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Fibre Potentials of *Spathodea campanulata* for Papermaking

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Abstract

Spathodea campanulata is a tree species valued for its aesthetics and medicinal uses. Shortage of wood species for paper production has resulted in the assessment of lesser-used species such as *Spathodea campanulata*, for the possibility of its use in pulp and paper production. However, there is limited information on the anatomical characteristics of this species. Therefore, this study was designed to assess the fibre characteristics of *Spathodea campanulata* wood.

Three stands of *S. campanulata* were obtained from Ibadan and cut into billets (50 cm) at 10%, 50% and 90% of the total height. Blocks of 2cm x 2cm x 5cm were obtained from the billets for anatomical properties. Wood slivers were taken from these, macerated with an equal proportion of acetic acid and hydrogen peroxide; and viewed under a light microscope for the measurement of the fibre dimensions. Derived fibre morphological indices were calculated according to standard procedures and data was analyzed using one-way analysis of variance at $\alpha = 0.05$.

Fibre length ranged from 0.80 ± 0.04 (50%TH) to 0.97 ± 0.02 (10%TH), while RR was highest at 10%TH (0.66 ± 0.03). Slenderness coefficient was significantly higher at 10%TH (47.78 ± 1.53) and least at 50%TH (39.36 ± 1.91). There was no significant effect of sampling height on the fibre characteristics. Fibre length was within the range (0.70–1.60 mm) recommended for hardwoods used in pulp and paper production. Fibre morphology of *Spathodea campanulata* is an indication that the species may be suitable for papermaking. Hence, it is recommended that studies be carried out on its optimum pulping conditions.

Keywords: Fibre, pulp, paper, *Spathodea campanulata*

INTRODUCTION

Wood remains a versatile material resource for the construction, furniture and paper industries. Contrary to alternatives found in the construction, furniture, and other industries, certain sectors, like the pulp and paper industries, survive solely on forest products such as wood. Therefore, these industries require a sustainable,

ideally indigenous, and swiftly growing availability of raw materials, particularly for the paper and pulp mills. Hence, this study focuses on *Spathodea campanulata*, a lesser-used wood.

The tree is indigenous to Africa's tropical dry forests, growing to a height of 7–25 meters and planted for its aesthetic purposes (USDA, 2015). Whether as an indigenous or exotic species, the use of *S. campanulata* as a medicinal plant is well documented. Extracts from its bark, stem, and leaves have been used as a molluscicide and to treat diabetes, malaria, and schistosomiasis (Consoli *et al.*, 1988; Makinde *et al.*, 1988, 1990). Although it is regarded as a inferior wood, *S. campanulata* wood is used for carving, charcoal and firewood in West Africa (Bekele-Tesemma *et al.*, 1993). It appears that the sole typical commercial use of the wood is that it is traded as African tulip plywood (in England) or tulipier plywood (in France). Given the aforementioned, it can be seen that this species is undervalued, particularly in Nigeria, which supports its consideration as a fibrous raw material for pulp and papermaking.

The study on the pulping potentials of any lignocellulosic material starts with the determination of its fibre characteristics. According to Johansson (2011) and Nagaraja Ganesh *et al.* (2023), the characteristics of the fibres present in a lignocellulosic material have an impact on the pulp and paper that are made from it. This is because the fibre length is regarded as an important indicator of paper quality as it affects bonding during sheet formation. The relationship between fibre length and fibre diameter gives a ratio known as the slenderness coefficient which is known to greatly affect the strength of paper. Lumen size and cell wall thickness of a fibre affect the rigidity and strength of the paper made from such fibre. The maximum average fibre length of any pulp will be the same as that of wood because fibre will be damaged regardless of the pulping method used; from fully chemical to fully mechanical (Page *et al.*, 2018). According to Rullifank *et al.* (2020), when pulping chemically, the damage is chemical degradation; but when pulping mechanically, it is physical cutting, bruising, etc. along with a lesser degree of polymerization.

Any wood species can be affected by axial or radial variations (Aderounmu and Adelusi, 2019; Riki *et al.*, 2019) in terms of fibre characteristics, chemical composition and mechanical properties. For this reason, this study uses sampling height to determine the impact of this factor on the fibre characteristics of the *Spathodea campanulata*. Any lignocellulosic material that is to be accepted for papermaking must be comprehensively studied for its physical attributes, fibre characteristics and chemical composition as these have profound effect on the strength properties of the pulp and paper made from such material. A material can be classified as a global fibrous material for papermaking if all these qualities can be ascertained in the right proportions. For this reason, understanding the fibre qualities of *S. campanulata*, is essential to deciding whether or not it is an appropriate fibre source for pulp and papermaking. This study therefore aims to evaluate the suitability of the African tulip wood, *S. campanulata*, as an alternative raw material for the production of pulp and paper through the characteristics of its fibres.

MATERIALS AND METHODS

Sample Preparation and Fibre Maceration

Three tree stands of *Spathodea campanulata* were felled from a woodlot along Ojoo-Arulogun road in Ibadan. Billets of 50 cm each were collected at 10%, 50% and 90% of the total height. These were further converted to outerwood, innerwood and corewood. Blocks of 2cm x 2cm x 5cm were obtained from the planks based on the radial positions and sampling height for anatomical properties. Following the Franklin (1945) method, each sample collected for each height was reduced to slivers and macerated separately in labelled test tubes using an equal volume of 30% hydrogen peroxide and 10% acetic acid (1:1). Using hydrogen peroxide as an oxidizing agent, the slivers were bleached white when soaked in the acetic acid and hydrogen peroxide mixture for three hours to become softened and digested. The chemical was decanted and the slivers were washed with distilled water until neutral to litmus paper. After that, the clumped fibres were separated by adding a small amount of water and shaking vigorously.

Fibre Measurement

A medical stopper was used to arrange the separated fibres on a slide (Sotannde, 2014). Under a light microscope with ocular eyepiece, fibre morphological features like fibre length, diameter, lumen width, and cell wall thickness were observed in their swollen state. For the fibre measurements of each (corewood, middlewood, and outerwood) at the 10%, 50%, and 90% sampling heights, a total of 20 fibres were randomly measured per slide to give a total of 180 fibre measurements.

Derived Morphological Indices

Based on the methodology used by Ververis *et al.* (2004), Oluwadare and Sotannde (2006), and Tutus *et al.* (2010), six derived morphological indices were computed. They consist of;

$$\text{Runkel Ratio} = \frac{2 \times \text{CWT}}{\text{LW}} \dots\dots\dots 1$$

Where,

CWT = Cell wall thickness (µm)

LW = Lumen width (µm)

$$\text{Slenderness coefficient} = \frac{\text{FL}}{\text{FD}} \dots\dots\dots 2$$

Where,

FL = Fibre length (mm)

FD = Fibre diameter (µm)

$$\text{Flexibility ratio} = \frac{\text{LW} \times 100}{\text{FD}} \dots\dots\dots 3$$

Where,

LW = Lumen width (µm)

FD = Fibre diameter (µm)

$$\text{Coefficient of rigidity} = \frac{\text{CWT} \times 100}{\text{FD}} \dots\dots\dots 4$$

Where;

CWT = Cell wall thickness (µm)

FD = Fibre diameter (µm)

$$\text{F-factor} = \frac{\text{FL}}{\text{CWT}} \dots\dots\dots 5$$

Where,

FL = Fibre length (mm)

CWT = Cell wall thickness

$$\text{Solid factor} = (\text{FD}^2 \text{ LW}^2) \times (\text{FL}) \dots\dots\dots 6$$

Where,

FD = Fibre diameter (µm)

LW = Lumen width (µm)

FL = Fibre length (mm)

Statistical Analysis

One way analysis of variance was used to determine the effect of sampling height on the fibre characteristics of *S. campanulata*.

RESULT AND DISCUSSION

Fibre Length

Table 1 showed that radially, there was no variation in fibre length from the corewood to the outerwood at the base (0.695), middle (0.433 and top (0.356) at $\alpha = 0.05$ for all the stands considered. However, for wood sampled at the base, there was a noticeable reduction in fibre length from 0.99 ± 0.66 mm to 0.94 ± 0.03 mm from the outerwood to the corewood respectively (Table 2). The reverse was observed for the wood samples taken from the middle, as there was an increase in fibre length (Table 2) from the outerwood (0.73 ± 0.09 mm) to the corewood (0.88 ± 0.06 mm). Meanwhile at the top, there was a decrease in fibre length from the outerwood (0.94 ± 0.02 mm) to the corewood (0.82 ± 0.08 mm). The mean fibre lengths for the top, middle and base were 0.86 ± 0.07 mm, 0.80 ± 0.04 mm and 0.97 ± 0.02 mm respectively. Moreover, the average fibre length of *Spathodea campanulata* as deduced from this study was 0.88 ± 0.02 mm. Wood obtained from the middle and top of the sampling heights do not vary significantly as observed from the result of the Duncan multiple range test presented in Table 3 but axially, there was a significant difference in the fibre length at $\alpha = 0.05$.

Fibre length is regarded as an important indicator of paper quality. *S. campanulata* fibre can be categorized as short fibre comparing well with those of other hardwoods and some non-woods. The fibre length obtained for *S. campanulata* here is longer than the 0.63mm and 0.61mm recorded for the same species by Shin *et al* (2015). This value is also higher than what Amira *et al.* (2017) found for *Eucalyptus camaldunensis* (0.78mm), closer to 0.93 for *Acacia nilotica* by the same authors and 0.72mm for *Parkinsonia aculeate* (Santos *et al.*, 2012). The range of 0.80mm to 0.97mm deduced for *S. campanulata* from this study is similar to 0.89mm and 0.94 mm reported for Nigerian grown *Persea americana* and *Mangifera indica* (Ajuziogu *et al.*, 2010). This value is not far-fetched as the extensive work on fibre characteristics both past and present showed most Nigerian trees to be short fibred (Cutter, 1971; Kpikpi and Olatunji, 1990; Uju and Ugwoke, 1997; Hurter, 2001). *S. campanulata* used for this study also relates to the 0.89mm, 0.92mm, 0.7mm-1.6mm for rice straws, *Sida acuta* and general hardwood species (Tutus *et al.*, 2004, Olotuah 2006, H'ng *et al* 2016). Since there are no axial and radial variations in the fibre lengths, it means that fibres from any part of the wood can be combined together for use.

Fibre Diameter

There was no significant difference in fibre diameter of the wood samples both axially and radially as presented in Table 1. The trend observed radially for the wood from the top and base of the sampling heights showed the middle wood to be lowest in fibre diameter with $20.28 \pm 1.25 \mu\text{m}$ and $20.50 \pm 1.32 \mu\text{m}$ respectively while the outerwood was lowest in fibre diameter ($21.20 \pm 0.56 \mu\text{m}$) for wood from the middle. For both top wood and basal wood, the outerwood had the highest fibre diameters. Mean fibre diameters for the top, middle and base were $21.72 \pm 1.04 \mu\text{m}$, $20.89 \pm 0.33 \mu\text{m}$ and $21.62 \pm 0.68 \mu\text{m}$ respectively (Table 2) while *S. campanulata* used for this study had an average fibre diameter of $21.41 \pm 0.68 \mu\text{m}$.

The relationship between cell wall thickness and lumen width is best described by the fibre diameter. The average fibre diameter for *S. campanulata* in this study was similar to the value submitted for hardwoods, 20.0 - 40.0 μm (H'ng *et al* 2016). It is however greater than the 18.7 μm reported by Shin *et al* (2015) for the soda and soda-anthraquinone pulps of the same species.

The importance of fibre diameter is usually based on its relationship with fibre length if it will be used in papermaking as the ratio of the two gives a derived morphology known as the slenderness coefficient or felting ratio.

Lumen Width

The samples collected from the middle were the only ones that showed radial variation at ($P = 0.052$) in lumen width (Table 1). At the base, lumen width was highest in the outerwood ($16.13 \pm 2.62 \mu\text{m}$) and lowest at the middle, $14.13 \pm 1.73 \mu\text{m}$, with a basal average of $14.83 \pm 1.13 \mu\text{m}$. At the middle, the lumen width was highest in the corewood (Table 2), $15.10 \pm 0.68 \mu\text{m}$ and lowest in the middlewood ($12.95 \pm 0.35 \mu\text{m}$) with a mean of 14.08 ± 0.38 .

However, radially at the top, the lumen was widest in the outerwood ($16.03 \pm 0.76 \mu\text{m}$) and narrowest in the middlewood ($12.70 \pm 0.97 \mu\text{m}$). The average lumen width for the top was $13.90 \pm 0.70 \mu\text{m}$. Axially, there was a

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decrease in lumen width from the base ($14.83 \pm 1.13 \mu\text{m}$) to the top ($13.90 \pm 0.70 \mu\text{m}$). Also, there was no significant variation in lumen width from the base to the top at $\alpha = 0.05$ (Table 3). However, the average lumen width for the *S. campanulata* used for this study was $14.27 \pm 0.45 \mu\text{m}$. Lumen width increased along the sampling height and lead to a decrease in cell wall thickness along the sampling height.

Cell Wall Thickness

From Table 1, there was no radial variation in cell wall thickness at the base (0.635), middle (0.408) and top (0.171). Table 2 revealed that axially, wood samples do not have a particular order for the cell wall thickness. At the base, the outerwood was thickest ($4.02 \pm 2.09 \mu\text{m}$) while the middlewood was thinnest ($3.75 \pm 2.52 \mu\text{m}$). For the middle, the middlewood was the thickest ($4.15 \pm 0.13 \mu\text{m}$) while the corewood was thinnest at $3.78 \pm 0.25 \mu\text{m}$ and the mean cell wall thickness for the middle wood samples was $3.99 \pm 0.25 \mu\text{m}$. However, at the top, the corewood had the highest value for cell wall thickness ($4.20 \pm 0.07 \mu\text{m}$) and the middlewood had the lowest ($3.75 \pm 0.18 \mu\text{m}$) with a mean value of $3.99 \pm 0.09 \mu\text{m}$. Table 3 showed that the thickest cell wall was observed at the middle and top, $3.99 \pm 0.11 \mu\text{m}$ respectively and the least at the base ($3.87 \pm 0.11 \mu\text{m}$). There was no variation in cell wall thickness along the tree axis as deduced from Table 3

There was a slight variation in radial lumen width of the middle wood compared to the others but axially, sampling height has no effect on both lumen and cell wall sizes. However, the average lumen width for the *S. campanulata* used for this study was $14.27 \pm 0.45 \mu\text{m}$. the average thickness for *S. campanulata* was $3.95 \pm 0.06 \mu\text{m}$. This is close to $3.34 \mu\text{m}$ for *Ailanthus altissima* (Samariha *et al.*, 2011).

The relationship between lumen width and cell wall thickness in this study gave a ratio of 4:1 making *S. campanulata* have a larger lumen width and a thinner wall which is expected to positively affect paper properties such as burst and tensile strengths as well as the folding endurance of the paper (Agnihotri *et al* 2010). Fibres having large lumen as well as thin walls collapse and flatten to ribbons during pulp and paper making (Wood 1981 in Sotannde 2014).

Table 1: Radial Variations in the Fibre Dimensions and Derived Morphological Values of *S. campanulata* Wood

Sampling Height	Df	FL	FD	LW	CWT	RR	SC	FR	CR
Base	2	0.695	0.730	0.757	0.635	0.799	0.666	0.833	0.957
Middle	2	0.433	0.222	0.052	0.408	0.286	0.377	0.593	0.107
Top	2	0.356	0.248	0.081	0.171	0.090	0.667	0.102	0.102
Error	54								

*p values > 0.05 are not significant at $\alpha = 0.05$

Table 2: Effect of Sampling Height and Radial Position on the Fibre Dimensions of *S. campanulata* Wood

Sampling Height	Radial Position	FL	FD	LW	CWT	RR	SC	FR	CR
Base	Outerwood	0.99 ± 0.06	22.63 ± 2.46	16.13 ± 2.72	4.02 ± 2.29	0.60 ± 0.08	45.88 ± 3.08	64.14 ± 3.04	18.26 ± 1.54
	Middlewood	0.96 ± 0.03	20.50 ± 1.32	14.13 ± 1.73	3.75 ± 2.53	0.64 ± 0.04	47.97 ± 1.43	62.20 ± 1.51	18.74 ± 0.71
	Corewood	0.94 ± 0.04	22.03 ± 1.80	14.25 ± 1.63	3.82 ± 1.03	0.65 ± 0.05	49.50 ± 3.45	62.76 ± 2.13	18.46 ± 1.06

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	Mean	0.97±0.0 2	21.72±1.0 4	14.83±1.13	3.88±1.1 3	0.63±0.0 3	47.78±1. 53	63.03±1.23	18.49±0.61
Middle	Outerwood	0.73±0.0 9	21.20±0.5 6	14.18±0.50 ab	4.05±0.1 8	0.67±0.0 4	35.42±3. 44	63.84±2.06	19.21±0.61
	Middlewood	0.79±0.0 8	21.82±0.4 5	12.95±0.35 a	4.15±0.1 3	0.70±0.0 3	41.63±3. 41	64.24±4.59	19.87±0.57
	Corewood	0.88±0.0 6	22.65±0.6 1	15.10±0.68 b	3.78±0.2 5	0.61±0.0 5	41.02±2. 94	69.67±4.55	15.46±2.27
	Mean	0.80±0.0 4	20.89±0.3 3	14.08±0.38	3.99±0.1 1	0.66±0.0 2	39.36±1. 91	65.72±2.17	18.18±0.94
Top	Outerwood	0.94±0.0 2	23.12±0.9 1	16.03±0.76	4.03±0.1 8	0.58±0.0 3 ^a	40.81±2. 47	65.44±1.03 ^a	17.28±0.51 ^a
	Middlewood	0.82±0.0 8	20.28±1.2 5	12.70±0.97	3.75±0.1 8	0.68±0.0 4 ^{ab}	43.02±1. 47	61.60±1.46 ^{ab}	19.20±0.73 ^{ab}
	Corewood	0.82±0.0 8	21.45±1.1 8	12.98±1.24	4.20±0.0 7	0.74±0.0 6 ^b	40.13±2. 82	59.77±2.30 ^b	20.12±1.15 ^b
	Mean	0.86±0.0 7	21.62±0.6 8	13.90±0.70	3.99±0.0 9	0.66±0.0 3	41.32±1. 27	62.27±1.13	18.87±0.57

* Means ± Standard error of mean of three replicate samples. Values with the same alphabet in each column are not significantly different at $\alpha = 0.05$ using Duncan multiple range test.

Derived Morphological Indices of the *S. campanulata* Wood

Runkel Ratio

No variation was observed in the radial Runkel ratio (Table 1) for the base (0.799), middle (0.286) and top (0.090). In Table 2, there was a radial increase from the outerwood (0.60±0.08) to the corewood (0.65±0.05) at the base with a mean of 0.63±0.03. However, at the middle, the middlewood had the highest Runkel ratio (0.70±0.03) while the corewood had the least (0.61±0.05). For the top, there was a radial increase in Runkel ratio from the outerwood (0.58±0.03) to the corewood (0.74±0.06). Table 3 showed that Runkel ratio was lowest at the base (0.63±0.03) and highest at both middle and top regions (0.66±0.02 each). There was no significant difference in the Runkel ratios from the base to the top (0.629) at $\alpha = 0.05$.

Runkel ratio is the proportion of cell wall thickness to that of lumen width. Meanwhile, the average Runkel ratio obtained for *S. campanulata* for this study was 0.65. A Runkel ratio that is less than 1 would be suitable for papermaking as they are more flexible, collapse easily and provide a large surface area for bonding. Hence *S. campanulata* used for this study with 0.66 Runkel ratio may be suitable for papermaking. This value is expected to positively affect the tensile, burst and folding endurance strength of *S. campanulata*. Ademiluyi and Okeke (1970) pointed out that the derived fibre values provide greater information about fibres and the pulp and paper to be made from them. The value obtained for *S. campanulata* in his study is greater than 0.394, reported for *Gmelina arborea* by Ajuziogu and Uju (2007). However, it is lower than the 0.82 and 0.95 for *Mangifera indica* and *Persea americana* (Azujogu *et al.*, 2010) but close to the 0.70 for *Dacryodes edulis* by the same author.

Slenderness Coefficient

Considering the slenderness coefficient from the outerwood to the middlewood to the corewood at the base (0.666), middle (0.377) and top (0.667) as observed in Table 1, there was no significant difference at $\alpha = 0.05$. On the other hand, Table 2 showed a steady increase in slenderness coefficient from the outerwood (45.88±3.08) to 49.50±3.45 in the corewood at the base. Moreover, at the middle, the middlewood had the highest value of 41.63±3.41 but the outerwood had the least (35.42±3.44) value for slenderness coefficient. For the top, as seen from Table 2, the middlewood (43.02±1.47) had the highest value while the corewood

(40.13±2.82) was least. There is a significant variation ($p = 0.002$) in slenderness coefficient along the tree axis as observed in Table 3. Moreover, the highest SC value was found at the base (47.78±1.53) and the least at the middle (39.36±1.91).

Slenderness ratio or felting power is the ratio of fibre length to fibre diameter. Generally, it is stated that if the slenderness ratio of a fibrous material is lower than 70, it is not valuable for quality pulp and paper production. The average slenderness coefficient for the *S. campanulata* used in this study was found to be 42.82. This average is higher than 27.58 for *Paulownia spp* (H'ng *et al* 2016) and may be suitable for papermaking as the acceptable value greater than 33 for slenderness ratio is considered best for papermaking. This value falls within the range of 50-75 listed for elastic fibres though it is lower compared to 75.96% for *Paulownia spp* fibres (H'ng *et al* 2016). Lower slenderness coefficient can affect the flexibility and resistance to rupture of the fibres (Maiti, 1997; Sotannde 2014).

Tutus *et al* (2010) opined that there is a positive correlation between paper strength and slenderness coefficient. Moreover, high flexibility of the fibres in *S. campanulata* is expected to have a positive influence on tensile, bursting and folding endurance strength of the handsheets produced from this wood (Ververis *et al.*, 2004, Sotannde. 2014)

Flexibility Ratio

The results in Table 1 showed no significant variation in flexibility ratio at the base ($p = 0.833$), middle ($p = 0.593$) and top ($p = 0.102$) from the outerwood to the corewood at $\alpha = 0.05$. The result presented in Table 2 on flexibility ratio showed a radial increase from 63.84±2.06 to 69.67±4.55 in the outerwood to the corewood respectively at the middle; as well as a radial decrease from 65.44±1.03 to 59.77±2.30 in the outerwood to the corewood respectively at the top. However, at the base, the outerwood had the highest slenderness coefficient (64.14±3.04) while the middlewood had the least (62.20±1.51). Table 3 showed no significant variation in flexibility ratio along the tree axis with $p = 0.283$ at $\alpha = 0.05$. However, the middle region was the highest flexibility value (65.72±2.17) while the top was least 62.27±1.13.

The Coefficient of flexibility determines the tensile strength property of the fibre; the higher the coefficient, the more flexible and tensile the fibre (Azujiogu *et al.*, 2010). This is the ratio of lumen width to fibre diameter expressed as a percentage usually affecting the burst and tensile strengths as well as paper printing properties. *Spathodea campanulata* was found to have a flexibility ratio of 63.67% from this study. This value is greater than 43.6%, 31.1% and 45.9% reported for *Mangifera indica*, *Anacardium occidentals* and *Dacryodes edulis* by Azujiogu *et al* (2010). Even the *Dacryodes edulis* ranked as the most promising in their work on four fruit trees for papermaking could not measure up to the *Spathodea campanulata* used in this study.

Coefficient of Rigidity

There was no radial variation at $\alpha = 0.05$ (Table 1) at the base (0.957), middle (0.107) and top (0.102). Table 2 revealed that a radial increase occurred at the top with rigidity ratio ranging from 17.28±0.51 at the outerwood to 20.12±1.15 at the corewood. For the basal region, the middlewood was highest (18.74±0.71) and the outerwood (18.26±1.54) was least in rigidity coefficient. However, at the middle, the corewood possess the least value (15.46±2.27) while the middlewood had the highest (19.87±0.57). In Table 3, the top part of the tree was found to have the highest coefficient of rigidity (18.87±0.57) and the middle had the least (18.18±0.94). Moreover, Table 3 showed that there was no significant difference in rigidity factor along the tree axis. Also, the average coefficient of rigidity as obtained from this study for *Spathodea campanulata* was 18.51±0.41.

The average coefficient of rigidity as obtained from this study for *Spathodea campanulata* was 18.51±0.41. Low rigidity coefficient give a higher degree of conformability within the sheet resulting into the production of sheets with higher density or lower bulk thereby giving rise to papers with good physical strength properties, low porosity, and high brightness characteristic of writing, printing, wrapping and packaging purposes (Sotannde 2014).

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However, Dutt and Tyagi (2011), submitted that any fibre with low rigidity coefficient will give a higher degree of conformability within the sheet resulting into the production of sheets with higher density or lower bulk thereby giving rise to papers with good physical strength properties, low porosity, and high brightness characteristic of writing, printing, wrapping and packaging purposes (Sotannde 2014). Higher value signifies high suitability for quality paper (Sadiku and Abdulkareem, 2019).

Table 3: Effect of Sampling Height on Fibre Dimensions and Derived Morphological Indices of *Spathodea campanulata* Wood

Sampling Height	FL	FD	LW	CWT	RR	SC	FR	CR
Base	0.97±0.02 ^a	21.72±1.04 ^a	14.83±1.13 ^a	3.87±0.11 ^a	0.63±0.03 ^a	47.78±1.53 ^a	63.03±1.23 ^a	18.49±0.61 ^a
Middle	0.80±0.04 ^b	21.89±0.34 ^a	14.08±0.38 ^a	3.99±0.11 ^a	0.66±0.02 ^a	39.36±1.91 ^{ab}	65.72±2.17 ^a	18.18±0.94 ^a
Top	0.86±0.04 ^b	21.62±0.68 ^a	13.90±0.70 ^a	3.99±0.10 ^a	0.66±0.03 ^a	41.32±1.27 ^b	62.27±1.13 ^a	18.87±0.57 ^a
Mean	0.88±0.02	21.74±0.42	14.27±0.45	3.95±0.06	0.65±0.02	42.82±1.08	63.67±0.02	18.51±0.41
P-value	0.009	0.966	0.681	0.644	0.629	0.002	0.283	0.800

***Mean±SEM of three replicate samples. Values with the same alphabet in each column are not significantly different at $\alpha = 0.05$ using Duncan multiple range test**

***p values >0.05 are not significant.**

CONCLUSION

From the results, majority of the fibres had their fibre lengths, flexibility and runkel ratios between 0.80-0.94mm, 62-65% and 0.62-0.66, respectively. The wood showed great similarity to softwoods and hardwoods already discovered to be suitable for pulp and papermaking. It is obvious that the fibres of *S. campanulata* can play a significant role in reducing the high cost of importing long fibre pulp for the pulp and paper mills in Nigeria.

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