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INVESTIGATION OF WOOD PROPERTIES AND RESISTANCE OF 25-YEAR-OLD *Gmelina arborea* WOOD SELECTED FROM CROWN REGION TO TERMITE ATTACK

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ABSTRACT

Gmelina arborea is widely planted and produces many useful products. However, the upper portion of the stem might be useful for some practical applications if properly managed and harvested. In order to explore the potential of this residues, this study investigated the physical, mechanical properties, and resistance of 25-year-old *Gmelina arborea* (gamhar) wood from the crown region to termite attack. This is with a view to enhance the use of harvesting residues of *Gmelina arborea* (gamhar) such that the wood in the crown region is used as the main trunk in various applications. The following wood properties including density, modulus of elasticity, modulus of rupture, and compression strength were investigated on crown wood of 25-year-old *Gmelina arborea* (gamhar). This study compared with results obtained from previous studies for the bole. Test for the natural resistance of the crown wood was carried out at the timber graveyard where the samples were exposed to termites for 10 weeks to determine the weight loss. The wood samples were rated weekly according to the America Standard of Testing Material. Our results showed that there were significant differences in the density of the crown wood of the three selected 25-year-old *Gmelina arborea* (gamhar) stands. The results for the mechanical properties of the crown wood of the three selected 25-year-old *Gmelina arborea* (gamhar) trees showed that there were significant differences in the compression and modulus of rupture of the wood samples from the crown region while there was no significant difference in the modulus of elasticity among the selected stands. Visual rating results showed that termite attack ranged from moderate to heavy attack, while the weight loss was not significantly different among the sampled trees. This study has shown that the density and mechanical properties of the crown wood are comparable to those from the trunk. Hence, the crown wood can be used in application as the stem wood. Also, the study has shown that wood from crown region of *Gmelina arborea* (gamhar) are prone to termite attack and non-durable as the wood obtained from the stem. Therefore, there is a need to apply treatments that can improve its durability and enhance its service life.

Keywords: Crown region, *Gmelina* wood, harvesting residue, mechanical properties, physical properties, termites.

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INTRODUCTION

Gamhar (*Gmelina arborea* Roxb.) is among the fastest-growing tree species used by the wood industry as an alternative source to the diminishing supplies of premium commercial timber species from the natural-grown forests. Plantations of gamhar (*Gmelina arborea* Roxb.) are mainly used for timber, poles, pulp and paper production (Egbewole *et al.* 2018).

gamhar (*Gmelina arborea* Roxb.) is a deciduous tree of the Verbenaceae family. One of the many advantages of gamhar (*Gmelina arborea* Roxb.) over other tree species used for construction is its ability to quickly produce coppices of more than five stems that can be thinned over time, and which can provide quick cover after cutting. gamhar (*Gmelina arborea* Roxb.) wood is used for furniture, carriages, sports, musical instruments and artificial limbs. Once seasoned, the wood is stable, moderately durable (class 3-4) and moderately resistant to termites (Scheffer and Morrell 1998).

Harvesting residues consist mainly of the crown region, which is left to rot on the field or is burned after logging operation is completed. While previous studies have examined various properties of the merchantable portions of gamhar (*Gmelina arborea* Roxb.) wood (Ogunsanwo and Akinlade 2011, Owoyemi *et al.* 2015), it is important to examine the properties of wood from the portion of the tree to determine its suitability for uses where wood from the main trunk is utilized. The increasing shortage in timber supplies in the face of rapid growth in population, there is a need to ensure an increase in recovery volume of tree stands at the point of harvesting.

The peculiarity of wood from the crown region is that it has a high proportion of juvenile wood as well as wood defects such as knots leading to inferior performance as sawn wood. Juvenile wood is characterized by large microfibril angles, short fibres with thin walls and lower density contributing to the lower quality of juvenile wood products (Zobel and Van Buijtenen 1989).

As a way of comparing the performance of crown wood to that of the main trunk, this study investigated wood properties of the wood from the crown region which will contribute to the utilization of timber from the crown region of the gamhar (*Gmelina arborea* Roxb.).

MATERIALS AND METHODS

Wood samples for this study were selected from three already felled 25-year-old trees of gamhar (*Gmelina arborea* Roxb.) at a plantation owned by the Department of Forestry and Wood Technology, Federal University of Technology, Akure. The branches from the crown of each tree were sawn separately and marked for identification. Thereafter they were transported to the Wood Workshop of the Department for further processing into required dimensions of 20 mm x 20 mm x 60 mm for the physical properties and compression tests parallel to the grain, 20 mm × 20 mm ×300 mm for flexural properties tests (modulus of elasticity and modulus of rupture) and 35 mm x 35 mm x 450 mm for durability test. From each tree, a total of 20 samples were selected for each property, this gives an overall total of 240 samples used for the experiment.

Wood density determination

After processing the samples, the initial weights (W_o) and dimensions of the samples were measured before oven-drying at 103 ºC ± 2 °C to a constant weight. Thereafter, the oven-dry weight (W_1) and dimensions were measured. The moisture content of the samples was determined from the initial and oven-dried weights of the samples, and density was determined on an oven dry basis Equation 1.

$$Density = \frac{Mass}{Volume}\left(kg / m^3\right) \qquad (1)$$

Analysis of mechanical properties

For the analysis of mechanical properties (bending tests and compression parallel to the grain), samples were tested in accordance with the American Standard for Testing Materials, ASTM D143.22420 (2000). Samples were mechanically tested using the Universal Testing Machine equipped with a 20 kN load cell (Jinan Hensgrand Instrument Co., Ltd., Jinan, China). For the mechanical tests, a loading rate of 2 mm/min was used to ensure that the samples reached failure within 90 seconds.

Durability test and exposure of wood samples to termites

The durability test was carried out at the timber graveyard of the Department of Forestry and Wood Technology, Federal University of Technology Akure, Nigeria. It is located on the latitudes 07° 16′ and 07° 18′ N and longitudes 05° 09′ and 05° 11′ E. It lies along Akure-Ilesa expressway, with Awule and Ibule as the neighboring villages (Agbelade and Akindele 2013). The mean annual temperature is about 26 °C (min. 19 °C and max. 34 °C) and rainfall of 1500 mm with bimodal rainfall pattern (Ogunrayi *et al*. 2016). *Microtermes* spp. and *Macrotermes subhylinus* Rambur are the most abundant termite species prevalent in the study site (Owoyemi *et al*. 2022).

Sample dimensions of 35 mm x 35 mm x 450 mm were selected to test the durability of the wood samples. All the samples were labeled for easy identification and their initial wet weight obtained using a weighing balance, after which they were oven-dried at 103 ºC ± 2 °C for 24 hours to a constant weight. The oven-dried weights of each sample were also noted, and this served as the starting (i.e., initial) weight of each of the samples with respect to weight loss assessment.

The wood species were buried to half their length below ground and at a spacing of 100 mm by 100 mm according to ASTM D 1758-06.2006 (2006). at graveyard for 10 weeks. During the period, visual ratings of the exposed samples was done every week to determine the extent of termite attack on the samples. The ratings were done as follows:

10 = Sound, surface nibbles permitted.

9 = Light attack

7 = Moderate attack penetration

4 = Heavy attack

0 = Failure

At the end of the exposure period, weight loss due to termite exposure was determined from the initial dry weight of the samples before exposure and the final dry weight (W_3) of the samples after withdrawn from the timber graveyard. The weight loss was calculated with the following equation Equation 2.

$$Weight\ loss = \frac{W_2 - W_3}{W_2} x\ 100 \qquad (2)$$

Where:

W_2 = conditioned weight after oven-drying (kg).

W_3= Oven dry weight after exposure to termites’ attack (kg).

Statistical analysis

The experimental design adopted for wood properties and natural durability test was a 3 x 2 factorial experiment (3 factors with 2 levels) in a Completely Randomized Design with five replicates for each test sample. Data obtained were analyzed using descriptive statistics and a chart was employed to assess variation patterns in percentage weight loss. The means and standard deviations of the data were subsequently determined. The means were separated using Duncan's New Multiple Range Test (DNMRT) at 0,05 level of probability.

RESULTS AND DISCUSSION

Density of *Gmelina* wood from the crown region

Wood density has long been considered the most important wood quality attribute (Walker 2006). To a large extent, wood density determines the suitability of a species for a specific end use. For the crown wood under study, the mean values of the densities of the gamhar (*Gmelina arborea* Roxb.) wood obtained from three selected trees are shown in Table 1. It can be observed from the results that wood obtained from tree 3 has the highest mean density, followed by wood obtained from tree 2, while wood obtained from tree 1 has the least mean density.

Table 1: Mechanical properties of *Gmelina arborea* for three different trees.

Trees	Density (kg/m^3)	MOE (MPa)	MOR (MPa)	Compressive strength (MPa)
Tree 1	$525,70 \pm 47,92^{b}$	$5954,21 \pm 834,26^{a}$	$78,13 \pm 8,18^{ab}$	$37,87 \pm 2,38^{a}$
Tree 2	$552,69 \pm 62,70^{b}$	$6359,09 \pm 1574,55^{a}$	$83,64 \pm 12,63^{a}$	$34,51 \pm 2,80^{a}$
Tree 3	$607,90 \pm 106,25^{a}$	$5508,40 \pm 1899,44^{a}$	$64,62 \pm 13,40^{b}$	$24,80 \pm 2,97^{b}$

Values are means ± SD; Values in the same column for each tree with the same superscript are not significantly different ($P > 0,05$) from each other.

The density of wood obtained from the crown region of the three selected 25-year-old gamhar (*Gmelina arborea* Roxb.) trees showed that wood obtained from the crown region has higher density than that of the stem which was recorded in the work of Owoyemi *et al.* (2015) where the overall mean density of 463,89 kg/m^3 was obtained in different plantation. Alao (2014) further reported 475,56 kg/m^3 as the mean value for density of gamhar (*Gmelina arborea* Roxb.), while Ogunsanwo and Akinlade (2011) reported an average relative density of 370 kg/m^3 for gamhar (*Gmelina arborea* Roxb.) wood between the ages of 18 years and 28 years selected from the trunk.

These results showed that there are variations in the density of the wood from the stem and the crown region wood. The reason for the differences in the results could likely be the age of the assessment and site or could be that trees used in previous studies have high juvenile wood as it is known to have poor wood quality (Walker 2006).

Bending and compression (parallel to the grain) properties of *Gmelina* wood from crown region

The MOE of wood obtained from the 25 years old plantation of gamhar (*Gmelina arborea* Roxb.) (Table 1) showed that Tree 2 had the highest mean MOE, followed tree 1, while tree 3 had the lowest mean MOE. In addition, results showed that the analysis of variance for the Modulus of Elasticity of crown wood of three selected gamhar (*Gmelina arborea* Roxb.) trees were not significantly different ($P > 0,05$) (Table 2).

Table 2: ANOVA Table for modulus of elasticity of *Gmelina arborea* wood obtained from three selected trees.

	Sum of Squares	Df	Mean Square	F	P	Sig.
Trees	1810599,870	2	905299,935	0,400	0,679	Ns
Error	27132248,776	12	2261020,731			
Total	28942848,647	14				

Ns = Not significant.

Results for Modulus of Rupture (Table 1) showed that Tree 2 had the highest mean of Modulus of Rupture, followed by wood obtained from tree 1, while wood obtained from tree 3 has the least mean Modulus of Rupture. From the foregoing it was observed that the Modulus of Rupture of gamhar (*Gmelina arborea* Roxb.) wood varies between the trees on average mean of 75,46 MPa ± 13,39 MPa. The result presented for MOR contradicted the high value reported for density of the trees and this could be that there is a presence of knots which impacts the strength of the wood.

Results in Table 3 shows the analysis of variance for the Modulus of Rupture of three selected gamhar (*Gmelina arborea* Roxb.) crown wood obtained from 25 years old plantation; from the Table 3, it was observed that there are significant differences ($P > 0,05$) in the Modulus of Rupture of crown wood obtained from the three trees.

Table 3: ANOVA Table for modulus of rupture of *Gmelina arborea* wood obtained from three selected trees.

	Sum of Squares	Df	Mean Square	F	P	Sig.
Trees	958,074	2	479,037	3,542	0,062	*
Error	1622,736	12	135,228			
Total	2580,811	14				

*Values less than 0,05 are significant.

Results obtained for the compression strength obtained from the crown region of the three selected 25-year-old gamhar (*Gmelina arborea* Roxb.) trees are low compared to the work of Ogunsanwo and Akinlade (2011) where the mean value for compression strength obtained from the bole of 18-year-old gamhar (*Gmelina arborea* Roxb.) was 34,69 MPa and 46,35 MPa for 28-year-old. This showed that wood from the crown region has lower compression strength than the bole of 18-year-old and 28-year-old gamhar (*Gmelina arborea* Roxb.).

Results obtained for the modulus of rupture from the crown region of the three selected 25-year-old gamhar (*Gmelina arborea* Roxb.) trees were higher compared to the work of Ogunsanwo and Akinlade (2011) where the mean modulus of rupture obtained from the bole of 18-year-old gamhar (*Gmelina arborea* Roxb.) was 46,30 MPa and 84,09 MPa for 28-year-old gamhar (*Gmelina arborea* Roxb.). This showed that wood from the crown region has a higher modulus of rupture than that of the trunk.

The results obtained for the modulus of elasticity obtained from the crown region of the three selected 25-year-old gamhar (*Gmelina arborea* Roxb.) trees corroborates with the work of Ogunsanwo and Akinlade (2011) where the mean modulus of elasticity obtained from the bole of 18-year-old gamhar (*Gmelina arborea* Roxb.) was 6910,35 MPa, and 9613,27 MPa for 28-year-old. The variations in the mechanical properties of the crown wood might have been as a result of the age of trees and variation in density between wood from the crown region and the trunk.

The higher mechanical properties of gamhar (*Gmelina arborea* Roxb.) wood from the crown region compared to those from the stem as shown from previous studies imply that the crown wood can be used for similar purposes as those of the trunk. The compression strengths of the gamhar (*Gmelina arborea* Roxb.) wood obtained from the crown region revealed that samples from tree 1 have the highest mean compression strength, followed by crown wood obtained from tree 2 , while those from the tree 3 has the least mean compression strength (Table 1). For tree 3, as observed also in the bending properties, had lower strength despite its higher density.

This may be as a result of defects such as grain deviation in the tested samples. Among the three trees, compression strength values of the crown wood of trees 1 and 2 were not significantly different but were significantly different from tree 3. The previous results obtained for the trunk of 18- and 28-year-old Gmelina wood by Ogunsanwo and Akinlade (2011) showed that the compression strengths of the trunk are comparable to those from crown wood. However, when the variations inherent in wood properties within and between trees and their ages are considered, then it can be observed that compression strength values obtained for the trunk are higher compared to that of crown wood.

Resistance of 25-year-old *Gmelina* wood selected from crown wood region to subterranean termites

Results obtained from visual assessment of termites' attack on crown wood of 25-year-old gamhar (*Gmelina arborea* Roxb.) that was done every week after it was buried at the timber graveyard for total of 10 weeks is shown in Figure 1.

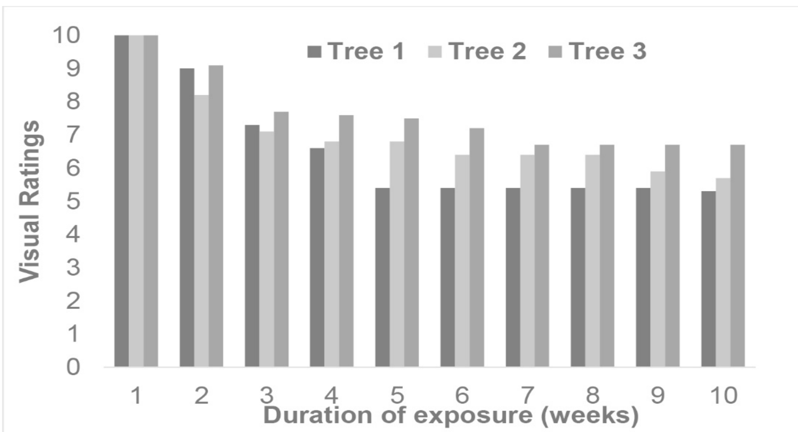

Figure 1: Visual ratings of crown wood of tree 1 after exposure to termites.

The result obtained for visual ratings of the tree selected trees of gamhar (*Gmelina arborea* Roxb.) after 10 weeks of exposure is lower in comparison to the work of Owoyemi *et al.* (2011) which recorded 7,92 as the mean visual rating for 25-year-old gamhar (*Gmelina arborea* Roxb.) wood after 18 months of exposure to termites. This showed that wood from crown region of 25-year-old gamhar (*Gmelina arborea* Roxb.) wood has lower resistance compared to the wood from the trunk. In addition, the mean weight loss values of the three trees after exposure to termites further showed that the highest weight loss was obtained for tree 1 (57,46 % ± 19,43 %), followed by wood obtained from tree 2 with 51,78 % ± 21,78 %, while wood obtained from tree 3 has the least mean weight loss of 46,76 % ± 24,29 % (Table 4).

The low resistance of the crown wood to termites might be as a result of less wood extractives in the wood from the crown region, as many of them may be active in transport of sap, implying higher proportion of sapwood compared to the stem. Miller (1999) and Rowell (2005) stated that the organic components of extractive influence some wood properties such as color, odor, taste, decay resistance, density, hygroscopicity, and flammability. The implication of this is that, where these organic components are absent, usually in the sapwood, the wood is prone to attack from insects and other bio-deteriorating agents.

Table 4: Weight Loss of *Gmelina arborea* wood obtained from three selected trees.

Tree	Weight loss (%)
Tree 1	$57{,}46 \pm 19{,}43^{a}$
Tree 2	$51{,}78 \pm 21{,}78^{a}$
Tree 3	$46{,}76 \pm 24{,}29^{a}$

Values are means ± SD; Values in the same column for each tree with the same superscript are not significantly different (*P* > 0,05) from each other.

CONCLUSIONS

This study has shown that there are variations in the mechanical properties and resistance of *Gmelina* wood from the crown region of 25-year-old trees to termites compared to those from existing research on the main truck of *Gmelina arborea* wood and, the crown wood can be used in application as stem wood.

As the crown wood tend to have a low resistance to subterranean termites, there is a need for chemical treatments that can enhance its durability. Hence, chemical modification processes or the use of environmentally friendly preservatives are suggested to improve its durability and enhance the service life of crown wood of *Gmelina arborea*.

Author contributions

S. O. O.: Conceptualization, methodology, supervision, writing–review & editing; E. A. I.: Conceptualization, methodology, writing–original draft, writing–review & editing; A. A. O.: Methodology, data analysis, writing–original draft, writing–review & editing.

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