The Characteristics of Beaten and Unbeaten Mixed Tropical Hardwood Kraft Pulp

Nyoman J Wistara, Hotman Effendi

Department of Forest Products, Bogor AgriculturalUniversity
Kampus IPB Darmaga, Bogor Indonesia 16680

Corresponding author: nwistara@ipb.ac.id (Nyoman J Wistara)

Abstract

In the present works, pulp fibers were fractionated with Bauer McNet fiber fractionators and were classified into long fiber (R30), short fiber (P30/R100) and fines (P100/R200). Water retention value (WRV), dimensions measurements and pulp viscosity of fibers were determined based on of the modified method of Thode *et al.* (1960), the standard method of SII 1883-1986 and TAPPI 230 om-94, respectively. The measurement of fiber dimensions were done on 200 individual fibers. The increase of short fiber fraction clearly indicated fiber shortening effect of beating process. Beating processes increased WRV of fines above that of long fiber fraction. Beating of pulp did not significantly change the derivative value of fibers, but significantly decreased pulp viscosity.

Key words: fiber classification, fines, pulp beating, water retention value (WRV).

Introduction

Paper quality is determined by pulp fiber characteristics and its production processes. Stock preparation and paper making change the properties and quality of fibers, mainly due to drying stage in which water evaporate from the fiber surface (Walsh 2006). Moisture content reduction bring about hornification of cellulosic fiber that has been proven to occur when moisture content of paper sheet drastically decreasing in the wire of paper making machine (Park 2006). Hornification is the change in physical and chemical properties of cellulose fiber due to irreversible hydrogen bond formation upon fiber drying. The process brings about physical contraction of the cell wall and obstruction of cell wall pores. Hornification reduces water adsorption and swelling of fibers (Park 2006), thus reducing interfiber bonding and paper strength.

In contrary to that of drying, pulp beating promotes fiber swelling and interfiber bonding potential. In beating process, fiber is subjected to mechanical treatment that results in fibrillation and increase the fiber surface area. These will increase strength properties of paper that require a good interfiber bonding such as that of tensile strength. However, pulp beating brings about fiber shortening and reduces strength properties that dependent on individual fiber strength such as that of tearing resistance (Scott & Abbott 1995). Secondary fines resulted from pulp beating have been known to improve interfiber bonding potential of paper (Hubbe & Heitmann 2007). Internal and external fibrillations of the fiber increase the flexibility of fiber and improve its swelling capacity. These are important properties to produce paper with a high strength (Walsh 2006).

Characterizations of fiber alteration after beating and drying exposure have been carried out by several researchers (Wistara *et al.* 1999, Kang & Paulapuro 2006, Park 2006). However, characterization of fiber change at various stages of stock preparation and formation has not been investigated to a greater extent. In the present research measurement of physical characteristics and fiber dimension due to beating and dewatering processes during paper making was carried out. This information is very important to determine beating level that result in specified paper strength.

Materials and Methods

In general, the present research included the measurement of moisture content, fractionation of pulp (into 30, 50, 100, 150 and 200 meshes), measurement of pulp viscosity, measurement of water retention value (WRV), and fiber analysis and its derivative. Unbeaten and beaten mixed tropical hardwood (MTH) kraft pulp samples were generously donated by PT. Riau Andalan Pulp and Paper, Sumatera-Indonesia. The scheme of the works is outlined in Figure 1.

Fractionation on beaten and unbeaten pulp was carried out in accordance with standard procedures of SNI 14-1552-1998 by Bauer McNet fractionators. WRV was measured following the method of Wistara (1999). Pulp viscosity was determined based on standard method of TAPPI T 230 om-94 and fiber dimension analysis was based on standard method of SII 1883-86. Fiber length measurement was carried out on 200 individual fibers and on 50 individual fibers for the measurement of fiber diameter and lumen. Light microscope equipped with camera and computerized processing unit was used in fiber dimension analysis. Magnification of 40 and 400 was applied to measure fiber length and fiber diameter and lumen, respectively. Fiber length, fiber diameter and lumen diameter were used to calculate Runkel ratio, felting power (slenderness), Muhlsteph ratio, coefficient of rigidity and flexibility ratio.

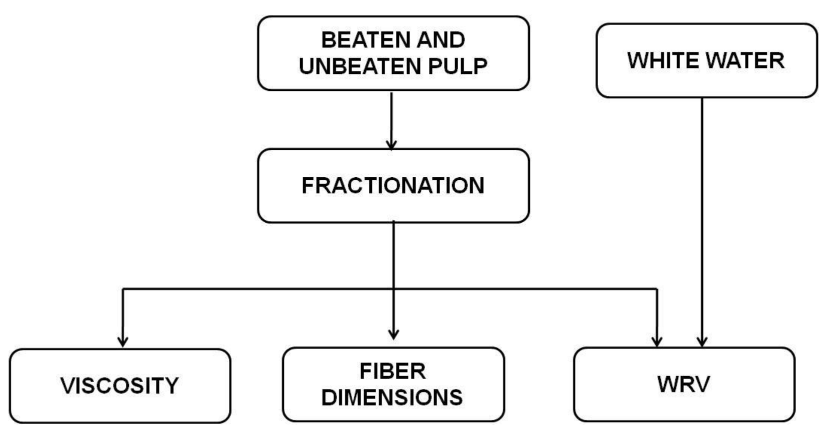

Figure 1 General outline of the present experiments.

Results and Discussion

Fractionation of beaten and unbeaten pulp was intended to determine the content of long fiber, short fiber and fines in pulp. We were unable to fractionate white water in the present experiment due to its very low fiber content and limited amount of sample was collected. The fiber content of white water was approximately 5% (Casey 1980). Figure 2 indicates the distribution of each fiber measurement. It can be seen that the content of short fiber (P30/R100) was the highest followed by fines (P100/R200) and long fiber (R30). Long fiber content of unbeaten pulp was higher than that of beaten pulp due to fiber shortening occurred by mechanical action of pulp beating (Park 2006). The increase of short fiber content will decrease certain pulp and paper strength (Walsh 2006), mainly tear strength that is dependent on fiber length (Hubbe & Heitman 2007).

Fines fraction of beaten pulp was higher than that of unbeaten pulp. External fibrillation of fiber cell wall of the beaten pulp (Hiltunen 2003) brought about the high content of very short fiber fragments that compose the fines (Paavilainen 1990 in Wistara 2000).

WRV of pulp indicates the capacity of pulp to retain water and indicative to the degree of fiber swelling or internal fibrillation. High WRV indicates that the fiber is well fibrillated and this could improve strength properties of paper (Klungness *et al.* 2000). The average values of the WRV of beaten pulp, unbeaten pulp and white water are depicted in Figure 3. It can be seen from Figure 3 that for the pulp that was not fractionated, the highest WRV was found for beaten pulp successively followed by these of pulp from white water and unbeaten pulp. WRV of white water was measured up to only R0 (unfractionated fiber) due to the very limited amount of sample. When pulp was fractionated, WRV of fiber fractions from beaten pulp successively increased from long fiber to fines. It was in contrary to beaten pulp, WRV of fiber fractions from unbeaten pulp successively decreased from long fiber to fines. These finding indicates that fines of beaten pulp was mainly composed of secondary fines and fines of unbeaten pulp was dominated by primary fines. It has been reported that the surface area and capacity to retain water of primary fines was low (Niskanen 1998).

WRV of beaten pulp was higher than that of unbeaten pulp presumably due to external and internal fibrillation of fiber in conjunction with the high content of fines in beaten pulp. The capacity of fines to retain water is higher than that of fiber (Hubbe & Heitmann 2007) and internal and external fibrillation of beaten pulp increases the swelling capacity of fibers. It has been understood as well, that secondary fines are important to improve interfiber bonding. Therefore, external and internal fibrillation of fiber and secondary fines can improve the strength properties of paper (Kang 2007).

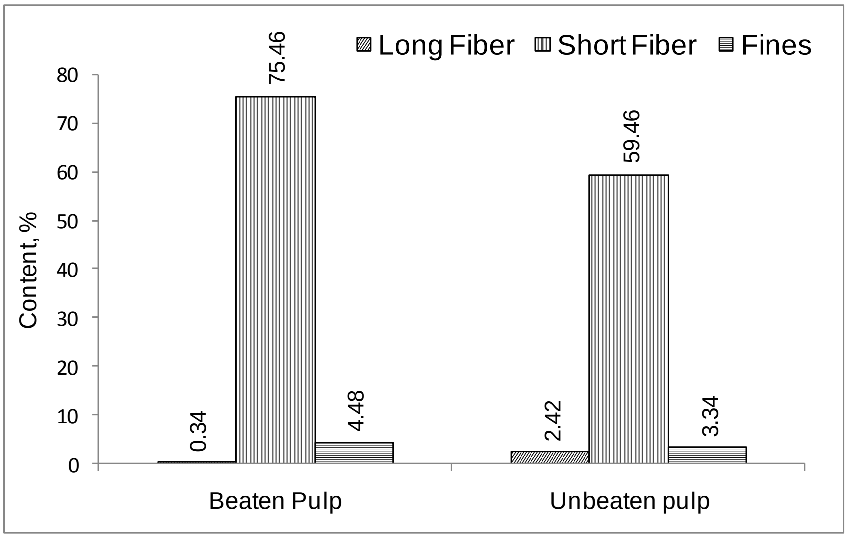

Figure 2 Distribution of long fiber, short fiber and fines resulted from fractionation of pulp by fractionators Bauer McNet.

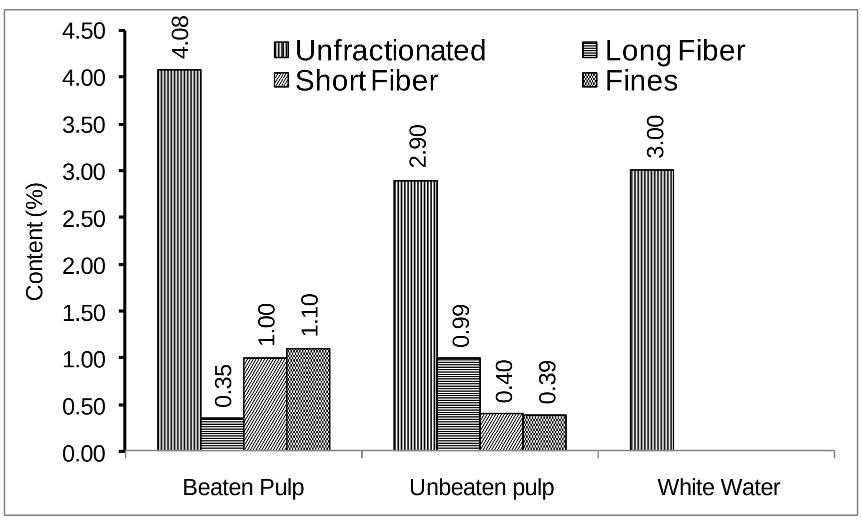

Figure 3 WRV of long fiber (R30), short fiber (P50/R100) and fines (P100/R150) fractions.

Pulp viscosity indicates the degree of cellulose polymerization and degradation. Cellulose degradation (Joutsimo 2004) and the decrease of fiber length (Spiridon & Duarte 2002) can reduce pulp viscosity and strength properties of pulp (Wathen *et al*. 2005). In the present research, pulp viscosity was measured only for unbeaten and beaten pulp. The average values of pulp viscosity are listed in Table 1.

Table 1 indicates that the average values of the viscosity measurement in the present experiments were ranging from 8.32 mPa.s to 10.44 mPa.s. Viscosities of unbeaten pulp tended to be higher than these of beaten pulp. Unbeaten pulp contains more long and intake fiber compared to that of beaten pulp (Park 2006). The cellulose of long fiber component possibly has longer cellulose chain (higher polymerization degree) and the degree of intake fiber degradation would seem to be relatively lower. These could be the origin of the higher viscosity of unbeaten pulp than the viscosity of beaten pulp (Spiridon & Duarte 2002).

Fiber dimension and its derivative values can be used to predict the resulting pulp properties. Pulpwood for paper is preferred to have long fiber with thin cell wall and wide lumen diameter. The average values of fiber dimension from beaten, unbeaten and white water measured in the present experiment are listed in Table 2.

Table 1 The average of pulp fractions viscosity

Pulp Type	Pulp Viscosity (mPa.s)		
	Unfractionated	Long Fiber	Short Fiber
Beaten pulp	8.75	8.49	8.32
Unbeaten pulp	10.44	9.94	9.32

Table 2 The average values of measured fiber dimensions

Fiber Source		Fiber Dimensions			
		Length (mm)	Fiber Diameter (µm)	Lumen Diameter (µm)	Cell wall Thickness (µm)
Beaten pulp (BP)	R0	1.17	26.50	12.14	7.18
	R30	1.14	33.12	15.29	8.92
	P50/R100	1.04	23.80	14.76	4.52
	P150/R200	0.65	23.66	14.19	4.73
Unbeaten pulp (UP)	R0	1.70	23.14	10.47	6.34
	R30	1.79	23.40	10.02	6.69
	P50/R100	1.15	25.67	12.80	6.44
	P150/R200	0.67	17.35	8.15	4.60
White water (R0)		1.72	29,81	13.75	8.03

Fiber length of all pulp types was ranging from 0.65 to 1.79 mm. The longest and the shortest fibers were found in unbeaten pulp and beaten pulp, respectively. White water is commonly dominated by short fiber and fines. However, an unusual fiber dimensions were found in the present experiment, in which the average fiber length was found relatively high compared to those of other fiber fractions of beaten and unbeaten pulp. These unusual values could be brought about by the fact that white water was not fractionated and some contaminant presence perhaps by its improper handling. Highly saturated fiber of a well beaten pulp in white water could result in higher fiber diameter, lumen diameter and cell wall thickness. Due to beating process, it is not unusual that fiber length of beaten pulp was lower than that of unbeaten pulp. A better interfiber bonding potential can be given by long fiber (Abubakar *et al*. 1995) and long fiber in pulp and paper can improve tear strength of paper (Hubbe & Heitmann 2007).

Therefore, a minimum beating degree should be carried out to produce paper with higher tear strength.

It has been well understood that the influence of fiber derivative value is more prominent than that of fiber dimension to the properties of pulp and paper sheet. FAO classification of fiber quality and the average of its derivative values are listed in Table 3.

Derivative values of fiber in Table 3 clearly indicate that pulp beating increased fiber potential to result in better properties of paper. Relatively higher Runkle ratio and flexibility ratio of beaten pulp indicates that fiber cell wall was thinner upon beating. Furthermore, slenderness decreased as indicated by the value of felting power. Decreasing slenderness is an indication of fiber shortening. Relatively high Muhlstep ratio indicates that the surface area of fiber from beaten pulp was higher and thus a better potential of interfiber bonding. The characteristics of fiber derivative values of the beaten pulp specified that beaten pulp has better tensile strength (Ogbonnaya *et al.* 1997, Ververis *et al.* 2004) compared to that of unbeaten pulp. Therefore, it can be assured that pulp beating of the pulp sample used in the present research was carried out in order to increase tensile and bursting strengths of the resulting paper (by pulp sample providing company).

Table 3 Criteria of Indonesian wood fiber for the raw material of pulp and paper

Fiber Dimension and its Derivative	Pulp Quality Classification (FAO 1980)			Pulp Types		
	I	II	III	Beaten pulp	Unbeaten pulp	White Water
Fiber length (mm)	> 2.00	1.00 - 2.00	< 1.00	1.17	1.70	172
Runkle Ratio	< 0.25	0.25 - 0.50	>0.5 -1.0	1.18	1.21	0.17
Felting Power	> 90	50 - 90	< 50	44.15	73.47	57.70
Muhlsteph Ratio	< 30	30 - 60	> 60	79.01	79.53	78.72
Flexibility Ratio	> 0.8	0.5 - 0.8	< 0.5	0.46	0.45	0.46
Coef. of Rigidity	< 0.1	0.1 - 0.15	> 0.15	0.27	0.27	0.27

FAO (1980) in Sulistyowati (1998)

Conclusions

In stock preparation stage of paper making, pulp beating increased the magnitude of secondary fines and decreased primary fines. Along with the production of secondary fines, pulp beating brings about internal and external fibrillation that increased the capacity of fiber swelling and to hold water as indicated by the increase of WRV. Upon pulp beating, the secondary fines have the highest capacity to hold water, and then successively followed by short fiber and long fiber. However, for the unbeaten pulp, the highest capacity of holding water was found in long fiber and then successively followed by short fiber and primary fines.

Improvement in bonding potential of fiber through beating stage only slightly changed its fiber derivative values and did not change its fiber quality class. This indicates that the original unbeaten pulp sample has already had a relatively good bonding potential.

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