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Effect of Beating Process to Soda Anthraquinone Pulp of Oil Palm Male Flower Spikes Fibre

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Abstract. This study was carried out to investigate the effect of beating process to the characteristics of pulp and paper produced from oil palm oil male flower spikes (OPMFS). OPMFS pulp was prepared according to chemical Soda-AQ pulping process. 60 gsm handsheet of oil palm male flower spikes paper were prepared from OPMFS pulp with four different beating times which are 0 revolution, 1000 revolutions, 2000 revolutions and 3000 revolutions. All physical and mechanical characteristics were investigated according to TAPPI and MS ISO standards. The results show that overall physical and mechanical characteristics of POMFS paper were influenced and enhanced by beating process between 0 until 3000 revolutions. This research demonstrate some potential characteristics of palm oil male flower spikes (OPMFS) paper to be investigated as a newly explored non-wood based raw material for papermaking raw material for papermaking.

Introduction

Nowadays, concerns in developing the alternative non-wood based fibre material has increased rapidly to ensure the sustainable fibre supply for pulp and paper industry. Non-wood based material help to offset the growing shortage of forest wood resources[1]. In Malaysia, oil palm has become the most important commodity crop in Malaysia and becomes a good availability of non-wood sources for pulp and paper raw material. As per December 2013, the total planted area was 5,229,739 hectares [2]. Besides the trunks, fronds and empty fruit bunches has been a good source of raw material for the production of various grades of paper products[3], oil palm male flower spikes (OPMFS) as shown in Fig. 1(a) has been investigated as newly explored alternative non wood based raw material for pulp and paper industry in this study. Oil palm male flower spikes were usually being wasted and abandoned. Besides, oil palm male flower phenomenon is one of the big problem happened in oil palm plantation due to some tree only producing male flower as Fig. 1(b).

PFI beating revolutions is one of the most strongly affecting the properties of paper obtained by kraft pulping of olive tree wood beside pulping temperature and active alkali concentration [1]. Beating of the Soda AQ EFB pulp is interesting because it influences on various pulp properties such as freeness, specific surface area, specific volume, surface charge, total charge and elastic modulus, that they really improve the stretch properties of paper sheets [4]. On the other hand, beating or refining the pulp need to be considered in order to enhance the characteristics of paper sheets.

The present study investigated the effect of beating process to the characteristics of pulp and paper sheets obtained by Soda-AQ pulping of oil palm male flower spikes fibre.

Methodology

Raw material preparation. Mature oil palm male flower spikes (OPMFS) was harvested in the area of Sungkai, Perak, Malaysia from 5-7 years old oil palm tree. After that, the collected OPMFS were cleaned and naturally dried under the sun as Fig. 1(c). Then, the threads of the fibres were extracted by using the shredding machine that available at the Forest Research Institute of Malaysia (FRIM). Then, the fibres were sieved by using chip classifier machine to remove the smallest pollen grain of the spikes. Sometimes, the fibre threads of OPMFS need to be manually pulled out by hand. 800 g of oil palm male flower spikes fibre oven dry (O.D) weight were prepared as per Fig. 1(d).

(a) (b) (c) (d)

Fig. 1. (a) OPMFS (b) OPMFS harvesting (c) naturally dried OPMFS (c) OPMFS fibre

Pulping process. An oven dry (O.D) weight of OPMFS fibres were calculated and weighted to be processed in Soda-AQ pulping method with rotary digester in pulp and paper laboratory, Forest Research Institute Malaysia (FRIM according to Table 1 after determine the OPMFS fibre moisture content percentage. Then, the softened OPMFS pulps from the rotary digester were disintegrated inside the hydropulper with water to removes the remaining black liquor. Then, the screening process undergo by using PTI Sommerville Fractionators according to TAPPI T-275 standard with a slot size of 0.15 mm. After that, OPMFS pulp were spin with a spinning machine to reduce moisture and water content. Furthermore, pulps were poured into the Hobart Mixer to disperse the pulp. In addition, the pulp was weighted to determine the pulp yield percentage. Finally, the OPMFS pulp as shown in Fig. 2 was stored inside the chiller at 6 °C. KAPPA number of the pulp was determined according to TAPPI T-236 "Kappa Number of Pulp.

Table 1. Soda AQ pulping conditions and parameters

Soda AQ Pulping Condition	Parameter
AQ (based on dry fibre) (%)	0.1%
NaOH (based on dry fibre) (%)	22%
Liquor/fibre ratio	7/1
Initial temperature (^{o}C)	35
Time to 170 ^{o}C (minutes)	90
Time at 170 ^{o}C (minutes)	120

Fig. 2. OPMFS Soda-AQ pulp

Beating process In order to produce paper with beating process, PFI mill machine was used to beat the screened pulp according TAPPI T-248 "Laboratory Beating of Pulp (PFI mill method)" up to three different beating times which are 1000 revolutions, 2000 revolutions and 3000 revolutions. Unbeaten pulp also has been produced as a control pulp. Fig. 3 shows the PFI mill machine located at Pulp and Paper Laboratory in the Forest Research Institute Malaysia (FRIM).

Papermaking process. Handsheet preparation prepared according to the Technical Association of the Pulp and Paper Industry (TAPPI), TAPPI T-205 "Forming Handsheets for Physical Tests of Pulp". Then, OPMFS paper sheet were prepared by using semi-automatic hand sheet paper forming machine. The value of freeness was determined according the TAPPI T-227 "Freeness of pulp (Canadian standard method)". Drainage time test was conducted according to TAPPI T-211 "Drainage Time of Paper Pulp".

Fig. 3. PFI Mill at Forest Research Institute of Malaysia

Testing procedure. Physical and mechanical of OPMFS 60 gsm paper characteristics tests were conducted according Technical Association of the Pulp and Paper Industry (TAPPI) at Forest Research Malaysia (FRIM) pulp and paper research programme laboratory. The structural, mechanical and optical properties of these papers were measured according to TAPPI T-220 "Physical Testing of Pulp Handsheets" in a controlled temperature and humidity environment as stipulated in TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products". Grammage and thickness test was conducted according to TAPPI T-410 and TAPPI T-411/ISO 534 respectively.

Result and Discussion

OPMFS fibre and pulp characteristics. Table 3 shows the amount of raw OPMFS fibre strands used in this study. The amount of oven dried weight of OPMFS fibre was calculated based on the moisture content of the raw material. OPMFS fibre used for this research recorded a value of 35.86% for moisture content percentage. Morphology test also recorded that OPMFS pulp recorded 0.99 mm in average length. Table 4 shows the characteristics of the OPMFS Soda-AQ pulp. OMPFS Soda-AQ pulp recorded 76.5% of moisture content percentage. OPMFS pulp shows low percentage of screened yield which is only 36.7% compared to standard yield range value of chemical pulping which is 40%-55%. Furthermore, compared to other previous study, OPMFS yield was lower than EFB reported by Wan Daud & Law [3] which is 45%-65%. Unbeaten OPMFS pulps show Kappa number value of 9.35 and fibre length of 0.99 mm.

Table 3. Characteristics of OPMFS fibre

Raw Material	OPMFS Fibre
Air dry mass (g)	1247
Oven dry mass (g)	800
Moisture content (%)	35.86
Oven dry content (%)	64.14

Table 4. Characteristics of OPMFS fibre pulp

Characteristics	OPMFS Soda AQ Pulp (unbeaten)
Moisture content (%)	76.5
Screen yield (%)	36.7
Kappa number	9.35
Fibre length (mm)	0.99

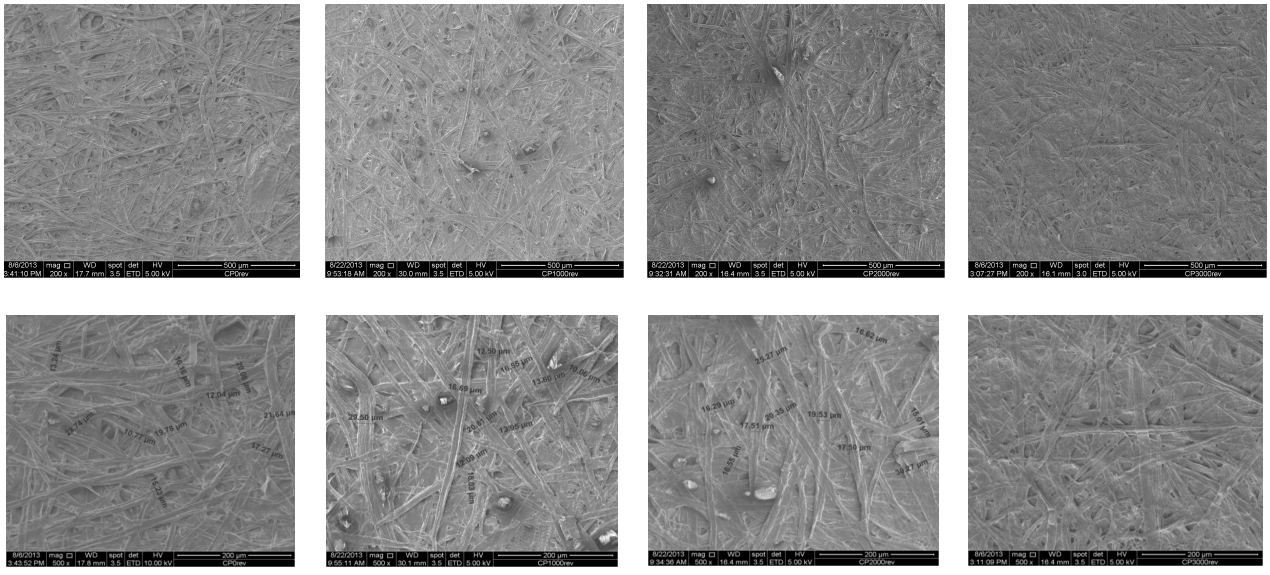
Physical and mechanical characteristics. Table 5 shows drainage time of OPMFS pulp increased and freeness of OPMFS pulp decreased as the beating time was increased which similar

pattern with previous study by Rushdan [5] . Rushdan [5] concluded this condition was due to the increase in pulp wetness, fibre shortening and fines production. Fines greatly reduce the drainage of water in paper formation by filling pores in the sheet, but provide at same time more fiber - fiber contact area [6]. Fines also retain more water than fibres and behave like a gel to cause pulp freeness to decrease [5]. Grammage (g/m^2) result shows that all paper condition achieved near the control value which is 60 gsm. Apparent bulk density increased as the beating revolutions increased and influences almost all mechanical, physical, and electrical properties [6],[7]. Tensile index, tearing index, bursting index and folding number for OPMFS paper sheet were enhanced by the increment of beating time. Table 5 shows that OPMFS pulp physical and mechanical characteristics were enhanced by the beating process between 0 revolutions until 3000 revolutions.

Table 5. Physical and Mechanical characteristics of OPMFS pulp and paper sheet

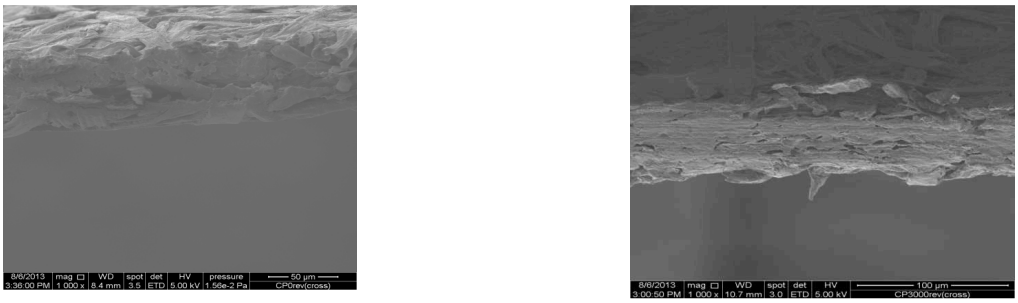
Characteristics	0 rev	1000 rev.	2000 rev.	3000 rev.
Drainage time(s)	6.42d	13.23c	16.32b	23.70a
Freeness(ml)	353.00a	195.00b	120.00c	103.00d
Grammage (g/m^2)	56.99	57.60	57.01	56.51
Bulking thickness (µm)	131.11a	94.39b	85.87c	81.62d
Apparent bulk density (g/cm^3)	0.43d	0.61c	0.66b	0.69a
Tensile Index (N.m/g)	39.10d	46.25c	52.52b	54.66a
Tearing Index ($mN.m^2/g$)	8.32d	8.56c	9.19b	9.25a
Bursting Index ($kPa.m^2/g$)	3.15d	4.23c	4.32b	4.37a
Fold endurance , No.	38.50d	190.00c	252.50b	347.00a

Scanning electron microscopy (SEM) image. SEM image in Fig. 4 shows the surface of OPMFS fibre paper for each beating condition at 200 x magnifications for above row and 1000 x magnifications for row in below. It can be seen fibre arrangement for beaten pulps was more uniform and higher bonding ability than unbeaten pulp as indicated from increment of apparent bulk density and mechanical characteristics in Table 5. From the side cross section SEM image in Fig. 5, the beaten pulp shows more dense structure than the unbeaten pulp as indicated from increment of apparent bulk density in Table 5. Fig. 4(a) until Fig. 4(d) shows that fibre bonding cross area was increased and the fibres were straightened with the increment of beating revolutions [7].



(a) (b) (c) (d)

Fig. 4. SEM Image of OPMFS Soda-AQ paper surface (a) unbeaten (b) 1000 revolutions beating time (c) 2000 revolutions beating time (d) 3000 revolutions beating time



(a) (b)

Fig. 5. Side view SEM image with 500x magnification (a) unbeaten pulp (b) 3000 revolutions

Conclusion

The characteristics results show some promising potentials of OPMFS as a newly explored raw material for papermaking. Overall physical and mechanical characteristics of Soda AQ oil palm male flower spikes were enhanced by the beating process between 0 until 3000 revolutions. For better results, beating time need to be increased more than 3000 revolutions to determine the decreasing point of mechanical properties especially tearing index. As a conclusion, this preliminary work determined the potential characteristics of Soda-AQ pulp of oil palm male flower spikes (OPMFS) fibre and offer future investigations about this newly explored non-wood based raw material.

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