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FIBER CHARACTERISTICS AND CHEMICAL COMPOSITION OF *Delonix regia* (Boj. ex Hook.) Raf. WOOD

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ABSTRACT

Delonix regia, a deciduous wood species with beautifully coloured flowers was analyzed for its fibre characteristics and chemical composition to assess its potential for pulp and paper making. Three twenty-year-old trees of D. regia were felled at a farm in the Ijokodo area, Ibadan. Afterward, 27 wood samples (2 x 2 x 2 mm^3) were collected axially (top, middle, and base) and radially (core, middle and outer). Slivers obtained from the samples were macerated in 1:1 volume of glacial acetic acid and hydrogen peroxide and placed in an oven for 2 hrs at 100 ^{o}C. Thereafter, a total of twenty whole fibres were selected per samples for the fibre measurement. For the determination of chemical composition, samples were crushed and test carried out according to standard method. The experiment was a 3×3 factorial experiment set up in a completely randomized block design (CRD), and data collected were subjected to statistical analysis. The fibre characteristics measured were fibre length (FL), fibre diameter (FD), and lumen width (LW), while Cell wall thickness (CWT) was determined with relevant equation. The chemical composition parameters determined are Lignin, Cellulose, and Hemicellulose. The mean results obtained in this study were fibre length (1.30 mm), fibre diameter (37.57 µm), lumen width (26.86 µm), and Cell wall thickness (6.62 µm). The chemical compositions of the species were: lignin (18.34) and holocellulose (73%).

Keywords; Fibre Characteristics, *Delonix regia*, Cellulose, lignin

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INTRODUCTION

Wood is a porous organic material comprising cellulose fibers held together by a matrix of Lignin which helps the fibres resist compression. It also helps to distribute nutrients and water between the leaves, other developing tissues, and the roots of a living tree (Hickey and King, 2001). The cellulose fibres is considered one of the most important raw material for pulp and paper production, thus play a vital role.

Consequently, information about a plant's fibre characteristics is germane before considering the utilization of such plant for pulp and paper production. Ogunwusi. (2010) noted that fibres are the most important parameter that determines how pulp ability of a wood species. Generally, wood with long fibres (≥ 1.6 mm) is considered most desirable in the paper industry. This is because the strength property of a paper depends largely on fibre characteristics.

On the other hand, the chemical composition of wood gives information on the potential suitability of the plant as a raw material for papermaking, pulping methods, and the paper strength of the wood material (Abdul-Khalil *et al.,* 2010). Typically, lignocellulose materials from wood and non-wood plant consist of cellulose, lignin, hemicelluloses, extractive, and some inorganic matter.

Lignin is an amorphous, very complex, predominantly aromatic polymer of phenylpropane units regarded as encrusting material. Only pulping and bleaching lignin is more or less released in degraded and altered forms (Kock, 2006). The lignin content of hardwoods is generally in the field of 18–25 percent, whereas the lignin content of softwoods fluctuates between 25 and 35 percent.

Hemicelluloses can be classified as the combination of polysaccharides that is synthesized in the wood. It contains a small amount of glucose, galactose, mannose, xylose, galacturonic acid, 4-O methylglucuronic acid, and arabinose residues only. They are closely related to cellulose, and also contribute to the structure of the plant.

Meanwhile, a high quality of cellulose is essential for a high-quality paper as it is the major constituent. The choice of the raw material and pulping methods can also influence paper quality. Furthermore, a good choice of raw material for paper making can be determined through the surface area of the pulp. Surface area per unit of dry mass has been found to be different in pulp of fibres from wood species. Stone and Scallan (1968) revealed that the specific surface area of never-dried pulp fibers can be beyond 100 square meters per gram

Delonix regia also called royal Poinciana, flamboyant tree, flame tree, peacock flower is after the greek "DELOS" meaning visible, and "ONYX", meaning claw, and the Latin "REGIA", meaning royal, magnificent. (Rojas-Sandoval *et al.*, 2013). It is of the family of Fabaceae/Leguminosae, indigenous to Madagascar. It is the world's most colourful tree and can rise to 9.1-12.2 meters tall, although its magnificent wide-spreading umbrella-like canopy can be more comprehensive than its height (Nawrocki, 2004). *Delonix regia* is a lesser-used wood species.

There has been an increasing demand and competitive interest of wood species (e.g. *Gmelina* and *Pinus caribaea*) commonly used for pulp and paper production for other purposes, thus threatening their availability for paper making. Consequently, Ajala and Noah (2019); Olaoye and Oluwadre, (2019), and Olaoye *et al.*, (2019) investigated the fibre characteristics of indigenous lesser-used wood species such as *Aningeria robusta*, *Boscia anguistifolia* for their potential suitability for paper production. Also, there have been many research studies on the leaves and bark of *Delonix regia*, with little or no information available regarding the potential utilization of the wood. There is a need, therefore, to carry out a study on the fibre characteristics and chemical constituents of *D. regia* wood to enable us to determine its suitability for pulp and paper production.

MATERIALS AND METHODS

Three, twenty-year-old trees of *D.regia* were felled at a farm in the Ijokodo area, Ibadan from which 27 wood samples (2 x 2 x 2 mm^3) were collected radially (core, middle and outer), and axially (top, middle and base) and taken to the wood anatomy laboratory of the Department of Forest Product Development and Utilization (FPD&U), Forestry Research Institute of Nigeria (FRIN), Ibadan where fibre measurements were taken in accordance with ASTM D 1030-95 (2007) and ASTM D 1413-61 (2007). The slivers were macerated using acetic acid and hydrogen peroxide and placed in an oven for 2hrs at 100 ^oC, and a vigorous agitation was made to allow for the individual separation of the fibers. A random selection of the macerated fiber was made and placed on a standard slide 7.5cm x 2.5cm using a procedure used by Dutt *et al.,* (2012)

The fibre length (FL) was measured by aligning the pulp fibers sideways to the graduated ruler in the microscope, while the Fibre Diameter (FD) was measured by placing the graduated ruler of the microscope in a horizontal direction in the middle of the fibre. The Lumen width (LW) was obtained by observing the cell cavity from the first wall side to the second wall side. All these were observed under the stage micrometer mounted on a Zeiss light microscope with an average of about 20 fibres from each sample and the cell wall thickness (CWT) was calculated using equation 1

$$CWT = \frac{FD - LW}{2} \dots \dots \ 1$$

The Lignin content was determined utilizing ASTM Standard Test Method for Acid-Insoluble Lignin in Wood (ASTM D 1106- 96). While the isolation of Hemicellulose was done by using a test specimen of 2.0 grams of extractive-free 60-80 mesh wood meal prepared according to the Tentative Method for Extractive-Free Wood Meal Preparation (ASTM D 1105).

The cellulose content was determined by the use of an Atomic Adsorption Spectrometer. About 5 g test specimen of sawdust and Lignin was saturated separately with a solution of 50% hydrogen peroxide and added one piece at a time to about 10 mls of concentrated sulfuric acid. The cellulose present was oxidized to carbon dioxide and water, and the heat of the reactions involved volatilizing the water. The solutions were heated separately until dense fumes of the acid evolved. The remaining solution was allowed to cool and transferred into a 50 ml volumetric flask and was made to mark with distilled water.

Statistical Analysis

The experiment was a 3×3 factorial experiment laid in a completely randomized blocked design. Data obtained were subjected to descriptive statistics and analysis of variance (ANOVA) at a 5% probability level.

RESULTS

The findings of this study were presented in Tables. As shown in Table 1, the pooled mean for Fibre Length of *D. regia* was 1.3 (0.11) mm, while Fibre diameter had 37.57(2.59) µm, Lumen width - 26.89 (2.86) µm, and a Cell Wall Thickness 6.62 (1.33) µm. Table 2 shows the P-values of fibre characteristics measured. On the other hand, the cellulosic content was highest ranging from 43.83% to 46.92% while lignin with the lowest chemical constituent ranging from 17.74 to 18.89% (Table 3). There were records of significant differences along and across sampling positions for some of the variables measured. Meanwhile, Plate 1 shows the sample of fibre of *D. regia* wood.

Table 1: Mean Fibre characteristics along the Axial and Radial Position of the sampled trees

	Radial Position	Axial Position			
		Top	**Middle**	**Base**	**Mean**
Fibre Length (mm)	Corewood	1.25	1.22	1.32	1.26 ± 0.05^a
	Middlewood	1.17	1.46	1.31	1.31 ± 0.14^b
	Outerwood	1.34	1.21	1.45	1.33 ± 0.11^b
	Mean	1.25 ± 0.07^a	1.29 ± 0.14^b	1.36 ± 0.08^c	1.30 ± 0.11
Fibre Diameter (µm)	Corewood	40.27	36.78	36.61	37.89 ± 1.99^b
	Middlewood	37.55	41.21	40.66	39.81 ± 1.83^c
	Outerwood	34.56	33.94	36.61	35.04 ± 1.28^a
	Mean	37.46 ± 2.57^a	37.31 ± 3.23^a	37.96 ± 2.15^a	37.57 ± 2.59
Lumen Width (µm)	Corewood	28.46	28.61	28.61	$28.21(0.92)^c$
	Middlewood	26.90	23.11	25.31	$25.10(1.71)^a$
	Outerwood	21.86	30.19	30.02	$27.36(4.14)^b$
	Mean	25.74 ± 3.99^a	27.30 ± 3.31^b	27.63 ± 2.12^b	26.89 ± 2.86
Cell Wall Thickness (µm)	Corewood	6.00	5.70	5.49	5.73 ± 0.32^a
	Middlewood	6.34	8.42	5.81	6.86 ± 1.20^b
	Outerwood	5.97	9.46	6.37	7.27 ± 1.67^b
	Mean	6.11 ± 0.25^b	7.86 ± 1.69^c	5.89 ± 0.45^a	6.62 ± 1.33

Mean ± Standard Error   Numbers in the same column/row carrying different alphabets are significantly different (P<0.05)

Table 2: P-values of Fibre Characteristics of *D.regia* Wood Tested at Axial and Radial Positions

Source of variation	Fibre Length (mm)	Fibre Diameter (µm)	Lumen Width (µm)	Cell Wall Thickness (µm)
Axial Position	0.01*	0.22ns	0.01*	0.01*
Radial Position	0.05*	0.01*	0.01*	0.01*
Axial Position * Radial Position	0.01*	0.01*	0.01*	0.01*

Table 3: Chemical Composition of *D.regia* wood

Chemical Composition	Radial Position	Axial Position		
		Top	Middle	Base
Cellulose (%)	Core	43.83	48.59	46.98
	Middle	43.66	48.54	46.92
	Outer	43.94	48.29	46.92
Hemicellulose (%)	Core	28.73	25.52	27.00
	Middle	28.11	25.14	26.96
	Outer	28.20	25.31	27.06
Lignin (%)	Core	17.41	18.89	17.84
	Middle	18.34	18.67	18.89
	Outer	18.41	17.89	18.83

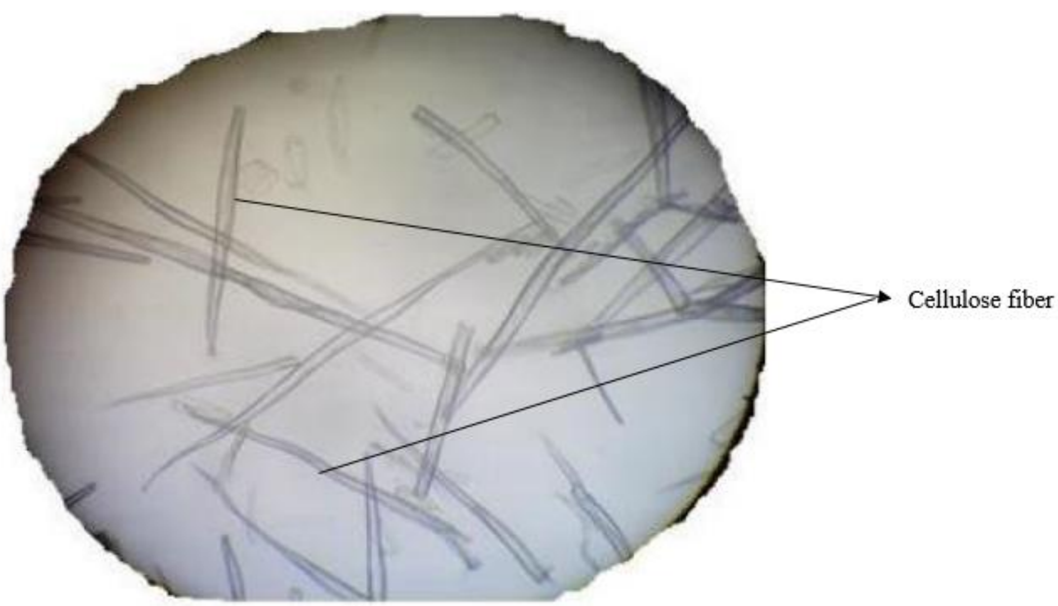

Plate 1: Macerated Fibres of *D.regia* wood

DISCUSSION

Fibre Length

The FL obtained in this study is within the values found in literature for known hardwood species in Nigeria. Thus, comparable with Ajala and Noah (2019) for *Gmelina arborea* (1.29mm), Roger (2007) for *Gerdenia Ternifolia* (1.38 mm), and Ogunleye *et al.*, (2017) for *Ricinodedron Heudelotii* (1.40 mm) respectively, while Oluwadare (2007) obtained a slightly lower value for *Leucaena leucocephala* (0.65 mm). According to Anon (1984), only fibre lengths ≥ 1.6 mm are considered long. So, *D.regia* fibers having a mean FL of 1.30 is a short fibre, and as such may be limited in their use for paper resistant to tearing (Oluwadare and Sotande, 2007). Similarly, Josiah and Oluwadare, (2002) recorded a value of 1.27 mm was the same species. Furthermore, a significant decrease from the top wood (1.25 mm) to base wood (1.36 mm) was observed, while there was also an increasing trend radially, with core wood having a significant value of 1.26 mm, from middle wood (1.31mm) and outer wood (1.33 mm). These variations observed are in accordance with what was observed by Huges (1996).

Fibre Diameter

The pattern of variation was inconsistent in the axial and radial positions (Table 1). However, there was a significant variation within the radial position only. Notwithstanding, there was a significant interaction between the axial and radial positions. This implies that the fibres at the middle wood along and across the axes were significantly wider. The value obtained was higher than what was reported for Teak in Nigeria by Izekor, and Fuwape, (2011), for *Gmelina arborea* in Costa Rica by Roque and Fo (2007), for *Gmelina arborea i*n Nigeria (Ogunkunle, 2010) and also for *R. racemosa* and *R. harrisonii* which are; 32.83µm, 18.5 – 27.5 µm, 36.09 µm and 34.25 µm respectively but lower to *Diospyros mespiliformis* (17.41 µm), *Triplochiton scleroxylon* (18.00 µm) (Adeniyi *et al*., 2013). Meanwhile, this value was similar to Josiah and Oluwadare (2020) for *D.regia* (41.7 µm).

Lumen width

The lumen width increased from base wood to top wood while a general decrease from Core wood to outer wood was observed radially similar to the result recorded by Ajala and Noah (2019) on *Aningeria robusta.* Also, there was a significant difference in lumen width along the axial and radial positions (P<0.05). The average lumen width of 26.89 µm observed in this study was higher than 16.18µm for *Aningeria robusta* (Ajala and Noah 2019), 14.80 µm for *Gerdenia ternifolia* (Noah *et al.*, 2015), 18.92 µm for (Teak) (Izekor and Fuwape 2011), 15.94 µm for *Rhizophora racemose* and 17.55 µm for *Rhizophora harrisonii* (Emerhi, 2012), respectively, but similar to Josiah and Oluwadare, (2002) who recorded 26.83 µm for *D.regia* wood. Bearing in mind the similar result obtained by Josiah and Oluwadare, (2002), it can then be reaffirmed that *D.regia* is among the indigenous wood species with a wider lumen diameter. The LW of *D.regia* wood therefore compared favorably with the species prominent in pulp and paper manufacturing.

Cell Wall Thickness

The pooled mean obtained (6.62µm) is higher than *Ricinodendron heudelotii* (4.6 µm) **(**Ogunleye *et al.*, 2017), *Vitex doniana* (4.9µm) (Ogunjobi *et al.*, 2014)**,** *Leucaena leucocephala* (2.90 µm) (Oluwadare and Sotannde 2007) and Teak (Izekor and Fuwape 2011), but fell within the range (5.0 – 10.0 µm) reported for Pine - a wood species considered as a long fibre pulp (PPRI 2011)**.** Radially, there is an increase from 5.73 µm at the core wood to 7.27 µm at the outer wood. There is a significant difference in cell wall thickness both along the axial and radial positions. The cell wall thickness is one of the major factors that determine the density and strength of wood thus the value obtained for *D.regia* can be considered as ranging between medium to thick cell walls which can prevent adhesives from penetrating.

Chemical Constituent of *Delonix Regia* Wood

Lignin

Abdul-Khalil *et al,* (2010) noted that Information on the chemical composition of wood is necessary to determine the suitable pulping method, and paper strength of a wood material. The mean value obtained for lignin is 18.34%. This falls within the standard range for hardwoods 18-25% (Biermann, 1996) and favourably compares with the findings of Casey (1980) where the lignin content of Keruing wood (*D.pachyphyllus*).

Holocellulose

Holocellulose is a combination of cellulose and hemicellulose. The higher the content, the better the quality of the paper (Zawawi *et al.*, 2014). Cellulose, which is the chief component of plant fibres used in pulping and the most abundant natural polymer in the world must be relatively high in any wood species recommended for pulping. The resulting high fiber strength is due to the Hydrogen bonding between the cellulose molecules (Biermann, 1996; Rowell *et al*., 2000). The value obtained for cellulose was 47% which compares favorably with what was obtained by Kollman *et al.*, (1968) who obtained cellulose content of 45%, 45%, and 48% for *Acer rubrum L, Fagus grandifolia Ehrh, Populus tremuloides* Michx, respectively.

According to Casey (1980), the holocellulose content for hardwood is 70-82%. The result obtained from this study was 73 % which falls within the range for hardwoods and compares favourably with results obtained by Dewi and Supartini (2017) for *D. glabrigemmatus* (72.7), *D. stellatus* (72.9) but lower than what was obtained for *D. pachyphyllus* (76.9). The high content of holocellulose also indicates high cellulose content in the wood.

CONCLUSION

The potential suitability of *D. regia* being a lesser-used wood species was successfully investigated in the study. Thus, fibre characteristics and chemical constituents of *Delonix regia* wood that were determined suggest that it can serve as an alternative for the commonly used Nigerian wood species for pulp and paper production.

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