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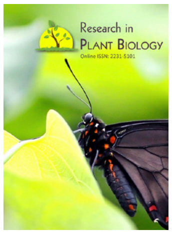

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Wood anatomical features of some Nigerian species of *Acacia* Mill and their suitability for paper making

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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 macerates 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 of taxonomic importance in the delimitation of the studied taxa. 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

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 confectionery, in the clarification of wine as with all adhesives, and as thickener, 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. dudgeoni* Craib ex Holl., *A. hockii* De Willd., *A. nilotica*, *A. senegal*, *A. seyal* and *A. sieberiana* DC) 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 dudgeon*, *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: Representative Herbarium specimens of *Acacia* species examined

	Keana, Lafia Division, Benue. Plateau State.	J.B. Hall	UIH 16439	03-1975
A. hockii	Tula near cone shaped Hill, Gombe.	J. Lowe	UIH 11401	19-02-1969
	Mile 71/2 Jos Bauchi.	J.A.D. Jackson	UIH 13513	03-09-1967
	Borgu G.R., Wawa-Luma road mp 180.	C. Geerling	UIH 18349	14-11-1978
	23 miles, Bauchi.	J. Lowe	UIH 11209	12-11-1968
A. *Senegal*	UI Botanical Gardens, Ibadan	D. P. Stanfield and M.G. Latilo	FHI 47792	3-2-1964
	Awun Forest Reserve, Jebba	H. D. Oyeachusim, T. K. Odewo and J. Olorunfemi	FHI 101441	13-6-1964
	Bakure Tureta Forest Reserve, Sokoto	H. D. Onyeachusim	FHI 44071	17-2-1960
A. nilotica	New site, Bayero University Kano.	J. Lowe	UIH 20474	28-12-1984
	West Kaniya gyade, Bauchi State.	E.O. Awosina	UIH 21151	12-01-1987
A. seyal	Shendam Division BP State.	W.J. Howard	UIH 15712	18-09-1973
A. sieberiana	2 miles from Wawa on Wawa to New Bussa Road.	A. D. Onyeachusim and A. Binuyo	UIH 12422	08-03-1966
Acacia dudgeon	Proposed grazing/reserve area near Bin Yauri, Sokoto.	J.B. Hall	UIH 14021	05-09-1972

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

Taxon	Locality	Collector (s)	Collector Number	Date of collection	GPS Reading
Acacia dudgeon	Mazah Hills, Gwong, Jos	Owolabi/Chukwuma	056	5 November, 2015	$9^0$55′N and $8^0$55′E
A. hockii,	Mazah Hills, Gwong, Jos	Owolabi/Chukwuma	067	5 November, 2015	$9^0$55′N and $8^0$55′E
A. Senegal	Shere Hills, Jos	Owolabi/Chukwuma	048	8 November, 2015	$9^0$57′N and $9^0$3′E
A. nilotica	Shere Hills, Jos	Owolabi/Chukwuma	074	8 November, 2015	$9^0$57′N and $9^0$3′E
A. seyal	Shere Hills, Jos	Owolabi/Chukwuma	023	8 November, 2015	$9^0$57′N and $9^0$3′E
A. sieberiana	Mazah Hills, Gwong, Jos	Owolabi/Chukwuma	068	5 November, 2015	$9^0$55′N and $8^0$55′E

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 cm^3. 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 (KNO_3) in 50 ml of Concentrated Nitric acid (HNO_3)] and 10% trioxonitrate V 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:

$$\text{Fibre wall thickness (FWT)} = \frac{FD - FLD}{2}$$

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

$$\text{Flexibility coefficient} = \frac{FLD}{FD} \times \frac{100}{1}$$

Where FLD= Fibre lumen diameter, FD= Fibre diameter

$$\text{And Slenderness ratio} = \frac{FL}{FD}$$

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 µm while the mean vessel diameter was 105.6±46.1 µm; pore diameter was 112.7±28.8 µm. 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

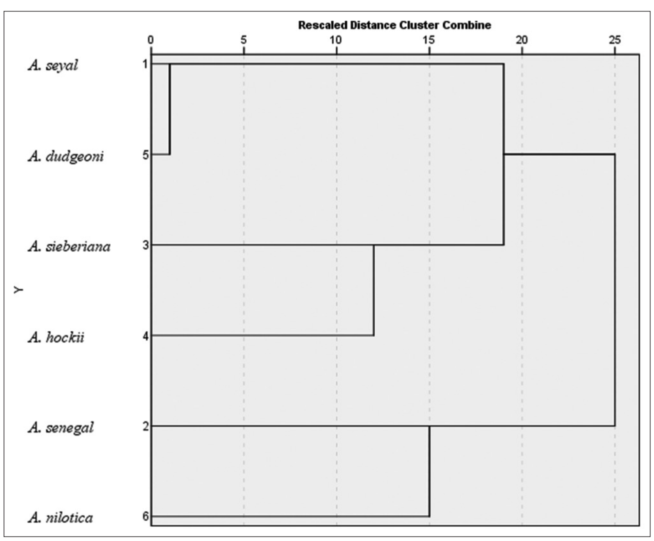

Figure 1: Dendrogram using complete linkage showing taxonomic relationship among six *Acacia* species studied

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 µm and diameter 52.0±9.3 µm.

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

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 µm, while the mean vessel diameter was128.8±57.0 µm, pore diameter was 138.1±27.2 µm. 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 heterogenous (comprising of both procumbent and

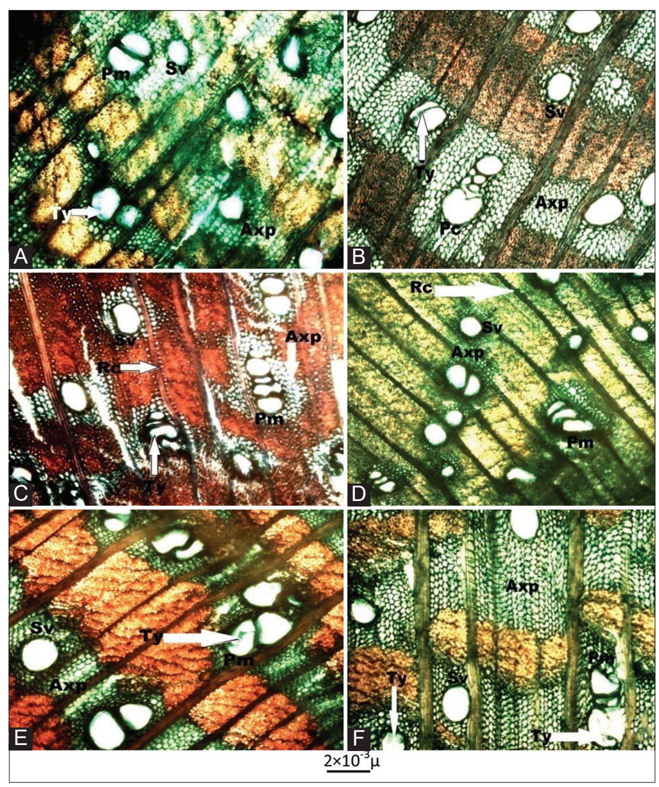

Figure 2: Transverse Sections (TS) of the wood of *Acacia* species studied. A: *A. dudgeoni*, B: *A. hockii*, C: *A. nilotica*, D: *A. senegal*, E: *A. seyal* and F: *A. sieberiana*. Legend: Pc-Pore cluster, Pm-Pore multiple, Sv-Solitary vessel, T-Tyloses, Axp-Axial parenchyma

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 63.4±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±246.1μm, 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,

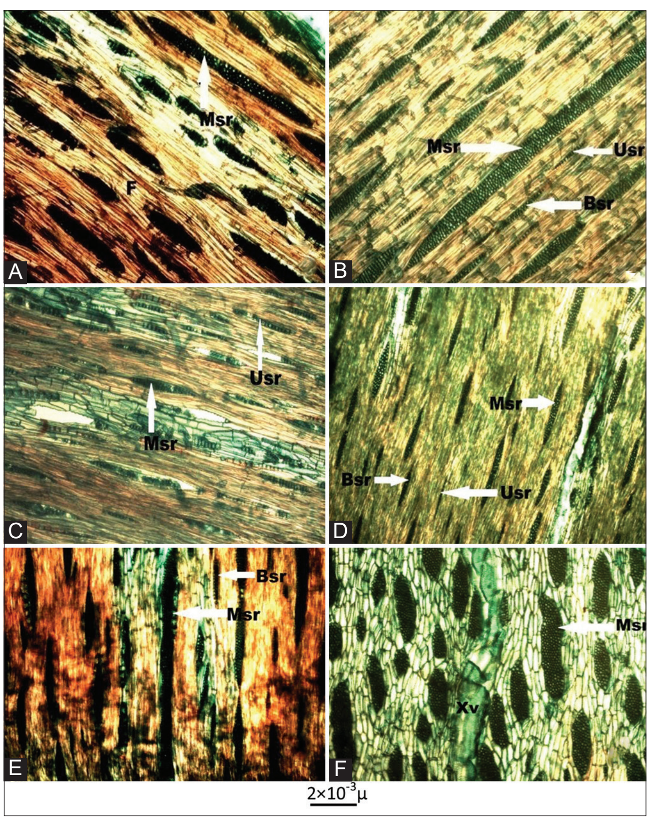

Figure 3: Tangential longitudinal Sections (TLS) of the wood of *Acacia* species studied. A: *A. dudgeon,* B: *A. hockii*, C: *A. nilotica*, D: *A. senegal*, E: *A. seyal* and F: *A. sieberiana* (F). Legend: Usr-Uniseriate ray, Bsr-Biseriate ray, Msr-Multiseriate ray, F-Fibre and Xv-Xylem vessel

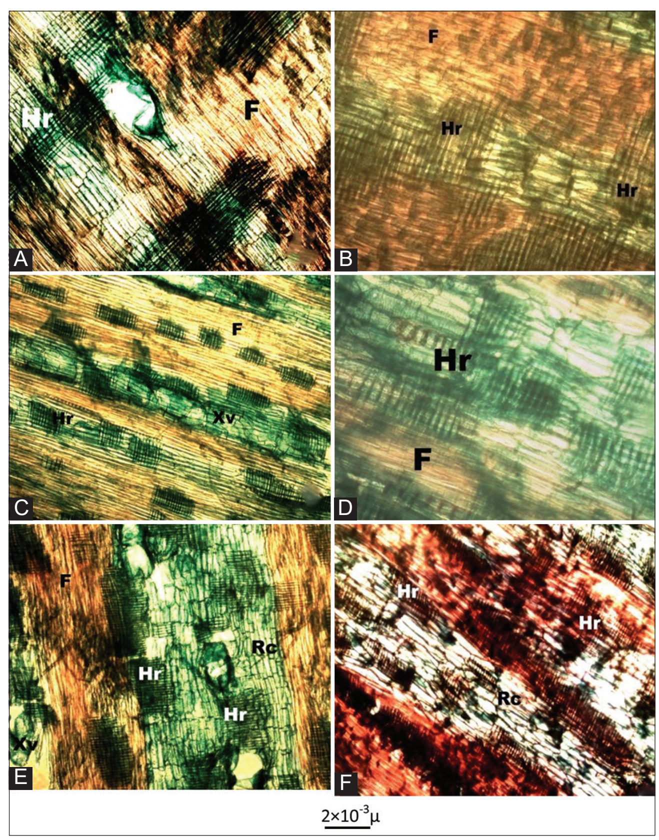

Figure 4: Radial Longitudinal Sections (RLS) of the wood of *Acacia* species studied. A: *A. dudgeon,* B: *A. hockii*, C: *A. nilotica,* D: *A. senegal,* E: *A. seyal* and F: *A. sieberiana*. Legend: Hr- Heterogenous ray, Rc-Ray cell, F-Fibre

polygonal, cylindrical, square and oval at tangential plane. Mean ray length 309.6±66.4 μm and diameter (36.0±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 212.0±50.9 μm, while the mean vessel diameter was 159.2±42.1 μm, pore diameter was 150.1±24.8 μm. Perforation plate simple, inclination oblique to transverse with few having a tail at one end, others having no tail at all, pitting simple and alternate.

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

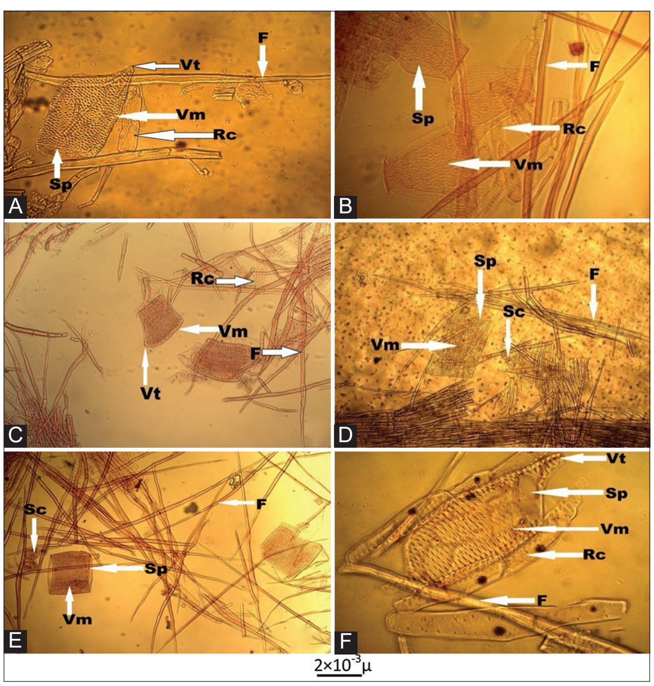

Figure 5: Wood macerates of *Acacia* species studied. A: *A. dudgeon,* B: *A. hockii,* C: *A. nilotica,* D: *A. Senegal,* E: *A. seyal* and F: *A. sieberiana*. Legend: F-Fibre, Vm-Vessel member, Vt-Vessel tail, Rc-Ray cell, Sp-Simple perforation and Sc-Sclereids

Acacia sieberiana (Figures 1F, 2F, 3F, 4F & 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 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 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. *dudgeoni* 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. *dudgoeni*, A. *sieberiana*, *and* A. *hockii* and group B consists of A. *senegal* and A. *nilotica*. *Acacia seyal* and A. *dudgeon* 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. *dudgeoni* 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 (Kpikpi, 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 Nigerian 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* (Ajuziogu *et al.*, 2010). A good wood suitable for pulping, must have fibres with satisfactory flexibility (Idu & Ijeomah, 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 their elasticity coefficient between 30 – 50 µm and the last is the highly rigid fibres group having elasticity coefficient less than 30 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. *dudgeoni* (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

NAME	A. *hockii*	A. *dudgeon*	A. *seyal*	*A. nilotica*	A. *senegal*	*A. sieberiana*
Fibre length (µm)	410-1430	450-1090	350-1260	250-1450	490-1090	260-1390
	804.0±317.3	721.2±155.8	727.6±217.1	892.4±246.1	805.6±153.5	744±250.1
Fibre diameter (µm)	10.0-22.5	17.5-40.0	12.5-22.5	12.5-27.5	12.5-27.5	12.5-30.0
	15.4±3.4	23.4±4.7	16.2±2.6	20.5±3.5	19.8±3.7	19.1±4.3
Fibre lumen	2.5-12.5	5.0-25.0	2.5-10.0	2.5-22.5	2.5-22.5	5.0-15.0
diameter (µm)	6.0±3.2	10.6±4.5	4.7±1.7	9.7±4.1	11.8±5.3	9.5±2.8
Fibre wall	2.5-7.5	5.0-10.0	5.0-7.5	2.5-7.5	2.5-5.0	2.5-7.5
thickness(µm)	4.7±1.3	6.4±1.6	5.8±1.2	5.4±1.4	4.0±1.3	4.8±1.6
Vessel length(µm)	140-320	100-380	150-360	100-250	140-330	110-270
	232.8±44.7	216.4±80.5	212.0±50.9	181.6±43.8	214±48.9	181.2±39.2
Vessel diameter (µm)	30-210	50-230	90-230	110-220	100-260	40-280
	128.8±57.0	105.6±46.1	159.2±42.1	168.4±31.6	178.8±43.6	179.2±62.2
Ray length (µm)	260-1770	180-650	270-820	230-760	200-490	230-700
	494.4±241.1	381.4±110.3	453.8±143.9	452.2±128.2	309.6±66.4	386.6±90.6
Ray diameter(µm)	40-100	30-70	30-70	40-70	30-60	50-120
	63.4±14.4	52.0±9.3	51.8±11.9	52.0±9.5	36±7.0	84.2±18.2
Pore diameter (µm)	75-185	57.5-190	82.5-197.5	50-162.5	62.5-162.5	87.5-237.5
	138.1±27.2	112.7±28.8	150.1±24.8	109.3±25.1	103.1±24.7	157.9±33.5

Mean±standard deviation

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

Fibre Indices	*A. hockii*	*A. dudgeon*	*A. seyal*	*A. nilotica*	*A. Senegal*	*A. sieberiana*
Runkel ratio (µm)	0.33-4.00	0.60-3.00	1.00-6.00	0.22-4.00	0.22-4.00	0.40-3.00
	2.14±1.32	1.46±0.82	2.84±1.40	1.39±0.83	0.99±0.85	1.11±0.57
Flexibility ratio(µm)	20.00-75.00	25.00-63.64	14.29-57.14	20.00-81.82 46.09±14.14	20.00-81.82	25.00-71.43
	37.86±16.20	44.52±12.78	29.07±9.15		57.08±18.23	50.18±11.32
Slenderness ratio (µm)	24.57-122.00	17.45-49.14	22.0-100.00	9.09-83.20	21.82-80.00	17.78-76.00
	54.34±24.93	31.46±7.26	45.78±15.58	44.87±14.24	42.78±14.19	40.13±14.61

Mean ± standard deviation

(Xu *et al.*, 2006). All selected species had high slenderness ratio except A. *dudgeoni* (29.07μm). 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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