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The Effect of Beating Duration of Laboratory Blender on Pulp Fibre Characteristics of Bamboo (Bambusa vulgaris SCHRAD)

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Abstracts

This study investigated the effect of beating duration of a laboratory blender on the pulp fibre characteristics of bamboo (*Bambusa vulgaris* Schrad.**),** and the influence on handsheet formation. Chips of *B. vulgaris* were subjected to Kraft pulping in a 10 litre electrically heated stainless steel digester. Beating of the pulp obtained was carried out in a laboratory blender at 1500 rpm for four different durations of 5mins, 10mins, 15mins, and 20mins respectively. Fibre dimensions such as fibre length, fibre diameter, and fibre lumen width at control (unbeaten pulp) and at each beating level, were determined under a microscope. Other fibre morphological indices like cell wall thickness and Runkel ratio were calculated, using appropriate formulae. Handsheets at control and at each beating level were made for visual assessment of formation property. The results showed a general decrease in fibre morphological indices as the beating time increases from the control to 20mins beating level for all the fibre parameters except Runkel ratio which showed inconsistency in values. Analysis of variance for fibre dimensions conducted at 0.05 level of probability showed no significant difference for all the parameters assessed. The results also showed a better sheet formation, enhanced surface smoothness, and a decrease in bulkiness of the handsheets produced with increasing beating time. Hence, a laboratory blender in the absence of traditional valley beater can be used to modify pulp fibres to make them more conformable for paper making.

Keywords: *Bambusa vulgaris*, pulp fibr es, beating duration, blender, handsheet, morphological fibre indices.

Introduction

Paper is an indispensable material to mankind; for there is hardly any home without paper in one usable form or the other. From time immemorial, the writing and printing grade has served as the medium for recording and preserving history (FAO, 1991). Practically, paper has no rival as base material for hygienic and sanitary conveniences. Its application as a packaging material has been of tremendous success in the handling of several articles of commerce (Kline, 1992). Therefore, paper and paper products are essential parts of modern living, and it would be hard to imagine how our life styles would be without them (Noah, 2009).

Today's pulp and paper products are made from a variety of fibre types, including natural and synthetic fibres. Of the naturally occurring fibrous materials, wood has remained the major competitive raw material on a global scale for the pulp and paper industry due to its abundant availability, pulpability and renewability (RMRDC, 2003). However, increase in the demand of wood for pulp and paper production has threatened to exhaust pulp wood reserves year by year (FAO, 1997). Among the non-woody plants, bamboo has recommended itself as a veritable source for supply of alternative paper making fibres (Famuyide and Adejoba, 2004).

Bamboo fibres are long and they produce pulp with high mechanical strength, in many ways similar to the spring wood fibres of coniferous trees (Clark, 1992). Fibres are the ultimate constituents of paper. However, paper making properties are not only a function of the inherent morphological fibre characteristics, but are also to a great extent, influenced by the post-production treatment the pulp fibres might have received (Na Ayudhya, 2000). Beating is one of the post-production mechanically induced actions on pulp fibres. Generally, fibre length, cell wall thickness and to some extent fibre lumen width affect paper properties such as mechanical strength, sheet formation, opacity and smoothness (Tiikaja et *al*., 1998).

Bamboo pulp fibres respond to beating more rapidly and easily than do wood fibres, largely due to the difference in secondary cell wall structure between the fibres (Wai *et al.*, 1985). When pulp fibres are subjected to beating, three modifying effects are observed on the fibre - shortening and breakage of fibre at any angle across the length, tearing of fibre surface to increase its total

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surface area with the attendant exposure of microfibrils, swelling and softening of the fibres to make them more flexible and collapsible. (Smook, 1992). These beating effects are determined not only by the type of equipment used, type and nature of pulp fibres, but to a large extent, are influenced by such beating variables as beating duration, stock consistencies and temperature, amongst others (Clark, 1992).

Pulp fibres irrespective of the source, when processed into paper without any form of mechanical treatment (beating) produce paper characterised by poor sheet formation, low strength and surface roughness (Bhardwaj *et al*, 2004). Subjecting the fibres to beating in a highly controlled manner makes them more conformable for paper making (Bowyer *et al*, 2007). This work therefore was carried out to assess the effect of beating duration on pulp fibres of *B. vulgaris* for paper making, using a laboratory blender in the absence of traditional laboratory beater.

Table 1: Cooking conditions of kraft pulping.

Parameters	range
Liquor conc. NaOH/Na_2S (%)	60/30
Liquor to non-wood ratio	5:1
Cooking temperature	170^0c
Cooking time	3 hrs.
Vessel capacity	10litre
Pressure	7 bar

At the end of the cook, the softened chips of *B. vulgaris* were disintegrated in a disintegrator for better defiberisation into a mass of liberated pulp fibres. The brown pulpy mass was washed with distilled water to remove residual cooking chemical. The washed pulp was later screened with a screen plate of 0.15mm slots, and thereafter allowed to air dry for a day before oven-dried samples were taken to determine the pulp yield according to the formula:

$$\text{Pulp yield (\%)} = \frac{\text{oven dry weight of bamboo pulp} \quad \text{X } 100}{\text{oven dry weight of original bamboo chips}} \quad (1)$$

Beating process and microscopy

Samples of the unbeaten pulp were randomly taken and viewed under the microscope for determination of fibre dimensions at control level. Thereafter, at four different beating durations of 5 mins, 10 mins, 15 mins and 20 mins respectively, the bamboo pulp was subjected to beating in a laboratory blender at 1500 rpm. Samples of the beaten pulp fibres at each beating level were similarly mounted on a microscope for fibre dimension examination and determination.

Parameters determined

The parameters determined using microscope, were:

1. Fibre length of the sample: this was measured using the microscope by aligning the pulp fibre length sideways to the graduated ruler in the microscope.
2. Fibre diameter of the sample: the fibre diameter of the sample was also measured by placing the graduated ruler in the microscope in horizontal direction at the middle of the fibre.
3. Lumen width: this is the cavity of the cell from the first wall side to the second wall side.

Parameters calculated

- Cell wall thickness: this was calculated by subtracting the lumen width from the fibre diameter and dividing the difference by two.
  $$Cw = \frac{D-Lu}{2} \quad (2)$$
- Runkel ratio: this measures the amount of cell wall thickness with respect to the cavity (lumen width) of the fibre. Mathematically,

$$Runkel\ ratio = \frac{2CW}{Lu} \quad (3)$$

Where:

D = fibre diameter (µm)
Cw = fibre wall thickness (µm)
Lu = Lumen width (µm)

Hand sheet preparation

Twenty grammes of unbeaten and beaten bamboo pulp at each beating level were respectively disintegrated in 20 litres of water and then stirred vigorously to obtain

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total separation of the fibrous pulp into uniform suspension of individual liberated fibres. Mould of 10 µm slot size was dipped into the fibrous suspension to form handsheets at control and at each beating duration respectively. The sheet produced in each case was allowed to air dry after which, it was couched off with the aid of spatula and later cut into sheet samples of 10cm×10cm for visual assessment of formation property.

Statistical analysis

Data collected during the study were subjected to analysis of variance (ANOVA) in a completely randomized design (CRD) to examine the level of significance of the effect of treatments. The mathematical model adopted for the designs is given below:

$$Y_{ij} = \mu + T_j + e_{ij}$$

Where,

Y_{ij} = Individual observation

μ = General mean

T_j = Effect of jth treatment

e_{ij} = Experimental error containing all uncontrolled sources of variation.

Results and discussion

Table 2: Cooking results

Parameter	value
Screened pulp yield	47.50%
Rejects	0.35%
Residual active alkali	18g/l as Na_2O
Sulphidity	30%

In Table 2, the kraft pulping of the bamboo chips gave a screened yield of 47.50%, which is slightly higher than 46.32%, reported by Sulphat *et al.,* (2007). The variation can be attributed to biotic factors affecting the bamboo species used and the kraft cooking conditions adopted.

Table 3: Mean values of beating effect on pulp fibre characteristics of Bambusa vulgaris

Parameter	control	5mins	10mins	15mins	20mins
Fibre length (mm)	2.65±0.20	2.55±0.34	2.33±0.16	2.22±0.35	1.91±0.21
Fibre diameter (µm)	15.88±1.87	15.10±2.18	13.95±1.96	12.06±1.63	11.62±1.80
Lumen width (µm)	9.82±1.13	9.22±1.54	8.35±1.13	7.07±0.99	6.85±1.10
Cellwall thickness (µm)	3.03±0.10	2.94±0.43	2.78±0.45	2.50±0.37	2.38±0.46
Runkel ratio	0.63±3.19	0.64±0.07	0.66±0.66	0.71±0.06	0.70±0.08

The results in Table 3 show mainly a decreasing pattern in the fibre characteristics of bamboo pulp fibres as the beating duration increases (Mollin and Daniel, 2004 and Rushdan, 2003).

Fibre length

The highest value for fibre length was observed at control (2.65mm) and the lowest value of 1.91mm after 20mins of beating duration. As the beating duration increases fibre shortening increases, resulting in the production of more fines to fill the interspaces between fibres for a better and even sheet formation (Noah, 2009). Furthermore, the influence exerted by the fibre length of the unbeaten pulp reflects low fibre-to-fibre bonding, resulting in weak paper with poor formation, coarse and rough surface characteristics (Oluwadare and Sotannde, 2007).

Fibre diameter

With increasing beating time the fibre diameter decreases from 15.88µm at control to 11.62µm after 20 mins of beating action. The reduction observed in the fibre diameter after treatment (beating) is somehow expected due to the tightening of the cell wall structure as the beating increases (Paavilainen, 1993).

Lumen Width

The lumen width has the highest value of 9.82µm at control and the lowest value of 6.85µm at 20 mins level of beating. This decreasing pattern is also in line with Ahmad (2011) in his work on bagasse CMP fibre characteristics. Fibre lumen width plays a major role in the beating property of pulp fibres. The larger the fibre lumen width, the better the response to beating of the fibres, largely due to the ease of penetration of liquid into the empty space of the fibre (Ghatak, 2003).

Cell wall thickness

The value of cell wall thickness decreases from 3.03µm to 2.38µm as the beating duration increases. Cell wall thickness is one of the variables in determining Runkel ratio, an important fibre morphology index in pulp and paper processing. As beating time increases, there is a reduction in the fibre cell wall order, making the fibre

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thinner and more flexible. Hence the fibres become more mobile to spread out before collapsing into uniform and evenly bonded paper web (Kure, 1997)

Runkel ratio

The suitability of pulp fibres for paper making can be adjudged by the ratio of the fibre cell wall thickness to its lumen width. This proportionality is called Runkel ratio. Fibres with low Runkel ratio (RR<1) are considered to be very good for paper making (Noah, 2009). In Table 3, the values of Runkel ratio obtained are less than 1, ranging from 0.63 at control to 0.71 as the beating time increases to 15mins before beginning to decrease to 0.70 at 20mins beating level. This pattern of variation is in line with Ahmad (2011) in his work on the effect of increasing beating values on CMP bagasse fibre characteristics.

Table 4: Analysis of variance of effect of beating duration on bamboo pulp fibre characteristics

		F calculated				
Sources of variance	D.f	F. l	F .d	L .w	C w t	R .R
Treatment	4	1.260^{NS}	0.959^{NS}	1.193^{NS}	0.041^{NS}	0.382^{NS}
Error	45					
Total	49					

NS – not significant at 0.05 level of probability.

Table 4 shows that at 0.05 level of probability, there was no significant difference in fibre length, fibre diameter, lumen width, fibre wall thickness, and Runkel ratio between the treatments (beating duration). This is contrary to Ahmad (2011) in his work on CMP bagasse pulp fibres and Rushdan (2003) in his findings on the effect of refining on fibre morphology and drainage time of soda pulp derived from oil palm empty fruit bunches (EFB). This may be attributed to the type and configuration of the beating or refining equipment used.

And for this study, it may be specifically due to space (clearance) between the walls of the containing vessel of the blender when compared to the compact contact area of a laboratory valley beater or industrial refiner.

Conclusion

The bamboo chips were successfully pulped for a screened yield of 47. 5%. The results of the work also showed that the pulp fibre characteristics of *B. vulgaris* were in the main decreased by increased beating duration in a laboratory blender. As the beating time increased, fibre shortening and production of fines intensified. The fibres also became more flexible and fibrillated, resulting in better sheet formation with enhanced surface smoothness.

The study showed that bamboo pulp fibres because of their long length should be modified by beating for better sheet formation, especially when producing paper grade for writing and printing purposes, where ink receptivity and printability are a function of formation property of the sheet. Laboratory blender can be used for research work in our institutes to modify pulp fibres for better web conformability, where the traditional valley beater is not available

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Figure 1: Handsheets produced at control and different beating levels
Figure 1: Handsheets produced at control and different beating levels

Control

5 Mins

10 Mins

15 Mins

20 Mins

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