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Examining the Physical Properties and Within Tree Variability in the Physical Properties of Two Lesser-Known Timber Species in Ghana

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ABSTRACT

This study was carried out to determine some physical properties of *Cola nitida* and *Funtumia elastica* two lesser- known timber species in Ghana that are not used for commercial timber purposes. The basic properties were determined based on British Standard 373 (1957). The main statistical tools used were Descriptive Statistics and Analysis of Variance (ANOVA). Variation in physical properties was analyzed within the trees of the two species. Three trees each per species were used in the study. Results of the study showed that initial moisture content were 66.6% and 79.4% for *Cola nitida* and *Funtumia elastica* respectively. The basic density of *Cola nitida* was 623.8 kg/m^3 and 499.6 kg/m^3 for *Funtumia elastica*. According to TEDB (1994), *Cola nitida* is a Medium-Heavy species and *Funtumia elastica* a Medium Weight species. Mean total tangential shrinkage from green to oven-dry was 7.25 and 6.78% for *Cola nitida* and *Funtumia elastica*, respectively. Mean partial tangential shrinkage from green to 12% MC is very small (under 2.5%) for *Cola nitida* and medium (4.0-5.5%) for *Funtumia elastica*. The corresponding mean partial radial shrinkage values also showed that shrinkage was very small (under 1.0%) for *Cola nitida* and medium (2.0–3.0%) for *Funtumia elastica*. The technical values for the two species compared favourably with those of some locally used species for timber production (like *Scottellia coriacea* and *Lannea welwitschii)*, and therefore could be considered suitable for timber utilization. The results of the analysis of variance (ANOVA) revealed that the three axial sections of the trees showed significant differences at 5% probability level ($p < 0.05$).

Keywords: *Lesser known, cola nitida, Funtumia elastica, physical properties, shrinkage and timber*

I. INTRODUCTION

Decreasing supply of most commercial wood as raw material inspires the forest products industry to look for other wood species which have similar or greater commercial values but are not currently utilized by the forest products industry. Wood is a versatile and an aesthetically pleasing material as well as the oldest building material used by man. But there is limited knowledge about the properties of a large proportion of timber-grade wood species. This knowledge base is essential for greater or proper utilization because of changes that occur in wood under different service conditions [1].

Ghana, in West Africa, is a land of savannah and forest. It is roughly the same size as the United Kingdom but with only one third as many people. It depends strongly on its exports of minerals, cocoa and timber and it is pioneering ecotourism based on its forests and wildlife. Ghana is recognized as one of the most advanced tropical African countries in established forest policy, legislation, forest inventory, management planning, and in having a National Forest Standard and principles, criteria and indicators for judging the quality of forest management and usage [2]. Ghana has established a conservation classification to ensure that the supply of Ghanaian hardwood species can be maintained. In practice, this means that harvesting of the better known and commonly used species (like the redwoods, African mahogany and Sapele wood) is more limited, and much more encouragement is being given to the harvesting of lesser known species [3].

The forest in Ghana, like most tropical forest, is being utilized commercially for a few highly priced timber species, which are mere fraction of the timber species that are potentially useful [4]. There is significant utilization of these few tree species to satisfy market demands to the neglect of about 90 species that are of merchantable sizes and commercial quantities [5]. These constitute over 45% of the standing volume of trees in Ghana’s forest [6]. Increases in population and the need to earn money from exports have put pressure on Ghana's forests which are limited in extent. Over the years, Ghana has worked to evolve sustainable use of forests which could go on to provide economic, social and environmental benefits. Increasing market demand, both locally and internationally, has resulted in the over- exploitation of these ‘traditional’ market species, rendering some of them like Odum, Sapele, and others endangered [3]. As prices of these traditional timber increase, and quality and quantities decline, manufacturers and producers have little option other than to pay attention to the lesser-known species that were previously ignored if they are to remain in business. One of the crucial questions in tropical forest management today is the future of lesser-known species [7]. Hundreds of potentially valuable trees are being left behind, often simply being burnt in forest clearing operations. Little is known at present about their possible end-uses or even their physical properties. There is, therefore, little hope for the future of the Ghanaian timber trade if diversification of market species is not encouraged to accommodate lesser-known species and to serve as a means for sustainable management of the tropical forest of Ghana.

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Cola nitida and *Funtumia elastic* are species that are in abundance in our forests and farms. These species have being left out of utilization due to lack of knowledge on their properties. It is therefore urgent to assess properties of these species to ascertain their possible utilization potentials. There are nearly seven hundred different tree species in Ghana [2]. Approximately 420 of these tree species attain timber size and therefore are of potential economic value [8]. Almost 126 of them occur in sufficient volumes to be considered exploitable as raw material base for the timber industry [6]. However, about 90% of the country's wood exports are covered by 10 species [9], and only 4 species contribute roughly 60% of the total production [10].

Historically, most dealers in the Ghana wood industry have relied mainly on a traditional knowledge based on experience of use but with little information on their properties. Most of the species are also not being put to wider utilization because of inadequate data on the physical and technological properties that relates to the utilization of the species. In many cases the limited use of the potential lesser-utilized timber species is caused by scarcity and inaccessibility of information regarding their wood properties [11]. The objectives of this study were to determine the physical properties (basic density, moisture content and shrinkage) of *Cola nitida* and *Funtumia elastica* species as well as examine the variation of the physical properties within the stems of *Cola nitida* and *Funtumia elastica* species in Ghana.

II. MATERIALS AND METHODS

Materials

Species used and their origin

Three matured logs each of *Cola nitida* and *Funtumia elastica* species were procured from Siana in the Asunafo South district of the Brong Ahafo region within the southwestern part of Ghana to provide wood for evaluation of the physical properties of the species. The logs were obtained from a cocoa farm in the same locality within the open forest of the area.

Conversion and Sampling

The logs were purposefully selected based on their diameters at the base (breast height) being greater than 40 cm and the overall straightness of the trunk. The clear boles were cut at heights of 50 cm and 70 cm from the ground respectively for the *Cola nitida* and *Funtumia elastica* trees. Although the standard breast height for cutting timber is 1.3 meters, these two species were cut at lower levels because of the unbuttressed nature of their bases so as not to waste the wood. From each log, a section (billet) of 50 cm long was removed from the butt, middle and the top portions of the clear bole. The sections were further sawn through and through to get flat sawn boards (planks). A 5-cm thick flat sawn board for density, shrinkage and moisture content tests was taken from the middle of each section.

Methods

Moisture content

The 5-cm flat-grain board (plank) of length 50 cm from the centre of the 50 cm section (billet) was sawn with the circular saw into 2.5 cm square section strips. One 2.5 cm x 2.5 cm x 50 cm strip was extracted from the sapwood and heartwood of each section for the determination of the green moisture content. The strips were planed, trimmed and cut off to 2 cm x 2 cm x 2 cm cubes. Twenty-five sapwood and 25 heartwood cubes were selected from each section. The green mass (W_i) of the specimen cubes was determined and over-dried at 103 ± 2°C until constant mass (W_{od}) was obtained. Moisture content (MC) of the specimen cubes were then calculated according to the formula:

$$\text{Moisture content} = [(W_i - W_{od}) / W_{od}] \times 100\%$$

Basic Density

The 5-cm flat-grain board (plank) of length 50-cm from the centre of the 50-cm section (billet) was sawn into two and from which 2.5 cm square section strips were produced to give their radial and tangential faces. The samples were extracted from both the sapwood and heartwood regions of the 50-cm section. The strips were planed, trimmed and crosscut to specific sizes of 2 cm x 2 cm x 2 cm in thickness, width and length respectively. From each section (billet) 25 sapwood and 25 heartwood cubes were selected, making it 75 sapwood and 75 heartwood cubes from each of the three logs for each wood species. To determine the volumes of the specimens, each set of cubes was soaked in water overnight or swollen by means of vacuum impregnation with water. The swollen volume was determined by the hydrostatic or immersion method as follows: The weight of a container and the water it contained were determined. The wood specimens were then immersed, and the weights of container plus water plus specimens were determined. From the law of floatation, the increase in weight or the weight of water displaced by the specimen in grams is numerically equal to the volume of water displaced in cm^3. The samples were then oven-dried at 103 ± 2°C to constant weight and their oven dry masses determined. Basic densities for the samples were calculated using the formula.

Basic density, (kg/m^3) = (oven-dry in mass kg) / (mass of water displaced by swollen specimen in m^3).

Shrinkage

Three 2.5 cm square strips of length 50 cm were further extracted from the 5 cm board sawn from the middle portion of each section of the three axial locations (B.M.T) for all trees.

Twenty clear samples each of sapwood and heartwood were planed, trimmed and cut-off to a size of 2 cm x 2 cm x 10 cm from each axial location for each log. One hundred and eighty each of sapwood and heartwood square samples for each wood species were dried at room temperature in the General

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Chemical Laboratory (FRNR) over 21 days, conditioned to 12% moisture content in constant humidity atmosphere. They were oven dried at 40°C, 60°C and 105°C, respectively. The samples were weighed periodically and their dimensional changes in length, width and thickness were monitored through measurements using a micrometer screw gauge in the radial and tangential directions and digital veneer calipers in the longitudinal direction. Shrinkage in drying at the various moisture contents and from the green to 12% moisture content and oven-dried state were calculated for the tangential, radial and longitudinal directions. It was expressed as a percentage using the formula:

Shrinkage = [(Change in dimension) / (Green dimension)] x 100%

III. RESULTS AND DISCUSSION

Results of Moisture Content Test

The amount of moisture in wood is termed moisture content and it is expressed as a percentage of the dry weight. Approximate moisture content of each 20 mm cube sample was determined by the oven dry testing method. The overall mean for all three *Cola nitida* trees was 66.61%, ranging from 44.32% to 115.22% high. Tree 2 had the lowest mean of 63.23% whiles tree 3 had the minimum moisture content of 44.32% at 95% confidence level. Both minimum and maximum moisture contents of the three trees were in line with Simpson [12] who stated that the moisture content of some species may be as low as 30% and as high as 200% due to variations in site and the seasons of felling.

The *Funtumia elastica* species also had overall mean moisture content for all trees at 79.4%. Tree 3 had the lowest moisture content of 78.3% with tree 1 having the highest mean moisture content of 80.22%. These results affirm that the moisture content of *Funtumia elastica* is higher than that of *Cola nitida*. This result is in tune with the range of moisture contents for species in Ghana by TEDB [2].

Table 1: Summary of descriptive statistics of the green moisture content of *Cola nitida* and *Funtumia elastic*

Green moisture content statistics	*Cola nitida*	*Funtumia elastica*
Mean MC (%)	66.61	79.41
SD	9.39	7.89
Minimum,%	44.32	60.5
Maximum, %	115.22	94.44
Count	450	450
95% Confidence Level	0.87	0.73

Table 2: Summary of ANOVA of mean green moisture content of individual trees of Cola nitida and Funtumia elastic

Wood species	Mean ± S.D	ANOVA between individual trees	
		Degrees of freedom	F
Cola nitida	66.61 ± 9.39	F (2,447)	26.29
Funtumia elastica	79.41 ± 7.89	F (2,447)	2.356

Table 2 is ANOVA for within tree moisture content tests for *Cola nitida* and *Funtumia elastica* trees which have F values of 26.29 and 2.36 respectively, an indication of a significant source of variation of moisture content in these two species.

The initial moisture content for the *Cola nitida* trees decreased from bark to pith. The sapwood had higher moisture content than the heartwood. There was significant differences between the sapwood and heartwood portions for all the three tress (F_{actual}, 13.7, 322.2 and 4.8 > $F_{expected}$, 3.9), respectively. This result is in line with Simpson [12], who contended that the sapwood moisture content in hardwood species was somewhat higher than or about equal to that of the heartwood. Also Walker [13] got 115% (heartwood) and 125% (sapwood) for shining gum *(Eucalyptus nitens).*

Results of Basic Density Test

The within tree average basic density range was 577.82 to 653.75 kg/m^3 for *Cola nitida* and 497.9 kg/m^3 to 501.3 kg/m^3 for the *Funtumia elastica* trees. The analysis of variance revealed that differences between average basic densities of the three trees were highly significant and highly insignificant for *Cola nitida* and *Funtumia elastica* respectively.
Table 3 has being presented to show the basic densities of the densities of the two species.

Table 3: Summary of descriptive statistics of the basic density of *Cola nitida* and *Funtumia elastica*

Basic density statistics	*Cola nitida*	*Funtumia elastica*
Mean , (kg/m^3)	623.75	499.57
SD	81.7	25.9
Minimum, (kg/m^3)	424	148.01
Maximum, (kg/m^3)	843.75	571.4
Count	450	450
95% Confidence Level	7.57	2.4

A summary of the analysis of variance (ANOVA) of the basic density of individual trees of the two species is shown in Table 4. The differences between the average basic density of the trees of each wood species were highly significant F

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(2,447) = 43.62 (p – value > 0.001 for *Cola nitida* and significant for *Funtumia elastica* F (2,447) = 0.67 (p – value > 0.001). The basic density values of the species could be classified as 'Medium Heavy (575-725 kg/m^3) for *Cola nitida* and 'Medium' (425-575 kg/m^3) for *Funtumia elastica* according to ATIBT [14] and TEDB [2].

By knowing the densities of these two species, it may in a way assist in predicting the wood strength as reported by Rowell [15] that basic density is closely related to end-use quality. Hoadley [1] also contended that wood density is a key factor that influences the wood strength.

Table 4: Summary of ANOVA of basic density of *Cola nitida* and *Funtumia elastica*

Wood species	Mean ± S.D	ANOVA between individual trees Degrees of freedom	F
Cola nitida	623.75 ± 81.7	F(2, 447)	43.62
Funtumia elastica	449.57 ± 25.9	F(2, 447)	0.67

Results of the three billets and plank divisions for *Cola nitida* and *Funtumia elastica* trees showed an inconsistent trend in basic density for *Cola nitida* trees. The *Funtumia elastica* trees had higher density means at the buttress and a decrease to the top and middle sections.

Results of Shrinkage Measurements

Below is a summary of the shrinkage measurements for *Cola nitida* and *Funtumia elastica*. *Cola nitida* had a higher tangential shrinkage of 7.25% as against 6.78% for *Funtumia elastica.* The total anisotropic factors were 2.65% and 1.8% respectively. Total longitudinal shrinkage was very high in *Funtumia elastica* (0.4) and normal in *Cola nitida* (0.29).

Table 5: Summary of some derived descriptive statistics of shrinkage of *Cola nitida* and *Funtumia elastica*

Shrinkage parameters (%)	*Cola nitida*	*Funtumia elastica*
Total Tangential, T	7.25 ± 1.33	6.78 ± 20.2
Total Radial, R	3.02 ± 0.9	3.2 ± 0.65
Total Longitudinal, L	0.29 ± 0.29	0.4 ± 1.04
Tangential at 12% MC, (T_{12})	1.05 ± 4.34	4.88 ± 0.76
Radial at 12% MC, (R_{12})	0.49 ± 1.84	2.79 ± 0.52
Longitudinal at 12% MC, (L_{12})	0.27 ± 0.32	0.3 ± 0.2
T / R Ratio	2.65 ± 1.36	1.8 ± 0.39
T_{12}/R_{12} Ratio	2.43 ± 2.67	1.79 ± 0.41

The tangential and radial shrinkage values obtained from the experimental results showed that shrinkage is very small in *Cola nitida* and medium in *Funtumia elastica* as presented in Table 5. The total longitudinal shrinkage from green to oven-dry was 0.29% and 0.4% for *Cola nitida* and *Funtumia elastica* respectively. According to Wengert [16] and Bauer [17] wood shrinks a maximum of 0.3% longitudinally which is so small to be ignored. *Funtumia elastica* exhibited excessive longitudinal shrinkage of 0.4%, whiles *Cola nitida* shrinked 0.29% which fell within the permissible range of 0.3%. Attention should be paid to *Funtumia elastica* when using it in designs where longitudinal stability is important. Both species had higher tangential to radial shrinkage index as shown in Table 5 which is above the acceptable index of 1.5 as proposed by Wengert [16]. The ratio of tangential shrinkage to radial shrinkage (T/R) is used as an index of dimensional stability. Ratios higher than 1.5 are considered pronounced [18]. The pronounced differential shrinkage in the two species studied is likely to cause wide splits, checks and distortions if the necessary precautions are not taken during the kiln drying of these species [19].

There was no dominant pattern of shrinkage variability in both species as shown. Tangential shrinkage from green to 12%MC was slightly higher in the heartwood than the sapwood for all the *Funtumia elastica* trees. Meanwhile the radial shrinkage was a little higher in the sapwood than the heartwood for all the *Funtumia elastica* trees. Tangential shrinkage from green to 12% MC was higher in sapwood than heartwood in all the *Cola nitida* trees. Radial shrinkage from green to 12% MC was higher in heartwood than in sapwood in the *Cola nitida* trees.

IV. CONCLUSIONS

This study on the development of kiln drying schedules for *Cola nitida* and *Funtumia elastica* was necessitated by the over dependence of the timber industry on few species and the lack of technical data on the many species growing in Ghana's forests. Mean green moisture content were 66.6% and 79.4% for *Cola nitida* and *Funtumia elastica* species respectively. Mean basic densities ranged from a high of 623.75 kg/m^3 for *Cola nitida* to a low of 499.59 kg/m^3 for *Funtumia elastica*. The basic density values indicate that the species are Medium heavy and Medium weight species respectively. The mean total tangential shrinkage from green to oven-dry was 7.25 and 6.78% for *Cola nitida* and *Funtumia elastica*. Mean partial shrinkage (tangential) values obtained shows that shrinkage from green to 12% MC is very small (under 2.5%) for *Cola nitida* and Medium (4.0-5.5%)

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for *Funtumia elastica*. The corresponding radial shrinkage values also shows that shrinkage is very small (under 1.0%) for *Cola nitida* and Medium (2.0 – 3.0%) for *Funtumia elastica*.

The total longitudinal shrinkage from green to oven-dry was 0.29 and 0.4% for *Cola nitida* and *Funtumia elastica* respectively. Typically, total longitudinal shrinkage is only 0.1-0.2% for most species and rarely exceeds 0.4% [15]. Both species exhibited excessive longitudinal shrinkage. Both species had higher tangential to radial shrinkage index which is above the acceptable index of 1.5. The ratio of tangential shrinkage to radial shrinkage (T/R) was very high (2.43 – 2.65) for *Cola nitida* and a high (1.8 – 1.79) for *Funtumia elastica*. The shrinkage values compared favourably with shrinkage values of some locally used species (like *Scottellia coriacea* and *Lannea welwitschii*) for timber production, and therefore could be considered suitable for timber utilization. The results of the analysis of variance (ANOVA) revealed that the three axial sections of the trees showed significant variations in densities and moisture contents at 5% probability level ($p < 0.05$).

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