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Understanding the Technical Properties of *Delonix regia* (HOOK.) RAF. Wood: A Lesser Used Wood Species

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Abstract

Properties of a lesser-used wood species were investigated to determine its potential for structural utilization. Trees of *Delonix regia* were felled and sampled at the base, middle and top and then sectioned to inner wood, middle wood, and outer wood for variation across the axial and radial directions. Hence, selected physical and mechanical properties as well as natural durability of *D. regia* along the radial and axial directions were examined. Obtained data were analyzed using analysis of variance (ANOVA) at $\alpha_{0.05}$. There was no significant difference in the Moisture content (MC) of the wood but specific gravity (SG) decreased from base to top ranging from 0.35-0.44. Water absorption, volumetric swelling, and volumetric shrinkage range from 46.18-51.86%, 2.57-4.02%, and 2.26-3.96% respectively along the axial plane. The weight loss for graveyard exposure and accelerated laboratory decay test ranged from 25.14-48.00% and 32.02-44.45% respectively. Modulus of Rupture and Modulus of Elasticity values range from 29.42-72.68 Nmm^2 and 3,834.54-8,830.37 Nmm^2 respectively. The SG values has confirmed the species as a medium density wood and values of other properties tested showed that the wood is dimensional stable and moderately resistance to fungi and termite. Hence, it could be used for light construction purposes such as furniture and other interior woodwork.

Key Words: *Delonix regia*, specific gravity, mechanical properties, swelling, weight loss

Introduction

Forests have been a source of diverse benefits to many individuals through the provision of food materials, energy production, and wood for construction materials. According to Fuwape (2000), wood is the oldest and most valuable material in every developmental stage of humans for structural work. Primarily, wood consists of natural polymers like cellulose, hemicelluloses, and lignin in a matrix, providing resistance to microbial activities and structural support for a living tree. These days, many popular wood species used for structural materials such as *Triplochiton scleroxylon* (Obeche), *Milicea excelsa* (Iroko), and *Termilania superba* (Afara) among others have become threatened in Nigeria and other African natural forests. Although, the satisfaction derived from these few species has made lesser-known

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wood species that are of merchantable sizes and commercial quantities be neglected (TEDB 1990). As prices of well-known tropical tree species increase and the quantities and quality decrease, wood users have no other option than to put the neglected lesser-used wood species into consideration. Thus, there is a need to encourage the use of lesser-known wood species in Nigeria to meet the high demand thereby reducing the exhaustion of well-known wood species (Barany et al. 2003).

Considering the lesser-used wood species in engineering applications to promote its effective utilization, properties and characteristics of such wood must be considered. Panshin and de Zeeuw (1980) discussed that the fitness of any wood for a particular use lies in its tree size, wood quality, their unique cellular structure, and properties. Hence, information on the technical properties of these lesser-used species must be developed to ascertain their utilization potential.

The application and suitability of any wood species for any structural purpose are determined by the physical and mechanical properties of wood. It is therefore imperative to study the properties of some of the lesser-known wood species before their use.

D. regia is a conspicuous, fast-growing almost evergreen legume tree that grows up to 10-30 m in height and is shallow-rooted. It is also called Royal Poinciana, flamboyant tree, flame tree, and peacock flower which belongs to the family of Fabaceae. Its trunk is tall and unbranched, sometimes with narrow, spreading buttresses extending from near the base (Anonymous 2011). It is native to Madagascar and Zambia and was introduced into many countries, such as Australia, Brazil, Burkina Faso, Cameroun, Cyprus, Egypt, Eritrea, Ethiopia, India, Israel, Jamaica, Kenya, Mexico, Niger, Nigeria, Puerto Rico, Singapore, South Africa, Sri Lanka, Sudan, Tanzania, Uganda and the United States of America. It is now widespread in most tropical and subtropical areas of the world (Anonymous 2011; Dukku 2011; Royal Botanic Gardens, Kew. 2011) *D. regia* is an outstanding flowering tree widely grown and cultivated for gardens, parks, along streets, and for large front yards. Mature trees provide excellent shade (Orwa et al. 2009).

The full knowledge of its technical properties in terms of physical and mechanical properties likewise the natural durability of *D. regia* wood is imperative. This can only be obtained through scientific research for right and efficient usage. Hence, this study was carried out to determine the technical properties of *D. regia* in terms of variation in physical, and mechanical properties and natural durability across the radial and axial directions.

Materials and Methods

Sample collection

A merchantable tree of *D. regia* was selected based on absence tendencies, bole devoid of crookedness (that is clear and straight bole), and absence of excessive knots. The tree aged 35 years with a height of 40.63 m and a diameter at breast height (DBH) of 102 cm. The tree was harvested with the aid of a chainsaw and bolts 50 cm long (length) were collected at three different positions along the length of the bole that is base, middle, and top representing 90, 50, and 10% respectively of the merchantable height of the tree forming the sampling height or axial position (Fig. 1).

Within tree sampling was carried out using a circular saw machine and planning machine in that discs of 5 cm in thickness were obtained from the bolts. Radial strips on two opposing planes of the surface of the disc through the pith were marked and converted to 20×20×300 mm and 20×20×60 mm. (radial×tangential×longitudinal). The radial strips were partitioned into three zones and named inner wood, middle wood, and outer wood based on the relative distance from the pith as done by Ogunsanwo (2000)

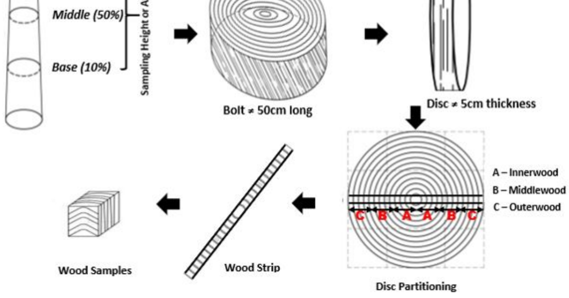

Fig. 1. Tree sampling height and position of wood samples in the *Delonix /regia.*

and Ajala (2006). Meanwhile, the converted dimensions 20 mm×20 mm×300 mm and 20 mm×20 mm×60 mm (radial×tangential×longitudinal) were used for mechanical and physical tests respectively.

Determination of physical properties

Moisture content

At each sampling position (i.e. top, middle and base), five wood replicates were taken from the outer wood, middle wood, and inner wood making a total of forty-five wood specimens. Moisture content was determined using the standard procedure described by ASTM D4442-07. In determining the moisture content, the initial weight of forty-five wood specimens of *D. regia* with dimensions; 20×20×60 mm were taken from the inner-, middle-, and outer wood along the top, middle, and base of the tree were recorded, afterward, the wood samples were placed inside the laboratory oven at a temperature of 103±2°C, the weight was recorded and repeated until no appreciable weight change occurred in a 3-h weighing interval. The moisture content of the wood samples was then determined using equation (1).

$$MC(\%) = \frac{W_1 - W_2}{W_2} \times 100 \qquad (1)$$

where,

W_1=Weight of wood

W_2=Oven dry weight

Specific gravity (SG)

Forty-five samples of *Delonix regia* comprising five wood replicates taken from each sampling position with dimensions 20 mm×20 mm×60 mm were tested for specific gravity. After the wood samples have been oven-dried, it was conditioned to a climate that was 25±2°C and 65±5% relative humidity (RH) to achieve 12% moisture content of the wood specimen. The specific gravity was determined using the standard procedure of ASTM 2395. The test materials were measured severally at a precision of ±0.2% to indicate volume and masses which are used in the determination of specific gravity. SG was determined using equation (2).

$$SG_M = \frac{Km_O}{V_O} \qquad (2)$$

where:

K=Constant, estimated by the units used to measure mass and volume:

1,000 mm^3/g when mass is in g and volume is in mm^3.

M_o=Oven-dry weight of the sample.

V_o=Oven-dry volume of sample.

Water absorption

Forty-five wood specimens of *Delonix regia* comprising five wood replicates taken from each sampling position with dimensions 20 mm×20 mm×60 mm were soaked in distilled water for seven days. Thereafter, the samples were retrieved and weighed and water absorption was determined using the standard procedure of ASTM 1037 (1999) according to equation (3).

$$\%\,WA = \frac{W_2 - W_1}{W_2} \times 100 \qquad (3)$$

where,

WA=Water absorption

W_2=Wet weight after soaking in water (g)

W_1=Initial oven-dry weight before soaking in water (g)

Volumetric swelling test

Five wood replicates were taken from each sampling position making a total of forty-five wood specimens. Volumetric swelling of the oven-dry specimens was determined by soaking the specimen in a water bath containing distilled water for seven days at a temperature of 20±1°C according to ASTM-1037 (1999). The swelling of the wood specimens was measured by using a digital veneer calliper at the end of each day for seven days. Volumetric swelling of the wood was determined using equation (4).

$$\%\ \textit{Volumetric Swelling} = \frac{T_2 - T_1}{T_1} \qquad (4)$$

Where,

T_1=Volume of the specimen before soaking in water (mm^3)

T_2=Volume of specimen after soaking in water (mm^3)

Volumetric shrinkage

The volumetric shrinkage of the samples was measured according to ASTM-1037 (1999). Forty-five wood specimens comprising five wood replicates taken from each sampling position were used to determine volumetric shrinkage. The samples were soaked in a water bath containing distilled water at a temperature of 20±1°C for seven days. Specimens were removed one after the other in wet condition to measure the dimensions while percentage shrinkage was determined after the specimen had been oven-dried. Volumetric shrinkage was calculated according to equation (5).

$$\%S = \frac{D_s - D_o}{D_o} \tag{5}$$

Where,

S=% Coefficient volumetric shrinkage

D_s=Dimension of soaked wood samples (mm^3)

D_o=Dimension of oven-dried wood samples (mm^3)

Determination of mechanical properties

Modulus of rupture (MOR) and modulus of elasticity (MOE)

Forty-five wood samples dimensioned into 20 mm×20 mm×300 mm (radial×tangential×longitudinal) according to the British Standards Institution (1957) comprising five replicates taken from each sampling position were used to determine Modulus of Rupture (MOR) and Modulus of Elasticity (MOE).

The specimens were conditioned to 12% moisture content 25±2°C and 65±5% RH before the test. The mechanical properties were determined using an MTS-SANS CMT 5000 Universal testing machine. The specimens were tested at a crosshead speed of 0.635 mm/min. The loads were applied until the failure of the sample occurred. The load at which each text sample failed was recorded. The MOR was calculated using equation (6).

$$MOR = \frac{3PL}{2\triangle bd^2} \tag{6}$$

where:

P=Load (N);

L=Span (mm);

b=Width (mm);

d=Thickness (mm)

The values obtained from the load-deflection graph during the test for MOR were used to calculate the modulus of elasticity. The MOE was calculated using equation (7).

$$MOE = \frac{3PL^3}{4\triangle bd^3} \tag{7}$$

where:

P=Maximum load at failure (N).

L=Span (mm).

b=Depth.

d=Width (mm).

△=Deflection of beam center at proportional load

Natural durability test

The procedure of the accelerated decay test for fungi (BS EN 350)

The preserved purified culture of white rot fungi (*Pleurotus ostreatus*) obtained from the Pathology Laboratory, Federal College of Forestry Ibadan, Nigeria was used. Potato Dextrose Agar (PDA) was used as a culture medium to culture the fungus incubated at room temperature in a petri dish. The McCartney bottles were prepared and used for the incubation of the specimens, and they were sterilized by autoclaving at 0.1 N/mm^2 (120°C) for a period of 20 minutes and the medium was inoculated with the test fungi. Forty-five specimens of *Delonix regia* comprising five wood replicates (inner wood, middle wood, and outer wood) taken from each sampling position (top, middle and base) with dimensions 20 mm×20 mm×60 mm were conditioned to 12% moisture content 25±2°C and 65±5% RH before the test. Afterward, the specimens were placed in the bottles containing actively growing test fungus such incubated at room temperature (27±2°C) for 16 weeks. After 16 weeks, the blocks were removed from the culture bottles, cleaned, and oven-dried at 103°C to a constant weight (Sarker et al. 2006; Adebawo 2019). The weight loss for the accelerated test (WLa) of the blocks was calculated using equation (8).

$$\%\mathrm{WL\ a} = \frac{T_3 - T_4}{T_3} \times 100 \tag{8}$$

T_3=Weight of test block

T_4=Weight of test block after fungi exposure

Graveyard test

The evaluation of the durability of the wood specimen was conducted by burying *D. regia* wood in the graveyard.

A total of fifty-four (54) wood specimens of *D. regia* with dimensions 20×20×300 mm were used. At each sampling position comprising the top, middle, and base; six wood replicates were taken from the outer wood, middle wood, and inner wood. The wood specimens were buried up to two-thirds of their lengths in the ground for 16 weeks and were placed 0.6096 meters apart (Emerhi et al. 2015; Noor et al. 2015). After 16 weeks, the test blocks were removed and conditioned to determine their weight loss for the graveyard test (WLg) using equation (9).

$$\%\mathrm{WLg} = \frac{T_3 - T_4}{T_3} \times 100 \qquad (9)$$

T_3=Weight of test block

T_4=Weight of test block after graveyard exposure

Data analysis

The experiment adopted 3×3 factorial experiments in a complete randomized design and was analyzed statistically using analysis of variance (ANOVA) to test significant differences in axial and radial positions. Meanwhile, the group that was significantly different at $\alpha_{0.05}$ were identified using Duncan Multiple Range Test (DMRT) for the comparison of means.

Results and Discussion

Moisture content and specific gravity

The results of variation in moisture content and specific gravity of *D. regia* across axial and radial planes are presented in Table 1. The moisture content of the air-dried *D. regia* ranged from 10.95-11.98% in the axial direction of the wood. There was an increase from the inner to the middle and somehow decreased to the outer part of the studied wood. Meanwhile, no significant difference was found in the moisture content of the specimen across radial and axial positions.

A significant difference in SG of the wood along the axial direction is observed (Table 1). SG of the wood in the axial direction ranged from 0.35-0.44. Across the radial plane, the base-inner has the highest SG and there is a significant difference in the values along the radial plane. The SG reduces from the inner to outer wood along the radial positions and decreases from base to top in axial positions. This is expected because the density of wood is normally higher at the buttress of the wood because of greater compaction of tissues put forth by overlapping cells along the tree bole (Ali 2010). Variation of a similar pattern along radial position was recorded for *Alstonia boonei* (De wild) however, it increased from base to top in the axial direction (Otoide 2017).

The SG of *D. regia* is higher than the specific gravity reported by Eyma et al. (2004) for some common hardwood species such as *Ceiba pentandra* Gaertn, 0.204; *Triplochiton scleroxylon* K. Schum, 0.315. SG is an essential wood property that influences the performance of any wood species. Usually, SG decreases from base to top (crown) and from inner wood (heartwood) to outer wood (sapwood) (Belleville et al. 2020). The pattern of variation of the SG is consistently decreasing from base to top axially and from inner wood to outer wood radially. SG is an important quality that determines properties of wood such as strength, hardness, durability, and other properties to determine its utilization.

It has been reported by TEDB (1990) that at 12% MC, SG of wood is graded high (very heavy) if greater than 0.5; medium if between 0.35-0.5; and low if it is less than 0.35. Thus, the specific gravity of *D. regia* along the radial and axial position falls within 0.35-0.5, using this criterion, it would be graded as medium-density wood. As medium-

Table 1. Moisture content and specific gravity of *Delonix Regia* in axial and radial position

Axial position	Radial position	Moisture content (%)	Specific gravity
Top	Inner	11.24 (0.77)^a	0.36 (0.02)^a
	Middle	11.98 (0.86)^a	0.36 (0.02)^a
	Outer	10.95 (0.83)^a	0.35 (0.00)^a
	Mean	11.39 (0.53)	0.36 (0.01)
Middle	Inner	9.88 (1.79)^a	0.41 (0.03)^c
	Middle	11.48 (1.03)^a	0.37 (0.01)^{ab}
	Outer	9.45 (4.11)^a	0.35 (0.03)^a
	Mean	10.27 (1.07)	0.38 (0.03)
Base	Inner	11.39 (0.51)^a	0.44 (0.04)^c
	Middle	10.76 (0.70)^a	0.39 (0.01)^b
	Outer	11.97 (0.67)^a	0.37 (0.01)^{ab}
	Mean	11.37 (0.61)	0.40 (0.04)
Pooled mean		11.01 (0.64)	0.38 (0.02)

Standard error in parenthesis; number carrying the same alphabet in the column is not significantly different ($p > 0.05$).

density wood, it would be useful for chairs, window frames, stools, and doors.

Water absorption (WA)

Variations in the rate of water absorption are presented in Fig. 2. The water absorption ranges from 38.58-56.13%. It could be observed from the result that the water absorption of the wood has a linear increase from day 1 to day 7. WA decreases from top-inner to top-outer wood and the same pattern of WA reduction was also seen in the base of the wood. Middle-outer wood had the highest WA of 56.13% while the middle-middle had the least WA of 53.87% after 7 days. The highest value for WA of *D. regia* is lower than some well-known tropical hardwoods. Shukla and Kamden (2010) reported 70% WA for *T. scleroxylon* and *Nauclea diderrichii* while 62 and 58% were recorded for *Distemonanthus benthamianus* and *C. excelsa* respectively. The variation in WA of *D. regia* could be due to the chemical composition of the wood (Salem et al. 2014), the proportion of heartwood to sapwood, and the percentage of void volumes or porosity relating to cell cavities and intercellular spaces in the wood.

Volumetric swelling (VS)

Volumetric swelling of *Delonix regia* along the axial and radial direction is presented in Fig. 3. The VS ranged from 2.29-4.02% along the axial position. Along the radial plane, the VS of the wood ranges between 3.57-4.02% from the top inner to the outer of the wood. The VS of the middle inner to outer ranges between 2.57-3.56% in the radial position and VS for the base-inner to the base-outer range from 2.66-2.57%. The VS reduced from top to base along the axial direction and reduced from outer to inner wood across the radial plane. This shows that pattern of VS from top to base of the wood is different and this is influenced by the proportion of earlywood to latewood. Additionally, the variation in the swelling between the inner and outer wood could be attributed to the density of the wood along the radial and axial plane. Since a low swelling value is an indication of high dimensional stability of the wood during water absorption, hence the VS of *D. regia* is somehow lower than the swelling value reported for some tropical hardwoods. Shukla and Kamden (2010) reported 5.47% for *T. scleroxylon*, 7.35% for Nuclei *diderrichii* and 5.45% for *C. excelsa*.

One of the major limitations of wood, when compared with non-renewable materials, is dimensional instability. The important factor affecting the quality of wood is dimensional stability (Baysal et al. 2004). However, from this study, it is worth mentioning that *D. regia* is dimensionally stable.

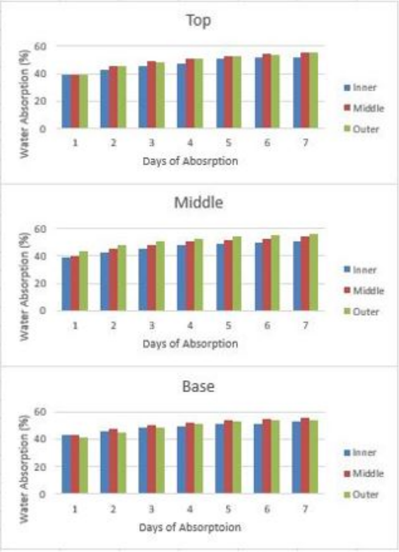

Fig. 2. Water Absorption of *Delonix regia* in axial and redial position.

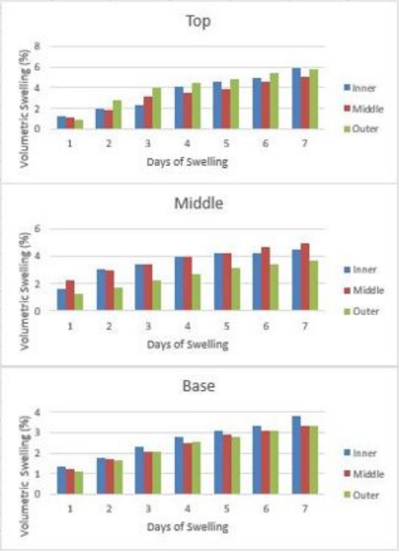

Fig. 3. Volumetric Swelling of *Delonix regia* in axial and redial position.

Table 2. Volumetric shrinkage of *Delonix regia* in axial and radial position

Axial position	Radial position	Volumetric shrinkage (%)
Top	Inner	3.00 (1.25)^{bc}
	Middle	2.72 (1.24)^{b}
	Outer	3.46 (1.99)^{c}
	Mean	3.06 (1.49)
Middle	Inner	2.80 (0.41)^{b}
	Middle	2.70 (0.68)^{b}
	Outer	2.26 (1.14)^{a}
	Mean	2.59 (0.74)
Base	Inner	3.96 (1.43)^{c}
	Middle	2.89 (1.73)^{b}
	Outer	2.83 (0.65)^{b}
	Mean	3.23 (1.27)
Pooled mean		2.96 (1.16)

Standard error in parenthesis; number carrying the same alphabet in column is not significantly different ($p > 0.05$).

Table 3. Weight loss of *D. regia* after sixteen weeks exposure to graveyard

Axial position	Radial position	Weight loss (%)
Top	Inner	48.00 (1.40)^{b}
	Middle	44.09 (3.52)^{b}
	Outer	35.46 (7.98)^{b}
	Mean	42.52 (4.27)
Middle	Inner	42.35 (1.47)^{b}
	Middle	43.02 (5.68)^{b}
	Outer	43.85 (10.63)^{b}
	Mean	43.07 (5.92)
Base	Inner	46.89 (1.44)^{b}
	Middle	37.20 (7.84)^{ab}
	Outer	25.14 (10.97)^{a}
	Mean	36.41 (6.75)
Pooled mean		40.67 (5.64)

Standard error in parenthesis; number carrying the same alphabet in the column is not significantly different ($p > 0.05$).

Volumetric shrinkage

VSH of *D. regia* is presented in Table 2. It ranged between 2.80-3.96%, 2.70-2.89%, and 2.26-3.46% for the inner, middle, and outer wood along the axial direction respectively. It could be seen that the highest VSH occurred in the inner part of the wood across the radial direction. This shows that heartwood has higher shrinkage. However, there is inconsistent variation in the VSH along the axial direction. The top has the highest VSH followed by the base and then the middle. However, Ali (2010) recorded a contrasting result for hardwood of both Ncurri and Ntholo wood, showing that VSH decreases from base to top of the wood.). The variation could be due to the presence of rays and vessels, crystals, and the proportion of heartwood to sapwood (Poku et al. 2001). Lower VSH values of *Delonix regia* show that the species is highly dimensionally stable. The major structural problems in the furniture industry are dimensional instability of wood which could result in problems in the opening and closing of doors and windows, furniture joints weakening, slackening of tool handles, cracking of tabletops, frame joints fracture, gluing problems, and poor coating performance (Eckelman 2020). Conversely, the low VSH observed in this species could be due to total extractives and lignin which have contributed to the density of the wood thereby making the wood to be low in shrinkage. Hence, the wood would be suitable for flooring, roofing, paneling, and exterior structural works.

Weight Loss after exposure to the graveyard

After 16 weeks of graveyard exposure, the percentage weight loss of *D. regia* wood is presented in Table 3. It ranged from 25.14-48.00% which decreases from top to base along the axial direction. The top inner of the *D. Regia* wood has the highest weight loss (48.00%) that increases from outer to middle and from middle to inner of the wood. However, the weight loss decreases from the inner to the outer part of the wood in the middle portion of the wood. Since high weight loss was observed in the top inner of *D. regia* wood and this could be due to the presence of juvenile wood which degrades rapidly during a few weeks of termite exposure. However, the lowest weight loss value was found in the base portion ranging from 25.14-46.89% with the weight loss decreasing from inner to outer wood. The observed decrease in weight loss in the base and middle portion of *D. regia* shows that there is a strong relationship between specific gravity and weight loss showing that with increasing wood specific gravity, weight loss decreases.

This result corroborates the findings of Peralta et al. (2004) who reported that there is a relationship between density and weight loss of termites attacked wood.

Owoyemi and Olaniran (2014) also reported that the resistance of wood species varies according to density in some selected Nigerian wood species. This indicates that the natural resistance of some wood species may be influenced by density while in the case of this study, the natural resistance of *D. regia* is not influenced by the density of the wood.

Weight loss (WL) after accelerated decay test

The weight loss obtained from accelerated decay tests on the wood of *D. regia* after incubation with *Pleurotus ostreatus* (white rot fungus) for 16 weeks is summarized in Table 4. The WL ranged from 32.02% for base-inner to 44.45% for top-inner. Only white rot fungus is used to test the natural durability of this hardwood species because it attacks all the components of hardwood, unlike brown rot which shows a preference for cellulose and hemicellulose leaving lignin undigested (Green and Highley 1997). Though there was a significant difference in the level of decay between the top and the base portion of the wood, the fungi attack all the wood significantly along the axial and radial positions. It is stated in ASTM D2017-81 that an average weight loss of 0-10% is highly resistant, 11-24% is resistant, 25-44% is moderately resistant, and any weight loss above 45% is slightly resistant, or non-resistant. Consequently, based on the ASTM standard and considering the weight loss caused by *Pleurotus ostreatus* which ranges from 32-44% across all the portions of the wood, *D. regia* is classified as a moderately resistant wood species. However, wood shows different durability in all applications. The durability of a wood species will depend on whether it would be used in ground contact exterior or above ground interior or exterior. Hence, a wood species may be considered durable when used for certain interior applications and non-durable when such species are used for exterior applications (AWPA 2002).

Table 4. Weight loss (%) of *Delonix regia* wood samples after accelerated fungi decay

Axial position	Radial position	Weight loss (%)
Top	Inner	44.45 (1.93)^{a}
	Middle	40.12 (2.70)^{ab}
	Outer	38.18 (3.92)^{b}
	Mean	40.92 (2.85)
Middle	Inner	32.93 (1.31)^{c}
	Middle	34.13 (3.19)^{bc}
	Outer	35.06 (2.17)^{b}
	Mean	34.04 (2.22)
Base	Inner	32.02 (0.09)^{c}
	Middle	36.36 (4.67)^{b}
	Outer	34.73 (5.57)^{bc}
	Mean	34.37 (3.44)
Pooled mean		36.44 (2.84)

Standard error in parenthesis; number carrying the same alphabet in the column is not significantly different ($p > 0.05$).

Table 5. Modulus of elasticity and modulus of rupture of *D. regia* wood along axial and radial position

Axial position	Radial position	MOE (N/mm^{2})	MOR (N/mm^{2})
Top	Inner	6,386.78 (961.55)^{d}	47.14 (17.18)^{bc}
	Middle	6,658.67 (954.60)^{e}	55.85 (22.03)^{d}
	Outer	3,834.54 (1,416.22)^{a}	37.24 (7.71)^{b}
	Mean	5,626.66 (1,110.79)	46.74 (315.64)
Middle	Inner	4,764.92 (312.54)^{b}	29.42 (1.99)^{a}
	Middle	4,890.35 (1,347.42)^{b}	31.72 (16.39)^{ab}
	Outer	6,088.19 (283.69)^{c}	60.97 (6.20)^{ef}
	Mean	5,247.82 (647.88)	40.70 (8.19)
Base	Inner	6,308.59 (5,512.21)^{d}	72.68 (7.23)^{f}
	Middle	8,830.37 (544.53)^{g}	44.66 (1.43)^{bc}
	Outer	7,843.79 (586.23)^{f}	60.02 (17.26)^{e}
	Mean	7,660.92 (2,214.32)	59.12 (8.64)
Pooled mean		6,178.47 (1,324.33)	48.86 (10.82)

Standard error in parenthesis; number carrying the same alphabet in the column is not significantly different ($p > 0.05$).

Mechanical properties

Modulus of elasticity (MOE) and modulus of rupture (MOR)

The results of MOE and MOR of *D. regia* wood ranged from 3,834.54-8,830.37 N/mm^2 and 29.42-72.68 N/mm^2 respectively along the axial and radial positions (Table 5). It could be seen that base-middle and top-outer wood had the highest and lowest MOE values respectively while the highest and lowest MOR was found in base-inner and middle-inner respectively. Although, there is an inconsistent pattern of variation in the MOE values along the axial and radial plane, however, MOE values for *D. regia* in this study fall within the range of values reported for some topical hardwood species. Jamala et al. (2013) reported MOE values for *Celtis mildbraedii* (7,088.69 N/mm^2), *Afzelia Africana* (6,311.58 N/mm^2), for *Khaya ivorensis* (8,192.54 N/mm^2), *Milicea excelsa* and (5,765.63 N/mm^2) *Triplochiton scleroxylon* (39,337.5 N/mm^2). Meanwhile, the MOE values for the base portion of *D. regia* wood are higher than the values reported by Ajala and Ogunsanwo (2011) for a lesser-known wood species, *Aningeria robusta* which was 6297.40 N/mm^2. There is a strong correlation between the MOE and SG. Thus, the highest MOE and SG were found at the base portion of the wood. An irregular pattern of variation is also seen in MOR values along the axial and radial planes. The MOR decreased from the base of the wood to the middle and then increased again. MOR is of great importance because it is the parameter used for measuring the bending strength of wood (Panshin and de Zeeuw 1980).

Conclusion

The technical properties of lesser-used wood species of *D. regia* have been studied. *D. regia* is a medium-density wood and its specific gravity decreased from the base to the top however, specific gravity relates positively with mechanical properties like MOE and MOR. The range of values obtained for volumetric swelling and shrinkage along axial and radial positions confirmed that *D. regia* wood is dimensionally stable while the wood is moderately resistant to fungi and termite attack. Comparing the results obtained for the physical and mechanical properties of *D. regia* in this study with other commonly used species, *D. regia* has good potential for structural applications.

References

Adebawo F, Ajala O, Aderemi T. 2019. Variation of physical and mechanical properties of *Boscia angustifolia* (A. RICH.) wood along radial and axial stem portion. Pro Ligno 9: 34-42.

Adebawo FG. 2019. Fungal Resistance of Obeche (*Triplochiton Scleroxylon* K. Schum) Wood Treated with Neem (*Azadirachta indica*, A. Juss) Seed Oil Extract. J Res For Wildl Environ 11: 90-96.

Ajala O, Ogunsanwo O. 2011. Specific gravity and mechanical properties of *Aningeria robusta* wood from Nigeria. J Trop For Sci 23: 389-395.

Ali AC, Chirkova J, Terziev N, Elowson T. 2010. Physical properties of two tropical wood species from Mozambique. Wood Mater Sci Eng 5: 151-161.

American Society for Testing and Materials. 1999. ASTM D1037-99: Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials. ASTM International, West Conshohocken, PA.

American Society for Testing and Materials. 2007. ASTM D4442-07: Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials. ASTM International, West Conshohocken, PA.

American Society for Testing and Materials. 2017. ASTM D2395-17: Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials. ASTM International, West Conshohocken, PA.

American Society for Testing and Materials (ASTM). 2012. Standard Test Method of Accelerated Laboratory Test of Natural Decay Resistance of Woods, D-2017. Philadelphia, 2012.

America Wood Preservers' Association (AWPA). 2002. AWPA Book of Standards. AWPA, Granbury, TX.

Anonymous. 2011. Agro-Forestry Tree Database. http://apps.worldagroforestry.org/treedb2/speciesprofile.php?Spid=648 Accessed 28 Dec 2022.

Barany M, Hammett AL, Araman P. 2003. Lesser used wood species of Bolivia and their relevance to sustainable forest management. For Prod J 53: 1-6.

Baysal E, Ozaki SK, Yalinkilic MK. 2004. Dimensional stabilization of wood treated with furfuryl alcohol catalysed by borates. Wood Sci Technol 38: 405-415.

Belleville B, Lancelot K, Galore E, Ozarska B. 2020. Assessment of physical and mechanical properties of Papua New Guinea timber species. Maderas Cienc Tecnol 22: 3-12.

British Standards Institution. 1957. Methods of Testing Small Clear Specimens of Timber. 2nd ed. British Standards Institution, London.

Dukku U. 2011. Delonix regia: an important naturalized beeplant in northern Nigeria. Bee World 88: 71-72.

Eckelman CA. 2020. The shrinking and swelling of wood and its effect on furniture. In: Forestry and Natural Resources Purdue University, West Lafayette, USA, 26 pp

Emerhi EA, Adedeji GA, Ogunsanwo OY. 2015. Termites' resistance of wood treated with *Lagenaria breviflora* B. Robert fruit pulp extract. Nat Sci 13: 105-109.

European Committee for Standardization. 1994. EN 350-1: Durability of Wood and Wood-based Products - Natural Durability of Solid Wood - Part 1: Guide to the Principles of Testing and Classification of the Natural Durability of Wood. European Committee for Standardization (CEN), Brussels, 14 pp.

Fuwape JA. 2000. Wood Utilization: From Cradle to Grave. Inaugural Lecture Delivered. Federal University of Technology, Akure, 33 pp.

Green DW, Evans JW, Craig BA. 2003. Durability of structural lumber products at high temperatures. Part I. 66°C at 75%RH and 82°C at 30%RH. Wood Fiber Sci 35: 499-523.

Green F III, Highley TL. 1997. Mechanism of brown-rot decay: paradigm or paradox. International Biodeterior Biodegrad 39: 113-124.

Jamala GY, Olubunmi SO, Mada DA, Abraham P. 2013. Physical and Mechanical Properties of Selected Wood Species in Tropical Rainforest Ecosystem, Ondo State, Nigeria. IOSR J Agric Vet Sci 5: 29-33.

Noor Azrieda AR, Salmiah U, Rahim S. 2015. Comparison of accelerated decay and graveyard test on selected Malaysian timber species. J Trop Resour Sustain Sci 3: 238-241.

Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A. 2009. Agroforestree Database: A Tree Reference and Selection Guide Version 4.0. https://worldagroforestry.org/output/agroforestree-database. Accessed 28 Dec 2022.

Owoyemi JM, Olaniran OS. 2014. Natural resistance of ten selected Nigerian wood species to subterranean termites' attack. Int J Biol Sci Appl 1: 35-39.

Panshin AJ, De Zeeuw C. 1980. Textbook of Wood Technology: Structure, Identification, Properties, and Uses of the Commercial Woods of the United States and Canada. 4th ed. McGraw-Hill, New York, NY, 722 pp.

Peralta RCG, Menezes EB, Carvalho AG, Aguiar-Menezes E. 2004. Wood consumption rates of forest species by subterranean termites (Isoptera) under field conditions. Rev Arvore 28: 283-289.

Poku K, Wu Q, Vlosky R. 2001. Wood properties and their variations within the tree stem of lesser-used species of tropical hardwood from Ghana. Wood Fiber Sci 33: 284-291.

Royal Botanic Gardens, Kew. 2011. Royal Botanic Gardens, Kew. http://www.kew.org/plants-fungi/Delonix-regia.htm. Accessed 28 Dec 2022.

Salem MZM, Abdel-Megeed A, Ali HM. 2014. Stem wood and bark extracts of Delonix regia (Boj. Ex. Hook): chemical analysis and antibacterial, antifungal, and antioxidant properties. BioRes 9: 2382-2395.

Sarker PK, Rahman MA, Bulbul MR, Das T, Ilias GNM. 2006. Standard test methods for wood preservatives by laboratory agar-block test, IRG/WP 06-20350. In: 37th Annual Meeting, The International Research Group on Wood Protection; Tromso, Norway; June 18-22, 2006.

Timber Export Development Board. 1990. Ghana: Forests, Wood, and People. Timber Export Development Board, Takoradi, 9 pp.