PHYSICAL AND MECHANICAL PROPERTIES OF *TRILEPISIUM MADAGASCARIENSE* AND *FUNTUMIA ELASTICA* WOOD

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OYAGADE, A. O. & FASULU, S. A. 2005. Physical and mechanical properties of *Trilepisium madagascariense* and *Funtumia elastica* wood. The physical and mechanical properties of two lesser-known tree species, namely *Trilepisium madagascariense* and *Funtumia elastica,* were examined. The properties investigated were wood density, shrinkage in the radial, tangential and longitudinal directions, modulus of elasticity, modulus of rupture, ultimate compressive strength parallel to the grain and shear strength parallel to the grain. The tests were carried out in accordance with BS 373. The average values of the properties evaluated for *T. madagascariense* and *F. elastica* respectively were as follows: density—569 and 457 kg m^{-3}, radial shrinkage—5.6 and 4.5%, tangential shrinkage—10.2 and 8.8%, longitudinal shrinkage—0.3 and 0.6%, modulus of rupture—160.4 and 94.4 N mm^{-2}, modulus of elasticity—6416 and 6158 N mm^{-2}, compressive strength parallel to grain—41.2 and 30.8 N mm^{-2} and shear strength parallel to grain—12.9 and 11.8 N mm^{-2}. Generally, wood density and mechanical properties of the two species decreased significantly with height while shrinkage properties increased.

Key words: Wood density – shrinkage – modulus of rupture – modulus of elasticity – compressive strength – shear strength

OYAGADE, A. O. & FASULU, S. A. 2005. Ciri-ciri fizikal dan mekanik kayu *Trilepisium madagascariense* dan *Funtumia elastica*. Ciri-ciri fizikal dan mekanik dua spesies pokok kurang diketahui iaitu *Trilepisium madagascariense* dan *Funtumia elastica* dikaji. Ciri-ciri yang dikaji ialah ketumpatan kayu, kecutan jejari, kecutan tangen, kecutan membujur, modulus kekenyalan, modulus kepecahan, mampatan selari ira dan ricihan selari ira. Ujian dijalankan berasaskan BS 373. Nilai purata untuk ciri-ciri yang dikaji ke atas *T. madagascariense* dan *F. elastica* adalah seperti berikut: ketumpatan—masing-masing 569 kg m^{-3} dan 457 kg m^{-3}, kecutan jejari—masing-masing 5.6% dan 4.5%, kecutan tangen—masing-masing 10.2% dan 8.8%, kecutan membujur—masing-masing 0.3% dan 0.6%, modulus kepecahan—masing-masing 160.4 N mm^{-2} dan 94.4 N mm^{-2}, modulus kekenyalan—masing-masing 6416 N mm^{-2} dan 6158 N mm^{-2}, mampatan selari ira—masing-masing 41.2 N mm^{-2} dan 30.8 N mm^{-2} serta ricihan selari ira—12.9 N mm^{-2} dan 11.8 N mm^{-2}. Secara amnya, ketumpatan kayu dan ciri-ciri mekanik kedua-dua spesies berkurang dengan ketinggian manakala ciri-ciri kecutan bertambah dengan ketinggian.

Introduction

Wood is a ubiquitous material that has established itself for a variety of applications despite the advent of more modern materials such as plastic, metals and concrete. It is a raw material for lumber, poles, plywood, particleboard and fibreboard

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production. It can also be processed to rayon, cellophane, photographic films, plastics and a variety of chemical products (Haygreen & Bowyer 1989).

According to Keay (1989), Nigeria's tropical lowland rain forests, which serve as raw material for the wood-based industry in Nigeria, contain about 560 species of trees, which can be processed to lumber. However, only a few species are being exploited for commercial production. The remaining, which are commonly referred to as lesser-known species, make up about 95% of the productive hardwood forests (Freezaillah 1984). Two of these lesser under-utilized species are *Trilepisium madagascariense* (Moraceace) and *Funtumia elastica* (Apocynaceae) that can attain a height between 20 and 30·m, and diameter at breast height of at least 48 cm (Keay 1989). As a result of dwindling forest estates, due to over-exploitation and the attendant scarcity of the major commercial species, many of the lesser-known species are gradually appearing in the market. Some of these now appear on the tariff list of some state forestry departments.

One major reason why many of the lesser-known tree species have hitherto remained unpopular as timber species is the lack of sufficient knowledge about their wood properties. In popularising a species or a group of wood, the properties have to be known as they serve as criteria for selection of timber for a particular application (Ritva & Riitta 1996). The objective of this study was to provide information on the wood density, shrinkage in the radial, tangential and longitudinal directions, modulus of rupture (MOR), modulus of elasticity (MOE), compressive strength parallel to grain and shear strength parallel to grain of two lesser-known but widely available indigenous tree species, namely *T. madagascariense* and *F. elastica*. Variations in these properties along and across the boles were also studied.

Materials and methods

Trees of *T. madagascariense* and *F. elastica* were felled from the forest area of Owo, south-west Nigeria, latitude 6° 40' and 7° 15' and longitude 5° 25' and 5° 55'. An area of 100 × 100 m was demarcated and trees with diameter at breast height (dbh) of 48 cm and above were enumerated and marked. Three trees each were randomly selected for this study.

Bolts of 50 cm long were cut from the base, middle and top of each tree, corresponding respectively to 25, 50 and 75% of the merchantable height. The cruciform cutting pattern was adopted in selecting wood test sample material from the bolt (ASTM 1987). Each bolt was quarterly sawn to obtain 20 mm thick radial strips, which were radially divided into five zones on the basis of their position to the pith. The zones were tagged: innerwood (wood zone nearest to the pith), outerwood (wood zone closest to the bark), middlewood (wood zone mid-way between innerwood and outerwood), wood zone between innerwood and middlewood, and wood zone between middlewood and outerwood. Wood samples, in the form of sticks, each measuring 20 (thickness) × 20 (width) × 500 (length) mm, were selected from the middle of each of the five zones.

From each stick, specimens of required sizes for each wood property to be evaluated were cut and tested in accordance with BS 373 (BSI 1989). The dimensions of wood samples for static bending test were 20 × 20 × 300 mm. For compressive strength and shear strength parallel to grain, specimens of 20 × 20 × 60 mm and 20 × 20 × 20 mm were used respectively. The strength tests were performed after conditioning to equilibrium moisture content in a room maintained at 65% relative humidity and 25 °C.

The mechanical properties were determined using Hounsfield tensiometer, which automatically plots load-deflection curve. From the load deflection-curve, the ultimate failing load (Pmax), increment in load on the straight-line portion of the load deflection-curve (dP) and increment in deflection corresponding to dP increment in load for calculating the mechanical properties were obtained.

The density and shrinkage in transverse directions were made on 20 × 20 × 60 mm specimens while longitudinal shrinkage were determined on 20 × 20 × 300 mm specimens. The shrinkage of wood in the three principal directions was determined from 12% moisture content to oven-dry condition.

The determination of wood density was based on oven-dry weight and oven-dry volume. Analysis of variance (ANOVA) was carried out using Statistical Package for Social Sciences (SPSS) to estimate the relative importance of the effects of the study variables such as species, sampling height, radial position and their interactions on wood properties.

Results and discussion

Wood density

The density values for *T. madagascariense* and *F. elastica* ranged from 555 to 582 kg m^{-3} with mean of 569 kg m^{-3} and 455 to 487 kg m^{-3} with mean of 468 kg m^{-3} respectively (Table 1). Results of the ANOVA (Table 2) indicated that species and sampling height exerted significant influences on wood density. No significant difference was observed between the radial positions. A slight decrease in wood density was observed with increase in sampling heights for both species (Table 1).

Wood density is identified as a wood quality index as it affects many other properties. It has been used as a guide to classify species into different areas of applications. Hoheisel (1972) considered wood species having densities of 450 to 750 kg m^{-3} as suitable for applications such as furniture, sheathing, lining, parquet, and veneer wood for peeling and slicing. The two lesser-known species investigated in this study had mean densities within the density range given by Hoheisel.

Tangential, radial and longitudinal shrinkages

For *T. madagascariense*, the shrinkage values were 10.2, 5.6 and 0.3% on the tangential, radial and longitudinal directions respectively (Table 1). The respective values for *F. elastica* were 8.8, 4.5 and 0.6% (Table 1). The values for the tangential, radial and longitudinal shrinkages reported in this study were in the range of widely reported values for each of the three principal wood directions. *Trilepisium madagascariense* had higher shrinkage values than *F. elastica* in both the radial and

Table 1 Physical and mechanical properties of *Trilepisium madagascariense* and *Funtumia elastica* wood

Wood property	Species	Sampling height (%)[a]			Overall [b] mean (SD)
		25	50	75	
Density (kg m^{-3})	*T. magadascariense*	582	569	555	569 (24)
	F. elastica	487	462	455	468 (32)
Tangential shrinkage (%)	*T. magadascariense*	9.33	10.29	11.02	10.22 (0.93)
	F. elastica	6.96	9.23	10.16	8.78 (1.42)
Radial shrinkage (%)	*T. magadascariense*	4.48	6.02	6.35	5.61 (0.83)
	F. elastica	3.81	4.40	5.40	4.54 (0.75)
Longitudinal shrinkage (%)	*T. magadascariense*	0.15	0.33	0.41	0.29 (0.12)
	F. elastica	0.57	0.49	0.71	0.59 (0.17)
Modulus of rupture (N mm^{-2})	*T. magadascariense*	171.5	153.0	156.8	160.4 (10.1)
	F. elastica	106.3	98.4	87.5	97.4 (12.76)
Modulus of elasticity (N mm^{-2})	*T. magadascariense*	6655	6565	6028	6416 (245)
	F. elastica	6702	6076	5697	6158 (588)
Compressive strength parallel to grain (N mm^{-2})	*T. magadascariense*	48.86	47.44	42.23	46.18 (2.96)
	F. elastica	31.79	32.17	28.49	30.82 (2.24)
Shear strength parallel to grain (N mm^{-2})	*T. magadascariense*	13.16	12.99	12.53	12.89 (0.38)
	F. elastica	11.95	12.34	11.01	11.76 (0.50)

[a]Each value is an average of 15 specimens.
[b]Each value is an average of 45 specimens.

Table 2 Analysis of variance of the effects of species, sampling height and radial position on density and shrinkage of *Trilepisium madagascariense* and *Funtumia elastica* wood

Sources of variation	Degree of freedom	Density	Radial shrinkage	Tangential shrinkage	Longitudinal shrinkage
Species (S)	1	188.56*	6.93*	6.14*	8.32*
Sampling height (H)	2	5.54*	6.08*	6.17*	1.38 NS
Radial position (R)	4	0.22 NS	0.62 NS	0.16 NS	0.35 NS
S × H	2	0.20 NS	0.48 NS	0.66 NS	0.57 NS
S × R	4	0.43 NS	0.55 NS	0.42 NS	0.30 NS
H × R	8	0.97 NS	1.21 NS	0.49 NS	0.70 NS
S × H × R	8	0.27 NS	0.71 NS	0.51 NS	0.77 NS
Error	60				
Total	89				

* = Significant at the 0.05 probability level, NS = not significant

tangential directions. However, longitudinal shrinkage was lower in *T. madagascariense* compared with *F. elastica*. Within each species, the mean tangential shrinkage ranged from 9.3 to 11.0% and 7.0 to 10.2% for *T. madagascariense* and *F. elastica* respectively. Radial shrinkage values were in the range of 4.5 to 6.4% for *T. madagascariense* and 3.8 to 5.4% for *F. elastica*. Longitudinal shrinkage values ranged from 0.2 to 0.4% and 0.5 to 0.7% for *T. madagascariense* and *F. elastica* respectively.

Generally, shrinkage along each of the principal direction slightly increased with increase in sampling height.

It has been reported that the presence of extractives in wood brings about bulking of the amorphous regions in the cell wall with an attendant increasing resistance to shrinkage (Choong *et al.* 1989). It is also widely known that wood extractive contents decrease from tree base towards the crown. Thus, the observed trend in the relationship between sampling height and shrinkage might be due to decrease in wood extractive contents with height.

Effects of species and sampling height were significant at the 0.05 probability level for both radial and tangential shrinkages (Table 2). In the case of longitudinal shrinkage, only the effect of species was significant. Effects of radial position on shrinkage in the three principal directions were not significant.

Mechanical properties

The overall mean values obtained for MOR and MOE of *T. madagascariense* were 160.4 and 6416 N mm^{-2} respectively. For *F. elastica*, the overall mean values were 97.4 and 6158 N mm^{-2} respectively. Modulus of rupture for *T. madagascariense* ranged from 153.0 to 171.5 N mm^{-2}, while that for *F. elastica*, from 87.5 to 106.3 N mm^{-2}. The overall mean values for MOR and MOE observed for *F. elastica* in this study were lower than those reported by Sanwo (1986) for plantation-grown *Tectona grandis* (teak) which had MOR ranging from 99.0 to 135.7 N mm^{-2} and MOE in the range of 9567.5 to 13 564.9 N mm^{-2}. In the case of *T. madagascariense*, while the MOR values obtained in this study compared favourably with those reported by Sanwo (1986), the MOE values were 37 to 50% lower. However, the two strength properties for *T. madagascariense* and *F. elastica* compared well with species such as *Alstonia boonei*, *Terminalia superba* and *Antiaris africana*, which were recommended for light construction (Okigbo 1965).

The ANOVA (Table 3) showed that species and sampling height significantly affected MOR. Radial position had no significant effect on MOR. Sampling height significantly affected MOE, while effects of species and radial position were not significant.

MOR of *F. elastica* decreased with sampling height (Table 1). For *T. madagascariense*, following initial decrease in MOR values from 25 to 50% sampling height, there was a slight increase from 50 to 75%. It has generally been observed that the static bending properties of wood tend to decrease with increase in sampling height (Panshin & DeZeeuw 1980, Rulliaty & America 1995). This trend of variations in MOR and MOE along the tree height can be explained by the decrease in maturity of wood and fibre length from the base to the top of the tree (Rulliaty & America 1995).

The overall mean values for compressive strength parallel to grain for *T. madagascariense* and *F. elastica* were 46.2 and 30.8 N mm^{-2} respectively (Table 1). The overall mean values for shear strength parallel to grain of *T. madagascariense* and *F. elastica* were 12.9 and 11.8 N mm^{-2} respectively (Table 1). *Funtumia elastica* was slightly lower than *T. madagascariense* in both compressive and shear strengths

Table 3 Analysis of variance of the effects of species, sampling height and radial position on modulus of rupture, modulus of elasticity, compressive strength parallel to grain and shear strength parallel to grain of *Trilepisium madagascariense* and *Funtumia elastica* wood

Source of variation	Degree of freedom	MOR	MOE	CS	SS
Species (S)	1	317.05*	2.007 NS	168.88*	11.68*
Sampling height (H)	2	8.34*	6.72*	7.12*	2.94 NS
Radial position (R)	4	1.29 NS	2.83 NS	0.17 NS	1.04 NS
S × H	2	1.54 NS	0.76 NS	0.66 NS	0.59 NS
S × R	4	3.30 NS	0.61 NS	0.25 NS	1.81 NS
H × R	8	1.34 NS	1.14 NS	0.60 NS	0.63 NS
S × H × R	8	0.76 NS	0.75 NS	0.34 NS	0.51 NS
Error	60				
Total	89				

MOR = modulus of rupture, MOE = modulus of elasticity, CS = compression strength parallel to grain, SS = shear strength parallel to grain
* = Significant at the 0.05 probability level, NS = not significant

parallel to grain. Both properties were found to decrease with increase in tree height for *T. madagascariense.* In the case of *F. elastica,* however, the two strength properties increased slightly from 25% sampling height to 50%, followed by a decrease.

The result of the ANOVA showed that the effect of species was significant on both compressive and shear strengths parallel to grain (Table 3). While the effect of sampling height was significant on compressive strength parallel to grain, the effect was not significant on shear strength. Radial position did not have significant influence on both compressive and shear strengths.

The compressive strength values reported by Okigbo (1965) for Nigerian hardwood species ranged from 8.96 N mm^{-2} for *Ricinodendron heudelotii* to 82 N mm^{-2} for *Cylicodiscus gabunensis.* For shear strength, Okigbo (1965) reported values ranging from 5.86 N mm^{-2} for *Alstonei boonei* to 19.72 N mm^{-2} for *C. gabunensis.* The overall mean values for compressive and shear strengths parallel to grain observed for *T. madagascenensis* compared favourably with the reported values for species such as *Mitragyna ciliata, T. superba, Daniellia ogea* and those for *F. elastica* were higher than those reported for *Triplochiton scleroxylon, Ceiba pentandra, Bombax buonopozense* and *R. heudelotii* (Okigbo 1965).

Conclusions

Based on the wood density values, the two lesser-known species investigated in this study were medium density wood species. Of the two species, *F. elastica* had higher shrinkage values in the radial and tangential directions. The contrary was the case with longitudinal shrinkage. With respect to mechanical properties, *T.*

madagascariense proved superior to *F. elastica*. Generally, for each of the species, wood density and mechanical properties decreased with increase in tree height. Shrinkage properties in the three principal directions of wood increased with height. Radial position did not affect the wood properties examined.

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