, torsion, and shear respectively. While the values obtained for *Aninigeria robusta* along and across the stem portions of the wood ranged from 4652.91 to 6305.48 Nmm^{-2}, 59.09 to 87.29 Nmm^{-2}, 27.97 to 34.66 Nm, 16.05 to 30.47 Nm, and 5.72 to 9.50 Nmm^{-2} for rupture, strength, compression, torsion, and shear respectively. As presented in Table 1, the mechanical properties values obtained at the heartwood portion of the wood species were higher than the values obtained at the sapwood portion of the wood for MOE (modulus), MOR (strength), and compression. Also presented in Table 1, the values obtained at the base portion of the wood were found to be higher than the values obtained for other portions of the wood in modulus but had lower values in strength and compression. The trend observed for some mechanical properties in wood species was different for torsion; it appears that each wood species follows a different direction for torsion. The torsion values obtained for *Newbouldia laevis* increase from the top portion of the wood to the base portion of the wood while that of *Aninigeria robusta* was reversed. The results of the analysis of variance for mechanical properties are presented in Table 2, in each of the main factors assessed in this study; all mechanical properties except torsion were significant at a 5% level of probability for wood portion and all mechanical properties except rupture was significant for wood species. Both compression and shear strength were significant at a 5% level of probability for the stem portion of the wood.

Table 2 – Results of analysis of variance for properties

Properties	ANOVA	Main factors			2 factors interaction			3 factors interaction
		WP	S	SP	WP x S	WP x SP	S x SP	WP x S X SP
Green density	F-cal	16.998	30.116	0.191	18.356	1.058	1.719	8.427
	Sig.	0.00*	0.00*	0.66^{ns}	0.00*	0.35^{ns}	0.20^{ns}	0.00*
Density @ 12% MC	F-cal	22.568	23.506	0.525	25.239	1.736	5.220	2.742
	Sig.	0.00*	0.00*	0.47^{ns}	0.00*	0.19^{ns}	0.03*	0.08^{ns}
Rupture	F-cal	3.482	2.008	0.034	6.990	13.505	3.398	4.847
	Sig.	0.047*	0.169^{ns}	0.855^{ns}	0.004*	0.000*	0.08^{ns}	0.017*
Strength	F-cal	4.552	15.300	2.411	1.692	9.507	2.076	1.338
	Sig.	0.02*	0.00*	0.13^{ns}	0.20^{ns}	0.01*	0.16^{ns}	0.28^{ns}
Compression	F-cal	429.538	105.769	168.307	193.956	20.667	57.867	32.815
	Sig.	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
Torsion	F-cal	2.480	19.874	3.316	13.841	0.229	0.404	5.504
	Sig.	0.10^{ns}	0.00*	0.08^{ns}	0.00*	0.79^{ns}	0.53^{ns}	0.01*
Shear	F-cal	1154.611	8260.321	260.801	2014.189	5478.008	1156.346	1427.472
	Sig.	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
Fibre length	F-cal	20.351	210.254	19.691	58.978	166.599	14.199	15.114
	Sig.	0.000*	0.000*	0.000*	0.000*	0.000*	0.001*	0.000*
Fibre diameter	F-cal	11.507	15.526	28.141	6.791	12.782	2.632	3.324
	Sig.	0.000*	0.001*	0.000*	0.005*	0.000*	0.118^{ns}	0.05*
Lumen width	F-cal	12.205	14.619	24.262	5.654	11.974	3.213	2.889
	Sig.	0.00*	0.00*	0.00*	0.01*	0.00*	0.08^{ns}	0.07^{ns}
Cell wall thickness	F-cal	2.622	5.569	13.736	3.837	4.905	0.295	1.637
	Sig.	0.09^{ns}	0.02*	0.00*	0.03*	0.01*	0.59^{ns}	0.21^{ns}
Runkel ratio	F-cal	2.326	0.007	11.713	3.034	.770	3.472	9.300
	Sig.	0.11^{ns}	0.93^{ns}	0.00*	0.06^{ns}	0.47^{ns}	0.07^{ns}	0.00*
Wall fraction	F-cal	14.009	1.842	7.861	3.779	0.625	0.532	37.438
	Sig.	0.00*	0.18^{ns}	0.01*	0.03*	0.54^{ns}	0.47^{ns}	0.00*
Flexibility	F-cal	13.889	0.499	11.629	5.393	0.274	0.648	35.926
	Sig.	0.00*	0.48^{ns}	0.00*	0.01*	0.76^{ns}	0.42^{ns}	0.00*
Felting power	F-cal	12.764	5.675	2.949	1.548	2.283	0.260	36.247
	Sig.	0.00*	0.02*	0.09^{ns}	0.23^{ns}	0.12^{ns}	0.61^{ns}	0.00*
Wall rigidity	F-cal	11.132	15.429	2.921	0.920	8.940	1.666	34.241
	Sig.	0.00*	0.00*	0.10^{ns}	0.41^{ns}	0.00*	0.20^{ns}	0.00*

*Note: NS represent not significant, * represents significant, WP represents Wood portion, S represents specie and SP represents stem portion.*

The anatomical properties values obtained in this study are presented in Table 1. The mean values ranged from 0.90 to 1.28 mm, 17.36 to 25.57 mm, 10.70 to 16.94 m and 3.63 to 4.31 for fibre length, fibre diameter, lumen width and cell wall thickness (Table 1). The anatomical properties values obtained for *Newbouldia laevis* ranged from 1.04 to 1.28 mm, 19.29 to 25.57 mm, 12.02 to 16.94 m and 3.63 to 4.31 m for fibre length, fibre diameter, lumen width and cell wall thickness, while the anatomical properties values for *Aninigeria robusta*, the values ranged from 0.90 to 1.14 mm, 17.36 to 22.81 mm, 10.70 to 14.76 m and 3.33 to 4.02 m for fibre length, fibre diameter, lumen width and cell wall thickness (Table 1). The fibre cell wall in the heartwood of *Newbouldia laevis* is higher than *Aninigeria robusta* while the fibre lengths are of the same dimension. As presented in Table 2, all factors assessed for anatomical properties were significant at a 5% level of probability.

Table 3 – Features present in wood species

Name of Species	Sheath cells	Multiseriate	Canals	Axial parenchyma	Storied Rays
Newbouldia laevis	+	+	+, traumatic	Paratracheal	+
Anigeria robusta	-	-	-	Apotracheal	+

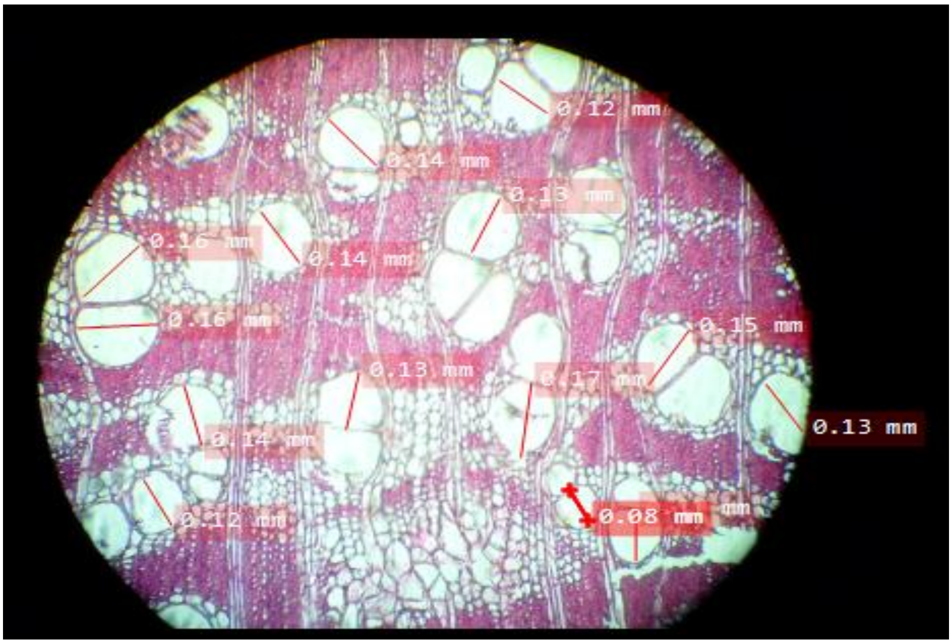

Plate 1 – Microscopic measures of *Newbouldia laevis*

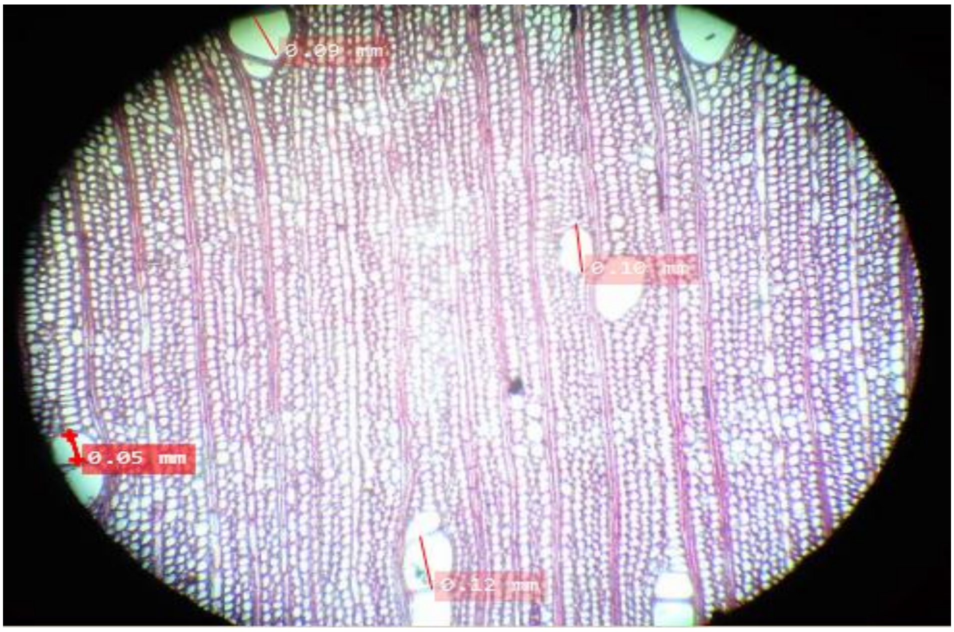

Plate 2 – Microscopic measures of *Aninigeria robusta*

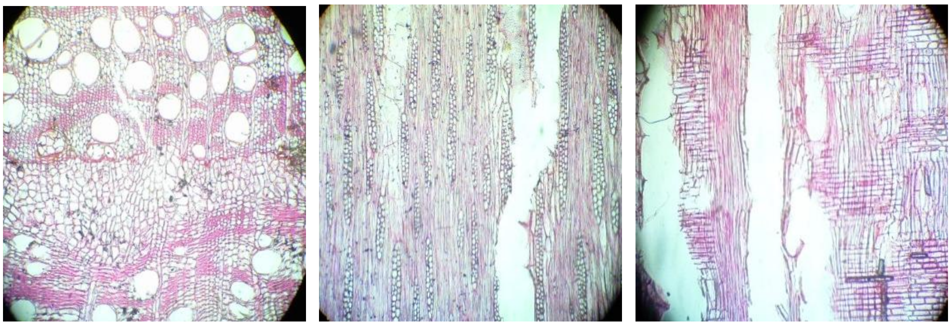

Plate 3 – *Newbouldia laevis* in transverse, tangential and radial

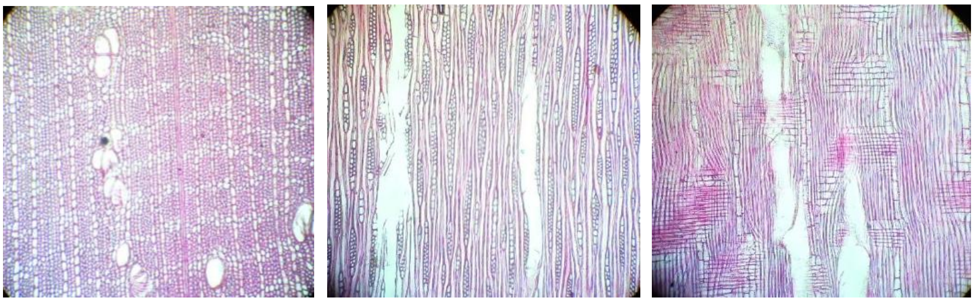

Plate 4 – *Aninigeria robusta* in transverse, tangential and radial

The microscopic features of each wood are shown in Plates 1 and 2. As shown in Plate 1 and 3, *Newbouldia laevis* has pores that were numerous, clusters and paired, diffused, and mostly round. The fibres were medium walled while the axial parenchyma was paratracheal and mostly unilateral; confluent and vasicentric. The rays were multiseriate of about 4-5 cells wide, the sheath cells were found to be present and the axial canals were traumatic. But in *Aninigeria robusta*, it was found in Plates 2 and 4 that the vessels were generally oval and diffuse and sometimes clusters, pores were also paired. The perforations were simple, axial parenchyma was diffuse and diffuse-in-aggregates. The fibres were found to be thin to medium walled while the rays were arranged in 1-2 seriate, heterogeneous according to (Zobel 1984).

CONCLUSION

Assessments and the comparison of two wood species *Newbouldia laevis* and *Aningeria robusta* with the test carried out for physical properties, anatomical, mechanical properties show that *Newbouldia laevis* is significantly influenced and has a higher density than *Aningeria robusta* the properties are good to produce. When also compared with other wood species such as *Gmelina arborea* density of 400-510 kg/m^3, MOE of 5500-10800 Nmm^{-2} and MOR of 55-102 Nmm^{-2}, compression of 20- 39, shear 6- 9 um, fibre length of 100 um, lumen width of 32 um, cell wall thickness of 5-5um, the flexibility of 81.7 um, felting power of 31.2um which is used for Light construction, general carpentry, decorative veneer, light flooring, musical instrument, particleboard good quality for pulp and paper. *Tectona grandis* density of 480-730 kg/m^3, MOE of 7600-17500 Nmm^{-2} and MOR of 81-196 Nmm^{-2}, compression of 70- 340 Nmm^{-2}, shear 5- 16 um, fibre length of 100 um, lumen width of 32 um, cell wall thickness of 5-5 um, the flexibility of 81.7 um, felting power of 31.2 um which is used for Bridge naval, boat hulls door and windows furniture cabinet, poles hardboard, particleboard, pulpwood. *Pinus patula* density of 330-650 kg/m^3, MOE of 5100-12800 Nmm^{-2} and MOR of 47-154 Nmm^{-2}, compression of 25- 57 Nmm^{-2}, shear 4- 12 um, fibre length of 200 um, lumen width of 36 um, cell wall thickness of 4-5 um, the flexibility of 81.7 um, felting power of 31.2 um which is used for light construction, light flooring, joinery, ceilings, paneling, shingles, furniture, cabinetwork, fence posts, poles, food containers, pallets, mine props, veneer, and plywood. *Dendrocalomus giganteus* density of 900 kg/m^3, MOE of 14000 Nmm^{-2}

and MOR of 93-179 Nmm^{-2}, compression of 39- 62 Nmm^{-2}, shear 4.5 um, fibre length of 200 um, lumen width of 19 um, cell wall thickness of 3.9 um, flexibility of 81.7 um, felting power of 31.2 um which is used for construction, flooring, and musical instruments, construction, scaffolding and rural housing, water pipes, buckets, boat masts, matting, wicker ware, and paper production. *Terminalia superba* density of 430-730 kg/m^3, MOE of 3625-16600 Nmm^{-2} and MOR of 50-157 Nmm^{-2}, compression of 26- 69 Nmm^{-2}, shear 4.5-10 um, fibre length of 200 um, lumen width of 19um, the cell wall thickness of 3.9um, the flexibility of 81.7um, felting power of 31.2um which is used for doorposts and panels, moldings, furniture, office-fittings, crates, matches, and particularly for veneer and plywood. It is suitable for light construction, light flooring, shipbuilding, interior trim, vehicle bodies, sporting goods, toys, novelties, musical instruments, food containers, vats, turnery, hardboard, particleboard and pulpwood. By comparing the properties of other wood species listed in Table 3, based on the result of findings from these studies, it shown that the wood species of *Newbouldia laevis* fall within the same range of properties with wood species source as *Mansonia Altissima* and *Gmelina arborea*, therefore, the wood species can also serve the same purpose in terms of utilization. *Aningeria robusta* species falls within the same range of properties as wood species such as *Tectona grandis* and *Pinus palula*, therefore, the wood species can also serve the same purpose in terms of utilization.

RECOMMENDATION

Based on the conclusion drawn from the study, it is therefore recommended that *Newbouldia laevis* be used for Light construction, general carpentry, decorative veneer, light flooring, musical instrument, particleboard as well as good quality for pulp because of its density and fiber characteristics.

CONFLICT OF INTEREST

Authors declare that there is no conflict of competing interest.

REFERENCES

1. Adjei-Sakyi, E., (2000). Yield maximization of sliced veneer: a case study. MSc Wood Technology degree thesis, Department of Wood Science and Technology, Institute of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. 49 pp.
2. Ajala, O.O and Ogunsanwo, O.Y. (2011): Specific gravity and mechanical properties of Aningeria robusta wood from Nigeria; Journal of tropical forest science 23(4): 389–395
3. ASTM D 1030-95 -Standard test method for fibre analysis of paper and paperboard. West Conshohocken, PA. 2007. Standard test methods for specific gravity of wood and wood based materials D239502.
4. ASTM D1413-61 – “Preparation of decayed wood for microscopical examination”, ASTM International, West Conshohocken, PA, 2007.
5. Akerele, J., Ayinde, B., Ngiagah, J. (2011). Phytochemical and antibacterial evaluations of the stem bark of Newbouldia leavis against isolates from infected wounds and eyes. Trop. J. Pharm. Res., 10(2): 211-218.
6. Anaduaka, E., Ogugua, V., Egba, S., Apeh, V. (2013). Comparative anti-diabetic effects ethanol extracts of Newbouldia laevis leaves and stem on serum lipid profle and lipid peroxidation status in alloxan induced diabetic rats. World J. Pharma. Sci., 2(3): 833-845.
7. Arowosoge, O.G.E. Ogunsanwo O.Y. and Labode, P. (2008). Techno–economic analyses of wood species Utilized in furniture industry in selected cities of Nigeria. Journal of Food, Agriculture & Environment, Vol.6 (3&4) 486.
8. Emerhi E. A. (2012): Variations in anatomical properties of Rhizophora racemosa (Leechm) and Rhizophora harrisonii (G. Mey) in a Nigerian mangrove forest ecosystem. International Journal of Forest, Soil and Erosion, 2(2): 89-96.

9. Ersan, Y., Ari, I., Koc, E. (2008). Ethanol extracts of Newbouldia laevis leaves and stem on serum lipid profle and lipid extract of Newbouldia laevis. Afri. J. Trad. Compl.Alternat. Med., 4(4): 476-48.
10. Forest Products Laboratory (FPL) (2010). Wood Handbook: Wood as an Engineering Material. General Technical Report, FPL –GTR 190. United States Department of Agriculture, Forest-service, Madison, Wisconsin.
11. Garces Sotillos, M.M., Blanco Carmona, J.G., Juste Picon, S., Rodriguez Gaston, P., Perez Gimenez, R. & Alonso Gil, L., (1995). Occupational asthma and contact urticaria caused by mukali wood dust (Aningeria robusta). Journal of the Investigational Allergology & Clinical Immunology 5(2): 113–114.
12. IAWA (1989). “IAWA list of microscopic features for hardwood identification”. By IAWA committee of the International Association of Wood Anatomist, edited by E.A. Wheeler, P. Baas& P.E. Gasson 13.Karl, F. W. (1984). “Forestry Handbook”, Society of American Foresters, pp. 616-623.
13. Ogunleye B. M, Fuwape J. A, Oluyege A. O, Ajayi .B and Fabiyi J. S (2017): Evaluation of Fiber Characteristics of Ricinodedron heudelotii (Baill,pierre Ex pax) for pulp and paper making. International journal of science and Technology, 6(1): 634 – 641.
14. Oluwadare, A. O. and Ashimiyu, O. S. (2007). The relationship between fibre characteristic and pulp sheet properties. Middle East Journal of Science Resources, 2(2):63-68.
15. Okai, R. (2003): Characterization of moisture content and specific gravity of branch wood and stem wood of Aningeria robusta and Terminalia ivorensis. Holz als Roh-und Werkstoff 61:155 -158.
16. Record, S.J. (2004): The mechanical properties of the wood. Including a discussion of the factors affecting the mechanical properties, and methods of timber testing. http://www2.cddc.vt.edu/gutenberg.
17. Von Arx, G., Crivellaro, A., L., Prendin, A., Cufar, K., and Carrer, M. (2016). Quantitative Wood Anatomy - Practical Guidelines. (H. Bolte A., Ed.) Frontiers in Plant Science, 7, 13.
18. Zobel, B. (1984): The changing quality of the world wood supply. Wood Sci. and Technol. 18:1-17.Mullins, E.J. and T.S. McKnight, 1981.Canadian Woods - Their Properties and Uses Third Edition, Supply and Services Canada, Ottawa.