Bulletin of the *Transilvania* University of Brasov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 16(65) Special Issue 2023
https://doi.org/10.31926/but.fwiafe.2023.16.65.3.16

VARIATION IN MOISTURE CONTENT AND DENSITY WHITIN AND AMONG FRESHLY FELLED *SCLEROCARYA BIRREA* AND *ANOGEISSUS LEIOCARPUS*

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Abstract: This papaer studiess the variations in moisture content within and among tree species of Sclerocarya birrea and Anogeissus leiocarpus, as well as the green density of a cubic meter of freshly felled wood from this species. The trees included in this research grew in Western Kordofan State, Sudan. Following their felling, tiny square samples of varying sizes (n=10) were gathered and weighed from each vertical position within the bole length (10, 50, and 90%). The results show that the average MC and the green density of the freshly felled wood were 109.97% and 686 kg/m^3 for S. birrea, while the values of A. leiocarpus were 35.55% and 980 kg/m^3, respectively. Furthermore, the findings of the analysis of variance revealed that the MC [%] varied significantly only between the tree species. Conversely, there was no significant difference in MC [%] within the vertical positions of the bole length for either species.

Key words: *moisture content, freshly felled, weight, variation.*

1. Introduction

The moisture content of wood is defined as the weight of water in wood given as a percentage of the oven-dry weight [7, 22]. The water content of wood in living trees (green wood) can range between 30 to 250% [19], depending on wood species. For instance, *Populus balsamifera* (L.) trees have a moisture content of around 140% [9]. The moisture content of wood can appear as either free water (macroscopical capillary water), which is held in macro-pores, or bound water (cell wall water), held in the cell wall bounding with hydroxyl groups [12]. The point at which all macroscopical capillary water has been eliminated from the cell cavity is referred to as the FSP (fibre saturation point) and is attained at approximately 30% [18].

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The actual amount of water varies between tree species and within individual trees depending on location, age, harvesting season, and tree size. The difference in moisture content between sapwood and heartwood is often greater in softwood trees than in hardwood trees because of their low density and many more gaps [10, 15, 17, 20, 26].

The amount of water content in sapwood or heartwood affects many attributes of the wood. Previous research has investigated the influence of different drying temperatures and moisture content on the colour coordinates of *Robinia* and *Populus* wood in Hungary [16]. Also, Mvondo et al. [14] found a negative correlation between the mechanical properties and moisture content of *Milicia excels* ((Welw.) C.C. Berg.)*, Nauclea diderrichii* ((De Wild.) Merr.), and *Erythrophleum suaveolens* ((Gruill. & Perr.) Brenan) wood growing in Southern Cameroon. Moreover, Aquino et al. [2] investigated the effect of moisture content on the physical and mechanical properties of *Cedrella odorata* L. (Cedro amargo) wood growing in Brazil. Furthermore, Dietsch et al. [4] mentioned that the changes in wood moisture content lead to changes in virtually all the physical and mechanical properties of wood, such as strength, stiffness, and density.

Green-wood moisture content is important because it is directly related to the weight of green logs and lumber [23]. The weight of wood is decreased by removing extra water, which decreases shipping and handling expenses [3]. In certain instances, for transportation purposes, it is advantageous to estimate the weight of wood at a specific MC if the wood's dry weight is known [8, 23].

The density of green wood is a significant attribute that impacts many aspects of the wood's properties and its applications, including furniture making and construction, by facilitating the selection of the most suitable wood variety for specific uses [29].

The goals of this study were to ascertain: *i.* the variation in moisture content between trees and within vertical positions of *Sclerocarya birrea* ((A. Rich.) Hochst.) and *Anogeissus leiocarpus* ((DC.) Guill. & Perr.), *ii.* the green wood density of the freshly felled trees.

2. Materials and Methods

2.1. Materials

Three trees (straight and free from natural defects) of each species of *Sclerocarya birrea* ((A. Rich.) Hochst.) and *Anogeissus leiocarpus* ((DC.) Guill & Perr.) were cut from the Lagawa Natural Forest Reserve in the state of Western Kordofan, Sudan. The trees were harvested on January 8, 2018, using a chainsaw [28].

S. birrea is a 15-meter-tall savanna tree [25]. Its bark is grey and fissured, peeling off in little or large scales; its slash is orange-pink with green borders; and its branchlets are thick and scarred. The sapwood has been described as expansive, and it cannot be distinguished from the heartwood with precision. *S. birrea* wood has a medium density of 0.52 g/cm^3 and a considerable extractive content of 13.85% [27, 28]. Its wood is used for flooring, cooking items, fencing posts, and fuel [21, 24].

A. leiocarpus is a medium-to-large tree that can reach a height of 20 m and has a fluted bole [21]. The bark is greyish white becoming dark grey and scaly; the branches are frequently thin and drooping

[5]. The heartwood is dark brown and the sapwood is yellowish. Its wood has a high extractive content of 17.38% and a high density of 0.92 g/cm^3 [27, 28]. *A. leiocarpus* wood is ring-porous and includes crystals and traumatic channels on its surface. It is used for producing firewood and charcoal [20]. In addition to industrial flooring, bridge members, tool handles, axles and shafts, it is used for producing firewood and charcoal.

2.2. Methods

2.2.1. The Moisture Content of Freshly Felled Logs

Tiny samples (n=10) with different sizes were collected as soon as the trees were felled from their vertical positions at 10 (bottom), 50 (middle), and 90 (top) percent of the bole's length. The samples were weighed and recorded before being delivered to the Laboratory of Wood Science, Faculty of Forestry, University of Khartoum. Then the specimens were dried in an oven at 103 ± 2°C. According to ISO 3130 standard [6] the MC [%] of the freshly cut wood was determined by (Equation (1)).

$$MC = \frac{W_m - W_0}{W_0} \cdot 100 \qquad (1)$$

where:

MC is the moisture content [%];
W_m – the initial mass of the sample [g];
W_0 – the oven-dry mass of the sample [g].

2.2.2. The Density of Freshly Cut Logs

The weight of the specimens was measured using a highly precise balance with an accuracy of ±0.01 grams. The green volume of the specimens was estimated using the water displacement method [7]. The green density was determined using Equation (2):

$$GD = \frac{W_g}{V_g} \qquad (2)$$

where:

GD is the density of freshly cut [kg/m^3];
W_g – the initial mass of the sample [kg];
V_g – the green volume [m^3].

2.3. Data Analysis

The analysis of variance (ANOVA) with R programming language (Version 4.1.2 2022) was performed to evaluate the variance in moisture content within the tree vertical positions (bottom, middle, and top) and between the tree species.

3. Results and Discussion

The moisture content [%] of the freshly cut trees of *S. birrea* ranged from 90.14 to 127.61 with a mean of 109.97±9.03, whereas that of *A. leiocarpus* ranged from 19.75 to 56.97 with a mean of 35.55±10.87 (Table 1). Table 2 shows the MC [%] of individual trees of *S. birrea*, while Table 3 displays their MC [%] at vertical positions (bottom, middle, and top). Similar outcomes were found for *A. leiocarpus* (Tables 4 and 5).

Mean MC [%] values of freshly felled S. birrea and A. leiocarpus Table 1

Tree species	Minimum	Lower Quartile (1st Qu.)	Median	Mean	Upper Quartile (3rd Qu.)	Maximum	Standard Deviation	Coeff. of variation [%]
S. birrea	90.14	104.81	108.42	109.97	113.95	127.61	9.03	8.21
A. leiocarpus	19.75	25.76	34.22	35.55	44.09	56.97	10.87	32.08

Mean values of MC [%] of each freshly felled S. birrea tree Table 2

Tree no.	Minimum	Lower Quartile (1st Qu.)	Median	Mean	Upper Quartile (3rd Qu.)	Maximum
1	108.1	111.1	120.6	118.3	123.7	127.6
2	90.14	102.26	104.31	102.44	105.89	107.90
3	103.6	105.9	109.7	109.2	112.6	114.2

Mean values of MC [%] within vertical positions of S. birrea trees Table 3

Simple statistics	Bottom	Middle	Top
Minimum	101.8	90.14	104.8
Lower Quartile (1st Qu.)	109.3	103.67	105.2
Median	113.7	106.28	107.2
Mean	113.8	106.41	109.7
Upper Quartile (3rd Qu.)	117.1	108.94	109.8
Maximum	127.6	123.15	123.8

Mean values of MC (%) of each freshly felled A. leiocarpus tree Table 4

Tree no.	Minimum	Lower Quartile (1st Qu.)	Median	Mean	Upper Quartile (3rd Qu.)	Maximum
1	23.33	26.76	34.22	33.11	36.94	44.76
2	19.75	22.73	26.26	25.36	28.10	29.65
3	40.85	43.60	48.66	48.19	48.19	56.97

Mean values of MC (%) within vertical positions of A. leiocarpus trees Table 5

Simple statistics	Bottom	Middle	Top
Minimum	19.75	23.33	21.88
Lower Quartile (1st Qu.)	25.28	26.04	31.05
Median	32.38	30.77	40.01
Mean	33.39	33.82	39.54
Upper Quartile (3rd Qu.)	40.93	38.93	47.33
Maximum	49.14	51.92	56.97

The analysis of variance (ANOVA) for MC [%] (Table 6) reveals significant variation (F= *8.94; P= 0.001*) between tree species of *S. birrea*. So far, there has been no significant difference among the vertical positions of the bole length (Table 7). Comparable tendencies were observed for *A. leiocarpus* (Tables 8 and 9). This finding is consistent with the findings of Al-Sagheer and Prasad [1], who revealed significant differences in the MC [%] among eight populations of *Dipterocarpus* species. However, the analysis of vertical positions shows different results from previous research. According to Majumdar et al. [11], the moisture content of *Hevea brasiliensis* (A. Juss.) decreases gradually from the top to the bottom. In contrast, Mmolotsi et al. [13] found that the upper part of *Acacia saligna* ((Labill.) H.L. Wendl.) stems had much more water than the middle and base.

Analysis of Variance for MC [%] between S. birrea trees Table 6

Variable	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Between trees	2	2 755.02	377.51	8.9416	0.002 **
Residuals	15	633.29	42.22		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance for MC [%] within vertical positions of S. birrea Table 7

Variable	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Vertical positions	2	164.67	82.337	1.00093	0.38
Residuals	15	1223.64	81.576		

Analysis of Variance for MC [%] between A. leiocarpus trees Table 8

Variable	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Between trees	2	1617.05	808.52	20.72	4.828e-05 ***
Residuals	15	585.31	39.02		

Analysis of Variance for MC [%] within vertical positions of A. leiocarpus Table 9

Variable	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Vertical positions	2	137.32	68.662	0.4987	0.617
Residuals	15	2065.03	137.669		

The average value of the green density per cubic meter (GD) of freshly felled *S. birrea* wood is estimated to be 868 kg/m^3, whereas for *A. leiocarpus* it is 980 kg/m^3 (Table 10).

In contrast to the basic density, the green density exhibits a higher value. This is due to the weight of the wood being reduced during the drying process because of water evaporation; the green volume remains the reference volume in both densities (Figure 1).

Table 10

The mean values of the green density (kg/m^3) of S. birrea and A. leiocarpus wood

Simple statistics	Green density of *S. birrea*	Green density of *A. leiocarpus*
Minimum	610	920
Lower Quartile (1st Qu.)	790	950
Median	905	965
Mean	868	980
Upper Quartile (3rd Qu.)	942	1010
Maximum	1130	1120

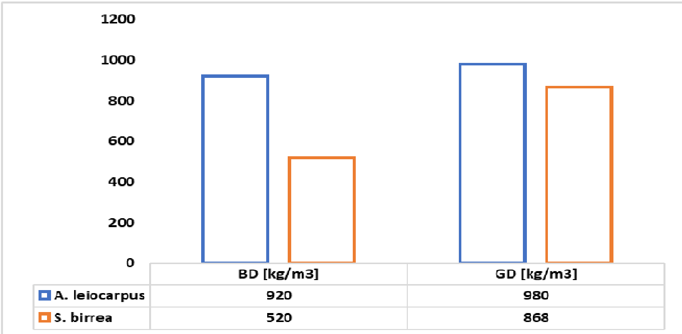

Fig. 1. *The differences between basic density (BD) and green density (GD) of S. birrea and A. leiocarpus*

4. Conclusions

The following conclusions were drawn from the results:

- According to the study findings, *S. birrea* trees had a higher fresh-felled moisture content [%] than *A. leiocarpus* trees;
- Within vertical positions, the bottom had higher MC [%] compared to the middle and top for *S. birrea* trees. However, for *A. leiocarpus* the top had a higher moisture content than the other positions;
- The results indicate that the moisture content varied considerably between tree species. However, within vertical positions there was no significant variation;
- The green density of *S. birrea* and *A. leiocarpus* wood is greater compared to the basic density.

Acknowledgments

The authors are grateful for the support of TKP2021-NKTA-43 "Enhancing the contribution of the forestry and timber sector to climate change mitigation: from carbon sequestration to bioeconomy development. Subproject 2.2: Exploring the technical parameters of wood raw materials, with a special focus on drought-tolerant species (led by Prof. Dr. Róbert Németh).

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