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Water Absorbency of Oil Palm Empty Fruit Bunch Paper

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Abstract. Paper-making raw materials are a mixture of pure wood pulp and recycled pulp. Recycled pulp is obtained from used paper imported from abroad, in addition to the development of paperless culture also has an impact on the reduced availability of raw materials. Empty bunch fiber of palm oil is one of the natural materials that have the potential to be used as an alternative to a pulp for the manufacture of cardboard paper because it has a high holocellulose content. This study has been successfully developed cardboard paper made from oil palm empty fruit bunch pulp with 6 variations of treatment, steam, no steam, NaOH 2.5%, NaOH 5% and mill duration (20 minutes and 30 minutes). The developed cardboard paper is then tested for its water absorbency. Water Absorbency value testing is done by the Cobb method (60). Based on the test results obtained the water absorption values is in the range of 500 - 600 g/m^2. Cartons that received treatment, no steam, added NaOH 2.5%, and milled for 30 minutes, has the lowest wter absorption value compared to others.

Keywords: Water Absorption, OPEFB, Pulp, Paper.

1. Introduction

Currently, there is an increase in palm oil production in Indonesia. Indonesia has been ranked number one in the world as a palm oil producer. The General Director of Plantations (2014) reported that palm oil exports amounted to 20.58 million tons in 2013 and then increased rapidly to 31.05 million tons of exports of CPO and its derivatives in 2016. The Ministry of Agriculture reports that Palm Oil Plantations (PKS) in 22 provinces in Indonesia is cover an area of about 11 million hectares [1]. Oil Palm Empty Fruit Bunches (OPEFB) is currently only used as boiler fuel for oil plants palm oil, compost, and potassium fertilizer. But this utilization has not provided optimal added value [2]. The highest content of OPEFB is cellulose, pentosan, lignin, extractive, and ash content which is about 41%, 29%, 22 %, 3%, and 2% [3]. OPEFB fiber has a fiber length of about 0.76 – 1.20 m and classifies as a short fiber [4]. Cellulose fiber is one of main material to make a paper. Nowadays paper is widely use as packaging paper because their biodegradability properties. Packaging paper is usualy made from a virgin woodpulp and non-wood pulp such as old corrugated cardboard (OCC) pulp or old news paper (ONP) pulp. Pulp from OPEFB has the potential to be used as an alternative source of cellulose fiber form non-wood material to replace OCC and ONP pulp due to its abundant availability in Indonesia [5].

One important parameter that must be considered on paper for packaging is the water absorption value. Water absorption is a measure of paper's ability to absorb water vapor in the surrounding air. If the water absorbency of the paper is high, it will result in paper easily absorbing water vapor in the air. The moisture content of the paper will affect the physical properties of the paper such as tensile, bursting index and paper stiffness. The higher the water content contained in the paper will decrease the physical properties of the paper [6]. In this article will be studied about the water absorbency of cardboard paper which has been made from the OPEFB pulp so that it can be used as a reference for further development.

2. Methods

2.1. Raw Material

OPEFB fiber were obtained from Lampung Oil Palm Plantation, South Sumatra, Indonesia. Sodium hydroxide was puchased from Merck and all other chemicals were analytical grade.

2.2. Fiber Morphology Analysis

The Fiber dimension analysis refers to SNI 01-1840-1990 [7]. The pulp tests that have been prepared are inserted into a test tube then added a solution of glacial acetic acid and hydrogen peroxide (1:1). The test tube is then covered with a cotton swab and put in a boiling water handler for 1-2 hours until the test sample is white. The test sample is then washed with a aquadest until it is free of chemicals. Opefb fibers are obtained by shuffling the test samples in a test tube containing an aquadest. After decomposing, the sample is added safranin dye, put that fibers in the object glass and closed with the cover then measure the fiber dimensions. The Fiber dimension measure using a microscope equipped with a digital camera and integrated with a computer which has installed image processing software for fiber length measurement.

2.3. Chemical Components Analysis

Determination of the chemical components of OPEFB raw materials is carried out to determine the potential aplication of OPEFB as an alternative paper pulp from non-wood materials. OPEFB fiber is chipped using willey mill then the powder is filtered using a sieve shaker until the powder is obtained that escapes a 40 mesh filter and is stuck in a 60 mesh filter. The powder is used as sampel to determine the chemical components which includes the value of holocellulose, alpha cellulose, lignin, pentosan, ash, silicate, extractive (alcohol-benzene extract), solubility in cold water, hot water and in 1% NaOH. Analysis of chemical components conducted according to the Indonesian National Standard (SNI).

2.4. Paper Making Procedure

OPEFB fiber is conditioning by soaking it in a weter with ration of 1:20 for a day or overnight, so that the water content is uniform. Then the OPEFB fiber is pulped mechanically using Masher for 4 cycles using different treatment variations which is describe on Table 1 so that we get 6 (six) type of pulp sampel. The OPEFB pulp was then refined using pulp refiner, continued to filtration, then beated using niagara beater to disintegrate and decompose the fibers to 300 mL CSF. The pulp suspension was diluted to a consistency of 2.5% on water. After that it is formed into a pulp sheet using paper sheet forming machine. The overall precedure is presented in Figure 1.

Tabel 1. Sampel Treatment Variation

Sample	Treatment		
	NaOH Concentration	Steam	Milling Duration per Cycle (minutes)
A1	2,5 %	No	30
A2	2,5 %	Yes	20
A3	2,5 %	Yes	30
B1	5%	No	20
B2	5%	No	30
B3	5%	Yes	20

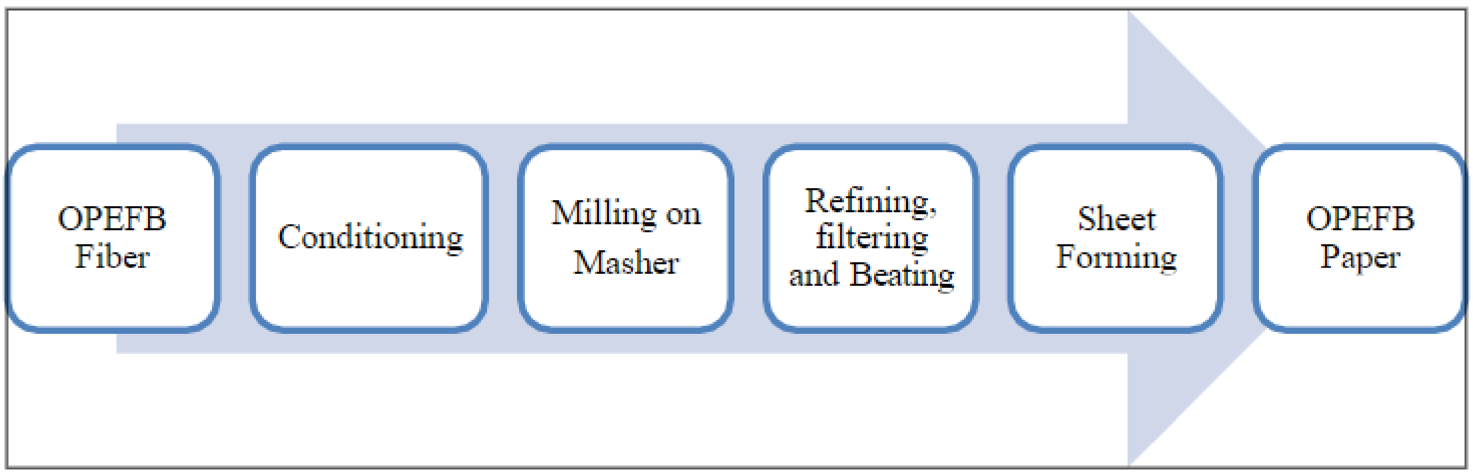


Figure 1. OPEFB Paper Making Procedure

2.5. OPEFB Paper Properties Testing

2.5.1. Thickness and grammage

The thickness of the paper was determined using a digital micrometer. Eight locations on each sample were measured, and the mean thickness was determined with an accuracy of ± 0.001mm. The grammage of paper was determined according to SNI ISO 536 [8]. Test pieces were weighted on a balance and masses were recorded to three significant figures. The grammage in grams per square meter was calculated using Eq 1 as follows:

$$\square = \frac{\square}{\square} \square\, 100 \qquad (1)$$

where *m* is the mass of the test pieces (*g*) and A is the area of the test piece (cm^2).

2.5.2. Paper Surface Roughness

The paper surface roughness is measure using bendstend methode. The test piece is clamped between a flat glass plate and a circular metal head and measuring the rate of airflow in ml/minute between the paper and head [9].

2.5.3. Water Absorption

The Cobb method was used to determine water absorptiveness of the paper according to SNI ISO 535:2016 [10]. Five samples of each type of bio-coated paper were kept in the conditioning atmosphere throughout the test. After weighing, the samples were slowly immersed in 100 ± 5 ml water (or proportionately less for a smaller test area) in a cylinder providing 10 mm head space, and the timer was immediately started. Fresh water was used for each determination. The samples were taken out of the liquid after 60 seconds, blotted with an absorbent paper to remove excess water, and weighed again. The procedure was repeated until reaching equal masses in two consecutive measurements (during 4 days), and the absorption capacity of the paper was calculated using Eq 2.

$$\square\square\square\square\square\ \square\square\square\square\square\square\square\square\square\square\square\square\square\square\square = (\square_2 - \square_1)\square \qquad (2)$$

where $\square_2$ is the wet mass of the test piece (g), $\square_1$ is the dry mass of the test piece (g) and F is 10.000/test area (for a typical test apparatus this is 100 cm^2)

3. Result and Discussion

3.1. OPEFB Fiber Morphology

The OPEFB Fiber morphology is generally influenced by the genetic characteristics of the plant. The average weight of OPEFB fiber is about 400 g per fruit bunch [11]. One whole OPEFB fiber consists of bunch base fiber, stalk fiber, spikelet fiber, and thorn fiber, with a total length of up to 20 cm. The base of OPEFB contains fiber with an average length of 1.2 mm while the tip (panicle) is about 0.76 mm [12]. OPEFB fiber which is between 1 – 2 mm in length is categories as short to medium while the diameter includes the group of small to medium diameter (2 – 2.5 m). In general, the physical and morphological properties of OPEFB fibers at the base were better than at the ends. The morphology of OPEFB which is used in this study is shown in Table 2 compared with the reference.

Table 2. OPEFB Fiber Morphology

No	Requirement	Scor and Quality Class	
		Reference OPEFB Fiber [11,12]	OPEFB in this Study
1	Fiber Length (μm)	0,76 – 1,20 ; III	0,63 – 2,60; III
2	Runkel ratio	0,87 – 1,05; III	0,89; III
3	Felting power/slenderness	52 – 71 ; III	55,38; III
4	Muhlsteph ratio (%)	77,4 – 76,2; III	72,1; III
5	Flexibility ratio	0,48 – 0,49; III	0,53; III
6	Rigidity coefficient	0,21 – 0,26; IV	0,24; IV
	Total score	275	275

Table 2 shows that the OPEFB fiber in this study has a fiber morphology that is equivalent to the reference. The total score of 275 on OPEFB used in this study indicates that the OPEFB fiber has a quality class no III that is good enough to be used as raw material for paper pulp.

3.2. Chemical Componen Analysis

Table 3. Chemical Components of OPEFB Raw Materials

No	Parameter	Units	Result	Test Methode
1	Water Content	%	5,76	SNI 08-7070 [13]
2	Ash	%	6,89	SNI ISO 2144:2019 [14]
3	Acid insoluble ash	mg/kg	12013,71	SNI ISO 776:2011 [15]
3	Pentosan	%	27,59	SNI 8430:2017 [16]
4	Extractive	%	3,15	SNI 8401:2017 [17]
5	Lignin	%	18,72	SNI 8429:2017 [18]
6	Holocelullose	%	69,55	*In house methode*
7	Alfacelullose	%	38,85	*In house methode*
8	Cold Water Solubility	%	14,73	SNI 01-1305 [19]
9	Hot Water Solubility	%	15,92	SNI 01-1305 [19]
10	NaOH 1% Solubility	%	29,88	SNI 14-1838 [20]

The chemical components of OPEFB raw materials are shown in Table 3. Chemical component analysis was carried out to determine the potential application of OPEFB fiber as an alternative to non-wood pulp. From Table 3, it can be seen that the holocellulose content is quite high, namely 69.55%. Holocellulose is the part of the fiber that is free of extractives and lignin in the form of a mixture of cellulose and hemicellulose, yellow white to yellowish in color. Holocellulose content is the total carbohydrate content or polysaccharide content in the raw material. Cellulose is a linear polysaccharide, consisting of anhydroglucose units with 1,4 β-glucosidic bonds which in the acid hydrolysis process will produce D-glucose. Cellulose consists of three parts, namely α -cellulose, β -cellulose and γ -cellulose. α -cellulose has a high molecular weight which is the part that remains after the other part of the cellulose dissolves on treatment with 9.45% sodium hydroxide. Expansion with 17.5% sodium hydroxide causes dissolution. Meanwhile, the portion of cellulose that is soluble in 9.45% sodium hydroxide is β -cellulose and γ -cellulose.

The high pentosan content of 27.59% will contribute additionally to the stiffness properties of the pulp and paper later. In addition to pentosan, this stiffness value is also obtained from the contribution of lignin which is still contained in the mechanical pulp. Extractive content generally consists of fatty acids, resins, waxes, gums, volatile and non-volatile materials [21]. Extractive content is a substance in wood or pulp extracted by alcohol-benzene as a solvent carried out at the boiling point of the solvent in a certain time. The extractive content for opefb fiber is 3.15%. In general, raw materials containing low extractive content will produce clean pulp. The percentage of OPEFB solubility in 1% NaOH is 29.88%. The solubility of raw materials in 1% NaOH, hot water and cold water is an indicator of many dissolved chemical components. The high solubility value of the raw material in 1% NaOH indicates that there has been degradation of chemical components due to microorganisms during the storage process of raw materials. OPEFB lignin content in raw materials is quite low, which is around 18.72%. The low lignin content indicates that this OPEFB raw material is easy to pulp because it requires less heat and mechanical energy. The OPEFB pulp developed in this study are shown in Figure 2 and the prototype of OPEFB paper is shown in Figure 3.

Figure 2. a) OPEFB Fiber b) Mashed OPEFB c) OPEFB Pulp

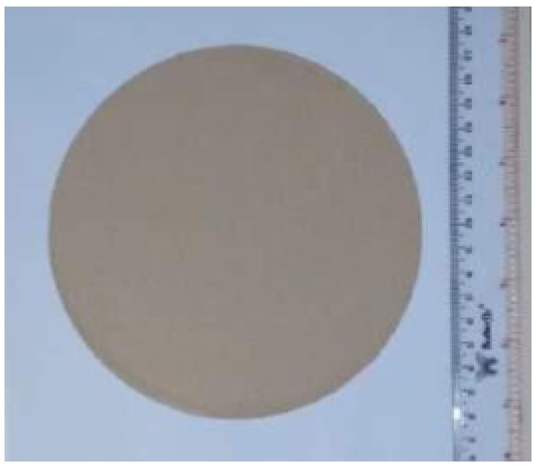


Figure 3. OPEFB Paper Prototype

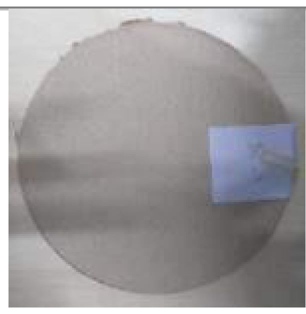
3.3. OPEFB Paper Properties

3.3.1. Grammage and Thickness

Paper products are categorized by their grammage, which is the mass per unit area. The grammage of handmade paper can be varied by increasing or decreasing the amount of pulp used for one sheet, and this will affect the paper thickness along with other physical properties of the paper. The grammage and thickness of opefb paper samples are shown in Table 4. Gramatur kertas opefb yang telah berhasil dikembangkan adalah pada kisaran 150 – 180 g/m^2 dengan ketebalan pada kisaran 0,4 mm. Karakteristik kertas berbahan dasar pulp opefb adalah ringan.

Table 4. The OPEFB Paper Grammage and Thickness

Sample	Grammage (g/m^2)	Thickness (mm)	
A1	161,7	0,4115	

A2	166,6	0,4115	
A3	150,5	0,429	
B1	168,3	0,424	
B2	169,2	0,4045	
B3	181,9	0,3821	

3.3.2. Paper Surface Roughness

OPEFB raw material is known to have a high roughness so that it will affect the value of water absorption value. Figure 4 shows the low Bendtsen roughness values found in the mechanical pulping process using 2.5% NaOH either with the help of steam or without steam, both in short and long processing times. The use of steam will open the surface pores of the OPEFB fiber so that it will absorb more air bubbles used in testing pulp sheets using the Bendtsen method.

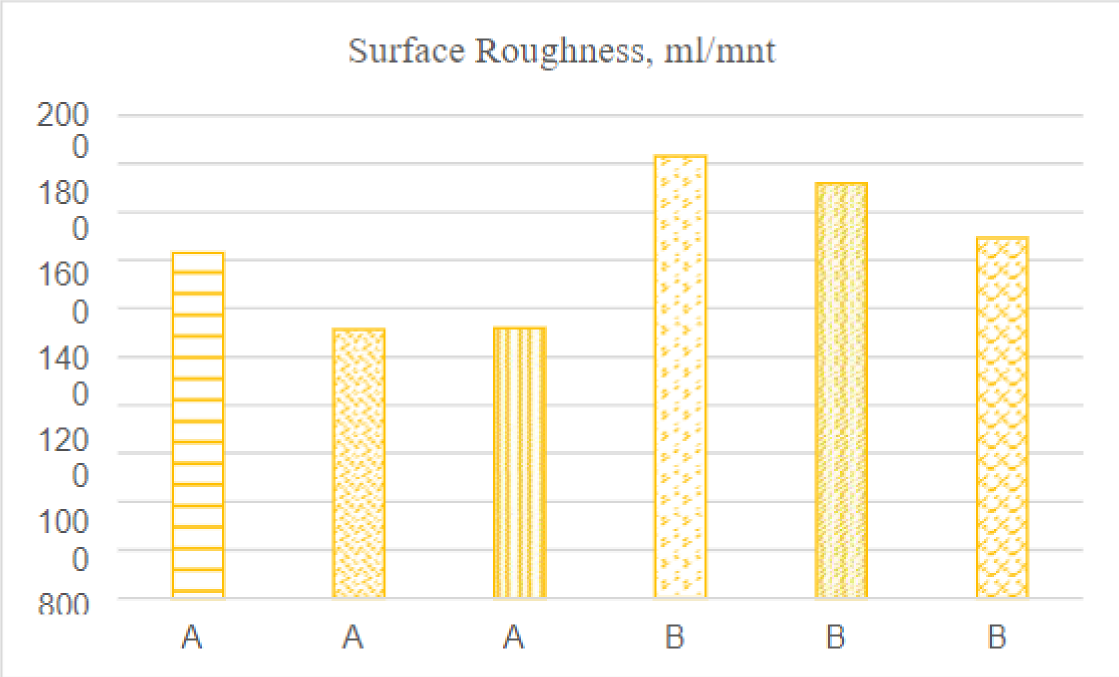


Figure 4. OPEFB Paper Surface Roughness

3.3.3. Water Absorption Analysis

The paper samples were tested for their water absorption, measured by the Cobb 60 method. Water absorption is an important parameter for paper and cardboard. The water absorption value of the top layer according to the SNI specifications for cartons is a maximum of 50 g/m^2. Figure 5 shows the value of water absorption which is still very high that is above 500 g/m^2. This is because the OPEFB pulp used in this study is 100%. Generally, in the manufacture of cartons, the raw material for pulp will be mixed with various additives that will increase the hydrophobicity of paper and cardboard. Sizing or other substances in the form of alkyl ketene dimer (AKD) and polyvinyl alcohol (PVA) both as internal sizing and external sizing are very commonly used in paper making to increase hydrophobicity or reduce water absorption. The water absorption value of the top layer of cardboard can also be reduced by adding coating materials commonly used in the production of cartons, including kaolin and CaCO3. This sizing agent also functions to control the penetration of liquid into the sheet. Humid conditions can cause the sheet moisture content to be high. Control of the moisture content of the paper sheet is necessary mainly because the gluing and printing processes are affected by this factor.

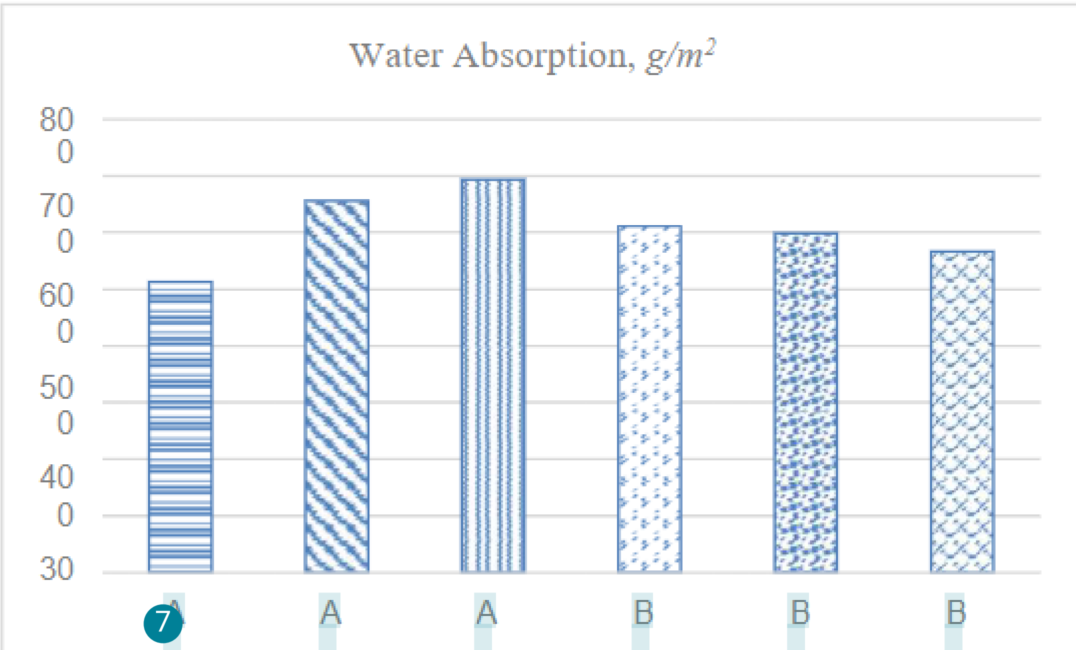


Figure 5. Water Absorption of OPEFB Paper

This research produces sheets of paper with a moisture content that is in accordance with the conditions in the factory, which is around 9 %. This is due to the paper storage process that has followed the guidelines for environmental accommodation conditions in the paper test laboratory, which is stored for at least 24 hours after the paper has dried at a room temperature of 23 °C with humidity of 50. This is important because the strength of the paper can also decrease with increasing sheet water content. The moisture content of the sheet is highly dependent on the environmental conditions in which the sheet is located and is always in equilibrium with its environment. Humid conditions (high RH) will cause the moisture content of the sheet to be high. The sizing process does not help much in controlling 10 the moisture content in the form of water but in the form of water vapor. The penetration of water vapor into the sheet is highly dependent on the structure of the pulp sheet, for OPEFB raw material the steam penetration process increases with the help of heat from the steam during the pulping process.

4. Conclusion

The results of water absorption of opefb paper is in the range of 500 - 600 g/m^2.This OPEFB pulp can be used as a basic pulp in the manufacture of cartons with the optimum process variation using 2.5% NaOH and mill duration of 30 minutes. This paper making condition produce paper with the lowest water absorption value compared to others. The steam treatment on mechanical pulping process will actually contribute to open the pores of the OPEFB so that increase the value of water absorption. The absorption value is still too high compared to cardboard paper standart. However, we can reduce the water absorption by adding fillers and plasticizers for further development.

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