E-ISSN: 2346-7290

Runkel, flexibility and slenderness ratios of *Anthocleista djalonensis* (A) wood for pulp and paper production

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ABSTRACT

The Runkel, flexibility and slenderness ratios of *Anthocleista djalonensis* were studied using three trees selected randomly from within Rivers State University of Science and Technology, Nkpolu, Port Harcourt main campus. At top, middle and bottom, wood billets were extracted along axial height and radially across the cross-section and put in bottles containing the slivers and glass beads in 1:1 of hydrogen peroxide and glacial acid at 64^{o}C oven for 24 hours; bleached slivers were brought out from the various sections of the species. After maceration, the samples were washed with distilled water and resulting macerated fibres measured using eyepiece electron microscope in analytical laboratory. The results based on fibre measurements showed that Runkel ratio was highest at the middle wood (3.25) followed by outer wood (1.94) and lowest at core wood (1.22) in the radial direction while in the vertical direction-merchantable height, the ratio was highest at middle (2.23) of the trees, followed by top (2.00) and bottom (2.19). The average Runkel ratio of the species was 2.1. The flexibility coefficient (FC) of fibres decreased from top to bottom 158.66±0.61 to 104.16±0.65 in vertical direction: average of 128.70 falls into the high elastic category. Slenderness ratio of the species decreased with height from top to bottom: 91.04±1.54 to 87.50±0.21. The wood for the species is recommended for purposes like dye and pharmaceutical industries instead of paper making because of its non-suitability for paper and Runkel ratio above 1.

Keywords: *Anthocleista djalonensis*, runkel, flexibility, slenderness

INTRODUCTION

The qualities of paper are influenced by the fibre characteristics which include length, diameter, lumen width, cell wall thickness, runkel ratio and flexibility (Zobel and Van Buijtenen, 1989). It is obvious that runkel ratio, flexibility and slenderness of species are dependent on the fibre attributes outlined above. Runkel ratio is the ratio of fibre cell wall thickness to its lumen which is a major measure of suitability of any woody and fibrous material for pulp and paper production.

The Runkel ratio is a microscopic extension of the wood density in that wall thickness and lumen width are basic factors used in its determination and should not be expected to provide much more basic information than the measured wood density which reflects differences in

performance of fibre-based products traced to pulp fibre (Samariha, *et al.*, 2011).

Runkel-ratio is a factor of importance. It is the ratio between the tubular fibre wall thickness and lumen diameter; which is the ratio between twice the wall thickness and the lumen diameter (2W/L), the appropriate limits of this ratio appear to be from 0.25 to 1.5 for species which produce pulp of reasonable quality (Sreevani and Rao, 2014).

Flexibility is the ratio of lumen width to its fibre diameter that confers bonding strength of individual fiber and by extension the tensile strength and bursting properties (Sreevani and Rao, 2014), while slenderness is the ratio of fibre cell thickness to fibre diameter which determines the buoyancy or relativity of each fibre in its position in wood and confers folding endurance on the pulp resulting paper (Dinwoodie 1965, Ona *et al.* 2001) indicating recovery of the paper from twisted (folded) or pressured; resistance to folding.

There exists a positive correlation between slenderness ratio and folding endurance (Dinwoodie 1965; Ona *et al.*, 2001), and between flexibility burst (Ona *et al.*, 2001), and breaking length and tear resistance (Mabilangan and Estudillo, 1996).

The implication of flexibility (percentage of lumen width over fibre width) during paper making collapsed fibre provides more bonding area and subsequently stronger papers produced; tensile and bursting strength and folding endurance were affected by bonding of individual fibre in paper sheet (Majih *et al.*, 2014); degree of bonding largely depends on fibre bonding of individual fibres (Zobel and van Buijtenen, 1989). Four groups of flexibility ratios have been observed by Bektas, *et al.*, (1999) as high elastic fibre (FR greater than 75), elastic (FR between 50 &75), rigid fibre (FR between 30 & 50) and high rigid fibres (FR less than 30).

Majih *et al.* (2014) observed that the values of Runkel ratio are less than 1 and that plum (*Prunus domestica*) stem had 1.56 and the branch 1.21 which were not suitable for pulp and paper and the accepted values of slenderness are over 33 and stem wood and branch wood of plum were 73.38 and 58.85 respectively which is suitable for paper production and classified as average fibre.

Anthocleista djalonensis (A) which is in the family *Loganiaceae,* is a marginally-used-species (MUS) with high wood quality attributes (David, 2013), but is over looked in the humid tropics. Fibre length is an index of intrinsic wood quality and their Runkel Ratio determines suitability for pulpability (Ogunsanwo and Omole, 2010). Majid *et al*., (2014) defined fibre length as the number of bonding sites available on an individual fibre to form and interwoven network of fibres measured from one end to the other. Though, the fibre characteristics of *A. djalonensis* have been examined by David-Sarogoro and Amakiri (2016), its ancillary properties and benefits have not being hitherto considered. This study evaluated Runkel, flexibility and slenderness and suitability of *Anthocleista djalonensis* wood for pulp and paper production.

MATERIALS AND METHODS

Fibre Characteristics Determination

Fibre maceration was carried out by shaking the bottles containing the slivers and glass beads in 1:1 of hydrogen peroxide and glacial acid at 64^{o}C oven for 24 hours; bleached slivers were brought out from the various sections of the species (Oluwadare, 2006). After maceration, the samples were washed with distilled water and resulting macerated fibres measured using eyepiece electron microscope analytical laboratory of Royal Nemascope Hospital and Labouratory Services, Port Harcourt.

Measurements of twenty five (25) fibres were taken at the top, middle and bottom of each ring in radial direction of three trees (David-Sarogoro and Amakiri, 2016) upon which the following ancillary properties of this species were calculated.

$$\text{Runkel ratio} = \frac{2 \times \text{Cell Wall Thickness}}{\text{Lumen width}}$$

$$\text{Flexibility ratio} = \frac{\text{Lumen width}}{\text{Diameter of fibre}} \times 100$$

$$\text{Slenderness ratio} = \frac{\text{Fibre Length}}{\text{Diameter of fibre}}$$

RESULTS

The ancillary fibre characteristics such as Runkel, flexibility and slenderness ratios were calculated based on the results from earlier analysis of main fibre properties (fibre length, diameter, lumen width and fibre wall thickness (Table 1) (David-Sarogoro and Amakiri, 2016).

Table 1: Fibre characteristics of *Anthocleista djalonensis*

	Radial Section	F. Length (mm)	F.Diameter (µm)	Lumen Width(µm)	F.W.Thickness (µm)
Top	outer	2.3	11.23	32.23	1.2
	middle	2.1	13.21	34.23	1.23
	core	1.5	13.87	21.24	1.4
	Average	1.96	12.77	29.23	1.27
Middle	outer	2.2	10.5	21.34	2.2
	middle	2.4	11.23	24.65	2.2
	core	2.1	13.24	25.67	2.3
	Average	2.23	11.65	23.88	2.33
Bottom	outer	2.3	21.34	12.45	2.3
	middle	2.1	21.75	13.45	2.5
	core	2.32	22.32	11.56	2.7
	Average	2.24	21.08	12.48	2.5

David-Sarogoro and Amakiri (2016)

Runkel Ratio of *Anthocleista djalonensis*

The result of Runkel ratio (Rr) of cross sections of the species showed that it is highest at the middlewood (3.25)

followed by outer wood (1.94) and lowest was at corewood (1.22) while in the vertical direction-merchantable height-the Runkel ratio was highest at middle (2.23) of the trees, followed by top (2.00) and bottom (2.19) (Figure 1). The difference in Runkel ratio between the cross section (radial) and vertical direction of the species is due to the orientation of the interstitial wood cells interfacing with their counterpart in the longitudinal section of wood.

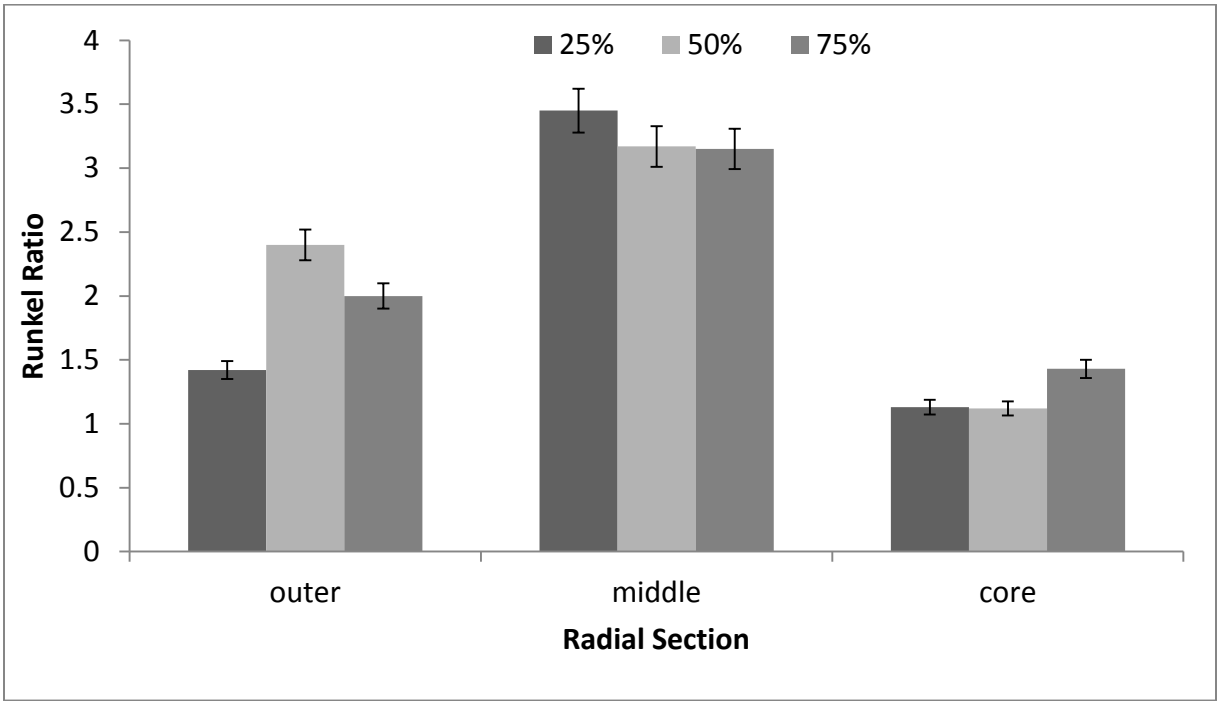

Figure 1: Runkel ratio of the *Anthocleista djalonensis*

Flexibility Ratio (FR) of *Anthocleista djalonensis*

The flexibility coefficient of *Anthocleista djalonensis* fibres decreased from top to bottom 158.66±0.61 to 104.16±0.65 (Table 2), in vertical direction and is higher than Paulownia (75), hornbean (44.59) and *Ailanthus altissima* -65.31 (Samariha *et al.*, 2011) with average FR 128.71.

Slenderness Ratio of *Anthocleista djalonensis*

The slenderness ratio of the species decreased with height from top to bottom-91.04±1.54 to 87.50±0.21 (Table 2) average was 87.76.

Table 2: Flexibility ratio of the species

Axial	Flexibility Ratio (%) Mean±Std. Dev	Slenderness Ratio Mean±Std. Dev
Top	158.66±0.61	91.04±1.54
Middle	123.30±0.43	84.75±3.53
Bottom	104.16±0.65	87.50±0.21

DISCUSSION

The average Runkel ratio of the species was 2.1 which was higher than hornbeam Rr of 1.24, cotton stalk (0.84); date palm rachis (0.8); Paulownia (0.34) and *Ailanthus altissima*-0.46 (Samariha, *et al.*, 2011). The limits of Runkel ratio ranged from 0.25 to 1.5 for species which produce pulp of reasonable quality and standard values of Runkel ratio are less than 1 (Screech and Rao,2014). Consequently, the average Runkel ratio of *Anthocleista djalonensis* was more than one ($R \geq 1$) indicating that the species is not suitable for paper making. The fibres are thickened with un-dissolved and sticky extractives that did not succumb to maceration or were partially macerated.

According to Bektas *et al.* (1999) flexibility ratio or elastic ratio is into four groups of fibers: (1) High elastic fibers having elasticity coefficient greater than 75: (2); Elastic fibers with elasticity ratio between 50 & 75; (3) Rigid fibers with ER-30-50; and (4) highly rigid fiber with FR less than 30. With this classification, *Anthocleista djalonensis* average flexibility coefficient which is 128.70, falls within the high elastic category. Since, there is positive relation between flexibility coefficient and burst (Ona *et al.* 2001), and breaking length and tear resistance (Mabilangan and Estudillo 1996), paper made from *Anthocleista djalonensis*, would be resistant to tear-tough and brittleness-shred. This finding disagrees with Samariha, *et al.*, (2011) which reported that more cell wall thickness of fibres causes more flexibility of fibre in the pulp refining process and that increase of cell thickness has direct effect on strength properties of fibres. Thus, the resulting paper strength and properties could be met.

Anthocleista djalonensis slenderness ratio (SR) of 87.76 is higher than *A. altissima* with 42.97 as reported by Samariha, *et al.*, (2011). Other species had the following SR- aspen (46.15); hornbeam (52.14); Paulownia (29.32) and cotton stalk (42.35). Plum stem and branch and Kiwi woods slenderness ratios were 73.28, 58.85 and 45.89 respectively (Majih *et al.*, 2014) while *A. djalonensis* had SR of 87.76. According to Xu *et al*. (2006) the acceptable value of SR for papermaking is more than 33, therefore, *Anthocleista djalonensis* 87.76 is quite suitable for papermaking from the SR perspective but not from Rr since the texture and brittleness of the wood cells are brittle. In terms of paper quality there is positive relationship between SR and folding endurance (Dinwoodie 1965, Ona *et al.* 2001).

In spite of the fact that the species is not suitable for paper making because of the Runkel ratio above 1, its flexibility is categorized highly elastic-fibre and the paper would be resistant to tear-tough and brittleness-shred. From slenderness ratio perspective, *Anthocleista djalonensis* 87.76 (more than 33 acceptable value SR) is quite suitable for paper making indicating the texture and brittleness of the wood cells. The resultant paper would have folding endurance and have recovery potency or poses resistance to folding or pressure on paper. The wood of the species is recommended for purposes like dye and pharmaceutical industries instead of paper making because of its non-suitability for paper and Runkel ratio above 1.

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