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Analysing biometrical properties of two species of *Ochlandra* culms for pulp and paper production

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Abstract
The culms of endemic reed bamboos seen in the Western Ghats of India, *Ochlandra wightii* and *O.travancorica* were selected for the study. This study evaluated various biometric properties and the suitability of these two species of *Ochlandra* for the pulp and paper production. The Runkel ratio, Slenderness ratio, Flexibility ratio and Shape factor of these *Ochlandra* species were studied using the culms selected from the two forest reserves. The culms of three different age groups, below 1year, 1-3years and above 3years were selected for both species from the forest reserves of Kallar and Bonacaud. Fibre maceration was done based on Jeffrey's method and the samples were stained and mounted on temporary slides using glycerine. The fibers were measured for length, width, lumen diameter and wall thickness. The microscopic evaluation and quantification of fibers were done using an Image Analyzer and the digitized images were analyzed with the help of Image Analysis Software. The results based on fibre measurements showed that the fibre characteristics help in evaluating the utilization values of bamboo fibres and influence the quality of paper. The present investigation shows variations in biometric properties over ages. It was analysed that the culms below 1 year and between 1-3 years were suitable for the production of better quality pulp and paper. Hence, these two reed bamboos of culms below 1 year and between 1-3 year old is highly suitable and recommended for the paper making instead of above 3 year old culms because of its non-suitability for the pulp and paper industry.

Keywords: flexibility ratio, *Ochlandra*, runkel ratio and shape factor and slenderness ratio

Introduction

Ochlandra is the 11 member genus with 10 species including the *Ochlandra travancorica* and *Ochlandra wightii* which are endemic to the Western Ghats of India and are seen only in the wet hill slopes and stream sides. Around 7.2 billion trees are needed to satisfy the global consumption of 400 million tons of paper (Brindha *et al*., 2021) [2]. Bamboos are the main raw material for the paper industry.

Hence, researches on different woody bamboos are being done over the past few years. But there has been very little work on the reed bamboos which determines the suitability of the culms for the pulp the paper making.

Bamboo fibers are sclerenchyma fibers mostly seen as sheaths. The fibre morphological features influence the tensile strength of paper (Clark, 1962). The fibre characteristics like fibre length, fibre diameter, lumen width and wall thickness affect the quality of paper (Zobel and Van Buijtenen, 1989) [11].

The biometric properties of fibre are dependent on these fibre characteristics. Samariha, *et al*., 2011[7], has explained that the runkel ratio is the factor that determines whether the fibre based specimen can be used for pulp making. Sreevani and Rao (2014) [8] and David-Sarogoro and Emerhi (2016) [3] has explained about the different ratios in their studies. Investigations on fibre dimensions of the fiber extracted from these reed bamboos have not been carried out so far. Hence, the fibers were extracted and analysed for various fibre characteristics to find out the suitability of the culms for the paper industry.

Materials and Methods

Sections of the culms were taken with the help of Sledge Microtome. Then, fiber maceration was done by following Jeffrey's method by mixing equal volumes of 10% Potassium dichromate and 10% nitric acid. The culm shavings were boiled in maceration fluid and kept aside for overnight. Then, the chips were washed thoroughly with distilled water to remove the acidity and stained with safranin for half an hour. The stained fibers were mounted on temporary slides with glycerine. Macerated fibres were measured using Image Analyser and analysed by the Image Analysis software. Measurement of 20 fibres were analysed at the three different age groups for both *Ochlandra* species and the following different properties were calculated.

Runkel ratio = 2 x Cell Wall Thickness /Lumen diameter
Slenderness ratio = Fibre length/Fibre diameter
Flexibility ratio = Lumen diameter/ Fibre diameter ×100
Shape factor= Fibre diameter^2- Fibre lumen diameter^2/ Fibre diameter^2 + Fibre lumen diameter^2

Result and Discussion

The fibre characteristics of both the species in different age groups (less than 1 year, 1-3 years, and above 3years) were calculated based on the analysis of fibres for their length, width, lumen diameter and wall thickness. Both broad and narrow fibres as well as long and short fibres were selected for the analysis.

Runkel ratio

The results for the analysis of runkel ratio (Table 1) show significance for both the species at all age groups in both the species. But both species have very little difference while comparing with their age groups. Runkel ratio is a very important factor in the pulp and paper industry. The limits of runkel ratio is found to be between 0.25- 1.5 for the species used in paper industry (Sreevani and Rao, 2014). But Volkomer (1969) [9], explains that if the Runkel ratio is less than one, the plant can be used in the pulp and paper industry. Fibres with runkel ratio below one is considered as fine raw material whereas equal to one as Secondary fibre raw material and greater than one as inferior fibre raw material. The values analysed for the culms of age group below 1year and 1-3 years shows a value less than 1and is considered as fine raw material. The average runkel ratio was more than 1 ($R \geq 1$) for the culms above 3 years of age in both the *Ochlandra* species. Hence, they are considered as inferior fibre raw material and these fibres will be stiff and less flexible. According to Bektas *et al*., 1999 [1], higher runkel values indicate lower paper strength properties. It indicates that the culms above 3 years of age are not suitable for making paper. The fibres will be more thickened and may not be completely macerated.

The results of ANOVA for the Runkel ratio, shows that there is significance in variation in both the species of *Ochlandra* and the values are significant at 0.05 whereas the analysis between the two species shows that there is not much variation within the same age groups in both the species for 1-3 years and above 3 years of age.

Table 1: Variation in Runkel ratio in the culm of *O.wightii* and *O.travancorica*

AGE	Species	
	O.wightii	***O.travancorica***
< 1 year	0.44 ± 0.06^{c}	0.65 ± 0.10^{b}
1-3 year	0.94 ± 0.08^{b}	0.92 ± 0.11^{b}
> 3 year	1.78 ± 0.15^{a}	1.50 ± 0.15^{a}
F-Value	39.90*	12.39*

*significant at 0.05 level

Means with same letter as superscript within column are homogeneous.

Slenderness ratio

Slenderness ratio is an aspect ratio that explains about the relativity of the fibers and the folding capacity of the specimen to be used in the paper industry (Dinwoodie, 1965; Ona *et al*. 2001) [4, 6]. There exist a positive correlation between the strength properties and slenderness ratio. Young (1981) [10] and Bektas *et al*., (1999) [1] have explained that if the slenderness ratio is less than 70, then it is not suitable for the production of better quality pulp and paper. Here, *O.wightii* shows all values above 70 for all age groups and *O.travancorica* shoes all values less than 70. Hence, according to those previous studies, it can be concluded that the culms of *O.wigh*tii is better compared to *O.travancorica* for the better production of Paper. But, Majid *et al*. (2014) [5], have observed that the accepted values of slenderness ratio have to be above 33 for the production of better paper. The bamboo culms are considered to be significant with a larger aspect ratio i.e., above 100 in many studies. If the aspect ratio is high, the expected fibre flexibility will also be more. The culms of both *O.wightii* and *O. travancorica* were above the accepted values as mentioned by Majid *et al*. (2014) [5]. But, *O.wightii* alone exhibited a value more than 70 in all age groups whereas *O.travancorica* shows a value between 40- 70 and were considered to be average fiber, suitable for paper production. The Analysis of Variance shows that, there exist variations in both the species of *Ochlandra* for the Slenderness ratio and the significance is at 5% level.

Table 2: Variation in Slenderness ratio in the culm of *O.wightii* and *O.travancorica*

AGE	Species	
	O.wightii	***O.travancorica***
< 1 year	90.73 ± 0.13^{b}	43.36 ± 0.92^{b}
1-3 year	110.92 ± 0.32^{ab}	49.03 ± 0.70^{ab}
> 3 year	122.90 ± 0.09^{a}	68.37 ± 0.45^{a}
F-Value	3.31*	3.80*

*significant at 0.05 level

Means with same letter as superscript within column are homo geneous

Flexibility ratio

Flexibility ratio explains about the bonding strength of the fiber and the tensile strength properties (Sreevani and Rao, 2014) [8]. According to Bektas, *et al*. (1999) [1], there are four groups of flexibility ratios. Ratio greater than 75 as high elastic fibre, between 50-75 as elastic, between 30-50 as rigid and less than 30 as high rigid fibres. Based on this classification, the culms below 1 year and 1-3 years old of both *Ochlandra wightii* and *O.travancorica* falls in the elastic category i.e., between 50-75. The culms in these age groups can be used in paper production. Also, above 3 year old culms fall in the category between 30- 50, which is considered as the rigid fibres. The present findings are in accordance with the findings of Samariha *et al* (2011). The results of ANOVA show significance at 5% in both *O.wightii* and *O.travancorica*. Also, there exist variations in the flexibility ratios of culms of 1-3year old and above 3 years old between both the species.

Table 3: Variation in flexibility ratio in the culm of *O.wightii* and *O.travancorica*

AGE	Species	
	O.wightii	***O.travancorica***
< 1 year	72.81 ± 0.99^{a}	66.72 ± 0.58^{a}
1-3 year	53.45 ± 0.54^{b}	57.07 ± 0.57^{a}
> 3 year	36.02 ± 0.19^{c}	43.36 ± 0.08^{b}
F-Value	39.64*	13.80*

*significant at 0.05 level

Means with same letter as superscript within column are homogeneous.

Shape factor

It has been found that fibres having low values for shape factor will yield better strength properties to the paper. The analysis shows that culms of both *Ochlandra* species, below 1 year exhibits lowest shape factor values compared to culms of other age groups.

The culms, above 3 years old, of both *Ochlandra* species showed the highest shape factor value. Hence the culms below 1 year and 1-3 years old can be used for better pulp and paper production. The results of ANOVA for Shape factor shows that there exist significant variations in both species of *Ochlandra*.

Table 4: Variation in shape factor (µm) in the culm of *O.wightii* and *O.travancorica*

AGE	Species	
	O.wightii	***O.travancorica***
< 1 year	0.31±0.03[c]	0.38±0.04[b]
1-3 year	0.55±0.03[b]	0.50±0.04[b]
> 3 year	0.75±0.03[a]	0.67±0.02[a]
F-Value	38.86*	13.80*

*significant at 0.05 level

Means with same letter as superscript within column are homogeneous

Conclusions

These fibre morphological ratios have great influence on paper properties and assessing the suitability of raw materials for pulping. The morphometric ratios are mainly depended on the fibre attributes. The investigations of different fiber ratios of both *O.wightii* and *O.travancorica* shows that the culms of age group below 1year and 1-3 years old is suitable for the production of paper than the culms above 3 years old. Hence the culms of below 1 year and1-3 years old of both these reed bamboos is highly recommended for paper making since these culms shows suitable Runkel, Flexibility and Slenderness ratios for pulp and paper making.

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