Experimental Evaluation of the Physical and Sorption Properties of *Gmelina Arborea* Timber for Development of Wood-based Materials

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Abstract:
The physical and sorption properties of wood are critical factors influencing its performance in various applications. These properties affect the strength and durability of wood products. Understanding these properties is essential for developing wood-based materials. This study focuses on the experimental investigation of *Gmelina arborea* timber to evaluate its sorption properties. The methodology involved a series of tests following ASTM, ISO, and BS standards to measure density, shrinkage and other various sorption properties. Key results showed a mean green moisture content of 141.28%, a basic density of 505.03 kg/m³, a dry density of 540.28 kg/m³, and a density at 12% moisture content of 555.17 kg/m³. The timber exhibits a volumetric shrinkage and swelling of 8.71% and 8.26%, tangential shrinkage and swelling of 5.19 and 4.96%, radial shrinkage and swelling of 3.72% and 2.82%, and longitudinal shrinkage and swelling of 1.19% and 0.48% respectively. The ratio of tangential to radial shrinkage was computed as 1.4, which indicates reliable dimensional stability of the timber. *Gmelina arborea* absorbs 94.7% water over a soaking period of 1272 hours and loses 83.18% moisture during drying to reach an equilibrium moisture content of approximately 12%. Therefore, *Gmelina arborea* shows good potential for use in the development of Engineered Wood Products such as Cross-laminated timber.

Keywords: Absorption, Desorption, Dimensional stability, hygroscopic properties, Shrinkage, Swelling

I. INTRODUCTION

Wood has been a vital construction and manufacturing material for decades, valued for its versatility, strength, and renewability. Wood is a hygroscopic material, meaning it absorbs and releases moisture depending on its surroundings. Its properties change considerably with varying moisture content (MC). When the moisture content is below the fiber saturation point (FSP), wood expands and contracts as the moisture levels increase or decrease. [1]. The physical and sorption properties of wood are critical factors influencing its performance in various applications. Physical properties such as density, MC, and dimensional stability affect the mechanical strength and durability of wood products [2, 3]. An increase in the moisture content (MC) in wood leads to dimensional changes, which can cause the coating film on the wood to crack and develop checks [4, 5]. Wood density depends on the quantity of wood material per unit volume and moisture content. A higher proportion of wood material results in greater density, enhancing the wood's mechanical properties. Density is considered the most reliable indicator of the strength of clear wood, with a higher density signifying increased strength. Sorption properties, which include shrinkage and swelling as well as the wood's ability to absorb and desorb moisture, play a significant role in its dimensional stability and susceptibility to biological degradation [6]. Moisture loss and gain cause wood to shrink and swell, respectively. These changes are anisotropic, meaning the rates of shrinkage and swelling differ depending on the direction. This directional variation, longitudinal, radial, and tangential, is primarily due to the cell wall structure. The differences between the longitudinal direction and the two lateral directions (radial and tangential) can be explained by the orientation of microfibrils within the layers of the secondary cell wall. Generally, factors that influence shrinkage and swelling include moisture content, density, and irregularities in the wood's structure. Higher-density wood tends to shrink and swell more because it contains more moisture within its cell walls. Therefore, understanding these properties is essential for developing wood-based materials that meet specific performance criteria, particularly in regions with varying climatic conditions.

Among the various timber species, *Gmelina arborea*, commonly known as Gmelina, stands out for its rapid growth and adaptability to diverse environmental conditions. Gmelina has gained popularity in the forestry and timber industries worldwide due to its favourable growth characteristics and wood properties [7]. In Nigeria, more than 112,000 hectares of land are currently occupied by Gmelina plantations. Although Gmelina has the potential to become a valuable material in the future, its applications so far have been mostly confined to paper and pulp production, as well as making furniture, door panels, models, and similar products [8]. Various plantations of the tree (Gmelina arborea) were established mostly in southern Nigeria about 53 years ago as possible pulp wood for paper industries [9]. It is among the most important species for plantations in tropical regions and can be widely cultivated in areas where it has not previously been grown [10]. Gmelina arborea has shown promise in multiple applications, including furniture construction and pulp production, owing to its relatively low density, ease of processing, and good workability. However, comprehensive data on its physical and sorption properties remain limited.

Research conducted on Gmelina includes a study that compared the physical and mechanical properties of *Gmelina arborea*, *Parkia biglobosa*, and *Prosopis africana* timber obtained from Idah, North Central Nigeria. The study found that Gmelina has an average density of 687 kg/m^3 [10]. Another study reported that in Gmelina, wood density gradually increases from the base to the top of the tree, with a high moisture content (MC) of 160% and an average density of 410 kg/m^3 [11]. Further research has shown that the moisture content of Gmelina ranges from 168% to 182%, with an average of 170% [12]. Additionally, the mechanical properties of *Gmelina arborea* were investigated. The result showed that its density ranges from 387 kg/m^3 to 528 kg/m^3 [9]. In a study that investigated selected wood species, including *Gmelina arborea* and four others, the strength and sorption properties were evaluated based on key index properties such as bending strength, density, and dimensional stability, all measured using standard techniques. The data from the experimental investigation showed that *Gmelina arborea* has a medium density of 552.8 kg/m^3. Additionally, the results of volumetric shrinkage and swelling are 7.84% and 6.69% for Gmelina, respectively [13]. *Gmelina arborea* wood was one of the Nigerian timber species whose properties were examined in another study. The study concluded that Gmelina has an average density of 700 kg/m^3 [14].

This study aims to experimentally evaluate these properties to offer a scientific rationale for the optimal utilization of *Gmelina arborea* in wood-based material development. The methodology involves the determination of the physical properties of *Gmelina arborea*, including basic density, dry density, and density at 12% moisture content, and assesses the sorption properties, focusing on the wood's moisture absorption and desorption behaviour, as well as analysis of the variability of these properties within and among individual trees to understand the implications for material development. Hence, by systematically investigating these aspects, this study will contribute to a deeper understanding of *Gmelina arborea's* suitability for various wood-based applications and inform best practices in its processing and utilization.

II. MATERIALS AND METHODS

A. *Materials*

1) Timber Specie

The Gmelina Arborea (green) logs that were used for this study came from a forest in the southern Kachia LGA of Kaduna State, Nigeria (which is located at Jaban Kogo, Sabon Sarki, on latitude 9° 39' 21" N and longitude 8° 5' 11" E). The logs were purchased from a supplier at the Old Panteka Timber Market in Kaduna. A total of nine (9) logs from three (3) different randomly selected trees were purchased, three (3) logs from each tree, with one log each gotten from the base, middle, and top sections of the tree trunk height, respectively. The exact dimensions of the trees, along with the environmental conditions at the time of harvesting, are presented in Table 1.

Table 1: Tree dimensions at the time of harvest.

Tree Designation	Tree 1	Tree 2	Tree 3
Age of trees (years)	20	20	20
Height of trees (cm)	1300	1200	1500
Diameter at breast height (cm)	43.3	41.7	39.8
Month of the year		July	
Season of the year		Rainy	

2) Apparatus and Equipment

The apparatus or equipment used for sample preparation and measurement includes a circular sawing machine, a digital measuring instrument (weighing balance and calipers), and an electric oven.

B. *Methods*

The methods involved in this study include specimen preparation, physical properties tests, and hygroscopic or sorption properties tests, all in accordance with relevant codes presented in Table 2.

1) Specimen Preparation

The trees were harvested with a power saw and cut into logs of 2.5 feet (70.6 cm) in length. The logs were divided into three sections: bottom, middle, and top. The bottom section consisted of the part of the tree between 0 and 2.8 meters, while the middle and top sections were defined as the portions between 2.8 and 5.6 meters and 5.6 and 8.4 meters, respectively. This segmentation was done to ensure that the test results accurately reflect the properties of the tree, as outlined in references [9, 12]. The green logs were transported to the Department of Civil Engineering, and a total number of 270 samples with the dimensions given in Table 2 were prepared.

Table 2: Dimension and number of specimens tested.

Test	Dimensions(mm)			No. of specimens	Reference
	b	d	l		
Density & MC	50	50	50	135	ASTM D2395-17 & BS 373
Shrinkage	20	20	30	45	ISO13061 (14)
Water absorption	30	30	60	45	ISO13061
Swelling	20	20	30	45	IS013061 (15)

2) Determination of Physical Properties

The tests for determination of the physical properties (both density and MC) were carried out on 135 samples in accordance with ASTM D2395-17 and BS 373 [15, 16] as shown in Table 2.

a) Moisture Content (MC)

The moisture content (MC) of each sample was determined by first measuring its initial mass (M_1) before drying, using an electronic weighing balance and digital calipers. The samples were then oven-dried at a temperature of 103 ± 2 °C until a constant weight was achieved after two consecutive measurements. The final mass (M_2) of each specimen was recorded. The moisture content was calculated using Equation (1).

$$\mathrm{MC} = \frac{\mathrm{M}_1 - M_2}{M_2} \times 100(\%) \tag{1}$$

b) Density

The Density of each sample was obtained by first measuring its initial mass (M1) and initial volume (V1) before drying using an electronic weighing balance and digital calipers respectively. The test specimens were then oven-dried at a temperature of 103±2 °C until constant weight was obtained after two successive measurements. The final mass (M2, oven dry mass) and the final volume (V2, oven dry volume) of each specimen were recorded. The Densities were obtained using equation (2) to (5). The Green density (ρg), Dry density (ρd) and Basic density (ρb), as well as Specific gravity (SG) for each sample, were obtained using equations (2), (3), (4) and (5) respectively:

$$\text{Green Density}\,(\rho\mathrm{g}) = \frac{\mathrm{M}_1}{V_1} \tag{2}$$

$$\text{Dry Density}\,(\rho\mathrm{d}) = \frac{\mathrm{M}_2}{V_2} \tag{3}$$

$$\text{Basic Density}\,(\rho\mathrm{b}) = \frac{\mathrm{M}_2}{V_1} \tag{4}$$

$$\text{Specipic Gravity (SG)} = K\,\frac{\mathrm{M}_2}{V_1} \tag{5}$$

Where K is constant determined by the units used to measure mass and volume ($K=10^{-3}$ m^3/kg when mass is in kg and volume is in m^3).

3) Determination of Sorption Properties

A total of 135 samples were used to determine the sorption properties of *Gmelina arborea*, with 45 samples allocated for each of the following measurements: volumetric shrinkage, volumetric swelling, and water absorption.

a) Volumetric Shrinkage

The stereometric method was used to determine the volumetric shrinkage (β_v) by measuring the volume of the test piece before and after drying to constant mass in accordance with ISO13061-14 [17]. Equations (6), (7) and (8) were used to determine the volumetric, radial and tangential shrinkage respectively, for each test piece:

$$\beta_{\mathrm{V}} = \frac{(l_{r1} \times l_{t1}) - (l_{r2} \times l_{t2})}{(l_{r1} \times l_{t1})} \times 100 \tag{6}$$

$$\beta_r = \frac{l_{r1} - l_{r2}}{l_{r1}} \times 100 \tag{7}$$

$$\beta_{\mathrm{t}} = \frac{l_{t1} - l_{t2}}{l_{t1}} \times 100 \tag{8}$$

Where

lr_1 and lt_1 represent the dimensions of the test piece in millimeters when it is fully saturated, measured in radial and tangential directions respectively; lr_2 and lt_2 represent the dimensions of the test piece in millimeters when it is completely dry, measured in the radial and tangential directions, respectively.

b) Volumetric Swelling

The stereometric method was also employed to determine the volumetric swelling (α_v) by measuring the volume of the test piece after it was dried to a constant mass and then soaked in water until it reached a constant volume, in accordance with ISO 13061-15 [18]. Equations (9), (10) and (11) were used to determine the volumetric, radial and tangential swelling respectively, for each test piece.

$$\alpha_{\mathrm{V}} = \frac{(l_{r2} \times l_{t2}) - (l_{r1} \times l_{t1})}{(l_{r1} \times l_{t1})} \times 100 \tag{9}$$

$$\alpha_r = \frac{l_{r2} - l_{r1}}{l_{r1}} \times 100 \tag{10}$$

$$\alpha_{\mathrm{t}} = \frac{l_{t2} - l_{t1}}{l_{t1}} \times 100 \tag{11}$$

Where,

lr_2 and lt_2 represent the dimensions of the test piece in millimeters when it is fully saturated, measured in radial and tangential directions respectively; lr_1 and lt_1 represent the dimensions of the test piece in millimeters when it is completely dry, measured in the radial and tangential directions, respectively.

The logistic growth function in Equation (12) was used to model the swelling behaviour of Gmelina using the parameters: L = 4.831, k = 0.00860530454, and x_0 = 149.13939682.

$$y(\%) = \frac{L}{1 + \exp[-k(x - x_0)]} \tag{12}$$

c) Water Absorption

All test pieces were first oven-dried and then immersed in a container filled with water to collect absorption data. At specific intervals, the samples were removed from the container and lightly dried on filter paper to eliminate surface water. The samples were then weighed to determine the amount of moisture absorbed before being returned to the container. This process was repeated until the moisture content stabilized. When the rate of moisture uptake was initially high, measurements were taken every two hours. As the moisture uptake rate slowed, the intervals between readings were extended. Once the water absorption process was complete, the samples were used for the desorption test. The fully saturated samples were dried indoors under natural air convection. At regular intervals, the samples were weighed to measure moisture loss, and this procedure was continued until the weight of the samples stabilized, following the method adopted by [19].

Equation (12), the logistic growth model function was also to fit the experimental data for water absorption. The model has the following parameters for water absorption: L (the maximum value, or carrying capacity): 93.548552, k (the growth rate): 0.007626 and x0(the inflection point, or the time at which the growth rate is highest): 155.131744. This model captures the behaviour of the data, showing an initial increase in water absorption that slows down as it approaches a maximum value (full saturation). For water desorption in terms of loss of moisture (LM) over time, the same logistic growth model in equation (12) was used to model the experimental data, the model has the following parameters: L (the maximum value, or carrying capacity): 80.9304582, k (the growth rate): 0.0392105 and x0(the inflection point, or the time at which the growth rate is highest): 44.0438231. However, for the water desorption, in terms of reduction in moisture content (RMC) of the samples over time, the exponential decay model was used to fit the experimental data. The exponential decay model has the following parameters: A: 80.1417823, B: 0.0189296 and C: 12.7083388. The model function is given by equation (13). This model captures the behaviour of the data, showing a rapid initial decrease in water content that levels off as it approaches a minimum value (equilibrium moisture content).

$$y(\%) = A\exp(-Bx) + C \tag{13}$$

III. RESULTS AND DISCUSSIONS

A. Physical Properties

1) Moisture Content (MC)

The results for moisture content of Gmelina trees are presented in Fig. 1 and summarized in Table 4. The MC for tree 1, tree 2 and tree 3 ranged from 121.6 % to 164.57 %, 119.76 % to 170.06 %, and 123.39 % to 171.82 % respectively.

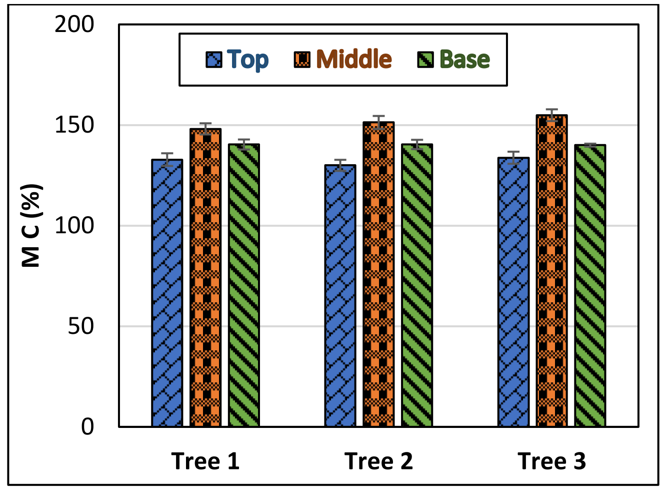


Fig. 1: Variation of MC along the height of the trees

From Fig. 1, it can be observed that for all three trees, the MC gradually increases from the top to the middle section and then slightly decreases down to the base. This is because early wood is found in the middle section and they are usually formed of thinner cell walls with large cell lumen or cavities which accommodates large amounts of moisture. The mean MC was obtained as 140.42 %, 140.53 % and 142.88 % for the three different trees respectively. The moisture content at the top is relatively consistent among the three trees, with values ranging from 129.97% to 133.76%. The variation (standard deviation) is also similar, suggesting that the top position of these trees maintains a stable moisture content. The middle position shows higher moisture content compared to the top and base. This is consistent across all three trees, with T3 having the highest moisture content (154.89 ± 2.94). The standard deviations are slightly higher in the middle position, indicating more variability in moisture content. The moisture content at the base is close to the overall mean moisture content for each tree, suggesting that the base has a stable and representative moisture content. The values are very similar among the three trees, with T3 showing the least variation (140.01 ± 0.73). The overall mean moisture content of the three trees shows a slight variation, with T3 having the highest value (142.88 ± 1.93). The differences in overall mean values are small, indicating similar moisture content across the three trees.

2) Density

The results for density of Gmelina are presented in Table 3 and summarized in Table 4 and Fig. 2. The basic density of Gmelina trees conducted on 135 specimens ranged from 406.93 kg/m^3 to 569.64 kg/m^3, 427.36 kg/m^3 to 558.47 kg/m^3, and 395.96 kg/m^3 to 558.03 kg/m^3 for tree 1, 2 and 3 respectively as presented in Fig. 7 and the results compares well with results [9, 11, 20].

Table 3: Average Dry & Basic Density for Three *Gmelina Arborea* Trees

Position	T1		T2		T3	
	Dry Density (kg/m^3)	Basic Density (kg/m^3)	Dry Density (kg/m^3)	Basic Density (kg/m^3)	Dry Density (kg/m^3)	Basic Density (kg/m^3)
Top	568.69 ± 10.14	531.00 ± 9.08	564.54 ± 5.57	525.57 ± 6.24	558.46 ± 9.87	519.83 ± 8.80

Middle	518.91 ± 10.18	484.94 ± 10.33	517.37 ± 9.73	483.41 ± 9.54	499.44 ± 12.71	464.62 ± 12.38
Bottom	546.40 ± 11.30	512.89 ± 10.90	544.33 ± 8.26	511.82 ± 7.64	544.37 ± 5.57	511.16 ± 5.39
	544.66 ± 6.70	**509.61 ± 6.39**	**542.08 ± 5.39**	**506.94 ± 5.19**	**534.09 ± 6.72**	**498.54 ± 6.40**

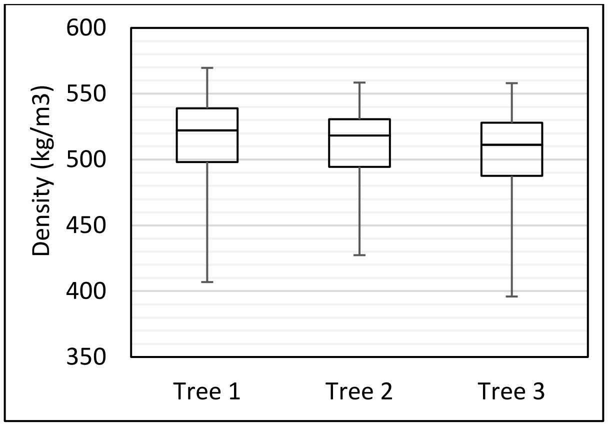


Fig. 2: Box plot for density results of the trees

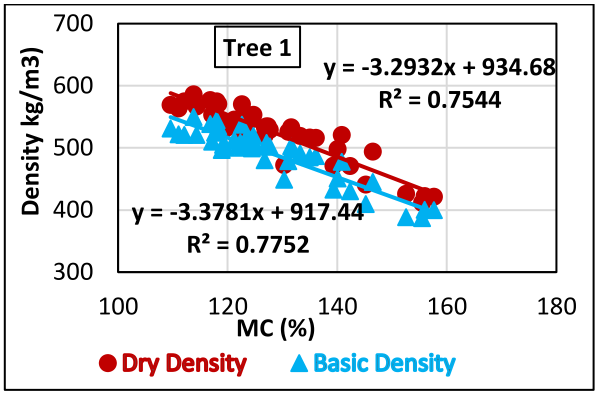
High density from the base, decreasing gradually for some distance to the middle and then increasing towards the top is observed as can be seen in Table 3. This can be attributed to the presence of tension wood at the top and bottom of the trees and also due to the high MC in the middle section which has a negative correlation with density. It can also be seen that the dry density at the top position is the highest among the three positions for each tree. The basic density follows a similar pattern. This indicates that the top position of the trees has a higher concentration of solid wood material compared to other parts. The variation (standard deviation) in density at the top is moderate, suggesting a consistent but slightly variable density at the top. The middle position shows the lowest dry and basic densities compared to the top and bottom positions. This indicates that the middle section of the trees has less dense wood. The standard deviations are slightly higher in the middle position, indicating more variability in wood density in the middle section. The bottom position has densities that are intermediate between the top and middle positions. The values are quite consistent across the three trees, suggesting that the base of the trees maintains a relatively stable density. The variation is slightly lower than the middle position but higher than the top, indicating a moderate consistency in density. The overall mean dry and basic densities of the three trees show a slight variation, with T1 having the highest values and T3 the lowest. This indicates a minor difference in overall wood density among the trees. The dry and basic densities are highest at the top position and lowest at the middle position. This pattern suggests that the wood is denser at the top and less dense in the middle, which could be due to factors such as age, growth rate, and environmental conditions affecting different parts of the tree. Analysis of variance was conducted to test the variance of mean MC and density values among the three trees as well as along the height of each tree. The result showed that the mean MC and density along the height of all the trees were significantly different (*P-value* < 0.05). The ANOVA result for MC and density within the three different trees also showed significant differences.

Table 4: Mean Values for Moisture Content & Densities for *Gmelina Arborea* Tree

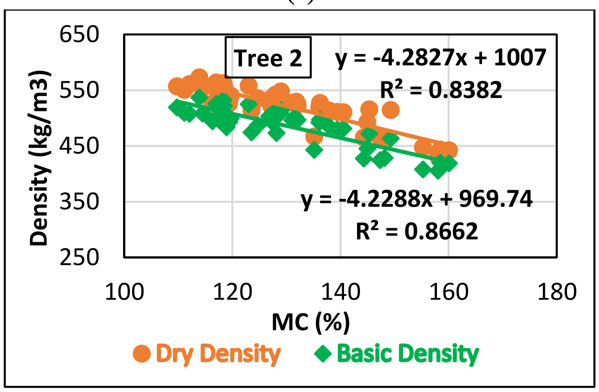
Property	MC (%)	Db (kg/m^3)	Do (kg/m^3)	Dg (kg/m^3)	D12% (kg/m^3)
MEAN	141.28	505.03	540.28	1213.88	555.17
SD	12.98	40.36	42.19	52.98	35.77
COV	9.19	7.99	7.81	4.36	6.33

Table 4 shows the mean, standard deviation (SD), and coefficient of variation (COV) for the basic density (Db), oven-dry density (Do), green density (Dg), density at 12% moisture content (D12%), and moisture content (MC) of samples taken from three different trees. The mean moisture content of the Gmelina is quite moderate at 141.28%, indicating a significant amount of water within the material. The SD of 12.98 and COV of 9.19 % suggest a relatively consistent moisture content across samples, with moderate variability. The mean basic density is 505.03 kg/m³, representing the density of the wood when completely dried of moisture. The mean dry density is slightly higher than the basic density at 540.28 kg/m³, likely due to a reduction in the volume of the specimen during the drying process. The mean green density is substantially higher at 1213.88 kg/m³, reflecting the density of the wood in its natural, wet state. The mean density at 12% moisture content is 555.17 kg/m³, which is a common reference point for wood density measurements. Gmelina shows high moisture content with relatively consistent density measurements. The densities at different moisture levels (Db, Do, D12%) indicate how the wood density changes with moisture content, providing insights into the material's behavior in different environmental conditions. The consistency in density measures (as indicated by low COV values) suggests reliable performance and uniformity in the wood samples, making them suitable for various applications where predictability of material properties is crucial.

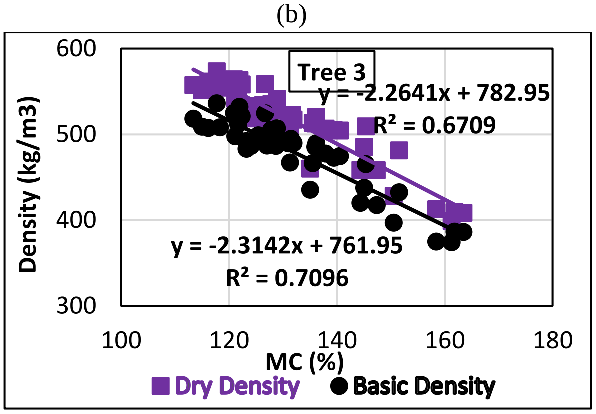
In order to understand the relationship between density and MC, linear regression analysis was conducted between these two important physical properties and the results are shown in Fig. 3 (a, b & c).



(a)



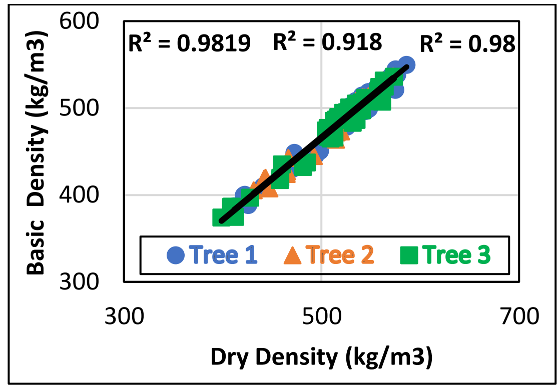
(b)



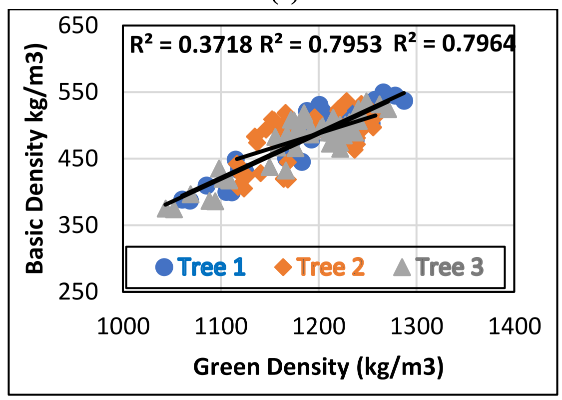
(c)

Fig. 3 (a, b & c): Correlation between Basic Density, Dry Density and Moisture Content for Different Trees

From the graphs in Fig. 3 (a, b, c), the results obtained show a strong negative correlation between densities (dry and basic) and MC for all the three Gmelina trees considered, with an R^2 value of 0.7752, 0.8662 and 0.6709 for tree 1, 2 and 3 respectively. Fig. 4 (a, b) shows the correlation between the dry, basic and green densities for the three trees, the results obtained indicated a perfect positive correlation between the basic and dry densities. However, a weak positive correlation was observed between basic and green density, which is the result of the influence of moisture variation along the height of the trees.



(a)



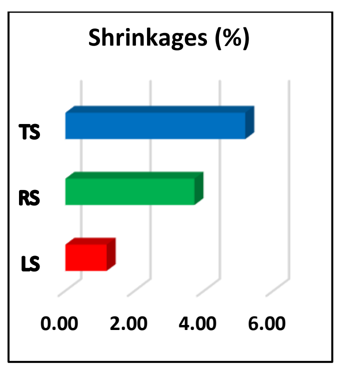
(b)

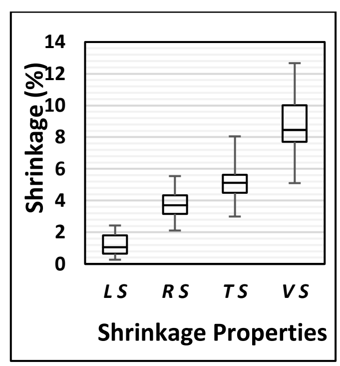
Fig. 4 (a & b): Correlation between Basic Density, Dry Density and Green Density for Different Trees

B. Sorption Properties

1) Shrinkage

The shrinkage results presented in Fig. 5(a, b) indicate that *Gmelina* has a mean longitudinal shrinkage (LS) of 1.19%, radial shrinkage (RS) of 3.72%, and tangential shrinkage (TS) of 5.19%. The volumetric shrinkage (VS) was measured at 8.71%, and the ratio of tangential to radial shrinkage (TS/RS) was calculated as 1.40, which reflects the dimensional stability of the *Gmelina* tree.





(a) (b)

Fig. 5: Shrinkage properties along the longitudinal, radial and tangential plane

2) Swelling

The swelling result presented in Fig. 6 indicates that Gmelina has a mean tangential swelling of 4.96%.

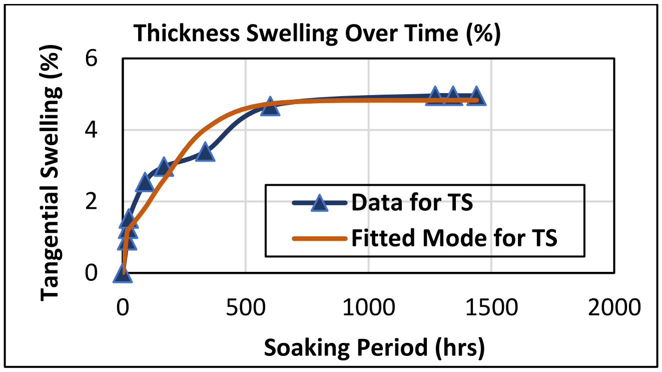


Fig. 6: Swelling values along the tangential plane

As presented in Table 5, the radial and volumetric swelling were measured at 2.82% and 8.26%, respectively. These low swelling values confirm the good dimensional stability of Gmelina.

Table 5: Experimental data for swelling properties

S/N	Soaking Period (Hrs)	Radial Swelling (%)	Tangential Swelling (%)	Volumetric Swelling (%)
1	0	0	0	0
2	18	0.28	0.92	1.23
3	22	0.32	1.24	1.56
4	24	0.36	1.53	1.89
5	91	0.63	2.55	3.16
6	168	1.12	2.97	3.78
7	336	2.17	3.39	5.26
8	600	2.82	4.67	7.81
9	1272	2.82	4.96	8.26
10	1344	2.82	4.96	8.26
11	1440	2.82	4.96	8.26

4) *Water Desorption*

The results of the water desorption test, shown in Fig. 8, indicate that the moisture content (MC) decreased continuously over the drying period. An initially rapid rate of moisture reduction (58.46%) was observed during the first three days, followed by a constant drying rate of 83.18% at 336 hours (14 days).

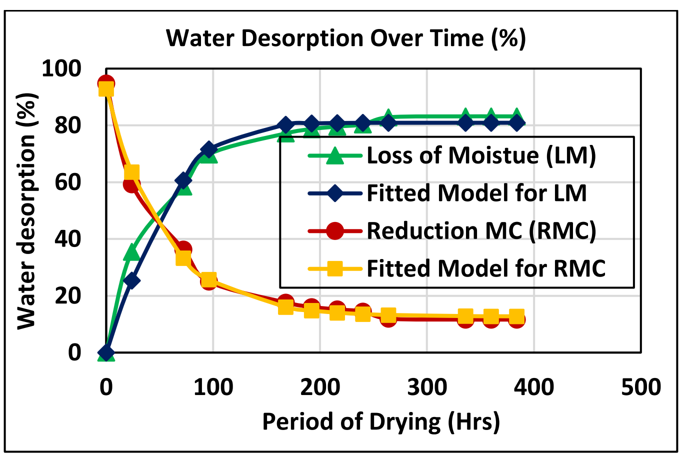


Fig. 8: Water desorption curves during soaking test of Gmelina samples in water

Table 6 summarizes the average values for the equilibrium moisture content (EMC), density, water absorption (WA), and the swelling and shrinkage in both tangential (T) and radial (R) directions for Gmelina arborea.

3) *Water Absorption*

Water absorption of the Gmelina samples is displayed in Fig. 7. The samples initially showed a high rate of moisture absorption, which gradually slowed down in the later stages. Gmelina attained almost 50 % to 55 % MC within a week (168 Hrs) of soaking, and it entered the relaxation phase after four weeks (672 Hrs). The water absorption ranged from 19.25 % for 18 hours to 94.7 % for 1272 hours (53 days).

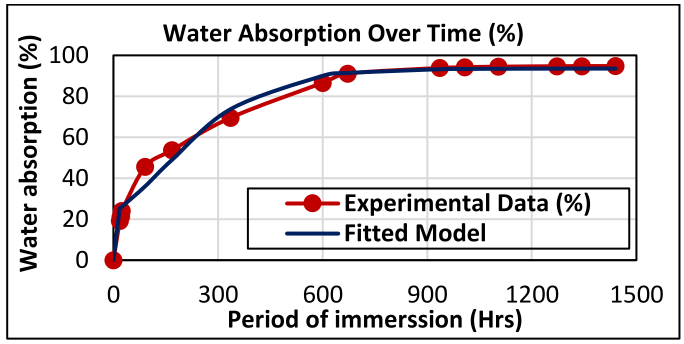


Fig. 7: Water absorption curve for Gmelina samples during soaking test in water

Table 6: Average values for EMC, density, WA, swelling and shrinkage

EMC	Density	WA	Swelling (%)		Shrinkage (%)	
(%)	(kg/m3)	(%)	R	T	R	T
11.8	505	94.7	2.82	4.96	3.72	5.19

Table 6 reveals that the EMC closely matches the reference MC of 12%. The low shrinkage and swelling values of Gmelina are very much related to its low water absorption, as timber with low water absorption is less likely to undergo significant swelling or shrinkage when exposed to changes in humidity or moisture levels, leading to greater dimensional stability. Additionally, lower water absorption typically means the timber is less susceptible to decay, mold, and fungal growth, which often occur in high-moisture environments. This makes the wood more durable and suitable for outdoor or high-moisture applications.

IV. CONCLUSIONS

From the results obtained from this study, the physical and sorption properties of *Gmelina arborea* timber determined from the experiments are as follows: a mean green moisture content (MC) of 141.28%, a basic density of 505.03 kg/m³, a dry density of 540.28 kg/m³, and a density at 12% moisture content of 555.17 kg/m³. The mean specific gravity was 0.51. The consistency in density measures (as indicated by low COV values) suggests reliable performance and uniformity in the wood samples, making them suitable for various applications where predictability of material properties is crucial. The timber exhibited volumetric shrinkage and swelling of 8.71% and 8.26%, tangential shrinkage and swelling of 5.19% and 4.96%, radial shrinkage and swelling of 3.72% and 2.82%, and longitudinal shrinkage and swelling of 1.19% and 0.48%, respectively. It absorbed 94.7% water from the dry to fully saturated stage over an average soaking period of 1272 hours (53 days) and lost 83.18% moisture during drying to reach an equilibrium moisture content of approximately 12%. The material properties of *Gmelia arboreal* timber established in this research showed good potential for use in the development of wood-based material. As a result of this study, Gmelina is recommended for use in the production of wood-based materials, notably Engineered Wood Products (EWP) such as glue-laminated timber (Glulam), structural composite lumber (SCL), laminated-veneer lumber (LVL), cross-laminated timber (CLT), and many more.

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