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EFFECTS OF AGE AND SAMPLING POSITION ON WOOD PROPERTY VARIATIONS IN NIGERIAN GROWN *GMELINA ARBOREA*

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ABSTRACT

Wood properties of plantation grown (Gmelina arborea Roxb.) were evaluated in this study. Eighteen trees from 3 age classes namely: 18, 28 and 36 years were sampled at the butt, 50% merchantable length ML and 90% ML, and were radially partitioned into inner wood, middle wood and outer wood, on the basis of distance from pith. Result obtained was analyzed using ANOVA at 5%level. Mean SG were 0.33 for age 18, 0.41 for 28 and 0.46 for the 36 year old Gmelina. While SG varied inconsistently in 18 year old Gmelina, it decreased significantly from butt to 90% ML in 28 and 36 year old trees. MOR ,MOE and MCS// decreased generally from base to top for all age classes except in 28 year old, where variation in MOE was inconsistent. All properties studied increased from inner wood to outer wood. Axial uniformity in strength properties ranged between 0.50 and 0.64, 0.65 and 0.73, and from 0.49 to 0.82 in MOR, MOE and MCS respectively. Radial uniformity index also ranged between 0.69 and 0.78 in MOR, 0.78 and 0.85 in MOE and between 0.76 and 0.80 in MCS. For all the properties studied, wood uniformity was best in 36 year Gmelina along the radial plane, while 18 year Gmelina had the best uniformity index along the axial plane. Effect of age was highly significant on strength properties and its variation patterns. In particular, there was about 44.8% increase in strength properties from 18 to 28 years and 19.1% increase from 28 to36 years. Woods of Gmelina arborea varied significantly along and across the bole, and should be treated as such in their conversion and utilization strategies.

Key words: *Gmelina arborea*, wood properties, variations, age, uniformity index

INTRODUCTION

Gmelina plantations were established in Nigeria at various locations, mainly in the southern part of the country about 40 years ago to provide pulp wood for the pulp and paper Industries which are being established in the country at about the same time. The plantations which have now outgrown their usefulness for paper are being harvested for saw logs to complement the supply of timber from the natural stock. In the past 5 years, Gmelina plantations in Nigeria have been subjected to indiscriminate harvesting without regard for age and other wood quality criteria. Today Gmelina sawn timbers are found on limited scale at the timber market all over the country, where they attract relatively low price compared to sawn wood of similar quality. This has a negative impact on the market and marketing of Gmelina both at the local and international levels. It is worrisome that despite the shortage being experienced in the supply of popular timber species, acceptability of Gmelina wood is still not encouraging. This has been due to limited knowledge of its wood properties and the potential to perform in structural applications. To adequately promote the use of plantation grown Gmelina at the local and international markets, comprehensive research on the physical and mechanical properties which must take account of its variation patterns within the tree must be embarked upon. It is necessary therefore to provide information on the wood properties of the species so as to initiate a quality driven market for the Nigerian *Gmelina arborea*. Specific Gravity of wood has been described as an important descriptor of wood quality, (Panshin *et al*1980, Haygreen and Bowler, 1982, Onilude and Ogunsanwo, 2002). Researchers have worked on the specific gravity of Nigerian grown Gmelina, especially on its variation pattern within tree; their reports were however based on wood sampled between the lower ages of 5 and 10 years. This may not be adequate to supply the required information for effective management of the species for timber production. Also, research on the strength properties of Nigerian Gmelina is scanty, Awoyemi, (1997) related cell types to some selected strength properties of Gmelina ,his work though pioneering, left much to be desired in terms of variation pattern along and across the bole. According to Cown 1980, the most significant source of variation in wood occurred within individual stem. This finding is very crucial in wood quality estimation, especially with species that are relatively unpopular in the local timber market. Furthermore,[22] states that individual logs can only be sent to the right sawmill and converted in a manner that is optimal for end users if adequate attention is given to wood property variation within tree, between tree and between geographical location.

Effect of age on wood property evaluation cannot be overstressed; juvenile wood which is known to contain wood of low density, Cown, (1992) is controlled by felling age. This study is therefore aimed at evaluating the wood properties of the Nigerian grown *Gmelina arborea* with regards to variation pattern within the tree as affected by differences in age of stand. This is with a view to exposing some quality that is peculiar to *Gmelinna arborea* from the Nigerian plantations

MATERIALS AND METHODS

Description of site Characteristics

The plantation from where the sample for this study was obtained is located in Gambari Forest Reserve, South West Nigeria. Geographically, it lies between Latitude 7^0.25N and Longitude 30^0.5E. The rock is of the Precambrian series shown as undifferentiated basement complex on the geographical map of Nigeria. The soil is sandy, 45cm deep with overlying clay and iron stone about 1.21m deep varying from place to place. The topography is generally gently undulating with average altitude ranging from 121.9m to 152.4m above sea level. The reserve is well drained southwards with Rivers, Awun and Ona. Average rainfall is about 1140mm, which falls as low as 254mm during the dry season and as high as 1275 during the rainy season. Average temperature is about 26.4^OC, and relative humidity of about 50% throughout the year, with a sharp drop during the dry season. The vegetation is low land rainforest, dominated by species like *Mansonia altissima, Triplochiton scleroxylon, Terminalia superba, Celtis zenkeri, Sterculia species,* and *Antiaris africana*.

Sampling strategy

Six trees each were sampled from age series 18, 28 and 36, at 20 metres away from the boundary so as to remove boundary effect. They were felled, delimbed and their merchantable lengths (ML) determined. Bolts of 75cm long were obtained at butt, 50%

and 90% of ML from each of the sampled tree and partitioned into inner wood (NEW), middle wood (DEW) and outer wood (TEW) on the basis of distance from the pith. This was done by simply dividing the radial length into three equal parts i.e. each radial zone represents one-third of the entire radial distance. Test samples of 20mm x 20mm x 750mm were cut from all sample demarcations and reconverted to various dimensions. Cubes of 20mm x 20mm x 20mm were removed from the base of each 750mm length for the specific gravity test before converting to the required length for strength property tests, in accordance with British Standard BS 373.

Determination of Specific Gravity

Wood specimens were subjected to a gravimetric procedure in which specimen were completely saturated with water by boiling. Each cube was then removed from the water, blotted to remove excess water and weighed. They were oven-dried to a constant weight at 103°C. Specific gravity was determined using the procedure developed by (Smith 1954) using the formula

$$G = \frac{1}{\frac{WO - WS}{WO} + \frac{1}{1.53}}$$

Where G = specific gravity
Ws = saturated weight of wood
Wo = oven dry weight of wood
153 = constant developed by (Stam, 1929) as the actual weight of wood substance

Modulus of Rupture

The static bending tests were carried out in accordance with British Standard Method BS 373. This involves the use of standard test specimens (20mm x 20mm x 300mm), in a Hounsfield Tensometer. The test samples were prepared in such a way that growth rings were made parallel to one edge. The load was applied at the rate of 0.1 mm/sec; with the growth rings parallel to the direction of loading that is specimens were loaded on the radial face. The bending strength of wood usually expressed as MOR which is the equivalent fibre stress in the extreme fibres of the specimen at the point of failure was then calculated using the expression below

$$MOR = \frac{3PL}{2bd^2}$$

Where P is load in Newton (N)
L is span in (mm)
b is width in (mm)
d is depth in (mm)

Modulus of Elasticity

The modulus of elasticity was calculated from the values obtained at the point of failure recorded during tests for MOR. While the MOR test was being carried out, a load-deflection graph was being plotted on the testing machine simultaneously. This provided for the calculations of deflection which was used to estimate the Modulus of elasticity MOE using the formula below

$$MOE = \frac{PL^3}{4\Delta bd^3}$$

Where P is load in Newton (N)
L is span in (mm)
b is width in (mm)
d is depth in (mm)
Δ is the deflection at beam centre at proportional limit

Compressive Strength (MCS) parallel to grain

The maximum compressive strength parallel to grain was determined. The test sample was 20mm x 20mm x 60 mm according to the provisions of BS 373, method of testing small clear specimen of timber. Wood samples were loaded at the rate of 0.01 mm/sec, and the corresponding force at the point of failure were taken directly . This was divided by the cross sectional area of the test specimen to obtain value for maximum compressive strength parallel to grain.

Estimation of Uniformity Index

Uniformity indices along the axial and radial planes were estimated using extreme values both along and across the bole as follow:
For Axial uniformity, AU = LAV/UAV
While Radial uniformity, RU = LRV/URV
Where, LAV = Lowest axial value of wood property
UAV = Highest axial value of wood property
LRV = Lowest radial value of wood property
URV = Highest radial value of wood property

RESULTS AND DISCUSSION

The mean values of the wood properties evaluated in this study are presented in table 1. Table 2 shows the level of significance of the variability in wood properties, uniformity indices of wood are expressed table 3, while the patterns of variation are illustrated in figures 1 to 4.

Axial variation in wood properties

Specific gravity decreased significantly from base to 90% ML, figure 1. This consistent trend of base to top decrease had earlier been reported for *Gmelina arborea* (Akachuku, 1980), (Espinoza, 2004). Similarly, Ogunsanwo and Onilude,(2000) observed the same trend in a 27 year old plantation grown Obeche, *Triplochiton scleroxylon* in South West, Nigeria. Though the variation pattern is similar for all age classes, axial uniformity is best in age class 18 and lowest in age 36, table 3, thus showing that axial uniformity decreases with age in *Gmelina arborea*. According to Panshin and deZeeuw(1980), high axial uniformity index is considered a plus in wood utilization especially in structural applications. This finding should therefore provide a guide for effective planning of harvesting regimes for plantation grown Gmelina.

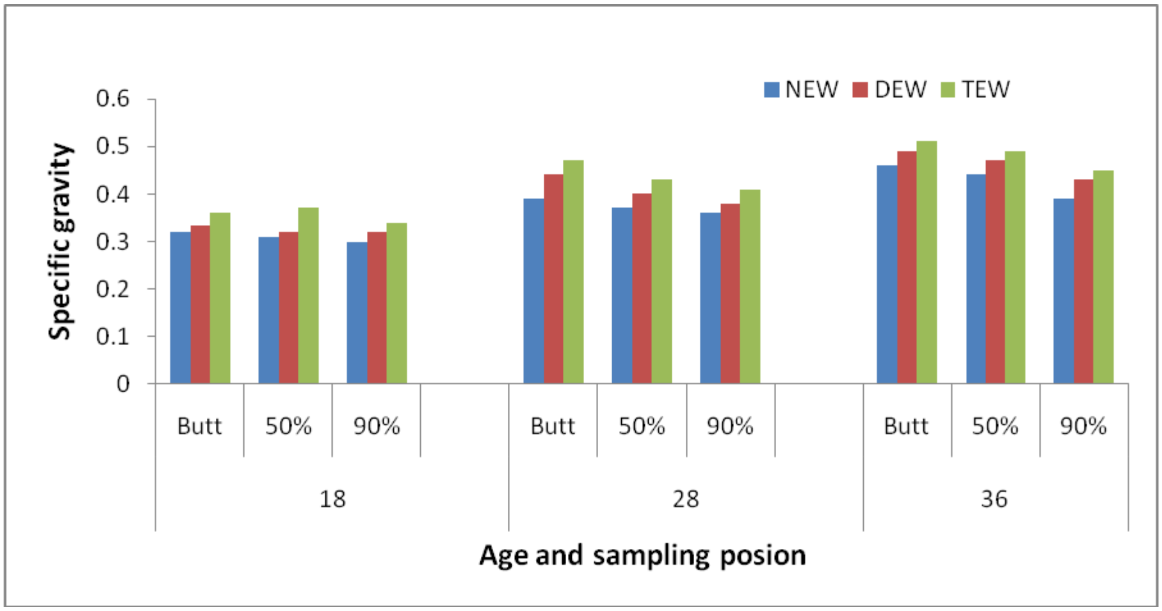

Fig.1: Variations in the Specific gravity of plantation grown *Gmelina arborea* from Nigeria

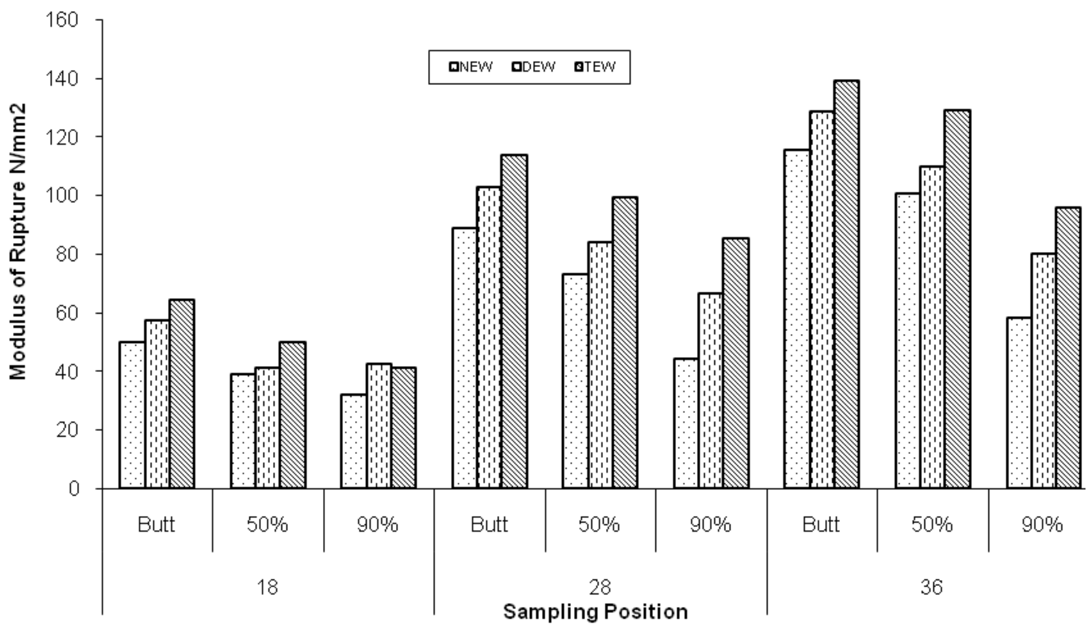

Fig. 2: Variations in the Modulus of rupture of Plantation Grown *Gmelina arborea* from Nigeria

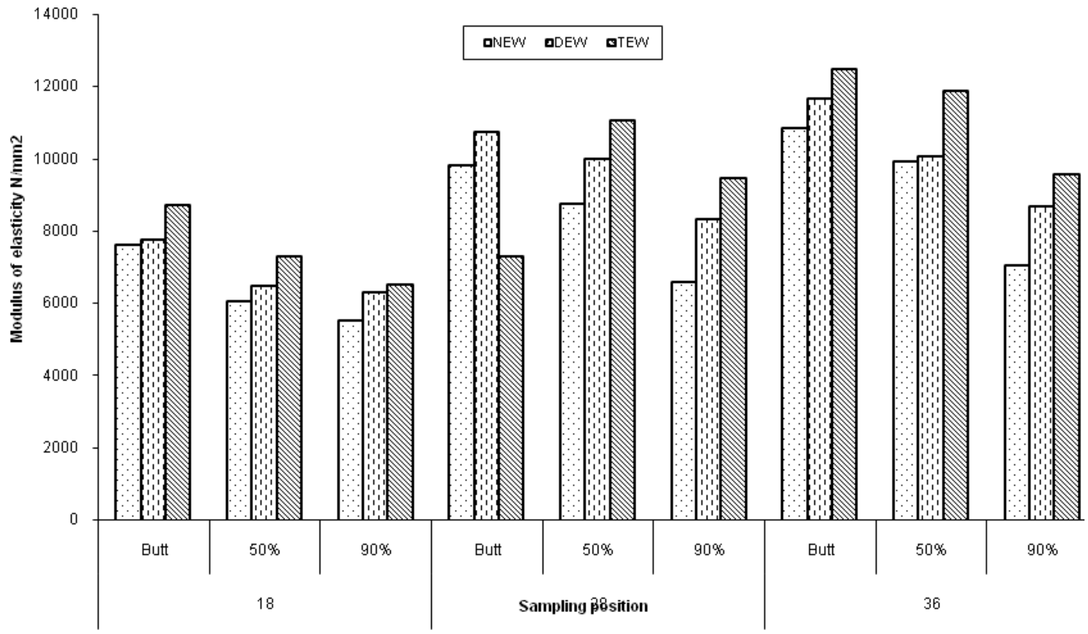

Fig. 3: Variations in the Modulus of elasticity of Plantation Grown *Gmelina arborea* from Nigeria

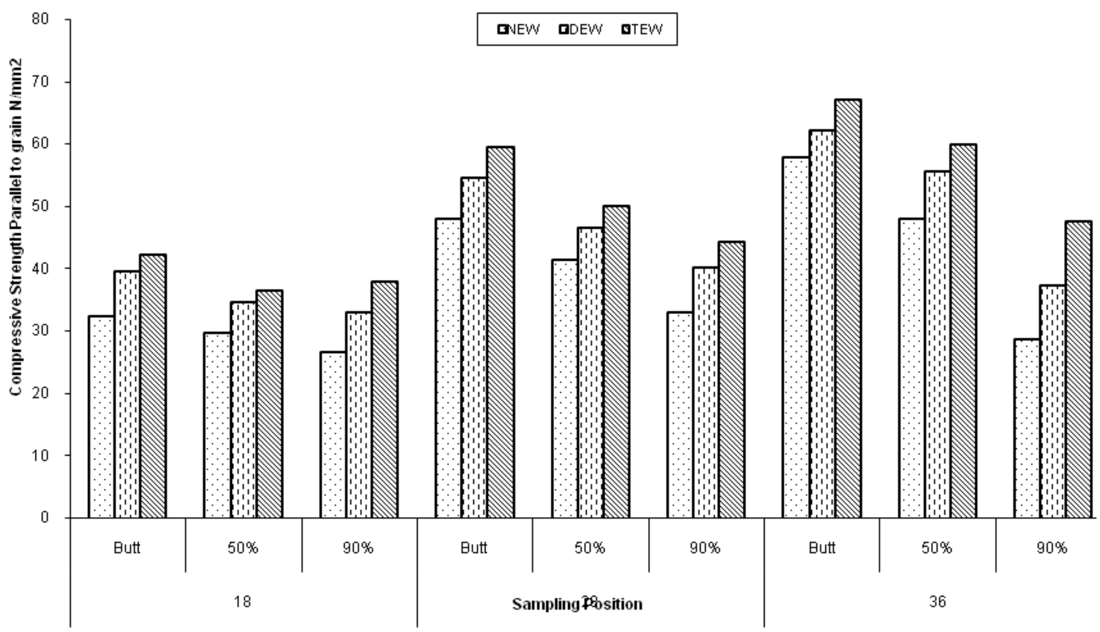

Fig. 4: Variations in the Compressive strength parallel to grain in Plantation Grown *Gmelina arborea* from Nigeria

Table 1: Mean values of wood properties of plantation grown *Gmelina arborea* from Nigeria.

Wood property	Age		
	18	28	36
SG	0.33 (0.04)	0.41 (0.03)	0.46 (0.05)
MOR (N/mm^2)	46.30 (10.84)	84.09 (17.30)	104.30 (17.12)
MOE (N/mm^2)	6910.35 (926.80)	9613.27 (1370.72)	10235.97 (960.40)
MCS (N/mm^2)	34.69 (6.22)	46.35 (5.91)	51.51 (8.78)

Values in parenthesis are standard deviation

Table 2: ANOVA table for selected wood properties of Nigerian grown *Gmelina arborea*

	F-Values at 5% level			
Property	Age	Replicate	Sampling Ht	Radial Position
SG	6.38*	0.43*	0.73*	1.22*
MOR	27.88*	1.44*	9.32*	4.41*
MOE	2.13*	0.15*	0.10*	0.05*
MCS	16.26*	2.72*	12.22*	6.72*

***** Significant at 5%

Table 3: Uniformity indices of wood properties across and along the bole of Nigerian *Gmelina arborea*

Wood axes	Age	Wood property			
		SG	MOR	MOE	MCS
Axial	18	0.94	0.64	0.73	0.82
	28	0.88	0.50	0.67	0.69
	36	0.84	0.51	0.65	0.49
Radial	18	0.86	0.78	0.85	0.76
	28	0.84	0.69	0.78	0.80
	36	0.90	0.71	0.82	0.77

There was a general decreasing trend in strength properties from butt to 90% ML, figures 2 to 4. For instance, MOR decreased from 57.08N/mm2 at the butt to 38.46N/mm2 at 90%ML in 18 year old Gmelina, from 101.66N/mm2 to 65.23N/mm2 in 28 years and from 127.56N/mm2 to 77.93N/mm2 in 36 years age class. The pattern of variation observed in this study conforms to the statement of Panshin and deZeeuw, (1980) and the findings of Malan, (1989), Biblis, (1990) and Onilude and Ogunsanwo, (2002). Though this trend is similar for all strength properties evaluated, the magnitude of variation differs from property to property thus affecting their axial uniformity indices. For MOR, Axial uniformity indices AU are 0.64, 0.50 and 0.51 respectively for 18, 28 and 36 age classes. Similarly, MOE has 0.73, 0.67, and 0.65; while MCS has 0.82, 0.69 and 0.49 respectively for age 18, 28 and 36. As observed for SG, AU values were also highest in age 18 compared to other age classes, with MCS having about 82% wood uniformity. Apart from MCS which has very low AU in age 36, uniformity does not appear to change appreciably from age 28 to 36, table 3.

Radial variation in wood properties

Specific gravity generally increased significantly from pith to bark. The trend, which is also similar for all sampling heights, had been reported by researchers in previous studies involving Gmelina and other tropical hard wood species. Hughes and Esan (1969), Akachuku, (1982),Ogunsanwo and Onilude,(2000) in plantation grown Obeche *Triplochiton scleroxylon* in Omo. Forest reserve south west Nigeria This trend was also reported by Espinoza, (2004) in a 5 year old Gmelina plantation in Venezuela. For all sampling heights, strength properties generally increased significantly at 5% level from NEW to TEW. MOR increased from 40.16N/mm2 in the inner wood to 51.81N/mm2 at the outer wood in age 18, in age 28 it varied progressively from 68.56N/mm2 to 99.35N/mm2, while increasing from 88.65N/mm2 to 121.20N/mm2 in 36 age class, showing that toughness in Gmelina increases with increase in distance from pith to bark. The result also shows that wood of *Gmelina arborea*, when partitioned, varies significantly in quality from innerwood close to pith to outerwood near the bark The variation pattern shown in this study is in tandem with the reports of Bendsten and Senft, (1986) in Eastern cottonwood and that of Molnar, (1989), which observed an increasing trend in static bending properties from pith to bark. This variation pattern is similar for all the strength properties evaluated figures 2 to 4. As observed along the axial plane, the magnitude of change from NEW to TEW is not the same for all age classes. This is reflected in the expression of Radial uniformity index RU Table 5, where RU for MOR was 0.78, 0.69 and 0.71 respectively for 18, 28 and 36 years Gmelina stands. MOE has 0.85, 0.78 and 0.82, while MCS has radial wood uniformity of 0.76, 0.80 and 0.77 for age 18, 28 and 36. Among the strength properties tested, MOE appears to have the highest RU, while the lowest was observed in MOR. This is very important where stiffness is of importance in Gmelina utilization

Effect of radial position on wood properties

Effect of sampling position along the radial plane is shown in table 1 and illustrated in figures 1 to 4. SG increased from 0.33 in age 18 to 0.46 in age class 36. An analysis of the rate of change in SG from one age class to the other shows an increase of 19.5% from 18 to 28 years while increasing at a decreasing rate of 10.9% from 28 to 36 years. It should be noted however that SG values obtained in this study are averagely lower than values obtained in similar studies (Akachuku, 1980) (Espinoza, 2004) and (Roque, 2004) in Gmelina stands of lower age. This is not surprising as site factors and geographical space have been implicated in SG variation, specifically, Roque,(2004) found SG of Gmelina in dry tropical site in Costa Rica 4% higher than those obtained in the humid site. Similarly, Akachuku, (1984) found 30% difference in SG of Gmelina due to geographical location. Also, significant an effect of management regimes on specific gravity has been demonstrated, Bada, (1990) Roque, (2004).

For strength properties MOR values were 46.3N/mm^2, 84.09N/mm^2 and 104.30N/mm^2 for ages 18, 28, and 36. The mean MOE were 6910.35N/mm^2, 9613.27N/mm^2 and 10235.97N/mm^2, while MCS were 34.69N/mm^2, 46.35N/mm^2 and 51.51N/mm^2 respectively for 18, 28 and 36 year old Gmelina. The result indicates that strength properties of Gmelina improve with age. Increase in strength properties with age had been reported in literature. For instance, Barret and Kellog, (1991) reported an increasing trend in compression strength with age in Douglas fir in Vancouver Islands

Canada. It should be noted however that despite the increase in wood properties with age, some sections along the vertical axis of the trees in the lower age category were found to be technically superior in quality than woods in older trees as a result of their position along the bole. For instance, woods obtained at the butt and at 50%ML of age 28 have higher MOR than wood at 90% ML in 36 year old Gmelina. In the same vein, the woods in the TEW of 28 year stand is similar in value to the DEW and the NEW of age 36, and as such could be regarded as woods of similar quality. It implies therefore that instead of categorising woods on the basis of mean wood quality index for different age classes, woods of similar wood quality should be brought together regardless of their age class and origin along and across the bole of tree. This falls in line with recommendations of Poku *et al* (2001) in a lesser-used species from Ghana. It is expected to reduce to the barest minimum, the intra and inter tree variability often observed in *Gmelina arborea*.

Uniformity indices along and across the bole are also affected by age. Radial Uniformity values were generally higher than AU in *Gmelina arborea* showing that wood of Gmelina may be more uniform across the bole than vertically along the bole, . In all the strength properties studied, MOE showed the highest uniformity both across and along the bole, thus giving an indication that *Gmelina arborea* may be more reliable in applications where stiffness is of importance.

CONCLUSION

The study was able to show that wood properties of *Gmelina arborea* decreased significantly from butt to 90% merchantable length, and increased from pith to bark. Wood processors should take note of this important finding in strategizing for efficient wood utilization. It may be necessary therefore to match wood of the same species on the basis of quality index so as to reduce variability within and between trees. It was further shown that there was an increase of 44.8% in MOR between18 and 28 years and 19.1% between 28 and 36 years, implying that harvesting should be done before age 36 for optimum return. While wood uniformity index decreases with age along the vertical axis, that along the radial plane improves with age of stand. Further research is however needed in the area of striking balance among harvesting age, wood quality and uniformity.

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