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Mechanical Properties of *Terminalia catappa* from Ghana

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Abstract

Ghana is rich in forest resources, of which *Terminalia catappa*, a wood species of common occurrence is one. Even though sometimes it is used for decorative purposes, however, it grows in the wild. It grows in almost all the regions of the country and does well in the tropics. The parts of the tree such as the leaves, fruits and seeds have been known to be very useful for medicinal and other uses. Some work on the strength properties of the leaves and other parts has also been done, however, strength properties of the wood are yet to be explored. In this study, its mechanical properties such as bending strength, compression parallel to the grain, and shear parallel to the grain properties were determined. The British (BS 373, 1957) and American Society of Testing Materials' specifications (ASTM D143, 1983) using testing methods for small, clear specimens of wood were used in determining the properties. The results showed that at 18% moisture content the wood has a density of 520 kg/m^3 with a mean modulus of rupture of 86.04 Mpa, compressive strength parallel to the grain of 42.02 Mpa, modulus of elasticity of 10,500 Mpa, and shear strength parallel to the grain of 16.42 N/mm^2. These strength properties are comparable to that of *Strombosia glaucescens.* Therefore, *T. catappa* can be used in applications where this species is used.

Keywords

Terminalia catappa, Modulus of Elasticity, Modulus of Rupture, Compression Parallel to the Grain, Shear, Lesser-Known Wood Species

1. Introduction

According to Hansom [1], a better definition of Lesser-known species (LKS) is a species whose full potential has not been utilized. Some species which were hitherto not being utilised are now being used due to more technological information on them, their promotion, and also the preferred species are becoming scarcer. *Terminalia catappa* belongs to the family Combretaceae (Combretum family) and in Ghana is called "Abrofo nkate" (Whiteman's peanut). *Terminalia catappa* is one of the most common trees to be found in Ghana. Even though it grows in the wild but is sometimes grown for decorative purposes. It is abundant in almost all the regions of the country as it grows well in the tropics, hence it is named Tropical almond (Oduro *et al.* [2]). According to Arbounier, [3] it grows to a height of about 10 m with a single stem and then branches horizontally with leaves at the end of the branches that form a rosette (Thomson and Evans, [4]). The leaves are characteristic of changing colour from green to red, yellow, or gold and copper brown during the dry season and then are shed. A lot of studies on the plant especially on the fruit have shown that it could serve a lot of useful purposes: the extracts of the flesh of the fruit have been found to be a good acid-base indicator (Untwal and Kondawar, [5]). The fruit itself has also been found to contain agents of chemoprevention of cancer because it contains antioxidant phytochemicals that can break up the chromosomes of insects that feed on it (Hayward, [6]). The aqueous extract of *T. catappa* exhibits superoxide radical scavenging activity preventing lipid peroxidation (Lin *et al.*, [7]). It has also been found to possess anti-HIV reverse transcriptase (Tan *et al.*, [8]), hepatoprotective, anti-inflammatory, aphrodisiac, and anti-diabetic properties (Nagappa *et al.*, [9]). Most of the research on mechanical properties is done are on the leaves, fruits, and seeds but none on the wood (Wood Technical Factsheet [10]). Eddowes [11], in discoursing the promotion of LKS in Papua New Guinea in relation to their technical aspects, identified some problems with the utilization of LKS, among the problems is inadequate data on the physical and mechanical properties of these species. These properties play a key role in the utilization and handling of wood. The knowledge of these wood properties will guide the woodworker not to use the wrong type of wood for a particular project.

A tree, as shown in **Figure 1**, of such abundance does not have any data on its mechanical properties. Studies, experimentation, and measurements of wood mechanical properties are important in assessing the overall relative strengths (*i.e.*, resistance to fracture) of different wood species, and in their tendency to deform under load. Such measurements also will enable users to have a good expectation of how well a particular wood will perform in service. Engineers, wood specifiers, and end-users have been relying on the few desired and known species because they are sure of their technical suitability in terms of mechanical properties, durability characteristics, wood stability in service and woodworking characteristics among other qualities. The mechanical properties of wood are measures that have been studied of its ability to resist applied forces that might tend to change its shape and size. Resistance to such forces depends on their magnitude and manner of application and on various characteristics of the wood such as moisture content and density. If more technical data are available on some of these species, they would shift in using these new ones and therefore pressure will be lessened on the preferred wood species. This study therefore was

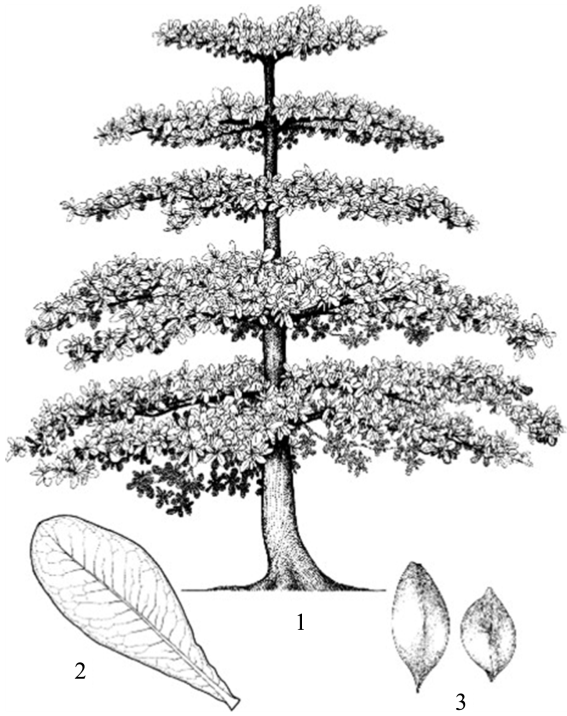

Figure 1. Structure of *Terminalia catappa* (Picture courtesy Sciendirect.com). 1. Pagoda-like structurer of the mature tree, 2. Single leaf, 3. Fruits showing their boat-shaped structure.

conducted to provide data on the mechanical properties of *Terminalia catappa* and rate it alongside other popular species for structural works using the BVRIO Guide by Blackham *et al.* [12] on lesser-known and lesser-used timber species. Blackham *et al.* [12] states that using these lesser utilized species is not only a good business decision but also has the potential to improve livelihoods and protect biodiversity. The 20 lesser-known and lesser-used species from Ghana displayed in this booklet have been selected based on their availability in terms of volume in the natural forests, their properties, and their levels of utilization. In the Guide, mechanical properties most experimented on, measured, and represented as "strength properties" for the design included modulus of rupture in bending, the maximum stress in compression parallel to the grain, compressive stress perpendicular to the grain, and shear strength parallel to the grain. Modulus of Elasticity (MOE) refers to the resistance to deformation of wood during bending. It is the stiffness or the flexibility of wood when external forces are applied. These species are classified into five (5) strength groups or classes in accordance with British Standard [13]. Modulus of Rupture (MOR) refers to the measure of the strength of wood before rupture during bending, also known as shear modulus. The hardwoods included in the Guide are classified as weak, medium, strong, and very strong. Compression parallel to the grain refers to the resistance to external forces acting longitudinally on a piece of wood. Shear parallel to the grain refers to the ability of a piece of wood to resist the internal slipping of one part upon another along the grain when external forces act upon it in such a way that one portion tends to slide upon another adjacent to it. These strength properties as applied to *Terminalia catappa* were studied in this work.

2. Materials and Methods

Sample Preparation

Samples for the investigation were obtained from three trees felled in Beposo off forest reserve, a suburb in the Western Region of Ghana. Using British Standard [14], samples were prepared for the test specimens. The boards were cut into the sizes, planned, and carefully examined for visible defects because the samples must be defect-free. The test specimens which were prepared for the determination of basic density, static bending (Modulus of Elasticity, Modulus of Rupture), compression parallel to the grain and shear parallel to the grain were tested on the Instron Universal Testing Machine, 50 KN. Twenty test specimens that were tested for each property were randomly selected and dressed, and tests were conducted at the timber testing laboratory of the Centre for Scientific and Industrial Research of the Forestry Research Institute of Ghana (CSIR-FORIG), Fumesua-Kumasi of Ghana. Using the American Society for Testing Materials [15], the density of the timber species was determined based on the volumes of the specimens at the time of the test and their weights when oven-dried. The lengths of the test specimens were 300 mm with a cross-section of 50 × 50 mm.

Determination of Mechanical Properties

Static bending: The mechanical properties determined from the static bending test were Modulus of Elasticity (MOE) and Modulus of Rupture ((MOR). The dimensions of the test specimens were 300 mm long, with a 20 × 20 mm cross-section using the specification outlined in the British Standard [14] for clear specimens (Pashin and De Zeeuw [16]). Replicates of twenty test specimens were prepared for each set of test variables. The actual specimen dimensions were measured with digital calipers calibrated with a 25 mm ± 0.1 μm slide. The specimens were conditioned in a room of relative humidity of 50% and a temperature of 23˚ Celsius for three weeks and equilibrated to approximately 12% Moisture Content (MC) (Quartey *et al.* [17]). The actual moisture content was determined after testing by using the moisture meter method and validated by the oven-dry method. The mean value for each set of the specimens was recorded.

Compression strength parallel to the grain: Using specimen dimensions of 300 × 50 × 50 mm in accordance with British Standard [14], tests were performed on a compression universal machine. As in the case of the static bending test, the specimens were conditioned in a room of relative humidity of 50% and a temperature of 23˚ Celsius for twenty-one days to allow the moisture content to equilibrate to about 12%. Using the electrical moisture meter, the actual moisture content of the specimens was determined. Specimen dimensions were measured to the nearest 0.001 mm before the testing.

Shear stress parallel to the grain: The specimens were prepared according to specifications in the American Society for Testing Materials [15]. The specimens were conditioned in a room of relative humidity of 50% and a temperature of 23˚ Celsius for three weeks to allow the moisture content to equilibrate to about 12% Quartey *et al.* [17]. The actual moisture content of the specimens was determined by an electrical moisture meter after testing. Specimen dimensions were measured to the nearest 0.001 mm before the testing.

3. Results and Discussions

The values and ratings as provided for in the BVRIO Guide by Blackham *et al.* [12] on lesser utilised and lesser-known species of Ghana is presented in **Tables 1-5**. The density of *T. catappa* is rated as a medium density wood with a value of 520 Kg/m^3 from **Table 5**. Density is a good indicator of strength, so this density makes this wood species moderately strong since it has implications for its strength.

Table 1. MOE strength groups or classes in accordance with BS 2568-2 as provided in the BVRIO guide.

	D30	D40	D50	D60	D70
Mean	9500	10,800	16,000	18,500	21,000
Minimum	6000	7500	12,600	15,600	18,000
	Very weak	Weak	Medium	Strong	Very strong

Table 2. MOR strength values as provided in the guide by BVRIO.

Classification	N/mm^2
Weak	30 - 69
Medium	70 - 99
Strong	100 - 169
Very strong	>170

Table 3. Compression values and rating as provided in the Guide by BVRIO.

Classification	N/mm^2
Weak	10 - 29
Medium	30 - 59
Strong	60 - 79
Very strong	>80

Table 4. Shear values and rating as provided in the guide by BVRIO.

Classification	N/mm^2
Weak	4 - 9
Medium	10 - 15
Strong	16 - 19
Very strong	>20

Table 5. Basic density values and rating as provided in the guide by BVRIO.

Classification	Kg/m^3
Low	300 - 450
Medium	450 - 600
Heavy	650 - 800
Very heavy	>800

3.1. Static Bending

Table 6 presents the mean values of the strength properties on twenty replicates of the wood of *Terminalia catappa* for the various tests. The Modulus of Elasticity (MOE) had a mean value of 10,500 Mpa with a minimum value of 8030 Mpa and a maximum value of 13,110 Mpa. The Modulus of rupture (MOR) was found to have a mean value of 86.02 Mpa, with a minimum value of 59.51 Mpa and a maximum value of 118.20 Mpa. The MOE of *T. catappa* is 10,500 Mpa (Table 6) and is rated in group D40 (Table 1), and the wood is weak in modulus of elasticity. Its MOR is given as 86.04 Mpa (Table 6) and is rated as a medium in Table 2. Knowledge of its MOE implies it cannot be used in areas where its elasticity will be needed.

3.2. Compression Strength Parallel to the Grain

The compression parallel to the grain of the wood was found to be of a mean value of 42.24 Mpa with a minimum value of 34.20 Mpa and a maximum value of 50.27 Mpa. For compression parallel to the grain, *T catappa* with a value of 42.24 Mpa (Table 6) is rated as medium from Table 3.

3.3. Shear Stress Parallel to the Grain

The shear parallel to the grain was found to have a mean value of 16.42 N/mm^2 with a minimum value of 14.06 N/mm^2 and a maximum value of 19.10 N/mm^2. And its shear strength of 16.42 N/mm^2 (Table 6) is rated as strong in Table 4. According to this research, the ability to resist the internal slipping of one part on another along the grain which is the shear stress is strong for this species.

The strength properties obtained from this research of *T. catappa* are that it has medium density, with MOE in group D40, medium MOR, medium compression parallel to the grain and strong shear parallel to the grain, are comparable to those for *Strombosia glaucescens*. According to the BVRIO Guide by Blackham *et al.* [12], *Strombosia glaucescens* has similarities with other species, such as African canarium/Aiele (*Canarium schweinfurthii*), Gmelina (*Gmelina arborea*), Koto/African pterygota (*Pterygota macrocarpa*), Akossika (*Scottellia klaineana*) and Sterculia yellow/Eyong/Ohaa (*Sterculia oblonga*). Therefore *T. catappa* has strength properties comparable to African canarium/Aiele (*Canarium schweinfurthii*), Gmelina (*Gmelina arborea*), Koto/African pterygota (*Pterygota macrocarpa*), Akossika (*Scottellia klaineana*) and Sterculia yellow/Eyong/

Table 6. Bending, compression and shear strength properties of *T. catappa*.

	Moisture Content	Density	Compression parallel to the grain	MOR	MOE	Shear parallel to the grain
	%	Kg/m^3	(Mpa)	(Mpa)	(Mpa)	N/mm^2
Mean	18	520	42.24	86.04	10,500	16.42
Standard deviation			4.80	23.33	2242	1.61
Minimum value			34.20	59.51	8030	14.06
Maxmum value			50.27	118.40	13,110	19.10
Co. Var (%)			11.30	27.12	21.34	2.50

Ohaa (*Sterculia oblonga* and can be used in areas where these species are used such as in heavy construction, sleepers, flooring, and turnery.

4. Conclusion

Most lesser-known species can be used in construction when the strength properties are known and are comparable to existing species that are already being used. Knowledge of the mechanical and physical properties will help in using the wood for design and construction purposes and therefore for the right project. *Terminalia catappa*, which was investigated is a medium density species with medium strength in elasticity and rupture but strong in shear strength. It possesses some of the structural properties of some existing wood species and therefore can be explored for structural engineering purposes such as sleepers among others. Therefore, apart from its other uses from the leaves and seeds, its wood can also be used as timber for structural applications.

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Conflicts of Interest

There is no conflict of interest.

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