WOOD RESEARCH doi.org/10.37763/wr.1336-4561/69.4.638646
e-ISSN 2729-8906
69(4): 2024 638 – 646 pp.

Short notes

MECHANICAL STRENGTH CHARACTERIZATION OF THREE LESSER-UTILISED TIMBER SPECIES IN GHANA

HARUNA SEIDU[1,2], RÓBERT NÉMETH[1], FRANCIS WILSON OWUSU[2]
[1]UNIVERSITY OF SOPRON
[2]CSIR-FORESTRY RESEARCH INSTITUTE OF GHANA, GHANA

(RECEIVED SEPTEMBER 2024)

ABSTRACT

This study investigates the mechanical properties of three lesser-utilized timber species in Ghana: *Blighia sapida*, *Gilbertiodendronlimba*, and *Lanneawelwitschii*. Despite their potential, these species are underexplored compared to widely used commercial timbers. Six trees, two from each species, were tested for properties such as modulus of elasticity (MOE), modulus of rupture (MOR), compressive strength, shear strength, hardness, and density. Results indicate that *Blighia sapida* has superior mechanical properties, placing it in the D50 strength class, suitable for high-resistance structural applications. *Gilbertiodendronlimba* and *Lanneawelwitschii* are categorized under the D40 strength class, appropriate for moderate load-bearing uses. This research demonstrates that lesser-utilized species can serve as viable alternatives to traditional timbers, potentially reducing pressure on overexploited species. By promoting their use, the study supports sustainable forestry practices and contributes to a more diversified and resilient timber industry in Ghana.

KEYWORDS: Mechanical properties, density, strength classification, lesser-utilized species.

INTRODUCTION

Ghana has a large forest area and can boastof over 680 timber species with less than 70 species studied(André Luis et al. 2013; Chimsah et al. 2013; Pappoe et al. 2010). Only a few have been successfully explored in terms of utilization since the properties of the greater chunk of these species remain unknown. However, with the global demand for tropical commercial timber, and the alarming rate at which forest timber species are being depleted,there is a needto explore the mechanical strength properties of lesser-utilized species (LUS) of timber in Ghana(Seidu et al. 2023; Ofori et al. 2010; Poku et al. 2001). Lesser-utilized species have been defined to mean timber species that are not extensively utilized in commercial applications (Welling et al. 2023; Kaba et al. 2022; Antwi-Boasiako and Boadu 2016). Some scientificstudies have shown that several LUShas been found to have desirable properties comparable to the premium timber species known on the international market from the tropics(Amarasekera 2012; André Luis et al. 2013).

In the case of Ghana, several research studies have highlighted the outstanding mechanical qualities of lesser-utilized wood species(Ewudzie et al. 2018; Kwaku et al. 2022; Ohemeng et al. 2023; Quartey 2022)demonstrated that these species could have qualities of equivalent or even superior strength to other regularly used timbers. Atagubaet al.(2015) added to this by recognizing*Gmelina arborea, Parkia biglobosa,* and *Prosopis africana* as structurally acceptable plants owing to their high mechanical and physical qualities.Quartey (2015) contributed to this by investigating the anatomical features of three underutilized Ghanaian hardwood species, so offering a better knowledge of their potential for varied uses.These findings show that these underutilized wood species in Ghana have a high potential for utilization in various building and structural applications. *Blighia sapida*, commonly known as ackee a middle canopy tree growing up to 25m tall with a branchless bole of 15m and a diameter of 80cm(Rashford 2001). G*ilbertiodendronlimba*, often referred to as limbali, is a medium-sized tree that can grow up to 25 m tall with a short bole of 15 m, with up to 70 cm in diameter, and *Lanneawelwitschii*, is a middle canopy tree grows up to 30–35 m tall with a bole branchless up to15 –26 m, and up to 100–120 cm in diameter(Senterre 2005). It is locally known as guganu, which are among the lesser-utilized species that have not been explored for better classification and utilization. The chosen species exhibit distinct characteristics, both in terms of their botanical features and ecological niches. *Blighia sapida*, for instance, is recognized for its fruit – ackee – yet its timber properties remain relatively unexplored. *Gilbertiodendronlimba*, a prominent timber tree in West Africa, and *Lanneawelwitschii*, with its versatile applicationsremaining rural, present additional dimensions to this exploration.

This study aims to explore the mechanical properties inherent in these timber speciesand grade the species for strength classesbased on service classes 1 and 2 according to BS 5268-2:2002 (Structural use of timber. Code of practice for permissible stress design, materials, and workmanship).

MATERIALS AND METHODS

Extraction site

All three species were cut from the Bobiri forest reserves located in the Ejisu-Juaben Municipality of the Ashanti region of Ghana.The forest is classified under a moist semi-deciduous ecological zone and positioned geographically atlatitudes 6°40′ and 6°44′N and longitudes 1°15′ and 1°22′W. In all 6 trees were extracted, that is, 2 trees per specie.The trees were labelled asB1,B2, G1, G2, L1, and L2 where B, G, and L represent*Blighia sapida, Gilbertiodendronlimba*, and *Lanneawelwitschii*respectively.

Sample preparation

The boards prepared to a thickness of 70 mm and 25 mm from the logs were air dried atambient temperatures between 25 – 29°C and a relative humidity of 76 – 85%. The samples were prepared according to BS 373: 1957. Test specimensincludedbending (20 x 20x 300mm), compression parallel to the grain (20 x 20 x 60 mm), shear (50 x 50 x 50 mm), and Janka hardness (50 x 50 x 150 mm). Also, the density samples were prepared to a dimension of 20 x 20 x 20 mm. From each tree, fifteen samples were prepared for each specific property being studied.These samples were carefully selected to ensure consistency during testing.

Conditioning and testing

The samples were conditioned ata temperature of 20°C and a relative humidity of 65% and tested according to BS 373: 1957.The Instron machine, 4482 model was used in conducting the test. The 3-point loading test was used for the bending test at a crosshead speed of 6.604 mm/min, both compression and shear tests were conducted using the crosshead speed of 0.635 mm/min and the hardness test at 6.350 mm/min.

RESULTS AND DISCUSSIONS

Determined mean mechanical and physical properties of the three species

Tab. 2 shows the mean mechanical properties and densities of all six trees from the three species labelled B, G and L used in the study. These properties were crucial for determining the suitability of these wood for different applications in construction, furniture, and other industries.According to the results, the mean values for trees B1 and B2 suggest superior mechanical properties and densities across the category of properties determined. The properties for trees G1 and G2 were moderate with the L1 and L2 recording the lowest across the category of properties from MOE to the density in the order as indicated in tab. 2. The standard deviations indicate variability within each treebut in tree B2 the variations were wide.

Tab. 1: Mean mechanical properties and densities of six trees from three species.

Property	Tree species					
	B1	**B2**	**G1**	**G2**	**L1**	**L2**
MOE (N/mm^2)	16907 ±2286	17329 ±3171	12684 ±1211	9996 ±1149	10777 ±1370	10331 ±1548
MOR (N/mm^2)	123.71 ±15.50	123.26 ±21.92	88.67 ±9.68	64.62 ±15.88	61.37 ±5.03	54.74 ±8.85
Comp‖g (N/mm^2)	52.79 ±6.67	54.91 ±3.87	34.88 ±3.26	36.91 ±2.93	32.22 ±2.92	29.16 ±3.57
Shear (N/mm^2)	17.10 ±3.04	17.97 ±2.18	11.79 ±1.11	11.83 ±1.14	7.66 ±0.62	5.44 ±1.47
Hardness (kN)	15.55 ±4.70	11.30 ±3.26	4.74 ±0.45	4.57 ±0.31	5.11 ±1.28	4.69 ±1.34
Density (kg/m^3)	649 ±28.98	653 ±31.52	519 ±11.87	505 ±18.26	475 ±21.65	463 ±32.47

*****B1 & 2 - *Blaghiasapida*, G1&2 - *Gilbertiodendronlimba*, L1 &2 - *Lannea welwitschia*, Comp‖g – compression parallel to the grain.

Variation between trees of the same species for mechanical and physical properties.

Tab. 3 presents the One-way ANOVA results of the three speciesand the comparison of the two trees of each species, B1-B2, G1-G2-, and L1-L2. Modulus of elasticity, modulus of rupture, compressive strength, shear strength, hardness and density were the properties analysed. Considering the modulus of elasticity (MOE), the F- statistics of comparing B1 and B2 and L1 and l2 were 0.163 and 0.652 respectively with p-valuesgreater than 0.05indicating an insignificant difference.

Tab.2: A one-way ANOVA.

Properties	Source	Sum of squares, SS	DF	Mean square MS	F statistics	Tukey P-value	Sig.
MOE (N/mm^2)	B1-B2	1,331,413.33	1	1,331,413.33	0.163	0.689	0
	G1-G2	54,190,080.00	1	54,190,080.00	36.302	0.001	1
	L1- L2	1,492,762.13	1	1,492,762.13	0.652	0.426	0
MOR (N/mm^2)	B1-B2	1.57	1	1.57	0.004	0.949	0
	G1-G2	4,337.07	1	4,337.07	23.395	0.001	1
	L1- L2	329.68	1	329.68	5.939	0.021	1
Comp (N/mm^2)	B1-B2	33.77	1	33.77	1.059	0.312	0
	G1-G2	30.74	1	30.74	2.991	0.095	0
	L1- L2	70.50	1	70.50	6.186	0.019	1
Shear (N/mm^2)	B1-B2	5.70	1	5.70	0.761	0.390	0
	G1-G2	0.011	1	0.011	0.008	0.928	0
	L1- L2	36.68	1	36.68	26.97	0.001	1
Hardness (kN)	B1-B2	135.17	1	135.17	7.725	0.009	1
	G1-G2	0.23	1	0.23	1.434	0.241	0
	L1- L2	1.32	1	1.32	0.714	0.405	0
Density (kg/m^3)	B1-B2	86.70	1	86.70	0.088	0.769	0
	G1-G2	1526.53	1	1526.53	6.006	0.021	1
	L1- L2	1,056.13	1	1,056.13	1.266	0.270	0

*DF- degree of freedom, Sig. – significance, 0 – no significance difference at 0.05 level of significance, 1- significance difference at the 0.05 significance level.

However, when G1 and G2 were compared, the F-statistics 36.302 with a p-value less than 0.001 indicates a significant difference. In the comparison of the trees for the modulus of rupture, the G and L species were significantly different with p-values less than 0.05. However, trees from the B species were not significantly different with p-values greater than 0.05. The compressive strength of the B and G species was insignificant when compared at the tree level. The p-values were greater than 0.05 while the L1 and L2 were significantly different. The shear strength followed the comprehensive strength pattern in terms of the level of significance. The G and L species showed no significant difference among the trees as indicated by the p-values greater than 0.05 for the Janka hardness property. Trees 1 and 2 of the B species, however, were significantly different with a p-value of 0.009 greater than far less than 0.05. The density corresponded with the pattern of the modulus of elasticity. The significant variation observed between trees among some species could be a suggestion that the two species though with similar DBH, are of different ages which could have influenced the density and eventually the mechanical properties determined, this assession has been confirmed by many studies(Newsom 2022; Wu et al. 2022; Mañkowski et al. 2016; Schniewind 1989). Although the species were extracted from the same forest, solid nutrition could be a factor in tree development.

Tab.4 shows the classification of the three speciesbased on BS 5268-2: 2002, which provides a table with the mean and minimum values of moduli of elasticity. The predetermined values are matched with the mean and minimum of the data set of the species under classification. Based on BS 5268-2: 2002,*Blaghiasapida* (B)matched the mean value of 15000N/mm^2 with the minimum value of 12600N/mm^2 placing species B in strength class D50. Both *Gilbertiodendronlimba* (G) and *Lannea welwitschia* (L) matched the mean value of 10800 N/mm^2 and minimum values of 7500 N/mm^{2}and 6500 N/mm^2 respectively. These place the two species in the strength class D40.Several studies (Oyediran et al. 2023; Lamidi 2022; Christoforo et al. 2019; Rodrigues and Christoforo 2019)have concluded that wood species of D50 strength class can be utilised for structural applications requiring high mechanical resistance, potentially suitable for demanding construction projects where strength and durability are paramount.Species of this classification are suitable for roof members such as rafters, king posts, columns, and struts where compressive stresses need to be resisted.Wood of the D40 strength class is used for beams that meet specific bending strength, modulus of elasticity, and density criteria, ensuring suitability for structural applications based on standardized classifications(Ravenshorst et al. 2004).According to studies carried out in Brazil (Batista et al. 2023; Lahr et al. 2021), the D40 strength class of hardwood, as per Brazilian standards, is utilized in timber structures for its stiffness properties, with a representative value of 14110 MPa, potentially impacting structural rigidity.

Tab. 4: Strength classification according to BS 5268-2:2002.

Parameters	B	G	L
Mean MOE, (N/mm^2)	17118	11340	10554
Minimum MOE (N/mm^2)	11160	7101	6510
Strength class	D50	D40	D40

*****B - *Blaghiasapida*, G- *Gilbertiodendronlimba*, L- *Lannea welwitschia*.

The strength class as determined for species B, G and L can be used for construction purposes as espouse in previous studies (Ravenshorst 2019; Ravenshorst and Van De Kuilen 2016). Still, based on the densities, species B can be used for construction purposes where much strength and density are considered. In contrast, species G and L may be considered for constructions with lighter strength capacities.

CONCLUSIONS

This study provides an in-depth assessment of the mechanical strength properties of three lesser-utilized timber species in Ghana: *Blighia sapida*, *Gilbertiodendronlimba*, and *Lanneawelwitschii*. The findings demonstrate that *Blighia sapida*suggested superior mechanical properties, placing it in the D50 strength class, and making it suitable for demanding structural applications. *Gilbertiodendronlimba* and *Lanneawelwitschii* fall under the D40 strength class, suggesting their use in applications with moderate strength requirements. The variation observed within species indicates that factors such as age and environmental conditions could influence the mechanical properties, emphasizing the need for comprehensive characterization of these species.

Also, it highlights the potential of these lesser-utilized species to diversify the timber industry and reduce the overexploitation of more commonly used species enhancing the sustainable forest management and contributing biodiversity conservation of the Ghanaian forest.Beyond the immediate technical considerations, the study holds broader implications for sustainable forestry management and biodiversity conservation. As global discussions on responsible forest resource management gain momentum (Kaba et al. 2022; Forster et al. 2015; Karsten et al. 2014), the findings of this study have the potential to reduce the pressure on the few commercial species, guide forest management strategies, and contribute to a more resilient and adaptive timber industry.

ACKNOWLEDGEMENT

We express our profound appreciation to the CSIR-Forestry Research Institute of Ghana, for making available their laboratory throughout testing.The BVRio for the financial sponsorship.We are grateful to Mr. Felix Boakye for preparing the samples for this experiment.

REFERENCES

1. Amarasekera, H. (2012). Alternative timber species. A review of their properties and uses. Proceedings of International Forestry and Environment Symposium, 0(1):76-86.
2. André Luis, C., Karen Anéris, B., André Luis Cerávolo de, C., Luiz Fernando Silva, R., & Francisco Antonio Rocco, L. (2013). Characterization of tropical wood species for use in civil constructions. Journal of Civil Engineering Research, 3(3): 98-103.
3. Antwi-Boasiako, C., & Boadu, K. (2016). The level of utilization of secondary timber species among furniture producers. South-East European Forestry, 7(1):39-47.
4. Ataguba, C.O., Enwelu, C., Aderibigbe, W., &Okiwe, E.O. (2015). A comparative study of some mechanical properties of *Gmelina Arborea, Parkia Biglobosa*and*Prosopis africana* timbers for structural use. International Journal of Technical Research and Applications, 3(3):320-324.
5. Batista, M., Amorim, A., Silva, D.A.L., Christoforo, A.L., de Moura Aquino, V.B., & Lahr, F.A.R. (2023). Representativeness of the fiber parallel elasticity modulus value referring to the Brazilian standard C40 strength class in the design of timber structures. Ciencia Rural, 53(3):1-7.
6. BS 373 (1957) Methods of testing small clear specimens of timber.
7. BS 5268-2 (2002) Structural use of timber. Code of practice for permissible stress design, materials and workmanship.
8. Chimsah, F.A., Nyarko, G., Yidana, J.A., Abubakari, A.H., Mahunu, G.K., Abagale, F.K., & Quainoo, A. (2013). Diversity of tree species in cultivated and fallow fields within Shea Parklands of Ghana. Journal of Biodiversity and Environmental Sciences, 3(2): 1-9.

9. Christoforo, A.L., Aquino, V.B. de M., Wolenski, A.R.V., De Araujo, V.A., & Lahr, F.A.R. (2019). Evaluation of the *Peltophorumvogelianum*benth. Wood species for structural use. Engenharia Agricola, 39(6): 763-768.
10. Ewudzie, J., Gemadzie, J., &Adjarko, H. (2018). Exploring the utilization of lesser-known species for furniture production. A case study in the western region, Ghana. OALib, 05(11): 1-13.
11. Rodrigues, E.F.C, & Christoforo, A.L. (2019). Evaluation of the potential use of oiticica-amarela wood for structural applications. International Journal of Materials Engineering, 9(2): 23-27.
12. Forster, R., Pokorny, B., & Zapata, J.L. (2015). Emerging markets for tropical lesser-known species and their impact on sustainable forest management in Southeast Mexico :1-13.
13. Kaba, G., Hinde, O., Desalegn, G., Belachew, A., Amanuel, S., Girmay, E., Mussa, M., & Gelan, A. (2022). Utilization of lesser-used timber species in clustered furniture industries of Ethiopia. Indonesian Journal of Social and Environmental Issues (IJSEI), 3(1):81-88.
14. Karsten, R.J., Meilby, H., & Larsen, J.B. (2014). Regeneration and management of lesser known timber species in the Peruvian Amazon following disturbance by logging. Forest Ecology and Management, 327: 76-85.
15. Kwaku, A., Tobias, C., & Kwasi, F.M. (2022). Variations of stem and branch wood properties of *Nesogordoniapapaverifera* in Ghana. Journal of Plant Sciences, 7(1): 32-41.
16. Lamidi, N.A. (2022). EN 338 Strength characterization and grading of four less-used timber species grown in Nigeria for structural uses. LAUTECH Journal of Civil and Environmental Studies, 8(1):29-37.
17. Mañkowski, P., Kozakiewicz, P., &Drodek, M. (2016). The selected properties of fossil oak wood from medieval burgh in P£oñsk. Wood Research, 61(2): 287-298.
18. Newsom, L. A. (2022). Archaeological wood. In Wood in Archaeology.
19. Ofori, J., Mohammed, A., Brentuo, B., Mensah, M., & Boamah-Tawiah, R. (2010). Properties of 10 Ghanaian high density lesser-used-species of importance to bridge construction – Part 2: Mechanical strength properties. Ghana Journal of Forestry, 25(1):67-77.
20. Ohemeng, E., Mensah, P., Melo, R.R. de, Ebanyenle, E., Owusu, F.W., Seidu, H., &Mitchual, S.J. (2023). Technological properties of *Memecylonlateriflorum* wood: a timber species from Ghana. Nativa, 11(3):256-267.
21. Oyediran, A.A., Ikumapayi, C.M., & Olufemi, B. (2023). Determination of the properties of some selected timber species for structural application. World Journal of Engineering and Technology, 11(02):256-267.
22. Pappoe, A.N.M., Armah, F.A., Quaye, E.C., Kwakye, P.K., & Buxton, G.N.T. (2010). Composition and stand structure of a tropical moist semi-deciduous forest in Ghana. Plant Science, 1(4):95-106.

23. 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 and Fiber Science, 33(2):284-291.
24. Rodrigues, E.F.C, & Christoforo, A.L. (2019). Evaluation of the potential use of *Oiticica-Amarela*wood for structural applications. International Journal of Materials Engineering, 9(2): 23-27.
25. Quartey, G.A. (2015). Anatomical properties of three lesser utilised Ghanaian hardwood species. Materials Sciences and Applications, 06(12):1111-1120.
26. Quartey, G.A. (2022). Mechanical properties of *Terminalia catappa*from Ghana. Materials Sciences and Applications, 13(05): 334-341.
27. Rashford, J. (2001). Those that do not smile will kill me: The ethnobotany of the ackee in Jamaica. Economic Botany, 55(2): 190-211.
28. Ravenshorst, G., & Van De Kuilen, J.W. (2016). Species-independent strength modeling of structural timber for machine grading. WCTE 2016 - World Conference on Timber Engineering. 941-950.
29. Ravenshorst, G., Van Der Linden, M., Vrouwenvelder, T., & Van De Kuilen, J. W. (2004). An economic method to determine the strength class of wood species. Heron, 49(4):297-326.
30. Rocco Lahr, F.A., de Moura Aquino, V.B., Arroyo, F.N., Dos Santos, H.F., Mello Silva, S.A., Vobornik Wolenski, A.R., de Carvalho, C.M., Boff Almeida, J.P., & Christoforo, A.L. (2021). Influence of stiffness related to the C40 strength class of the hardwood group established by the Brazilian standard in the design of timber structures. Wood Research, 66(4): 582-594.
31. Schniewind, A. P. (1989). Physical and mechanical properties of archaeological wood.
32. Seidu, H., Németh, R., Owusu, F.W., Korang, J., Emmanuel, A. K., Govina, J. K., Younis, F.A.A.A., & Ibrahim, S. (2023). Mechanical properties of PF and MUF bonded juvenile hybrid eucalyptus plywoods produced in Ghana. Wood Research, 68(3):87-109.
33. Senterre, B. (2005). Recherchesméthodologiques pour la typologie de la végétation et la phytogéographie des forêtsdensesd'Afriquetropicale. Acta Botanica Gallica, 152(3):409-419.
34. Welling, J., Bartolo-Cuba, J.A., Sánchez-Blanco, J.C., Ahrens-Castillo, J.L., & Ugarte-Oliva, J.A. (2023). Wood/water relations of 15 south American lesser-used wood species. Maderas: Ciencia y Tecnologia, 25: 1-12.
35. Wu, M., Han, X., Qin, Z., Zhang, Z., Xi, G., & Han, L. (2022). A quasi-nondestructive evaluation method for physical-mechanical properties of fragile archaeological wood with TMA: a case study of an 800-year-old shipwreck. Forests, 13(1):1-15.

HARUNA SEIDU*, RÓBERT NÉMETH
UNIVERSITY OF SOPRON
FACULTY OF WOOD ENGINEERING AND CREATIVE INDUSTRIES
BAJCSY-ZSILINKY STR 4. H-9400 SOPRON
HUNGARY
*Corresponding author: haruna.seidu@phd.uni-sopron.hu

FRANCIS WILSON OWUSU
CSIR-FORESTRY RESEARCH INSTITUTE OF GHANA
P. O. BOX 63, FUMESUA - KUMASI
GHANA