INTRODUCTION

The genus *Acacia* Mill. (Mimosoideae - Fabaceae) comprises about 1,380 species (Saini et al., 2008) indigenous to tropical and subtropical savannas mainly in Australia and Africa (Cronquist, 1981). Most species of *Acacia* occur in regions where the rainfall is markedly seasonal or low; only few inhabit the rainforest areas. Many phytochemicals have been reported in *Acacia*, such as hydrolysable and condensed tannins, flavonoids, terpenes, alkaloids, cyanogenic glycosides and gums (Malan & Roux, 1975; Secor et al., 1976; Flath et al., 1983; Bennie et al., 2001; Seigler, 2003). The wood of *A. nilotica* (L.) Willd. ex. Del. is suitable for carved and turnery products (Krisdianto & Damayanti, 2007). Gums from the slashed trunk of *A. senegal* (L.) Willd. and *A. seyal* Del. are known to be of great economic importance in the clarification of wine as with all adhesives, and as thickeners, stabilizer or emulsifier in a wide variety of foodstuffs. The existing classification of *Acacia* species has been based mainly on their macro-morphological characters; classification based on or incorporating wood anatomical characters is quite rare. Despite the economic importance of the species, there is paucity of information on the anatomical features of the Nigerian taxa. Therefore, the aim of this study is to assess the wood micro-characters of the six common *Acacia* species in Nigeria (*A. dudgeonii*, *A. hockii*, *A. nilotica*, *A. seyal* and *A. sieberiana*) for their taxonomic importance and determine the suitability of the taxa for pulp and paper production.

MATERIALS AND METHODS

Specimens of five of the six *Acacia* species were studied at the University of Ibadan Herbarium (UIH), Ibadan (Table 1) while specimens of *A. senegal* were studied at the Forest Herbarium (FHI) of the Forestry Research Institute of Nigeria, Ibadan, Oyo State. Fresh wood was collected from matured branches of *Acacia dudgeonii*, *A. hockii*, *A. nilotica*, *A. senegal*, *A. seyal* and *A. sieberiana* from different locations in Mazah and Shere Hills, Jos, Plateau State (Table 2). The identification and authentication were done at the Forest Herbarium (FHI), Ibadan. The wood samples were preserved in 50% ethanol for further use.

Table 1

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td><em>A. dudgeonii</em></td>
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<tr>
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<td></td>
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<tr>
<td><em>A. sieberiana</em></td>
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</table>

ABSTRACT

A comparative wood anatomical study of six species of the genus *Acacia* commonly found in Nigeria was carried out. Wood samples were collected from matured branches of plants in different locations in Mazah and Shere Hills, Jos, Plateau State, Nigeria. Transverse, tangential and radial longitudinal sections as well as wood macroscapes were prepared and mounted unto microscopic slides using standard anatomical methods. All the species had diffused porous wood, heterogeneous rays, aseptate fibres and predominantly solitary vessels with simple perforation plate, few pore clusters and pore multiples. Banded paratracheal axial parenchyma was common in all taxa except in *A. senegal* which was predominantly paratracheal without bands. Multiseriate rays were common features in all taxa except in *A. nilotica* which had predominantly uniseriate rays. Quantitative wood anatomical characters such as fibre length, fibre diameter, fibre lumen diameter, fibre wall thickness, vessel length, vessel diameter, ray length, ray diameter and pore diameter were measured and statistically evaluated. The Runkel ratio of *A. senegal* (0.99µm) compared favourably with some hardwood species in the Nigerian rainforest ecosystem hence this taxon could be exploited for pulp and paper in Nigeria.

KEYWORDS: *Acacia*, anatomy, features, fibre, paper, pulp, taxonomy, wood

Wood anatomical features of some Nigerian species of *Acacia* Mill and their suitability for paper making

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**Table 1: Representative Herbarium specimens of *Acacia* species examined**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Locality</th>
<th>Collector(s)</th>
<th>Collector Number</th>
<th>Date of collection</th>
<th>GPS Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. hockii</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 14021</td>
<td>5 November, 2015</td>
<td>9°55’S and 8°55’E</td>
</tr>
<tr>
<td><em>A. Senegal</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 12422</td>
<td>5 November, 2015</td>
<td>9°55’S and 9°3’E</td>
</tr>
<tr>
<td><em>A. seyal</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 067</td>
<td>5 November, 2015</td>
<td>8°57’N and 9°3’E</td>
</tr>
<tr>
<td><em>A. nilotica</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 048</td>
<td>8 November, 2015</td>
<td>9°57’N and 9°3’E</td>
</tr>
<tr>
<td><em>A. sieberiana</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 023</td>
<td>8 November, 2015</td>
<td>9°57’N and 9°3’E</td>
</tr>
<tr>
<td><em>Acacia dudgeon</em></td>
<td>Proposed grazing/reserve area near Bin Yauri, Sokoto</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 14021</td>
<td>5 November, 2015</td>
<td>9°55’S and 8°55’E</td>
</tr>
</tbody>
</table>

**Table 2: Locations of collections of *Acacia* species used for the study**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Locality</th>
<th>Collector(s)</th>
<th>Collector Number</th>
<th>Date of collection</th>
<th>GPS Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia dudgeon</em></td>
<td>Mazah Hills, Gwong, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 14021</td>
<td>5 November, 2015</td>
<td>9°55’S and 8°55’E</td>
</tr>
<tr>
<td><em>A. hockii</em></td>
<td>Mazah Hills, Gwong, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>U1H 11401</td>
<td>19-02-1969</td>
<td>9°55’S and 8°55’E</td>
</tr>
<tr>
<td><em>A. Senegal</em></td>
<td>Mazah Hills, Gwong, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 13513</td>
<td>03-09-1967</td>
<td>8°57’N and 9°3’E</td>
</tr>
<tr>
<td><em>A. seyal</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 18349</td>
<td>14-11-1978</td>
<td>9°55’S and 9°3’E</td>
</tr>
<tr>
<td><em>A. nilotica</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 11209</td>
<td>12-11-1968</td>
<td>9°55’S and 9°3’E</td>
</tr>
<tr>
<td><em>A. sieberiana</em></td>
<td>Shere Hills, Jos</td>
<td>Owolabi/Chukwuma</td>
<td>UIH 16439</td>
<td>12-11-1968</td>
<td>9°55’S and 9°3’E</td>
</tr>
</tbody>
</table>

**Sectioning:** Wood blocks of approximately 10×10×10 cm was obtained from the wood samples of the matured branches of each plant species and small blocks were cut into cubes of 8 cm³. The blocks were boiled in 5% aqueous solution of Sodium hydroxide (NaOH) to soften the wood. Transverse sections (TS), tangential longitudinal sections (TLS), and radial longitudinal sections (RLS) of the wood samples were cut at 10 microns thickness using Reichert Austria sledge microtome and were preserved in 50% ethanol prior to staining. Each section was stained for 5 minutes in Safranin O, then rinsed in water thrice to remove excess stain and counter stained in Alcian blue for another 5 minutes. The counter-stained sections were rinsed in water thrice before passing them through treatment in series of ethanol solutions (50%, 70%, 80%, 90% and 100%) to remove water molecules (dehydration process) and to remove excess stain (differentiation process). The dehydrated and differentiated sections were cleared in ethanol and xylene mixtures in series (ethanol/xylene, 50/50, 40/60, 30/70, 20/80, 10/90 and absolute xylene). Each section was mounted on a clean glass slide in DPX (mountant).

**Maceration:** Wood samples of each *Acacia* species were sliced into small pieces using pen knife and macerated using Schulz’s fluid obtained by mixing equal volume of chromic acid (dissolved 1gm of Potassium Nitrate (KNO₃) in 50 ml of Concentrated Nitric acid (HNO₃)) and 10% trichloroacetic Acid. The maceration was carried out in a beaker heated on a hot plate in the fume cupboard for 40 minutes. This treatment removed the middle lamella to free the cells and their constituents. The macerated wood samples were washed in several changes of water and preserved in 50% ethanol prior to staining with Safranin O for 5 minutes and then carefully rinsed in water once. Macerates were mounted in 25% glycerol on clean slides with the edges of the cover slips sealed with nail varnish.

**Microscopy:** Microscopic observations of prepared slides of the sections and macerates were done using LEICA DM500 binocular light microscope. Wood characters studied included xylem vessels, axial parenchyma cells, fibres, rays, tyloses, secretory ducts/canals and crystals. Photomicrographs of the slides showing anatomical features of the wood were taken using Accu-scope trinocular microscope with 3.2 MP CMOS digital camera.

The following parameters were measured using the stage and eye piece micrometers:
1. Fibre length and width, lumen and wall thickness in the macerates
2. Vessel pore diameter at the Transverse Section (TS), vessel length and vessel width in the macerates
3. Ray height and width at the T.L.S. plane

The characters studied in wood macerates were used to derive the anatomical properties and morphological indices such as the Runkel ratio, slenderness ratio, flexibility coefficient, fibre length (FL), fibre diameter (FD), fibre lumen diameter (FLD), fibre wall thickness (FWT), vessel diameter (VD), vessel length (VL), ray height (RH), ray diameter (RD), and pore diameter (PD)

The Fibre wall thickness was obtained with the formula:

\[
FWT = \frac{FD - FLD}{2}
\]

Where FD = Fibre diameter and FLD = Fibre lumen diameter
The Runkel ratio was obtained with a formula:

$$RR = \frac{2FWT}{FLD}$$

Where RR = Runkel Ratio
Flexibility coefficient = \( \frac{FLD \times 100}{FD} \)
Where FLD = Fibre lumen diameter, FD = Fibre diameter
And Slenderness ratio = \( \frac{FL}{FD} \)
Where FL = Fibre length, FD = Fibre diameter

All data were subjected to Cluster Analysis using SPSS version 20. Descriptive terminologies and measurements were in accordance to the International Association of Wood Anatomists (IAWA) list of Microscopic Features for Hardwood Identification (IAWA, 1989).

RESULTS

Wood Anatomical Description of the Studied Taxa

Acacia dudgeoni (Figures 2A, 3A, 4A & 5A)

Wood porosity: Diffuse porous

Vessels: Solitary vessels dominant, radial pore multiple ranged from 2-4 and pore clusters from 2-4. Pore shape at transverse plane circular, oval, cylindrical and arch; tyloses present in some vessels. Mean vessel length was 216.4±80.5 \( \mu m \) while the mean vessel diameter was 105.6±46.1 \( \mu m \); pore diameter was 112.7±28.8 \( \mu m \). Perforation plate simple, inclination oblique to transverse with a tail at one end or absent; pitting simple and alternate.

Axial parenchyma: Paratracheal, aliform-confluent, in bands more than three cells wide.

Ray: Predominantly multiseriate, few uniseriate or biseriate. Rays, non-storied and heterogeneous (comprising of both procumbent and upright cells). Ray cells circular, polygonal, cylindrical and oval at tangential plane. Mean ray length 381.4±110.3 \( \mu m \) and diameter 52.0±9.3 \( \mu m \).

Fibre: Libriform, non-storied, non-septate; average fibre length 721.2±155.8 \( \mu m \), diameter 23.4±4.7 \( \mu m \), lumen diameter 10.6±4.5 \( \mu m \) and wall thickness 6.4±1.6 \( \mu m \).

Acacia hockii (Figures 2B, 3B, 4B & 5B)

Porosity: Diffuse porous

Vessel: Solitary vessels dominant, radial pore multiple ranged from 2-3 and pore clusters 2-6. Pore shape at transverse plane circular, oval, cylindrical and arch; tyloses present in few vessels. Mean vessel length was 232.8±44.7 \( \mu m \), while the mean vessel diameter was 128.8±57.0 \( \mu m \), pore diameter was 138.1±27.2 \( \mu m \). Perforation plate simple, inclination oblique to transverse with a tail at one end or two tails, one at each end or no tail, pitting simple and alternate.

Axial parenchyma: Paratracheal, aliform-confluent, in bands more than three cells wide.

Ray: Multiseriate and uniseriate rays in equal number. Rays non-storied and heterogeneous (comprising of both procumbent and
upright cells). Ray cells are circular, polygonal, cylindrical and oval at tangential plane. Mean ray length was 494.4±241.1 μm and diameter was 65.4±14.4 μm.

**Fibre:** Libriform, non-storied, non-septate; average fibre length 804.0±317.3 μm, diameter 15.4±3.4 μm, lumen diameter 6.0±3.2 μm and wall thickness 4.7±1.3 μm.

**Acacia nilotica (Figures 2C, 3C, 4C & 5C)**

**Porosity:** Diffuse porous

**Vessel:** Solitary vessels dominant, radial pore multiple ranged from 2-5 and pore clusters 2-5. Pore shape at transverse plane circular, oval, cylindrical and arch; tyloses present in few vessels. Mean vessel length was 181.6±43.8 μm, while the mean vessel diameter was 168.4±31.6 μm, pore diameter was 109.3±25.1 μm. Perforation plate simple, inclination oblique to transverse with a tail at one end or no tail, pitting simple and alternate

**Axial parenchyma:** Paratracheal, in bands more than three cells wide, winged aliform and vasicentric

**Ray:** Predominantly uniseriate with a few biseriate and multiseriate. Rays non-storied and heterogenous (comprising of both procumbent and upright cells). Ray cells are circular, polygonal, cylindrical and oval at tangential plane. Mean ray length was 452.2±128.2 μm and diameter was 52.0±9.5 μm.

**Fibre:** Libriform, non-storied, non-septate; average fibre length 892.4±246.1 μm, diameter 20.5±3.5 μm, lumen diameter 9.7±4.1 μm and wall thickness 5.4±1.4 μm

**A. senegal (Figures 2D, 3D, 4D &5D)**

**Porosity:** Diffuse porous.

**Vessel:** Solitary vessels dominant, radial pore multiple ranged from 2-3 and pore clusters 2-4. Pore shape at transverse plane circular, oval, cylindrical and arch; tyloses present in few vessels. Mean vessel length was 214.0±48.9 μm, while the mean vessel diameter was 178.8±43.6 μm, pore diameter was 103.1±24.7 μm. Perforation plate simple, inclination oblique to transverse with a tail at one end or no tail at all, pitting simple and alternate

**Axial parenchyma:** Paratracheal, confluent and vasicentric

**Ray:** Predominantly multiseriate with few uniseriate and biseriate. Rays non-storied and heterogenous (comprising of both procumbent and upright cells). Ray cells are circular,
polygonal, cylindrical, square and oval at tangential plane. Mean ray length 309.6±66.4 μm and diameter (56.0±7.0 μm).

**Fibre:** Libriform fibres non-storied, non-septate; average fibre length 805.6±153.5 μm, diameter 19.8±3.7 μm, lumen diameter 11.8±5.3 μm and wall thickness 4.0±1.3 μm.

**Acacia seyal (Figures 1E, 2E, 3E 4E & 5E)**

**Porosity:** Diffuse porous.

**Vessel:** Solitary vessels dominant, radial pore multiple ranged from 2-4 and pore clusters 2-6. Pore shape at transverse plane circular, oval, cylindrical, saucer and arch; tyloses present in few vessels. Mean vessel length was 181.2±39.2 μm, while the mean vessel diameter was 179.2±62.2 μm, pore diameter was 157.9±33.5 μm. Perforation plate simple, inclination oblique to transverse with a tail at one end or two tails, one at each end or no tail at all, pitting simple and alternate.

**Axial parenchyma:** Paratracheal, vasicentric in bands more than three cells wide. Ray: Predominantly multiseriate with few uniseriate and biseriate. Rays non-storied and heterogenous (comprising of both procumbent and upright cells). Ray cells are circular, polygonal, cylindrical and oval at tangential plane. Mean ray length 453.8±143.9 μm and diameter 51.8±11.9 μm.

**Ray:** Predominantly multiseriate with few uniseriate and biseriate. Rays non-storied and heterogenous (comprising of both procumbent and upright cells). Ray cells are circular, polygonal, cylindrical and oval at tangential plane. Mean ray length 453.8±143.9 μm and diameter 51.8±11.9 μm.

**Fibre:** Libriform, non-storied, non-septate; average fibre length 727.6±217.1 μm, diameter 16.2±2.6 μm, lumen diameter 4.7±1.7 μm and wall thickness 5.8±1.2 μm.

**Acacia sieberiana (Figures 1E, 2E, 3E, 4E & 5F)**

**Porosity:** Diffuse porous.

**Vessel:** Solitary vessels dominant, radial pore multiple ranged from 2-3 and pore clusters 2-3. Pore shape at transverse plane circular, oval, cylindrical and arch; tyloses present in few vessels. Mean vessel length was 744±250.1 μm, diameter 19.1±4.3 μm, lumen diameter 9.5±2.8 μm and wall thickness 4.8±1.6 μm.

**Axial parenchyma:** Paratracheal, vasicentric in bands more than three cells wide.

**Ray:** Predominantly multiseriate with few uniseriate and biseriate. Rays non-storied and heterogenous (comprising of both procumbent and upright cells). Ray cells are circular, polygonal, cylindrical and oval at tangential plane. Mean ray length 386.6±90.6 μm and diameter 84.2±18.2 μm.

**Fibre:** Libriform, non-storied, non-septate; average fibre length 744±250.1 μm, diameter 19.1±4.3 μm, lumen diameter 9.5±2.8 μm and wall thickness 4.8±1.6 μm.

**DISCUSSION**

Wood anatomical data are known to have diverse applications in plant systematics and evolution; such data have been employed in the identification and classification of flowering plants (Herendeen & Miller, 2000). Evidence from the present study also suggests that in addition to macro-morphological data, wood anatomical data are useful in identifying and delimiting the six Acacia species studied. The diffuse porous wood, dominance of solitary vessels, paratracheal axial parenchyma, occasionally banded axial parenchyma, simple perforation plates and absence of storeyed rays and fibres are unifying characters of the Acacia species. This supports the work of Evans et al. (2006) who reported the above listed characters as the most distinctive anatomical characters of the wood of Acacia sensu lato. The occurrence of tyloses in vessels, though few in the taxa, as reported in this study lay credence to the taxonomic importance of this character as employed by Metcalfe and Chalk (1989) who used presence or absence of tyloses in differentiating the taxa in the family Sterculiaceae. Banded and paratracheal axial parenchyma cells were present in all species except in A. senegal which exhibited strictly paratracheal type, thus diagnostic for the species. All the Acacia species studied had predominantly multiseriate and few uniseriate and biseriate rays except for A. nilotica which had predominantly uniseriate rays with few multiseriate and biseriate rays. This report is in contrast to Mundotiya et al. (2016) who reported predominantly multiseriate rays for A. nilotica. The difference may be attributed to environmental influence which needs to be further investigated in the taxon. The nature of the perforation plate is a character that is important in wood identification because of its conspicuousness (Carlquist, 2001). Simple perforation
plates were reported in all the species investigated in this study. According to William (1967), the constancy of simple perforation between vessel elements and alternate intravascular pitting, crystal sands and presence of libriform wood fibres indicate a trend towards phylogenetic specialization in some cells and tissues. In spite of the taxonomic value qualitative wood anatomical characters, the importance of the quantitative wood anatomical characters cannot be overlooked. Elongated and narrow vessels are primitive characters while short and wide vessels are advanced characters (Metcalfe & Chalk, 1950), it may therefore be inferred that *A. hockii* is the most primitive and *A. dudgeonii* the most advanced species of all the species considered (Table 3).

The dendrogram of the relationships among the taxa (Figure 1) splits them into two main groups. Group A consists of *A. seyal*, *A. dudgeonii*, *A. sieberiana*, and *A. hockii* and group B consists of *A. senegal* and *A. nilotica*. *Acacia seyal* and *A. dudgeonii* are very closely related but distantly related to *A. sieberiana* and *A. hockii*. *Acacia nilotica* is also distantly related to *A. senegal*.

The increasing demand for pulp and paper can only be achieved by sourcing many woody plant species with appreciable fibre characteristics (Oluwadare & Ashimiyu, 2007). Measurements from the wood macerates of individual species of *Acacia* were used to obtain the fibre morphological indices such as the Runkel and Slenderness ratios as well as the Flexibility coefficient (Table 3). *Acacia nilotica* had the longest fibres while *A. dudgeonii* had the shortest fibres. Fibre length and distribution has been reported to play important roles in the processing and mechanical performance of fiber-based products such as paper and fiberboard (Migneault et al., 2008). The good wood for pulp and paper production is expected to have a Runkel ratio of less or equal to 1 (Kipkii, 1992). The Runkel ratio of *A. senegal* (0.99 µm) compares favorably to that of *Anthonotha macrophylla* (0.99 µm) and *Dialium guineensis* (0.99 µm) which are hardwood species in the Nigerain rainforest ecosystem (Ezeibekwe et al., 2009), and higher than the reported 0.79 µm for tropical *Pinus* species (Ajala, 1997) and 0.70 µm for *Dacryodes edulis* (Apuziogu et al., 2010). A good wood suitable for pulpning, must have fibres with satisfactory flexibility (Idu & Ijomah, 2000). In relation to flexibility ratio, fibres are grouped into four (Betkas et al., 1999); the first group is the high elastic fibres group with elasticity coefficient greater than 75.2 µm, the second is the elastic fibres group with elasticity coefficient between 50 – 75 µm, the third is the rigid fibres group having elasticity coefficient between 30 – 50 µm and the last is the highly rigid fibres group having elasticity less than 50 µm. Considering this classification, the flexibility ratios of *A. senegal* (57.08µm) and *A. sieberiana* (50.18µm) are within the elastic fibre group, *A. hockii* (37.86µm), *A. dudgeonii* (44.52µm) and *A. nilotica* (46.09µm) are within the rigid fibres group while only *A. seyal* (29.07µm) belongs to the highly rigid fibres group (Table 4).

Slenderness ratio of wood signifies the wood’s tearing strength. It is the ratio of fibre length to the fibre diameter. The acceptable mean value for slenderness ratio in papermaking is ≥33 µm.

### Table 3: Quantitative anatomical characters of the *Acacia* Species studied

<table>
<thead>
<tr>
<th>NAME</th>
<th><em>A. hockii</em></th>
<th><em>A. dudgeonii</em></th>
<th><em>A. seyal</em></th>
<th><em>A. nilotica</em></th>
<th><em>A. senegal</em></th>
<th><em>A. sieberiana</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre length (µm)</td>
<td>410 ± 1430</td>
<td>450 ± 1090</td>
<td>350 ± 1260</td>
<td>250 ± 1450</td>
<td>490 ± 1090</td>
<td>260 ± 1390</td>
</tr>
<tr>
<td>Fibre diameter (µm)</td>
<td>804.0 ± 317.3</td>
<td>721.2 ± 155.8</td>
<td>727.6 ± 217.1</td>
<td>892.4 ± 246.1</td>
<td>805.6 ± 153.5</td>
<td>744 ± 250.1</td>
</tr>
<tr>
<td>Fibre lumen (µm)</td>
<td>10.0 ± 22.5</td>
<td>17.5 ± 40.0</td>
<td>12.5 ± 22.5</td>
<td>12.5 ± 27.5</td>
<td>12.5 ± 27.5</td>
<td>12.5 ± 30.0</td>
</tr>
<tr>
<td>Fibre diameter (µm)</td>
<td>15.4 ± 3.4</td>
<td>23.4 ± 4.7</td>
<td>16.2 ± 2.6</td>
<td>20.5 ± 3.5</td>
<td>20.5 ± 3.7</td>
<td>21.0 ± 4.3</td>
</tr>
<tr>
<td>Fibre wall (µm)</td>
<td>2.5 ± 12.5</td>
<td>5.0 ± 25.0</td>
<td>5.0 ± 25.0</td>
<td>5.0 ± 22.5</td>
<td>5.0 ± 25.0</td>
<td>5.0 ± 15.0</td>
</tr>
<tr>
<td>thickness(µm)</td>
<td>6.0 ± 3.2</td>
<td>10.6 ± 4.5</td>
<td>4.7 ± 1.7</td>
<td>9.7 ± 4.1</td>
<td>11.8 ± 5.3</td>
<td>9.5 ± 2.8</td>
</tr>
<tr>
<td>Vessel length(µm)</td>
<td>140 ± 320</td>
<td>100 ± 380</td>
<td>150 ± 360</td>
<td>100 ± 250</td>
<td>140 ± 330</td>
<td>110 ± 270</td>
</tr>
<tr>
<td>Vessel diameter (µm)</td>
<td>232.8 ± 44.7</td>
<td>216.4 ± 80.5</td>
<td>212.0 ± 50.9</td>
<td>216.0 ± 43.8</td>
<td>214 ± 46.9</td>
<td>181.2 ± 39.2</td>
</tr>
<tr>
<td>Vessel length(µm)</td>
<td>30 ± 210</td>
<td>50 ± 230</td>
<td>90 ± 230</td>
<td>110 ± 220</td>
<td>100 ± 260</td>
<td>100 ± 280</td>
</tr>
<tr>
<td>Ray length(µm)</td>
<td>128.8 ± 57.0</td>
<td>105.6 ± 46.1</td>
<td>159.2 ± 42.1</td>
<td>168.4 ± 31.6</td>
<td>178.8 ± 43.6</td>
<td>179 ± 62.2</td>
</tr>
<tr>
<td>Ray diameter(µm)</td>
<td>260 ± 1770</td>
<td>180 ± 650</td>
<td>270 ± 820</td>
<td>230 ± 760</td>
<td>200 ± 490</td>
<td>230 ± 700</td>
</tr>
<tr>
<td>Pore diameter (µm)</td>
<td>494.4 ± 241.1</td>
<td>381.4 ± 110.3</td>
<td>453.8 ± 143.9</td>
<td>452.2 ± 128.2</td>
<td>396.9 ± 66.4</td>
<td>386.6 ± 90.6</td>
</tr>
<tr>
<td>Mean ± standard deviation</td>
<td>40 ± 100</td>
<td>30 ± 70</td>
<td>30 ± 70</td>
<td>30 ± 70</td>
<td>30 ± 60</td>
<td>50 ± 120</td>
</tr>
</tbody>
</table>

### Table 4: Fibre Morphological indices and biometrical coefficient of *Acacia* Species

<table>
<thead>
<tr>
<th>Fibre Indices</th>
<th><em>A. hockii</em></th>
<th><em>A. dudgeonii</em></th>
<th><em>A. seyal</em></th>
<th><em>A. nilotica</em></th>
<th><em>A. Senegal</em></th>
<th><em>A. sieberiana</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Runkel ratio (µm)</td>
<td>0.33 ± 0.00</td>
<td>0.60 ± 3.00</td>
<td>1.00 ± 6.00</td>
<td>0.22 ± 4.00</td>
<td>0.22 ± 4.00</td>
<td>0.40 ± 3.00</td>
</tr>
<tr>
<td>Flexibility ratio(µm)</td>
<td>2.14 ± 1.32</td>
<td>1.46 ± 0.82</td>
<td>2.84 ± 1.40</td>
<td>1.39 ± 0.83</td>
<td>0.99 ± 0.85</td>
<td>1.11 ± 0.57</td>
</tr>
<tr>
<td>Slenderness ratio (µm)</td>
<td>20.00 ± 75.00</td>
<td>25.00 ± 63.64</td>
<td>14.29 ± 57.14</td>
<td>20.00 ± 81.82</td>
<td>46.09 ± 14.14</td>
<td>20.00 ± 81.82</td>
</tr>
<tr>
<td>Mean ± standard deviation</td>
<td>37.86 ± 16.20</td>
<td>44.52 ± 12.78</td>
<td>29.07 ± 9.15</td>
<td>57.08 ± 18.23</td>
<td>50.18 ± 11.32</td>
<td>40.13 ± 14.61</td>
</tr>
</tbody>
</table>
(Xu et al., 2006). All selected species had high slenderness ratio except A. dudgeoni (29.07 µm). These differences have important roles in the strength and mechanical properties of wood for various uses.

CONCLUSION

Acacia senegal is recommended as a good material for pulp and paper production due to its appreciable Runkel ratio (0.99 µm). Flexibility ratio (57.08 µm) and slenderness ratio (42.78 µm). However, the utilization potential of this species will be enhanced if its pulp is combined with other pulpable wood species like Gmelina arborea Roxb. which has a Runkel ratio of 0.25 µm to achieve desirable pulp and paper yield.

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REFERENCES


