

Comparative Anatomical Studies on the Wood and Bast Fibres of *Gmelina arborea*

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Authors' contributions

This work was carried out in collaboration between both authors. Author GCA designed the study, wrote the protocol and edited the first draft of the manuscript. Author EOO performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

Article Information

Editor(s):

(1) Dr. Chong Leong, Gan, Malaysia.

Reviewers:

(1) Bruno Charles Dias Soares, Federal University of Lavras, Brazil.

(2) Abdelwahed Fidah, Forest Research Center, Morocco.

(3) Carlos Eduardo Silveira da Silva, Federal Rural University, Brazil.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/57820>

Original Research Article

Received 14 April 2020

Accepted 20 June 2020

Published 03 July 2020

ABSTRACT

Aim: Fibre serves primarily as support to the plant and its characteristics are essential for growth, being also a considerable factor for pulp and paper production. Debarking of tree logs is one of the steps in converting wood into chips suitable for pulping. However, the bark of logs also so contains certain amount of fibre known as the bast fibre. This study aimed to evaluate the applicability of bast fibre in pulp and paper making in comparison with the wood fibre.

Methods: The bark and wood of *Gmelina arborea* were collected from the same branch of different trees in the Botanical Garden of the Department of Plant Science and Biotechnology, University of Nigeria Nsukka, Nigeria. The samples were macerated and the vessel member was measured analyzing the fibre length, cell wall thickness, lumen diameter, and diameter.

Results: The wood fibre had significant higher length and lumen diameter while the bast fibre had thicker cell wall. Similarly wood fibre presented significantly higher coefficient of flexibility and slenderness ratio with an average of 0.718 ± 0.016 and 26.262 ± 1.518 while the Runkel ratio was higher in the bast fibre.

Conclusion: Wood fibres of this plant were more suitable for papermaking than bast fibres that lack the anatomical features required for this purpose.

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Keywords: *Gmelina arborea*; wood fibre; wood anatomy; pulp and paper making.

1. INTRODUCTION

The term 'fibre' in anatomical sense refers to the sclerenchymatous fibres, compounds that are related as support to the plant. In industrial sense, it includes sclerenchymatous fibres, trachieds and vessels. The quantity and properties of fibre, affects the suitability of tree species and their genetic entries as a raw material for mechanical wood processing and pulp and paper production [1,2]. The pulp and paper quality tends to relate closely to fibre dimensions with particular reference to trachieds and libriform fibres [3].

Fibre characteristics are essential when taking into consideration the deployment of any plant for pulp and paper making. Fibres are the major variable used in determining the level of efficiency of wood species in pulping [2,4]. The strength properties of paper are a function of the fibre characteristics used. The characteristics of fibre in wood have been shown to differ widely and consequently exert diverse influence on fibre strength, bulk density and inter-fibre bonding [5]. Woods with long fibres are frequently desirable in the paper industry, because the longer the fibre, the higher the tear resistance of the paper produced from them [6-8]. Thick wall fibres affect the tensile strength, folding endurance and bursting strength of paper. Wood species with high Runkel ratio (measures the amount of wood in respect to the cavity or lumen of the fibre) usually have stiff fibres that are less flexible and poor bonding ability. Fibre with higher Runkel ratios produces bulkier paper as compared to fibres with lower Runkel ratios. Therefore, any wood species that is of good quality for pulp and paper production must have a Runkel ratio ≤ 1 [9]. Fibre variables such as length, diameter, lumen width, cell wall thickness and their derived values (slenderness ratio, flexibility coefficient, and Runkel ratio) exhibits a significant relationship with the strength of pulp and paper [10].

Gmelina arborea is a deciduous tree locally known as Melina. *G. arborea* belongs to the family verbenaceae. The tree is approximate 40m tall and 140 cm in diameter, the tree form is fair to good, with 6–9 m of branchless stem, often crooked trunk and a large, low-branched crown. The colour of bark is gray and bark is thin. *G. arborea* wood at 12% moisture content has a 55–102 N/mm² modulus of rupture,

modulus of elasticity 5500–10,800N/mm², compression parallel to grain 20–39 N/mm², shear 5–11 N/mm², cleavage 12–15 N/mm and Janka side hardness 2335–3380N. The wood is suitable for general utility purposes, especially light construction and structural work, general carpentry, packaging, carvings, utility furniture and decorative veneers, with excellent woodworking properties. It produces good-quality pulp; unmixed semi-chemical pulp is only suitable for carton board or low-grade writing paper, kraft pulp is suitable for higher grades of writing paper [11–14].

Several kinds of research had been carried out on *G. arborea* and have been found suitable for making low grades paper which has found tremendous usage in the newspaper and packaging industries. For this reason, the government of Nigeria in the 1960s established a pulping mill at Oku-Iboku in Akwa-Ibom State which processes *G. arborea* pulp for local consumption [7]. When wood arrives at a pulp mill wood storage in the form of raw logs or as chips from harvesting process, the wood is converted into chips suitable for pulping in a series of steps which most of the times includes debarking. However, the bark of logs also so contains certain amount of fibre known as the bast fibre. This study therefore, seeks to evaluate the suitability of bast fibre in pulp and paper making in comparison with the wood fibre.

2. MATERIALS AND METHODS

2.1 Sample Collection

The samples (bark and wood) of *Gmelina arborea* were collected from the same points in three trees from the Botanical Garden of the Department of Plant Science and Biotechnology, University of Nigeria Nsukka, Nigeria. The samples were reliably identified in the herbarium of the same Department.

2.2 Maceration Techniques for the Determination of Fibre Dimensions

Small blocks approximately the size of a match-stick of the bark and heartwood of *Gmelina arborea* were made and oven-dried at 40°C for 24hrs to remove moisture in readiness for the maceration process. The maceration was carried out according to the method of Schultz's as adopted by Ajuziogu et al. [7]. According to this

method, the small blocks of the wood and bark chips of *Gmelina arborea* were placed differently in long labelled test-tubes and 2 g of 2% potassium chlorate (KClO₃) crystals were added to each of the test tubes. 10ml of conc. Further, 10 ml of concentrated nitric acid (HNO₃) was carefully introduced into the test-tubes. The set-up was allowed to react in a fume cupboard while standing on a test-tube rack until the chips are softened and bleached. In tubes when the reactions were slow, the racks were put in an oven and heated to 60°C until the maceration of the chips occurred. Distilled water was poured in each of the tubes, covered and shaken and allowed to stand in a rack till the pulp settles. Excess solutions were decanted from the test-tubes and the softened bleached chips were washed several times with distilled water until they became clear. The resultant samples were then separately transferred into well-labelled specimen bottles. A drop of formalin was added to each bottle to prevent fungal attacks, while a drop of glycerine was added to removes air bubbles from the mass, and the samples were stained with safranin [7].

2.3 Determination of Fibre Dimensions

The stained fibres were mounted differently on a slide in 30% glycerine, carefully covered with a cover slide, and then examined and measured under a calibrated light microscope. The fibre dimensions were measured using KARL KAPS asslar/Wetzlar Nr39805 microscope, to which an ocular micrometer was fitted in the ocular tube. The ocular micrometer was first calibrated using a stage micrometer placed on the stage of the microscope by aligning its zero mark with that of the ocular. The number of units of the ocular which aligns with a given unit of the stage micrometer, in a given magnification was noted. Hence, magnification value was used as the

conversion factor in the subsequent measurements. The conversion factors were worked out as follows:

- At ×40 magnification (20units of ocular = 0.55 mm; 1 unit of ocular = 0.55 mm/20 = 0.0275 mm)
 - The conversion factor at ×40 = 0.0275mm
- At ×100 magnification (40 units of ocular = 0.54 mm; 1 unit of ocular = 0.54/40 = 0.0135 mm)
 - The conversion factor at ×100 = 0.0135 mm
- At ×400 magnification (71units of ocular = 0.25 mm; 1unit of the ocular = 0.25 mm/71 = 0.004 mm)
 - The conversion factor at ×400 = 0.004 mm

The measured fibre dimensions include: length (L), cell wall thickness (C), lumen diameter (l), and diameter (D). Fifteen fibres each from three trees samples were measured for each of the specimens. Runkel ratio, Coefficient of flexibility and Slenderness ratio were derived using the formula:

$$\begin{aligned} \text{Runkel ratio (RR)} &= 2C/l \\ \text{Coefficient of flexibility (CF)} &= l/D \\ \text{Slenderness ratio (SR)} &= L/D \end{aligned}$$

Data collected were subjected to a paired sample T- test using Statistical package for social sciences (SPSS; IBM ver 20).

3. RESULTS AND DISCUSSION

The microscope images of the wood and bast fibres are shown in the plates below (Plates 1a and b), exhibiting that wood fibres were longer in length compared to bast fibers.



Plate 1a. Photomicrograph of wood fibre (×100)

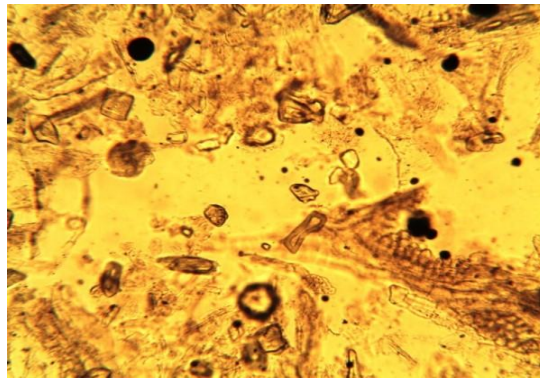


Plate 1b. Photomicrograph of bast fibre (x100)

As presented on Fig. 1, the wood fibre length (0.798 ± 0.039 mm) was significantly longer as compared to the bast fibre which had a length of 0.148 ± 0.009 mm. However, both fibres are classified as short fibre because they are below 1.6 mm [7]. However, the bast fibre presents a disadvantage in paper making since the longer the fibre would have higher tear resistance of the paper produced from them [9]. The wood fibre lengths obtained were comparable with the wood fibre length range of *G. aborea* reported by Ajuziogu et al. [7], Roque et al. [15] and Moya Roque et al. [16]. Alternatively, the mean wood fibre diameter (0.031 ± 0.001 mm) did not significantly differ ($P > 0.05$) from that of the bast (0.035 ± 0.002 mm) (Fig. 1).

From Fig. 2, the wood fibres were significantly wider in the lumen (0.022 ± 0.001 mm) while the bast fibre had significantly thicker cells

(0.011 ± 0.001 mm). The wider lumen diameter observed in wood fibre would ensure better collapsibility and the inter-fibre bonding qualities of fibres in papermaking than the bast fibre [7,8].

The result of the fibre derived characters shows that the bast fibre had significantly higher Runkel ratio (2.96 ± 0.35). Values of lower Runkel ratio (< 1) is preferred for papermaking because papers made from fibre with high Runkel ratios are porous and stiff. In this regards, bast fibre will be of disadvantage if utilized in paper making [1, 7,17-19]. The Runkel ratio recorded from the wood fibre were also much lower than that of *E. pellita* wood a popular fast growing plant for pulp and paper making reported by Lukmandaru et al. [20]. Similarly the Runkel ration of *G. aborea* wood was lower than the Runkel ratio of all the species reported by Sadiku and Abdulkareem

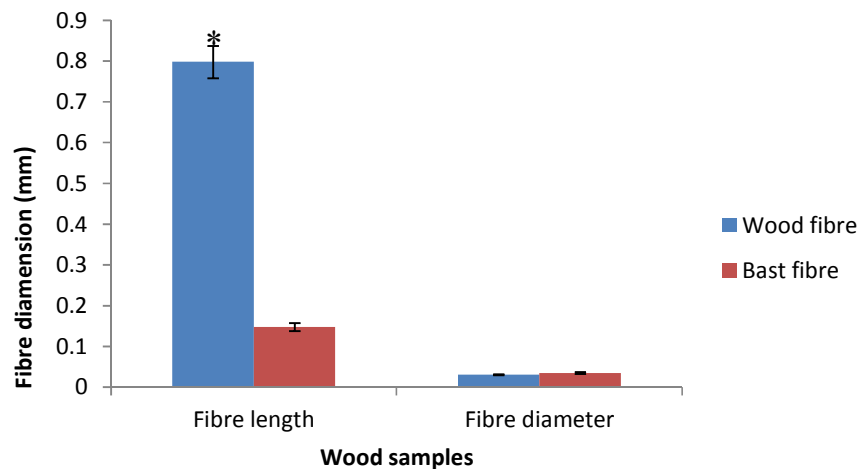


Fig. 1. Mean values of length and diameter of wood and bast fibres of *Gmelina aborea* (Significant higher mean bars at $P \leq 0.05$ are represented with an asterisk)

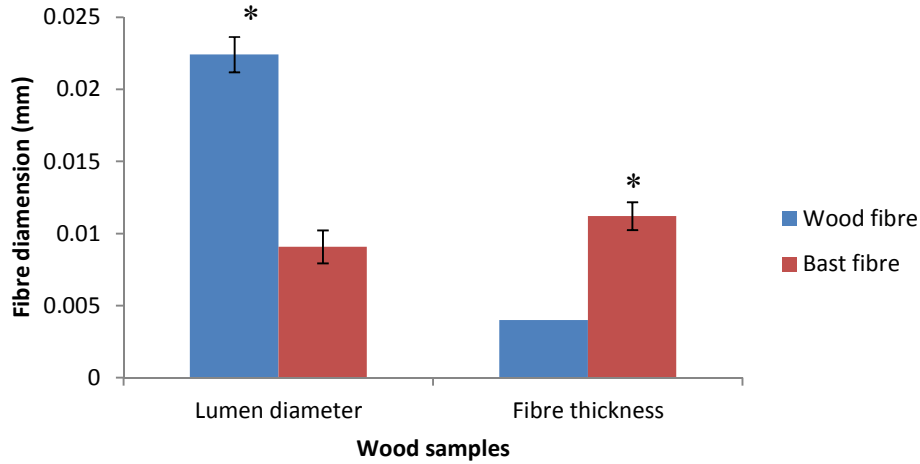


Fig. 2. Mean values of lumen diameter and cell wall thickness of wood and bast fibres of *Gmelina arborea*
(Significant higher mean bars at $P \leq 0.05$ are represented with an asterisk)

[21] from Nigerian guinea savannah timber species.

The wood fibre recorded significantly higher coefficient of flexibility and slenderness ratio with an average of 0.718 ± 0.016 and 26.262 ± 1.518 respectively (Figs. 3 and 4). The standard values for hardwood and softwoods coefficient of flexibility are 0.55-0.70 and 0.75 respectively, whereby fibres having coefficient of flexibility ranging from 0.50-0.75 are considered as highly elastic fibres [18,20]. The coefficient of flexibility of *G. arborea* wood is comparable to the

Isobertina doka, *Khaya ivorensis*, *Albizia zygia*, *Vernonia colorata*, *Irvingia gabonensis*, *Vitellaria paradoxa*, *Azalia africana* and *Lannea welwitschii* collected from the guinea savannah region of Nigeria [21]. This indicates the suitability of the wood fibre of *G. arborea* for paper-making while the bast fibre did not fall within this range. Similarly if the postulate by Ademiluyi and Okeke [22] that the higher the slenderness ratio, the greater the tear resistance of the paper, then it is reasonable to say that from our data bast fibre will not show the good tear resistance as compared to the wood fibre.

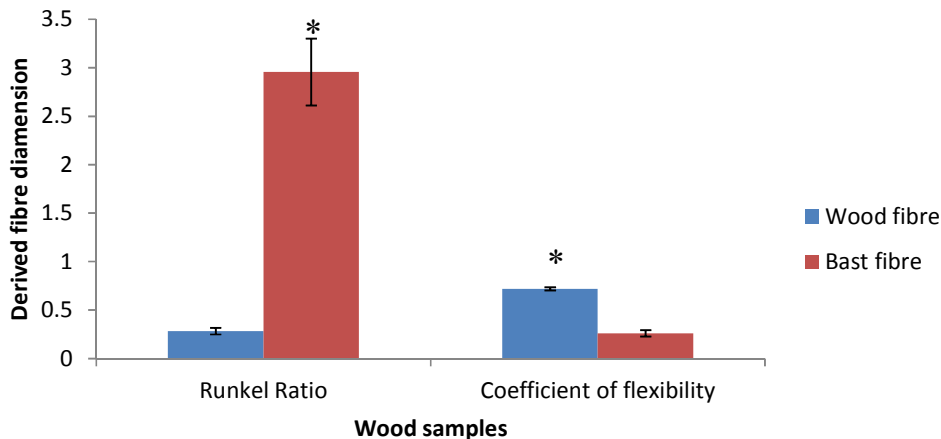


Fig. 3. Mean values of Runkel Ratio and coefficient of flexibility of the wood and bast fibres of *Gmelina arborea*
(Significant higher mean bars at $P \leq 0.05$ are represented with an asterisk)

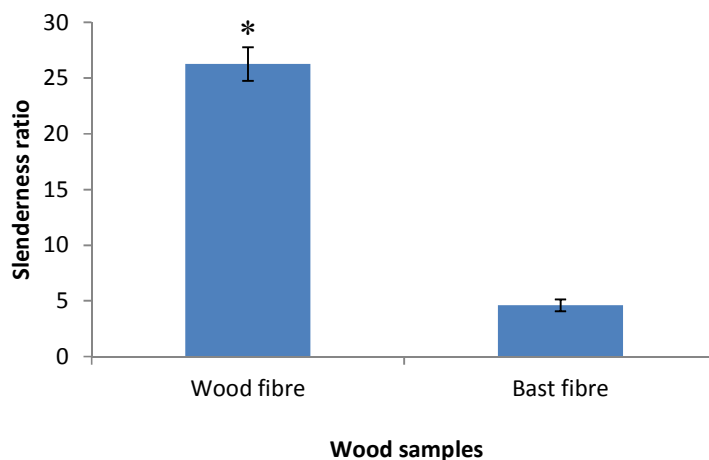


Fig. 4. Mean values of slenderness ratio of the wood and bast fibres of *Gmelina arborea*
(Significant higher mean bars at $P \leq 0.05$ are represented with an asterisk)

4. CONCLUSION

This study investigated the fibre morphology of *G. arborea* wood and bark, it could be concluded that the wood fibre are better than the bark. The wood fiber obtained is considered suitable for pulp and paper making based on its fibre length and low Runkel ratio. Although logs of wood are been debarked before pulping because they contains fibre which contains high content of extractives, dark in colour, and often carries large quantities of grit, this study also shows that the bast fibre lacks the anatomical qualities required for pulp and paper making. Therefore results of this present investigation have further portrayed the suitability of wood fibres for papermaking as compared to bast fibre.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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