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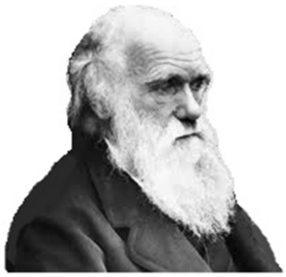

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Anatomical assessment of the fibers in the trunk of *Alstonia boonei* for some derived indexes

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ABSTRACT

Derived anatomical indexes, such as Runkel's ratio, Flexibility coefficient, and Felting power / Slenderness ratio of the fibers in the trunk of *Alstonia boonei* were assessed using standard procedures and formulae. Significant differences (P≤ 0.05) existed in the Runkel's ratio and Flexibility coefficient of the fibers along the axial position of the trunk, whereas along the radial position, the differences were not significant (P≤0.05). Conversely, the Felting power/ Slenderness ratio of the fibers, along the axial and radial positions of the trunk were not significantly different (P≤0.05) from one another. Totals of 0.65 ± 1.33, 68.32 ± 15.39, and 39.89 ± 15.41 were the Runkel's ratios, Flexibility coefficient, and Felting power/Slenderness ratio of the fibers. In view of the results obtained in the present assessment, assertions confirming the suitability of the trunk of *Alstonia boonei* as alternative sources of raw material for pulp and paper production were made.

***Keywords*:** Fibers, mean, axial and radial positions, Runkel's ratio, Flexibility coefficient, Felting power / Slenderness ratio, *Alstonia boonei*

1. INTRODUCTION

Burkhill (1985) described *Alstonia boonei* De Wild, as a tall forest tree, which can reach 45 metres (148 ft) in height and 3 metres (9.8 ft) in girth, the bole being cylindrical and up to 27 metres (89 ft) in height with high, narrow, deep-fluted buttresses. The leaves are borne in whorls at the nodes, the leaf is oblanceolate, the apex rounded to acuminate and the lateral veins prominent and almost at right angles to the midrib.

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The flowers are yellowish-white and borne in lax terminal cymes. The fruits are pendulous, paired, slender follicles up to 16 centimeters long, containing seeds bearing a tuft of silky, brown floss at either end to allow dispersal by the wind. The latex is white and abundant (Otoide, 2016).

According to Gill *et al.* (1983), the need to thoroughly investigate the basic structure of tree plants from the tropics has been stressed by Metcalfe (1972). To the author's knowledge, this demand has not received the much expected attention. In the recent time, many researchers are primarily concerned with the phytochemical and medicinal values of tropical plants with a little interest in the study of the structure of the cells and tissues that serve as the framework for the biochemical and medicinal properties of plants.

Consequently, information on the internal structures of the trunk of tree plants in the tropics is scanty, inaccessible, and old. The recent ones are few and needs to be added upon to meet the increasing demand for the anatomical information by students and researchers in plant anatomy, plant pathology, plant ecology, plant taxonomy, forestry and agronomy. In order to bridge the gap, however, the author and his collaborators in the recent time have studied the tissues and cells in some tropical tree plants and herbacious species, as reported in Otoide *et al.* (2012), Otoide (2013a and b), Otoide (2014a and b), Otoide (2015), and Otoide (2016). Otoide *et al*., (2012) studied the percentage moisture content and vessel elements in stem of *Adansonia digitata* and reported variations in the length and diameter of vessels, as well as in percentage moisture contents along the axial and radial directions of the trunk.

Similarly, Otoide (2013a) reported poor leaf development, ruptured stomatal ledges, plugged stomatal pores, and irregularly fused cell boundaries in the leaves of *Euphorbia heterophylla*, *Chromolaena odorata*, *Commelina diffusa*, and *Kyllinga pumila*, growing naturally within the radii of 0.1 m to 0.25 m from the exhaust-pipe of domestic power generators commonly used in homesteads in Nigeria.

In the same vein, Otoide (2013b) reported the presence of libriform, non-septate and medium sized fibres in the stem of a fully grown species of *Adansonia digitata*. Similarly, Otoide (2014a) studied the fibres in the stem of *Afzelia africana* by measuring their lengths and diameters in micrometer. He reported an extremely short nature of fibres and recommended that the species be exploited for construction works and any other production in which woods with extremely short fibre length would not negatively affect the end product of productions. Otoide (2014b) observed the stomatal types, epidermal cell structures, damaged epidermal cells, and plugged stomatal pores in the polluted leaves of some group of plants, such as *Polyalthia longifolia*, *Digitaria gayana*, and *Trianthema portulacastrum* growing within the radii of 0.1-0.25 m to exhaust-pipes of power generators.

Moreso, Otoide (2015) studied the dimensions of the vessels and rays in the trunk of *Afzelia africana* and reported short and narrow, open-ended vessels containing simple perforation plates. He also recommended multiseriate and heterogeneous nature of rays in the species. In the same vein, Otoide (2016) studied the axial and radial variations in wood density and moisture of the trunk of *Afzelia africana* and reported that the wood density and moisture of the species increased with the height of the trunk and varied both in axial and radial directions of the trunk.

The present assessment seeks to provide additional information about the fibers in the stem of *Altonia boonei*, particularly its application in pulp and paper productions (Ojewole, 1980, 1981, 1984; Bowman, 1964; Foster, 1960; Kerbs 1932).

2. MATERIALS AND METHODS

2. 1. Collection of Materials

A fully grown tree of *Alstonia boonei* which could be of about 40 years old was felled at the diameter at chest height (1.3 meters above ground level), from Igbo-oluwa quarters in Iworoko village, Ekiti State, Nigeria. The log was thereafter taken to the Department of Wood Technology and Utilization (WT&U) of the Forest Research Institute of Nigeria (FRIN), Ibadan, Nigeria, for identification and microscopic preparations for anatomical study.

2. 2. Experimental Procedures and Maceration of Wood Samples

The procedures used in this assessment strictly followed Otoide (2016). The bole length of the felled tree was measured with the aid of a measuring tape from the level of chest height, to the crown and the value was 1.10 meters. Thereafter, a transverse disc of 20 cm thick axially was cut from the base, middle and the top of the log. A total of three transverse discs was cut out of the entire log. Each of the discs was divided longitudinally into two semi-circular hemispheres with the line of division passing through the pith. One of the two semi-circular hemispheres was tagged as the Northern hemisphere and the other one, the Southern hemisphere. Only the Northern semi-circular hemispheres were used for the whole of the experiments while the Southern semi-circular hemispheres were discarded. The base, middle and the top semi-circular hemispheres were further divided into three regions, with the lines of division parallel to the equator, which passes through the centre of the pith. These three regions were labelled as:

- **Core** (C)
- **Middle** (M), and
- **Outer** (O).

Five blocks of the dimension, 2 cm × 2 cm × 2 cm and another five blocks of the dimension, 2 cm × 2 cm × 6 cm cut out of the core, middle and outer blocks earlier extracted from the three semi-circular hemispheres, each of which was cut out from the base, middle and the top of the log. On the base disc, five replicate extracts, each from the core, middle and the outer regions of the semi-circular hemisphere were cut out, making a total of 15 blocks of the dimension, 2 cm × 2 cm × 2 cm and also a total of 15 blocks of the dimension, 2 cm × 2 cm × 6 cm. A total of 30 blocks were extracted separately from the Base, Middle and the Top of the log. Ground total of 90 blocks of wood pellets was extracted from the whole of the tree trunk/log. All the 90 blocks of wood pellets were used for the whole of the experiments involved in the study.

2. 3. Maceration of Wood Samples

In order to determine the length and width of vessels and rays in the trunk of this species, the method outlined by Otoide (2016) was followed.

Thin slivers of wood materials were removed from the whole of the 2 cm × 2 cm × 2 cm blocks and placed in separate test tubes containing a mixture of equal amount of hydrogen peroxide and acetic acid (*i.e.* in ratio 1:1) individually, such that no slivers of different blocks were placed together in a test tube. The test tubes were then placed inside an electric oven for 4 hours at 80 °C. The test tubes were then removed from the oven and shaken properly so as to defibrize the slivers. The test tube samples were then dropped on clean cover slides with the aid of a pipette and the slides were viewed under a calibrated microscope. Length and width measurements of vessel members and rays were averages of 50 measurements.

2. 4. Experimental Design

The Experimental Design adopted for this work is a two Factorial in a Complete Randomized Design (C.R.D.) with different replications of the test Samples.

Factor A: The longitudinal direction (Base, Middle and Top) of the trunk.

Factor B: The radial directions, where the sample sticks were collected (The Core, Middle and Outer) region of the trunk.

2. 5. Statistical Analysis

Analysis of Variance (ANOVA) was conducted to test the relative importance of various sources of variation on the length (µm) and width (µm) of the vessels and rays. The main effects considered were differences along the longitudinal (*i.e.* Axial) and Radial Positions. The Follow up test was conducted, using Duncan Multiple Range Test (D.M.R.T). This was done to know the significant difference between the two Means at $P \leq 0.05$.

The mathematical Model for the two Factors factorial experiment is given as:

$$Yij = u + Ai + Bj + (AB)ij + Eij$$

where:

μ = General mean of individual observation
Ai = Effect of Factor A
Bj = Effect of Factor B
(AB)ij = Effect of interaction between Factors A and B
Eij = Effect of interaction Error term.

2. 6. Determination of the derived indexes

From the data, the average fiber dimensions were calculated and then the following derived indexes were determined:

$$\text{Runkel ratio} = \frac{2 \times \text{Wall thickness}}{\text{Lumen Width}}$$

$$\text{Flexibility coefficient} = \frac{\text{Lumen Width of Fiber}}{\text{Diameter of Fiber}} \times 100$$

$$\text{Slenderness ratio} = \frac{\text{Length of Fiber}}{\text{Diameter of Fiber}}$$

3. RESULTS AND DISCUSSION

The results obtained in the present assessment have been summarized in **Tables 1-3**. The total Runkel's ratio, Flexibility coefficient, and Felting power/Slenderness ratio of the Fibers in the woody trunk of *Alstonia boonei* De Wild were 0.65, 68.32, and 39.89 respectively (Table 1, 2 and 3). The Runkel's ratios of the fiber in the base, middle and top axial positions of the trunk were 0.35 ± 0.20, 0.52 ± 0.32, and 1.09 ± 2.22, respectively, while in the core, middle and outer woods of the trunk, the Runkel's ratios were 0.51± 0.28, 0.49 ± 0.32, and 0.96 ± 2.25, respectively (Table 1).

The flexibility coefficients, on the other hand, were 75.48 ± 9.57, 68.37 ± 12.66, and 61.10 ± 19.02 at the base middle and top axial positions of the trunk, respectively, while at the core, middle and outer woods, the flexibility coefficients were 68.32 ± 11.12, 69.71 ± 13.29, and 66.91± 20.36, respectively (Table 2).

The felting power/slenderness ratios of the fibers at the base, middle, and top axial positions of the trunk were 40.16 ± 15.81, 38.05 ± 13.78, and 41.47 ± 16.56, respectively, while at the core, middle and outer woods they were 38.72 ± 18.09, 39.76 ± 14.06, and 41.20 ± 13.87, respectively (Table 3).

Table 1. Runkel's ratio of fibers in the trunk of *Alstonia boonei*.

AXIAL AXES	RADIAL AXES			
	Core Wood	**Middle Wood**	**Outer Wood**	**Axial Means**
BASE	0. 46 ± 0.24	0.27 ± 0.14	0.32 ± 0.16	0.35 ± 0.20[a]
MIDDLE	0.49 ± 0.24	0.55 ± 0.35	0.52 ± 0.37	0.52 ± 0.32[b]
TOP	0.58 ± 0.34	0.66 ± 0.30	2.02 ± 3.70	1.09 ± 2.22[c]
Radial Means	0.51 ± 0.28[a]	0.49± 0.32[a]	0.96 ± 2.25[a]	0.65 ± 1.33

Means with same letters on the rows are not significantly different from one another at P ≤ 0.05 but means with different letters on the column are significantly different.

Table 2. Flexibility coefficient (%) of fibers in the trunk of *Alstonia boonei*.

AXIAL AXES	RADIAL AXES			
	Core wood	**Middle wood**	**Outer wood**	**Axial means**
BASE	70.29 ± 10.26	79.54 ± 7.63	76.61 ± 8.61	75.48 ± 9.57[a]
MIDDLE	68.95 ± 10.63	67.40 ± 13.71	68.76 ± 13.98	68.37 ± 12.66[b]
TOP	65.71 ± 12.41	62.21 ± 11.65	55.37 ± 27.85	61.10 ± 19.02[c]
Radial means	68.32 ± 11.12[a]	69.71 ± 13.29[a]	66.91 ± 20.36[a]	68.32 ± 15.39

Means with the same letters on the rows are not significantly different at P ≤ 0.05 but means with different letters on the column are significantly different.

Table 3. Felting power of fibers in the trunk of *Alstonia boonei*.

AXIAL AXES	RADIAL AXES			
	Core wood	**Middle wood**	**Outer wood**	**Axial means**
BASE	43.79 ± 20.09	35.25 ± 7.21	41.43 ± 16.73	23.47 ± 15.81[a]
MIDDLE	33.20 ± 9.05	37.60 ± 14.76	43.35 ± 15.35	38.05 ± 13.78[a]
TOP	39.16 ± 21.71	46.41 ± 16.47	38.82 ± 8.41	41.47 ± 16.56[a]
Radial means	38.72 ± 18.09[b]	39.76 ± 14.06[b]	41.20 ± 13.87[b]	39.89 ± 15.41

Means with the same letters on rows are not significantly different from one another at P ≤ 0.05

Significant variations (P ≤ 0.05) existed between the Runkel's ratio of the fibers at the base, middle and top axial positions of the trunk. This scenario might be as a result of the differences in the locations of the fibers in the trunk. Conversely, the Runkel's ratios of the fibers in the core, middle and outer woods of the trunk were not significantly different from one another at P ≤ 0.05. This might be due to uniform pattern of growth of the fibers in the trunk (Table 1).

The flexibility coefficient of the fibers at the base, middle and top axial regions of the trunk were significantly different (P ≤ 0.05) from one another. This could be attributed to the different periods of growth and development of the fibers in the different axial regions. Thus, the flexibility coefficients in the core, middle and outer woods were not significantly different from one another (P ≤ 0.05).

In another vein, there were no significant differences (P≤0.05) in the felting power/slenderness ratio of the fibers at the base, middle and top axial positions of the trunk as well as in the radial positions (core, middle and outer woods) (Table 3).

Runkel's ratio, flexibility coefficient and felting power are the major determining indexes for selecting suitable woods for pulp and paper making. In the present assessment, Runkel's ratio of 0.65 was derived for the fibers in the woody trunk of *Alstonia boonei*. Consequently, the woody trunk of this species is a suitable alternative source of raw materials for pulp and paper making for having Runkel ratio of less than 1.

This assertion is corroborated by the previous assertions of Sharma *et al.* (2013), Otoide (2015), and San *et al.* (2016). Furthermore, results obtained in the present assessment provide that the flexibility coefficient of the fibers was 68.32%. This percentage, according to San *et al.* (2016), falls into the class of elastic fibers.

This is another property which makes the stem of *Alstonia boonei* suitable for pulp and paper making. In the same vein, the slenderness ratio/felting power derived for the fibers was 39.89.

This value is more than the generally acceptable one (>33). According to San *et al.* (2016), a high value of slenderness ratio provides a better forming and well-bonded paper. Consequently, it is believed that the trunk of *Alstonia boonei* would be able to meet this standard if used as raw material.

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