Journal of Forestry Research and Management. Vol. 19(4).79-85; 2022, ISSN 0189-8418

www.jfrm.org.ng

Effects of Beaten Time on Fibre Characteristics of *Ceiba Pentandra Linn.* (Araba)

Ademola A. Adeola[1]*, Adekunle E. Abiodun[2], Alao, J. Oluwaseyi[1] Ayodele O. Olubunmi[1,4], Isola F. Bose[3], Adeniyi M. Ifedayo[1]

[1]Forest Products Development & Utilization, Forestry Research Institute of Nigeria, PMB 5054, Dugbe, Ibadan, Nigeria.
[2]Biotechnology Department, Forestry Research Institute of Nigeria, PMB 5054, Dugbe Ibadan, Nigeria
[3]Research coordinating Unit, Forestry Research Institute of Nigeria, PMB 5054, Dugbe Ibadan, Nigeria
[4]Nanoscience Department, The Joint School of Nanoscience & Nano engineering, University of North Carolina, North Carolina 27401, USA
*adeolaademola47@gmail.com, or ademola.aa@frin.gov.ng

ABSTRACT

Ceiba pentandra is one of the wood specie whose fibre length among other morphological indices is used in determining the paper potential of wood species and beating is a function of of the quality of paper thatt would be produced. Beating time and suitability of *Ceiba pentandra* for pulp and paper production were investigated in this study. Test samples were collected and chipped into smaller sizes before beating at different periods namely 5 minutes, 10 minutes, 15 minutes and 20 minutes. After pulping, the fibres were macerated in equal volume of acetic acid and hydrogen peroxide and were measured under a light microscope. The were analysed using Complete Randomized Design (CRD) was adopted for the analysis of variance at 5 % level of probability The results showed that average fibre length, fibre diameter, fibre lumen width and fibre cell wall thickness of *Ceiba pentandra* wood were 2.32 mm, 50.00 µm, 40.00 µm, and 5.00 µm. Runkel ratio was 1.00, while the wood had a high percentage of tensile and bursting strength (co-efficient of suppleness) of 67.90 % and felting power of 68 %. Continuous beating time showed decrease in the fibre length, by 26.78 %, (Fibre diameter by 91.79 %, lumen width by 161.61 %, fleting power by 21.97 % and runkel ratio by 112.77 %. The other parameters such as cell wall thickness and slenderless increase by 61.17 % and 20.82 %. This show particular trend in variation. These show that the beating time had a great influence on the wood fibre dimensions.

Keywords*:* Pulping, *Ceiba pentandra*, fiber, characteristics, beating time.

Introduction

Wood is one of the most important forest products from plants (trees) which have a vast array of application and use in furniture making, medicinal purpose, construction, erosion control, making tools, shelter belt, domestic cooking utensils, ornamentals, manufacture of pulp and paper, manufacture of cellulose derivatives and many more. Paper and paper products are being produced from a variety of fibre types which includes natural and synthetic fibre (Thakur and Thakur, 2004). However, properties of paper has been connected and traced to dinmensional characteristics of the fibres like fibre length, lumen width, cell wall thickness and fibre diameter (Akpan Noah, 2009).

Pulp is a product derived from wood and other cellulosic plant materials through mechanical or chemical treatment. In pulp and paper technology, the selection of pulping process is identified based on the type of fiber, final product, and economic factors (Ainun *et al.,* 2018). The continued growth and economic considerations of the pulp and paper industry depends on availability of wood with propitiate quality and cost (Walia *et al*., 2009). Pulps are produced in the integrated pulp and paper mills, and softwood kraft or sulfite pulp is added to provide the strength requirements to the paper (Bajpai 2015) The process of Pulping of wood or other biomass material has to undergo some degree of chemical or mechanical action to free the fibers either individually or as fiber bundles from an embodying matrix (Ilyas *et al.*, 2022). there are four broad categories of pulping processes: (1) chemical, (2) semi-chemical, (3) chemi-mechanical, and (4) mechanical pulping.

These are in order of increasing mechanical energy required to separate fibers and decreasing reliance on chemical action (Bajpai 2015). The mechanical pulping process uses intensive electrical energy to beat the fibres and produces paper of higher color reversion rate due to the high content of lignin, to degrade and dissolve the lignin, which at the end leaving high strength cellulose fibers from the cell wall (Page, 2018). The research effort on beating of fibres has been substantial and protracted, this technique has been dated back to the early years of the 20th century (Page, 2018). The existing state of knowledge of the beating principles involves in pulping process is distinctly unsettled. Some articles have show better paper qualities through beaten technique, Ilyas *et al*., (2022) reported in his study that beating bamboo fibre high tensile index results in low tear strength than when which is a behavior between both the tensile index and tear strength of beating pulp. It has also showed that beaten fibres gives high inter-fiber bonding strength which resulted to higher tensile index, higher tear index, higher folding endurance and gives a good of burst index (Daud *et al.,* 2018).

Although much is known of the structure of wood pulp fibre, too little of this knowledge has been applied in beating research, because there are no rapid generally available techniques for measuring the relevant parameters. The average fibre length and its distribution can be rapidly measured as well as the average coarseness (Page, 2018). However, there is no technique presently available to measure the distribution of coarseness in paper making. Moreover, coarseness is not itself an adequate descriptor of the transverse fibre dimensions. It has been known that fibre of the same coarseness can have quite different wall thicknesses, and presently no rapid method of determination the wall thickness. Researchers still find it difficult to know whether the coarser the fibre of a furnish the more or less resistant to beating, the answer to the coarseness may shed considerable light on the action of the beater. It has also being rare for researchers to characterize their pulps by providing values of fibre length, coarseness and wall thickness, and yet it is difficult for others to interpret their results unless this is done . At the cell-wall structural level of the wood, the layers P, S1, S2 and S3 play a key role, of which certainly the S1 and S2 layers play separate roles in the beating effect. It is known to differ greatly in thickness from spruces to pines (Page, 2018).

Meanwhile considering the time influence to technical effect of beating time in pulp and paper making, it is important to carry out research on effect of beating mechanisms on tropical wood species. Some tropical wood species have been found to be suitable for production of pulps and there is need to understand the effects of time taken in beating technique. Among those tropical wood species, is found to be *Ceiba pentandr*a. *Ceiba pentandra* was considered for this study because it has large lumen cells with exceptional liquid retention capability (Teik and Xiaofeng,2007). Therefore the aim of this study was to investigate the effects of beating time on fibre characteristics of *Ceiba pentandra* that is indigenously known as Araba.

Materials and Method

Wood samples of *Ceiba pentandra* were collected from Iwo in Osun state. The samples were chipped into smaller sizes and then prepared into slivers of 3mm x10mm and macerated in equal volume of acetic acid and hydrogen peroxide (1:1) and placed in an oven for 2hours at a temperature of 100°C beat for different periods namely 5 minutes, 10 minutes, 15 minutes and 20 minutes respectively through crushing. Maceration after beating was done at Wood Anatomy Laboratory in Forestry Research Institute of Nigeria, Ibadan in accordance with ASTM D 1413-61 (2007). Twenty-five (25) macerated fibres were randomly selected and dropped on a microscopic slide (Dutt *et al.*, 2012).

All the characteristics namely, fibre length, fibre diameter, lumen width was viewed under a stage micrometer mounted on a Zeiss light microscope (Standard 25) at 80×. Twenty-five (25) fibres were measured from each sample slide. Complete Randomized Design (CRD) was adopted for the analysis of variance at 5 % level of probability, the level of significance between the different time of beating was determined using follow up test while mean values was obtained using descriptive statistic. **Derived Morphological Indices**

Four derived morphological indices (Equation 1-4) of the fibre were calculated based on the methods adopted by Saikia *et al.* (1997); Ogbonnaya *et al.* (1997); Ververis *et al*., (2004); Oluwadare and Sotannde, (2006), Thus,

$$Cellwall\,thickness = \frac{Fibre\,diameter - Lumen\,width}{2} \quad \ldots\ldots\ldots\ldots (1)$$

$$Slenderness = \frac{Fibre\,length}{Fibre\,diameter} \quad \ldots\ldots\ldots (2)$$

$$Flexibility\,ratio = \frac{Lumen\,width}{Fibre\,diameter} \times \frac{100}{1} \quad \ldots\ldots (3)$$

$$Runkel\,ratio = \frac{2 \times cellwall\,thickness}{Lumen\,width} \quad \ldots\ldots (4)$$

Results and Discussion

Beating Time Variation

Results from Table 1 showed that the highest FL (2.37 ± 0.04 mm) was observed in the control. Decrease in fiber length was observed with continuous beating time, that is, the longer the period of beating, the more the fibre length reduces. Just like fibre length, other parameters (Fibre diameter 50.00± 2.00(μm), lumen width 40.00 ± 2.00 (μm), cell wall thickness2.00 ± 1.00 (μm) and runkel ratio 1.00 ± 0.47 decreased with increase in beating time except for flexibility ratio? 68.00 ± 0.10 % and slenderness? 67.90± 10.33 which does not show any particular trend of variation (Table 1).

Table 1: Fibre Characteristics after beating at regular intervals

TIME (min)	FL (mm)	FD (µm)	LU (µm)	CW (µm)	F%	SL	R.R
0	2.32 ±0.63[a]	50.00 ± 2.00a	40.00 ± 2.00a	2.00 ± 1.00d	68.00 ± 0.10a	67.90 ± 10.33c	1.00 ±0.47a
5	2.09 ± 0.11b	30.72 ± 0.64b	19.33 ± 0.26b	7.83 ± 0.17a	63.11 ± 0.09b	68.86 ± 0.07b	0.90 ± 0.00b
10	1.97 ± 0.07c	27.94 ± 1.01c	18.39 ± 0.14c	5.87 ± 0.16b	61.70 ± 0.36c	63.64 ± 0.02e	0.86 ± 0.01c
15	1.97 ± 0.05c	26.84 ± 0.16d	16.99 ± 0.13d	5.19 ± 0.42c	58.93 ± 0.07e	77.85 ± 0.08a	0.59 ± 0.01d
20	1.83 ±0.09d	26.07 ± 0.14e	15.29 ± 0.15e	5.15 ± 0.14c	59.75 ± 0.29d	65.75 ± 0.16d	0.47 ± 0.02e

Denotes : FL = Fibre Length; FD = Fibre Diameter; LU = Lumen Width; CW = Cell Wall thickness R. R = Runkel ratio; C.F =Flexibility; S.L =Slenderness

Table 2: Analysis off variance for beating time

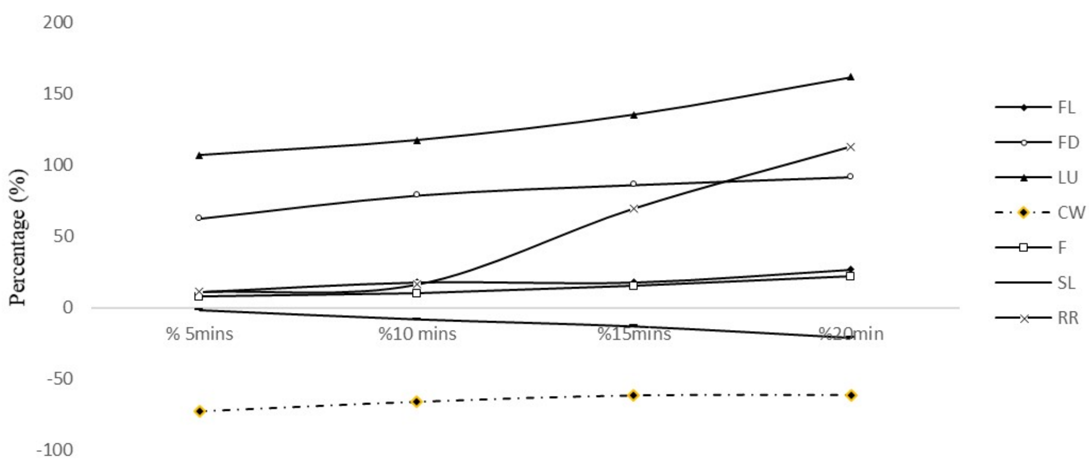
Source of variance	df	Fibre lumen		Fibre diameter		Lumen		Cell wall		Runkel ratio		Coefficient factor		Slenderness	
		F Cal	Sig.	F Cal	Sig.	F Cal	Sig.	F Cal	Sig.	F Cal	Sig.	F Cal	Sig.	F Cal	Sig.
Beaten time	4	7.29	0.00*	13.13	0.00*	14.76	0.00*	77.34	0.00*	30.32	0.00*	28.48	0.00**	28.46	0.00*
Error	10														
Total	14														

*represents significant at $p < 0.05$

The outcome of the analysis of variances are summarised in Table 2. As presented in Table 2, all the values obtained for significances were lower to the standard value of level of probability at 0.05. since the values are lower than the level of significance, it ther implies that beaten time investigated are significant across all the properties assessed. The outcome of the analysis of variance presented in Table 2 shows that there was need for follow up test which was carried out using Duncan Multiple Range Test at 5 % level of probability. Trhe outcome of Duncan Mutiple Range Test were presented as alphabetical letters attachment alongside with the mean values on Table 1. The parameters such FL, FD, LU, F% and RR had the highest values for fibres beaten at 0 mins followed by 5 mins, then 10 mins and 15 mins and 20 mins. It was also presnted in Table 1 that fibre beaten at 0 mins had lowest values for CW and SL.

This study shows that as the beaten period increases, the values for FL, FD, LU, F% and RR decreases while CW and SL increases (Figure 1). The values obtained in this were found to be in agreement with the work of Samariha, (2011) and Akpan Noah, (2014). Oluwadare, (2007) reported that fibre length generally influences the tensile strength of paper, the greater the fiber length; the higher will be the tearing resistance of paper formed. The effect of beaten time influence the fibre length and others properties such as the tensile strength of the paper that will also be reduced. As illustrated in Figure 1, the fibre length, fibre diameter, lumen width, runkel ratio and coefficient of flexibility had percentage decrease accordingly from 5 mins to 20 mins by 26.78 percents, 91.79 percents, 161.61 percents, 112.77 percents and 21.97

percents while cell wall and slenderness had percentage increase by 61.17 percents and 20.82 percents. In this study, the average value of fibre length obtained for *Ceiba pentandra* is 2.316 mm and was found to be higher that the fibre length recorded for *Gmelina arborea* at 1.5 mm which had been recommended for pulp making (Ademiluyi and Okeke, 1973). This study also revealed that at 20 mins beaten time, the fibre length of *Ceiba pentandra* was found to be higher than the proposed fibrelength for *Gmelina arborea*. This study did not only revelaed the best beaten period for paper making but also proven that fibre length of *Ceiba pentandra* is also good for paper making.



FL reps. Fibre length; FD reps. Fibre diameter; LU reps Lumen width; CW reps Cell wall; F % reps. Coefficint; SL reps Slenderless and RR reps Runkel ratio

Figure 1: Percentage changes in pulp characteristics to beaten time

The coarseness found in wood could be as a result of large diameter of fibre, big lumen width and as sizes of cell wall have a great influence on coarseness and smoothness of the paper. It was seen in this study that as the beaten period increases, fibre diameter and lumen width decreases implies that coarseness and smoothness of the paper graually improves. This in turn will either reduce or increase the cost of feelers during paper making. Runkel ratio of 0.89 and the co-efficient of suppleness (67.90%) also support the wood species for paper making as co-efficient of suppleness or flexibility co-efficient is generally used as a guide for assessing the degree of fiber –bonding of the paper made from particular specie (Ververis *et al.,* 2004). The higher the co-efficient, the greater is the tensile strength paper and so is the corresponding bursting strength, because of the good inter- fibre bonding. Hence *Ceiba pentandra* with high co-efficient of suppleness (67.90 %), is expected to yield well–bonded pulps than medium and high-density woods with low co-efficient. The influence of felting power on paper properties is small compared to the effect of fiber- length and cell wall thickness. Therefore, while considering the result obtained from the experiment, it added to the fact that the wood of *Ceiba pentandra* is suitable in pulp and paper making which follows the dictate that the accurate size of average fiber for any woody materials must be in the range of about 2.5 mm in length and Runkel ratio must be less than 1 in order to have a very good fibre quality. Yet, increasing the beating time for *Ceiba pentandra* during wood pulping could have a negative impact on the fibre length. This decrease in fibre length as a result of increase in beating time is in line with the finding of Moliu and Daniel (2004).

Conclusion

The chips from C*eiba pentandra* wood were successfully beaten with different time variations to determine pulping potential. Based on the result obtained from the maceration of *Ceiba pentandra* from this study has shown that the fibre of *Ceiba pentandra* after beaten process made it to be suitable for pulp and paper making. It has been revealed that beating time can as well affect the size of fibre length for paper making which significantlty affects the tensile strentgh of paper.

Recommendations

In order to encourage the use of indigenous wood species for paper making in Nigeria. The need to study and investigate low cost production techniqnies is highly important for paper industry. This study therefore recommend beaten time as an important criteria for paper quality in paper making industry in Nigeria.

References

Ademiluyi, E. and Okeke, R.E. (1973). Studies on the Specific Gravity and Fibre Characteristics of *Gmelina arborea* in some Nigerian Plantations. *Nigerian Journal of Sciences* 13: 132 – 242.

Ainun Z.M.A., Muhammad, K.I, Rasmina, H., Hazwani, H.A, Sharmiza, A, Naziratulasikin, A.K. and Latifah, J. (2018). Effect of chemical pretreatment on pulp and paper characteristics of bamboo *Gigantochloa scorthechinii*. Kraft fibers. *IOP Conference Series: Materials Science and Engineering*, 368: 012044. DOI 10.1088/1757-899X/368/1/012044

Akpan Noah, J.K, Abiola.,S.S.Okokoro. and Oluwatobi Aba (2014). The Effect of Beating Duration of Labratory Blender on Pulp Fibre Characteristics of Bamboo, (*Bambusa vulgaris* SCHRAD). *International Journal of Engineering Sciences &Research Technology*. 3(8): 804-809

American Society for Testing and Materials (ASTM) (2007). ASTM D1413-61 – "Preparation of decayed wood for microscopical examination", ASTM International, West Conshohocken, PA, 2007.

Bajpai, P. (2015). *Green chemistry and sustainability in pulp and paper industry*, 1st edn. Springer International Publishing, pp 65–84

Daud, Z., Hatta, M.Z.M., Ridzuan, M.B., Awang, H., Adnan, S. (2018). Studies on physical and mechanical properties by soda-AQ pulping of Napier grass. *Defect and Diffusion Forum*, (DDF), 382: 318-321.

Dutt D., Arvind Kumar S., Swarnima Agnihotri and Archana Gautam, (2012). Characterization of Dogs Tooth Grass and its Delignification by Soda pulping process. *Journal of Science and Technology*, 1(8): 434-447

Iiyas R.A, Harussani M:M, Ibrahim Z:M:A. Ainum,(2022). Pulp and Paper Making from

Sustainable Lignocellulosic Bamboo.8 Postgraduate Seminar on Natural Fibre Composites & Undergraduate Seminar on Fabrication and Characterization of the Composite Materials. (FCCM2022). ISSN: 2821-3351

Moliu. U and Daniel, U. (2004). Effect of Refining Online Fibre Structure of Kraft

Pulps as revealed by SEM and TEM. *Holzfirschung*. 58(53): 226-232.

Ogbonnaya C.I, H. Roy-Macaulay, M.C Nwadozie and D.J.M Annerose, (1997). Physical and Histochemical Properties of Kenaf (*Hibiscus cannabinus*) Grown under water on a sandy soil Ind. *Crop Production* 7: 9-18

Oluwadare A. O, Sotande O.A. (2006). Variation of the fibre dimensions in the Stalks of Miraculous berry (*Thaumatococcus daniellii* Benth). *Production Agriculture and Technology (PAT) Journal*, **2**(1): 85-90

Oluwadare, A.O. (2007). Wood Properties and Selection for Rotation Length in Caribean Pine (*Pinus caribaea* Morelet) grown in Afaka. *American-Eurasian J. Agric. & Environ. Sci*., 2 (4): 359-363

Page, D.H. (2018). *The beating action of chemical pulps—The action and the effects in The Fundamentals of Papermaking*, Trans. IXth Fund. Res. Symp. Cambridge, 1989 (C.F. Baker and V. Punton, Eds.), FRC, Manchester, pp. 1-38

Saikia, S.N., Goswanni, T. and Ali, F., (1997). Evaluation of pulp and paper making characteristics of certain fast growing plants. *Wood Sci. Technol*. 31: 467-475

Samariha, A. (2011). Effect of Beating Value on Bagasse CMP Pulp Fiber Characteristics. *World Appl. Sci. J.,* 12(11): 1987-1988.

Sherif S.Z. Hindi (2017). Some Promising Hardwoods for Cellulose Production: I. Chemical and Anatomical Features. *Nanoscience and Nanotechnology Research*. 4(3):86-97. doi: 10.12691/nnr-4-3-2

Teik-Thye Lim, Xiaofeng Huang, 2006. Evaluation of kapok (*Ceiba pentandra* (L.) Gaertn.) as a natural hollow hydrophobic–oleophilic fibrous sorbent for oil spill cleanup. Journal of Elsevier, chemosphere 66 (5): Pp 955-963. https://doi.org/10.1016/j.chemosphere.2006.05.062

Thakur, V. K. and Thakur, M. K. (2004): Processing and characterization of natural cellulose fibers/thermoset polymer composites. *Carbohydrate Polymers*, 109: 102-117.

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P. and Santas, R. (2004). Fiber Dimensions, Lignin and Cellulose Content of Various Plant Materials and Their Suitability for Paper Production. *Industrial Crops and Products*, 19: 245-254. http://dx.doi.org/10.1016/j.indcrop.2003.10.006

Walia, Y. K., Kishore, K., Vasu, D., and Gupta, D. K. (2009). Physico-chemical analysis of *Ceiba pentandra* (Kapok). *International Journal of Theoretical and Applied Sciences,* 1(2): 15-18