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Strength and some Physical Properties of *Allanblackia Parviflora* for Furniture Production in Ghana

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ABSTRACT

In Ghana, many of our traditional wood species are over exploited and threatened to extinction. The utilization of other lesser-used and lesser known wood species needs to be looked at urgently as a possibility of increasing the wood resource base. And a successful expansion of the resource base is dependent on adequate knowledge of the properties of the lesser-used species such as *Allanblackia parviflora* which can be a good substitute to some of the dwindling species. It was against this background that the strength and some physical properties of *Allanblackia parviflora* trees were determined to predict the suitability of the species for furniture production and structural raw material for downstream processing of wood products. Three *Allanblackia parviflora* trees were used for the study. The main statistical tools used were descriptive statistics and one-way analysis of variance (ANOVA). Mechanical strength test specimens were prepared and tested in accordance with the British Standard BS 373: 1957. Mean green moisture content was 81.19%. Mean basic density was 539.00kg/m^3. The range of mean strength values in N/mm^2 in the 'green' and dry (12 % M.C) conditions for the three wood species were as follows: Modulus of Rupture: 50.00 - 56.00 (85.00 - 94.00), Modulus of Elasticity: 6,387.00 - 6,951.00 (8,287.00 - 8,875.00), compression parallel to grain: 24.00 - 28.00 (13.00 - 14.00) and shear parallel to grain 6.83 - 7.74 (9.62 - 10.82). Mean ratios of dry to 'green' MOR and MOE were 1.68 and 1.28. Almost all strength tests conducted showed a consistent trend that, the heartwood portion of each division was slightly stronger in terms of resistance to failure than its corresponding sapwood portion. Comparing the strength of *Allanblackia parviflora* to an existing classification (grade), strength is 'medium' in *Allanblackia parviflora* tree wood. It compared favourably with known species such as *Aningeria altissima*, *Terminaria ivorensis,* and *Antiaris toxicaria* in several properties and strength which are suitable for furniture production.

Keywords: *Allanblackia parviflora, Furniture production, Green Moisture Content, Basic Density, Modulus of Rupture, Modulus of Elasticity, Compression parallel to grain, and Shear parallel to grain*.

I. INTRODUCTION

Ghana has considerable wealth in tropical hardwood timber resources. There are about 680 different species of trees in the forest reserves of Ghana. Approximately 420 of these tree species attain timber size and therefore, are of potential economic value. About 126 of them occur in sufficient volumes to be considered exploitable as raw material base for the timber industries [1]. However, about 90% of the country's wood exports are covered by only 10 species [2], and only 4 species contribute roughly 60% of the total production [3]. The lesser-used species (LUS) occur in abundance in the forest, but increased harvesting must be on a sustainable basis to ensure continued harvesting potential.

Allanblackia parviflora, an evergreen tree widely distributed in tropical forest in Ghana belongs to the family *Guttiferae* [4]. A tree up to 30m high, bark reddish brown, furrowed, stringy, stem blotchy-white [4]. This tree can be described as a hardwood (pored timber) because it bears flowers, its seeds are encased in fruit, it has a broad leaves and branches usually grow out at different levels, at the most two at the same level.

There are about half-dozen varieties of Allanblackia trees in tropical Africa. *Palviflora, Floribunda, Gabonensis, Stuhlmannii, Ulngurensis* are some of the varieties of Allanblackia tree [5]. In Ghana it is known by various local names as Apesedua/Okusidua (Asante) Okisidwe (Denkyira), Suankyi (Wassa), Sonkyi (Nzema) [6]. Most farmers from about four regions in Ghana have started commercial plantations of *Allanblackia parviflora* tree purposely for extraction of oil for both local and foreign market. Field planting started in early 2007. The project is establishing community nurseries at Appeasuman (near Bogoso), Afosu, Sureso (nearAsankragua), New Edubiase, Offinso, and Twifo Praso where farmers can have access training on how to plant Allanblackia seedling and will also be supplied to farmers, from these sites. It takes Allanblackia seeds 10 to 18 months to germinate and 10 years to bear fruits if it is not grafted or budded but to reduce fruit bearing period, seedlings produced would have to be grafted to start bearing fruits in a shorter period of time estimated at 4 years. And it is known that the fruit yield reduces as the tree matures (i.e. from 45 to 60 years) [7].

II. OBJECTIVES

The main objective of the study was to determine the strength/mechanical properties and some physical properties and to assess its suitability for furniture production. Specifically, the study intended to determine the physical properties such as moisture content, basic density along the bole of each *Allanblackia parviflora* tree, to determine the properties through mechanical tests such as static bending (MOR and MOE), compression and shear parallel to grain for

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within and among tree variation of *Allanblackia parviflora* to compare the determined properties with an existing quality standards (grades) and properties of three traditional wood species to know its suitability for furniture production.

III. MATERIALS AND METHODS

Materials

The Study Area

Three trees of *Allanblackia parviflora* were extracted from a cocoa farm (Moist semi-deciduous forest) at Powuako near Ayanfuri in the Wassa Amanfi East District of Western Region of Ghana.

The District is located in the middle part of the Western Region of Ghana. It lies between latitudes 5, 30` N, 6, 15` N, longitudes 1, 45` W, and 2, 11` W. Trees of *Allanblackia parviflora* were purposefully selected because of the availability and known age of trees from the plantation. The diameter of tress harvested were 45cm, 48cm and 50cm respectively at breast height. Clear boles of each tree was divided into four billets to determine the within and among tree variation. The billet of each selected portion/part was divided into four (i.e. North, South, East and West) and sawn into three planks (1-3) from the pith portion of the billet to the bark portion of the tree to represent heart and sapwood part (1, 2, 3) of the tree. Marking and sawing were carefully done to ensure that the heart and sapwood portion of each billet was obtained. The juvenile wood portion of each billet was rejected.

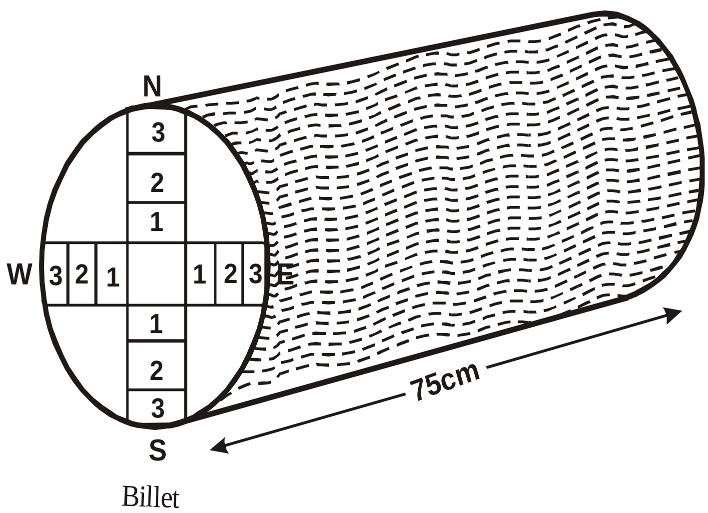

Figure 1: Extraction of samples from billet

Methods

Preparation of test specimen for the strength properties

The samples were prepared based on BS 373 [8] and ASTMD 1666-143 methods of testing small clear specimen of timber. It utilizes small, clear, straight-grained pieces of wood, which represent maximum quality that can be obtained. For each tree, four (4) portion/parts of the billets were used to determine the strength and the physical properties.

Samples were carefully selected from the prepared stakes of each board free from defects such as knots, sloping grain and other deterioration caused by insects and fire as from literature these factors reduces some strength properties of wood[9].

The boards were divided into two; half were immediately prepared for green tests after harvesting. Whiles the other half were sawn into smaller sizes and stacked to air dry. After the preparation, samples of a given strength test (of each billet) were kept in polythene bags to prevent changes in moisture content. One hundred and eighty (180) samples (made up of heart, sapwood portions and billet divisions) of each tree were prepared for green and one hundred and eighty (180) samples for dry compression parallel to grain, modulus of elasticity (MOE) and modulus of rupture (MOR) tests. And one hundred and eight (108) samples each for green and dry shear parallel to grain test, making a total of three hundred and sixty (360) samples for compression parallel to grain, modulus of rupture (M.O.R), modulus of elasticity (MOE) and two hundred and sixteen (216) samples for shear parallel to grain test making a grand total of one thousand, two hundred and ninety six (1,296) samples for all mechanical tests.

Determination of moisture content and basic density of the fresh wood samples

Before the determination of the strength properties, fresh wood samples from twelve billets of *Allanblackia parviflora* were prepared to determine moisture contents and basic density. Moisture content is expressed as the percentage of the oven dry weight of the wood [10].

Fresh samples destined for M.C. and Basic density were cut into dimension of 2cm x 2cm x 2cm. These samples were prepared from samples made up of sapwood and heartwood division (sawn planks 1-3) extracted from the three trees of *Allanblackia parviflora*. One hundred and twenty (120) samples from four (4) billets of each tree were used for the determination of each physical property (moisture content and basic density). After the preparation of the test, specimen /samples were immediately weighed by an electronic balance and oven-dried. The initial weights (W_1) and the oven-dry weight (W_O) were substituted in M.C. equation for moisture content determination.

The same test specimens of MC were used for the basic density test, where each 2cm x 2cm x 2cm cubes was soaked in water over twelve hours. The basic density on swollen volume and oven-dry mass basis was determined by the immersion method.

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The wood specimen was submerged in the water, and the mass of container plus water plus specimen was determined by electronic balance. The increase in mass of water displaced by the specimen in grams is numerically equal to the volume of water displaced in cm^3. The wood blocks were then oven-dried at a temperature of 101°C - 105°C to constant mass and oven dry mass determined.

Determination of strength properties of the wood

Immediately after preparation of test specimens, strength properties were determined. Compression parallel to grain and static bending (MOR) tests were tested on a Universal (multiple) 50 – ton Avery Machine. And a shear parallel to grain test was carried out on Instron -4482 machine with load cell capacity of 100kn. In all, four strength properties were determined, namely, compression strength parallel to grain, modulus of rupture (MOR) and modulus of elasticity (MOE) of static bending and shear strength parallel to grain. The straining rate for MOR and MOE was 0.26 in/min while shear and compression were strained at the rate of 0.25 in/min each. After loading of each sample test, the load that caused each wood sample to fail was recorded and immediately kept in polythene bag to prevent moisture content changes.

The moisture content of each wood sample was immediately determined after the test of each strength property. Small portions of wood samples (2cm x 2cm x 2cm) near the portion of rupture (of test pieces for MOR) were used to determine moisture content. However, the whole test piece (for each strength test) for compression and shear parallel to grain was used for moisture content (MC) determination. The value of MC of each specimen (of a particular test) so obtained was recorded with the results of the particular test to which it refers. The formulae used in calculating strength values from the test data were those given in the British Standards BS 373: 1957 which was followed in the test programme of this study. The bending strength modulus of rupture and modulus of elasticity was computed using the central loading method (2cm standards test piece).

P= maximum load in Newton's
L=span = distance between the points of support of the test piece = 280mm
h=breadth of test piece in mm
h=height of test piece in mm
A=area of cross-section of test piece in mm^2
It is necessary to adjust strength values obtained at different moisture content levels before any comparison can be made [11]. Hence after the tests, each strength property at moisture content w_1 was adjusted to strength at 12% moisture content.

Methods of Statistical Analysis

The data was analyzed statistically to assess the significant difference within each division of each tree and the variability between strength properties of three trees of *Allanblackia parviflora* using Excel analysis Tool pack (tools for scientific data analysis) in finding the descriptive statistics and a single factor analysis of variance (ANOVA) to describe relationships.

III. RESULTS

Moisture Content Of The Fresh Wood Samples

One hundred and twenty test samples from each tree were used for moisture content determination. Statistical results indicate the means of tree 1, 2 and 3 as 79.02, 82.52 and 82.05 percent with a standard deviation of 13.63, 11.20, and 8.29 respectively. Table 1 and 2 depicts summary of the basic statistics and ANOVA of the green moisture content.

Table 1: Summary of basic statistics of the green moisture content of *Allanblackia parviflora*

STATISTIC	MEAN ± SD
TREE 1	79.00 ± 13.60
TREE 2	82.52 ± 11.20
TREE 3	82.05 ± 8.29
AVERAGE	81.19 ± 11.33

Table 2: Summary of ANOVA of mean Green Moisture content

Allanblackia parviflora	Mean (±σ n-1)*	ANOVA between each Tree	
		Df	F
Tree 1	79.0±12.6	F (6, 113)	2.912
Tree 2	82.5±10.9	F (6, 113)	1.000
Tree 3	82.1±8.3	F (6, 113)	0.448

4.3 Basic Density of the Fresh Wood Samples

One hundred and twenty test samples from each tree were used for basic density determination. Statistical results indicate the means of tree one, two and three as 447.00, 539.00, and 536.00 kg/m^3 with a standard deviation as 70.15, 51.50 and 50.56. Table 3 and 4 depicts the summary of the statistics and ANOVA of the basic density of the fresh wood samples.

Table 3: Summary of basic statistics of the green basic density of *Allanblackia parviflora* trees

STATISTIC	MEAN ± SD
TREE 1	446.65 ± 66.34
TREE 2	539.03 ± 51.65
TREE 3	536.88 ± 49.77
AVERAGE	507.50 ± 52.22

Table 4: Summary of ANOVA of Mean Green Basic Density

Allanblackia parviflor	Mean (±σ n-1)*	ANOVA between each Tree	
		df	F
Tree 1	446 ± 66.1	F (6, 113)	1.960
Tree 2	539 ± 51.7	F (6, 113)	0.216
Tree 3	536 ± 49.8	F (6, 113)	0.943

Static bending tests [modulus of rupture (MOR) and modulus of elasticity (MOE)]

Sixty test samples were used for both green and dry MOR determination. Statistical results indicate the means of tree one, two and three when green and at (12% M.C) as 50.3 (91.9), 54.3 (84.7), and 55.1 (93.9) with a standard deviation as 0.56 (0.49), 0.50 (0.40) and 0.33 (0.54).

Table 5: Statistics of 'Green' Modulus of Rupture N/mm²

Tree No.	Mean	P_05	Std. Dev.	Mean test MC
1	50.31	49.20	0.56	52.60
2	54.70	53.70	0.50	54.30
3	55.10	54.50	0.33	53.40

Table 6: Statistics of Modulus of Rupture at 12% M.C

Tree No.	Mean	P_05	Std. Dev.
1	91.90	90.90	0.49
2	84.70	83.90	0.40
3	99.90	92.80	0.54

Same sample number used for M.O.R were used for MOE statistical results indicate the means of tree one, two and three when green and at (12% M.C) as 6,387.00 (8,287.00), 6,951.00 (8,875.00), and 6,556.00 (8,475.00) with a minimum of 5,987.00 and a maximum of 11,084.00. The mean test moisture content of three trees for green tests ranges from 52.60-64.30. Table 7 and 8 show the basic statistics for both green and dry (12% M.C) test results for MOE.

Table 7: Statistics of 'green' MOE (N/mm²)

Tree No.	Mean	P_05	Std. Dev.	Mean test MC
1	6,387.00	6,149.00	121.00	52.60
2	6,951.00	6,704.00	126.00	54.30
3	6,556.00	6,336.00	112.00	53.40

Table 8: Statistics of MOE at "12% MC"

Tree No.	Mean	P_05	Std. Dev.
1	8,287.00	8,038.00	127.00
2	8,875.00	8,626.00	127.00
3	8,475.00	8,247.00	116.00

4.5 Compression Parallel to Grain Test

For compression parallel to grain, sixty test samples for both green and dry were used for the test. Basic statistical results indicate the means of tree one, two and three when green and at (12% mc) as 23.60 (12.90), 27.90 (13.00) and 22.80 (14.10). Table 9 and 10 show the basic statistics for both green and dry (12%) test results for compression parallel to grain.

Table 9: Statistics of 'green' comp. parallel to grain N/mm²

Tree No.	Mean	P_05	Std. Dev.	Mean test MC
1	23.60	21.20	1.23	55.70
2	27.90	25.10	1.04	57.10
3	22.80	20.90	1.16	56.70

Table 10: Statistics of compression parallel to grain at 12% M.C.

Tree No.	Mean	P_05	Std. Dev.
1	12.90	12.50	0.23
2	13.00	12.40	0.31
3	14.10	13.50	0.32

4.6 Shear parallel to grain test

For shear parallel to grain, thirty six test samples was used for both green and dry test of each tree statistical results of tree one, two and three, green and (dry) were as follows: 7.74 (9.92), 6.83 (9.62) and 7.08 (10.82) as mean values. Mean test moisture content ranges from 89.6-94.8 for green and 16.40-17.00 for dry. Table 11 and 12 show results of the basic statistics for green and dry shear test conducted.

Table 11: Statistics of 'green' shear parallel to grain N/mm2

Tree No.	Mean	P_05	Std. Dev.	Mean test MC
1	7.74	7.14	0.14	89.60
2	6.83	6.65	0.09	94.80
3	7.08	6.94	0.07	93.70

Table 12: Statistics of 'dry' shear parallel to grain

Tree No.	Mean	P_05	Std. Dev.	Mean test MC
1	9.92	9.55	0.19	16.4
2	9.62	9.44	0.09	16.9
3	10.82	10.55	0.14	17.0

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IV. DISCUSSIONS

Moisture Content of the Fresh Wood Samples

Strength properties of wood samples are related to the moisture content of the wood [12] and hence it was expedient to determine the moisture content of fresh wood samples.

The green moisture content for all 360 specimens ranged from a minimum of 43.90% to a maximum of 100.70%. The overall average was 81.19% with standard deviation 11.33. The analysis of variance (ANOVA) indicates that, differences between the average green moisture contents of the three trees were not significant (P – value > 0.001). *Allanblackia parviflora* tree wood had a moisture content of 81.19% as an average which is higher than the three known species when compared. *Aningeria altissima* had 60.00% M.C, *Terminaria ivorensis* had 74.35% M.C, and *Antiaris toxicaria* had 50.00% M.C.

From literature, these known species had more moisture in the sapwood portion than the heartwood portion [13]. For variations among the trees, the trend did not change, sapwood portion had higher mean moisture content than the heartwood portion. Moisture content of each tree varies but their variations are not significant. These results could be attributed to the fact that, trees were harvested from one location and of the same age. A variation within tree (billet divisions) also varies, but their variations are not significant. Again the trend did not change; sapwood portion had higher mean moisture content than the heartwood portion. The tree had consistent trend of moisture content in all divisions where the sapwood portion had higher mean moisture content than the heartwood portion.

The analysis of variance indicates that differences between the average green moisture contents of three trees were not significant (P – value > 0.001).

Basic density of the fresh wood sample

The basic density of all trees ranged from 285.00 to 621.00 kg/m^3. The overall average was 507.50kg/m^3 with standard deviation of 52.22. The analysis of variance (ANOVA) indicates that differences between the average basic densities of three trees were not significant (P – value > 0.001).

Allanblackia parviflora tree wood showed similar trend when compared to the three known species.

The results revealed that, the heartwood portion of each sawn-planks division had a higher density than the corresponding sapwood portion. The mean basic density of heartwood is 621.00 kg/m^3 as compared to 285.00 kg/m^3 of its respective sapwood.

From [13], *Aningeria altissima* had 540.00-590.00 kg/m^3, *Terminaria ivorensis* had 545.00 kg/m^3 and *Antiaris toxicaria* had 433.00 kg/m^3. For variations among trees, basic density of each tree varies but their variations are not significant. Within tree billet divisions also varies, but their variations are not significant as depicted in Table 3. The tree had consistent trend of basic density in all divisions where the heartwood portion recorded higher mean density than the sapwood portion.

A summary of the analysis of variance (ANOVA) of the basic density of each tree is indicated in Table 4. The differences between the average basic densities of the three trees were not significant (P –value > 0.001).

Strength properties of trees of *Allanblackia parviflora* at 12% moisture content

It is very essential that only the results for woods with the same moisture content or values reduced to the same moisture content be compared [12].

The data for the various strength properties of the wood samples adjusted to 12% moisture content. [14] found that, the heartwood of wood sample is slightly stronger than the sapwood. This idea is true in the research conducted. Almost all strength tests conducted shows that, the heartwood portion of each division is slightly stronger (in terms of resistance to failure) than the sapwood portion.

According to [15], there is no significant difference in the strength of sapwood and heartwood per se within a given species. Although, the heartwood portion of almost all the strength test conducted shows a slightly stronger resistance to failure than the sapwood portion, the difference is not significant; therefore both heart and sapwood portions can be used for furniture and other production.

Strength Values

Table 13 gives summaries and results of the descriptive statistics of the Modulus of Rupture, Modulus of Elasticity, Compression and Shear parallel to grain values for three *Allanblackia parviflora* trees in the ‘green’ and 12% moisture conditions.

Modulus of Rupture (MOR)

The static bending strength values of the trees when ‘green’ and at 12% moisture content are shown from the range of mean strength values in the ‘green’ and dry (12% M.C) condition for three species was as follows: - Modulus of Rupture: 50.00 – 56.00 N/mm^2 and dry (85.00 – 94.00 N/mm^2). At 12% moisture content, it was observed that, the heartwood portion (1) and (2) of *Allanblackia parviflora* recorded the highest mean static bending (MOR) which was 98.36 N/mm^2 while the least mean bending strength (MOR) was 80.22 N/mm^2 was found in sapwood portion (3) of each sawn –planks divisions within the tree. It is therefore realised from the result that the resistance of heartwood to static bending (MOR) was higher than that of the sapwood at the same moisture content.

When compared to the tree known species, MOR in *Aningeria altissima* had 93.00 -130.00 N/mm^2, *Terminaria ivorensis* had

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83.00 N/mm^2 and *Antiaris toxicaria* had 59.00 N/mm^2. These results are closely related to that of *Allanblackia parviflora*. Again, the heartwood portion has a higher resistance to static bending (MOR) than the sapwood portion from literature of these three known species. Among trees MOR varies but their variations were not significant. Again within tree variation (billet divisions) also varies but their variations were also not significant. The overall order of decreasing MOR of the three species was as follows: Tree "Three" > Tree "two" and Tree two > tree "one", when green and at 12% M.C.

Modulus of elasticity (MOE)

MOE is a measure of resistance to bending and is calculated by formula PL^3/4bd^3 (method A) BS 3731: 1957. The MOE strength values of 3 trees when green and at 12% M.C are shown in Table 7 and 8. The range of mean strength values in the green and dry conditions for three trees was as follows: MOE green 6,387.00 – 6,951.00 and 12% M.C (dry) 8,287.00 – 8,875.00 N/mm^2. At 12% MC, it was observed that, the modulus of elasticity (MOR) for each sawn-planks division 1, 2, 3 did not show consistent variations, that is the divisions varies but their variations are not significant. When compared to the three known species ,*Aningeria altissima* 11,100.00 N/mm^2, *Terminaria ivorensis* 9300.00 N/mm^2, *Antiaris toxicaria* 7200.00 N/mm^2, and *Allanblackia parviflora* 5,987.00 – 11,084.00 N/mm^2, from Table 14. These values are closely related and predict *Allanblackia parviflora* tree wood performance when used for furniture production. Among trees, (MOE) varies but their variations are not significant so as the variations within tree (billet divisions). The overall order of decreasing MOE of three trees was as follows: Tree "two" > Tree 'three', and tree 'three' > tree 'one'.

Compression Parallel to Grain Test

The range of mean strength values in the 'green' and (dry) conditions for three trees was as follows: - Compression parallel to grain 24.00 – 28.00 N/mm^2 and dry 13.00 – 14.00 N/mm^2. At 12% moisture content, it was observed that, the heartwood portion (1) and (2) of *Allanblackia parviflora* recorded highest mean compression parallel to grain which was 14.10 N/mm^2 while as compared to 13.00 N/mm^2 of its respective sapwood portion (3) of each sawn-planks division within the tree. It was therefore realised from the result that, the resistance of heartwood to failure in compression parallel to grain was higher than that of the sapwood at the same moisture content.

When compared compression results to the three known species, *Allanblackia parviflora* performed a little below the known species. *Aningeria altissima* had 52.00 - 57.00 N/mm^2, *Terminaria ivorensis* had 35.00 N/mm^2 and *Antiaris toxicaria* had 54.00 N/mm^2. There are variations among the three trees of *Allanblackia parviflora* from Table 10 but their variations are not significant. The overall order of decreasing compression parallel to grain of three trees was as follows: - Tree "two" >, Tree "one" ≥ Tree "three". When green and Tree "three" > tree "two" and tree two is ≥ tree "one" when at 12% M.C.

Shear parallel to grain test

The shear parallel to grain strength values of 3-tress when green and at 12% M.C. were shown, and the range of mean strength values in the green and dry Condition for three trees was as follows; shear parallel to green. 6.80-7.70 N/mm^2 and dry (9.60-10.80 N/mm^2) At its dry state, it was observed that, the heartwood portion (1) and (2) of *Allanblackia parviflora* recorded highest mean shear parallel to grain which was 10.80 N/mm^2 as compared to 9.60 N/mm^2 of its respective sapwood portion of each sawn-planks divisions within each tree. It is realised from the results that, the resistance of heartwood to failure in shear parallel to grain was higher than that of the sapwood at the same moisture content.

When compared shear results to the three known species, *Allanblackia parviflora* had 9.60 N/mm^2 and relates to *Aningeria altissima* (6.80 – 9.50 N/mm$^{2)}$, *Terminaria ivorensis* (12.10 N/mm$^{2)}$ and *Antiaris toxicaria* (7.90 N/mm$^{2)}$. There are variations among the three trees of *Allanblackia parviflora*. In Table 12, but their variations are not significant. The overall order of decreasing shear parallel to grain of three trees was as follows:

Tree one > Tree "three"-and Tree three ≥ tree two when green. And Tree 'three' is > tree 'one' and tree 'one' is ≥ tree 'two' when dry.

Assigning grades to Allanblackia parviflora TEDB (1994) Weight classification, kg/m^3 at 12% moisture content.

Light → 350 or less
Light-Medium → 350 – 450
Medium → 450 – 575
Medium-Heavy → 575 – 725
Heavy → 725 – 900
Very Heavy → 900 or higher

The overall average mean of basic density (weight) of *Allanblackia parviflora* tree wood was 507.50k/gm^3. And from [16] weight classification, (5.9.1), weight is medium in *Allanblackia parviflora* tree wood. From the classification this tree can exhibit medium level of strength, natural durability and toughness and therefore can be used for furniture and other productions.

Ratio of Dry to Green 'Clear' Mechanical Strength Values.

Many of the mechanical strength properties are affected by changes in moisture content below the fibre saturated point. Generally, most of the strength properties increase as wood is dried. Above the fibre saturation point, most of the mechanical properties are not affected by changes in moisture content [15]. Table 13 shows the ratio of the mechanical strength at 12% moisture content (dry) to that when 'green' for the species studied and the comparative range ratios for USA hardwood.

[17] ratio for the Ghanaian hardwoods were generally highest in Modulus of Rupture (MOR) followed by compression parallel to grain (1.84), shear parallel to grain and Modulus of elasticity. Mean ratios for MOR was (1.68) compression parallel to grain (1.84) shear parallel to grain (1.40) and MOE (1.28).

Table 13: Ratio of dry to green mechanical strength values

Tree Nº.	MOR	MOE	Cll_g	Shear ll_g
1	1.68	1.29	1.83	1.28
2	1.68	1.27	2.08	1.40
3	1.70	1.29	1.62	1.53
Mean	1.68	1.28	1.84	1.40
Ghanaian hardwood	1.20 – 1.61	1.13 – 1.39	1.4 – 1.75	1.39 – 1.71
USA hardwood	1.20 – 2.10	1.11- 1.52	1.61 – 260	1.13 – 1.82

Dry means 12% moisture content

Source: [17]

From Table 13 the ratio of dry to green mechanical strength values indicates that almost all mechanical test falls at the highest range for both Ghanaian hardwoods and USA hard woods ranges. This predicts the tree's suitability for furniture production.

Assigning Grades to the Results Based on Timber Export Development Board – Ghana (1994)

[16] have classified strength of species based on the MOE at 12% moisture Content as follows:

'Very High' ⟶ [19,000 N/mm^2 and more]
'High' ⟶ [14,000 N/mm^2 – 19,000 N/mm^2]
'Medium' ⟶ [11,000 N/mm^2 – 14,000 N/mm^2]
'Low' ⟶ [below 9,000 N/mm^2]

The above classification indicates the strength of *Allanblackia parviflora* trees studied to be in range of 10,381.00 – 11,084.00 N/mm^2 "medium" and this would be suitable for furniture production.

Based on Bolza and Keating (1972)

S2 ⟶ [MOR of 134 N/mm^2 and more]
S3 ⟶ [MOR of 114 N/mm^2 - 134 N/mm^2]
S4 ⟶ [MOR of 93.7 N/mm^2 -114 N/mm^2]
Source: [18]

The above classification also indicates the strength of *Allanblackia parviflora* trees studied to be in a range of 84.70 – 93.90 N/mm^2 "S4" and this also confirm the trees suitability for furniture.

Table 14: Allanblackia parviflora compared to other known species suitable for furniture production in N/mm2

Species	MC %	Density	MOR	MOE	Cll	Shear llg
Allanblackia parviflora **(Sonkyi)**	81	539	85-94	5987-11084	14	9.6
Aningeria altissima **(Asanfena)**	60	540-590	93-130	11100	52-57	6.8-9.5
Terminaria ivorensis **(Emeri)**	12	545	83	9300	35	12.1
Antiaris toxicaria (Kyenkyen)	50	433	59	7200	54	7.9

Source: [13]

Allanblackia parviflora tree has similar strength and other physical properties compared to species like Aningeria altissima (**Asanfena**), Terminaria ivorensis (**Emire**), Antiaris toxicaria (**kyenkyen**) and others in Table 14. These species are well known to be species suitable for furniture and other production. These again predict *Allanblackia parviflora* tree's suitability for furniture production.

The Relationship between Modulus of Elasticity and Modulus of Rupture of *Allanblackia parviflora* tree wood

The precision with which a mechanical grading system can sort small clear samples into strength classes (grades) is dependent upon the degree of correlation between bending strength (MOR) and bending stiffness (MOE) [19]. For three trees tested in this study, the ratio of dry to green values between MOE and MOR correlates in Table 14 and therefore predicts the tree(s) suitability for furniture production.

V. CONCLUSION

The physical and mechanical tests were conducted to predict the performance of *Allanblackia parviflora* tree wood for furniture production. The results from all tests predict the tree(s) suitability for furniture production.

The variation among trees based on four strength and two physical tests conducted indicates that variations among 3-trees are not significant. For within tree billet divisions, each division varies but their variations were not significant. But for variations within tree sawn- planks (Heart to sap division -1, 2, 3) indicates that, the strength of division one (1) and two (2) are higher than division three (3). Based on the strength tests results, division one and two can be described as the heartwood

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portion and division three (3) as sapwood portion respectively. Although the heartwood portion of almost all the strength and physical tests conducted shows a slightly stronger resistance to failure than the sapwood portion, the differences are not significant, therefore both heart and sapwood portion can be used for furniture production. From literature, there is no significant difference in the strength of sapwood and heartwood presence within some given species, therefore both heart and sapwood portions of *Allanblackia parviflora* tree wood can be used for furniture production. But processing technologies like seasoning and preservation have to be studied to maximise opportunities for value-adding and improving sapwood durability.

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