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Characteristics of Empty Palm Bunch Fibers as Alternative Pulp Material

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Abstract: Material characteristics in this research become the focus to see the possibility of oil palm Empty Fruit Bunches (EFB) becoming pulp raw material in the future. The oil palm empty fruit bunch fibers are divided into two parts, namely the inner and outer parts, which are the focus of this research. Tests carried out using the TAPPI standard include testing water content, ash content, extractive, lignin, cellulose and hemicellulose. While fiber morphology was observed by the maceration technique in EFB, including fiber diameter, fiber length, cell wall thickness and lumen diameter. The test results state that characteristics of fiber parts and the outside, in general, do not differ significantly, the difference in value ranges from 1-2%, the length of the fiber and the value of the dimensions of the fiber is included in the category of fiber grade II quality. The holocellulose content is of less quality, while the lignin and extractive contents are of good quality. Based on the levels of chemical components, the morphology of fibers and their derivatives, in general, there is no need to distinguish the inner and the outer part of the EFB in the pulping process.

Keywords: EFB, Inner Part, Outer Part, Fiber Morphology, Pulp

Introduction

Palm oil (*Elaeis guineensis* Jacq) is one of the most productive commodity crops in Indonesia. Oil palm Empty Fruit Bunches (EFB) are a collection of fibers left after separating the fruit from sterilized fresh fruit bunches (Shijoj *et al*., 2011). The availability of abundant EFB can be decomposed, non-toxic and is a natural fiber, resulting in EFB as an exciting product to be investigated for broader use. So far, EFB has not been used optimally, EFB has only been used as animal feed and compost fertilizer (Shijoj *et al*., 2011). This shows that EFB waste could be further processed into useful and economically valuable products (Abdulrazik *et al*., 2017; Hassan *et al*., 2010; Sukiran *et al*., 2009). Some studies suggest that oil palm empty fruit bunches are natural materials that contain thick and rough filaments and can be used as acoustic materials (Al-Rahman *et al*., 2014). Oil palm empty fruit bunches can be used as a material in a variety of applications, including electricity generation, composite formulations and the papermaking industry.

The calculation results obtained the calorific value of the EFB at 30% moisture content of 3,498 kcal kg^{-1} and its use in polymer composites can solve environmental problems, especially those related to palm oil waste disposal (Nyakuma *et al*., 2014). Oil palm empty fruit bunches can be converted into high-value products such as biofuel (Kim *et al*., 2008; Binod *et al*., 2010; Piarpuzán *et al*., 2011; Chang, 2014) and the results of chemical analysis of EFB show that there are components of cellulose, hemicellulose and lignin (Svagan *et al*., 2010) which allows it to become pulp and paper raw material. Some research has been done to make pulp and paper from EFB, related to the process pulping and paper making (Risdianto *et al*., 2016; Erwinsyah *et al*., 2012; Law and Jiang, 2001; Gonzalo *et al*., 2007; Rushdan *et al*., 2007) and morphology and chemical content (Erwinsyah *et al*., 2012; Ferrer *et al*., 2011; Law and Jiang, 2001; Law *et al*., 2007; Darnoko *et al*., 1995). All research is done generally without separating the parts that are on EFB.

Although there have been many kinds of research on oil palm empty fruit bunches specially for pulping material, there have not been many studies that distinguish the inside and the outside of the EFB fiber. Based on the description, the purpose of this study is to determine the characteristics of inner and outer EFB fibers from the aspect of fiber morphology and its chemical content. This research is part of a series of

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studies related to the use of EFB as raw material for pulp and paper that is being carried out.

Material and Methods

Materials

The material used in this study is oil palm empty fruit bunches, which are divided into two parts, namely the inside and the outside (Fig. 1) material collected from corps plantations in Sukabumi-West Java.

The chemicals used are glacial acetic acid, hydrogen peroxide, technical alcohol, glycerin, safranin (Merck, Darmstadt, Germany). Extruder (Single Screw Lab Extruder, Extrumech) for separating fibers and refiners (Lab Disc Refiner, UEC-2019), microtomes (BK-MT358S, Biobase Meihua Trading Co., Ltd), microscopes (BA310E Elite Compound Microscope**)**, loupe, object glasses, cover glasses, weigh bottles, watch glass, pipette (Duran Pyrex) and chemical properties testing equipment such as Erlenmeyer flasks (Duran Pyrex) and others.

Maceration and Chemical Process

The oil palm empty fruit bunches fibers are heated slowly to a temperature of 130°C in a test tube containing a mixture of hydrogen peroxide solution and glacial acetic acid in a ratio of 1: 1 (v/v). Separated fibers are washed thoroughly with running water from the faucet then stained with safranin. The dyed fiber is placed in the glass of the object, which has been dropped by glycerin. The fiber is spread evenly then covered with glass cover and then the preparations are ready to be observed under a microscope.

Parameters observed were fiber length, fiber diameter, lumen, fiber wall with 30 replications each. As for the analysis of the chemical components of the EFB, the fiber was previously smoothed using a ring flaker, hammer mill, disk mill until all of them passed through the No. sifter. 40 Mesh and held at 60 Mesh. Then the sample is dried using an oven with a maximum temperature of 40°C. Samples are stirred and stored in airtight plastic/containers before further testing. The testing of chemical component analysis follows the procedures as referred to in Table 1.

The morphology of the fiber was obtained by measure of fiber length, fiber diameter, lumen diameter, cell wall thickness and the derivative value of fiber dimensions such as felting, muhlsteph ratio, flexibility, runkel ratio and rigidity coefficient. The value of morphology fiber and the chemical properties of the EFB are analyzed quantitatively and then tabulated and compared with the standard assessment characteristics of the material for the pulp. The micrograph of fiber (Fig. 2) was taken using video microscope, Alphasystec SV 32 (Anyang, Korea).

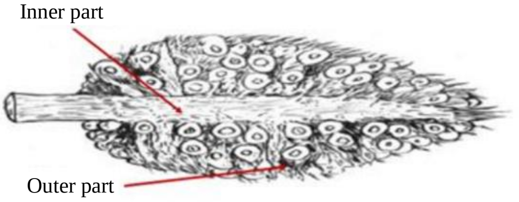

Fig 1: Part of empty oil palm bunches (Rahmasita *et al*., 2017)

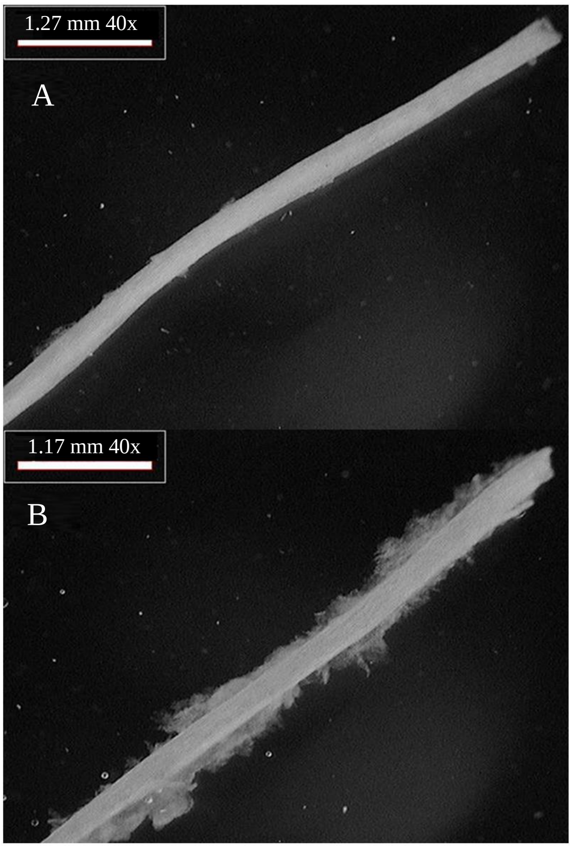

Fig. 2: Micrographs of the morphology of EFB fibers: (A) inner part and (B) outer part

Table 1: Methods of testing EFB chemical components

Test	Method
Ash Content (%)	T 204 (1997)
Lignin Content (Insoluble) (%)	David and Tina (1995)
Lignin Content (Soluble) (%)	David and Tina (1995)
Holocellulose Content (%)	Wise *et al.* (1964)
Alpha cellulose Content (%)	Rowell (2005)
Hemicellulose Content (%)	

Results and Discussion

The morphology of oil palm empty fruit bunches results of maceration testing is shown in Table 2.

Characteristics of fiber between the inner and outer parts, in general, do not differ significantly; the difference in value ranges from 1-2%, except for the value of the fiber length. The length of inner EFB fiber is 1.27 mm, while the outside is 1.17 mm. This value is included in the quality class II fiber category (Table 3). The length of the fiber for the pulp is critical because it is one indicator of the strength of the pulp in paper products, including tensile strength, folding strength and tear resistance. The longer fiber will provide a full contact area and better woven between one fiber with another so that more hydrogen bonds occur between these fibers (Hirn and Schennach, 2015; Kerekes and Schell, 1995). The diameter of the fiber both inside and outside is relatively the same, ranging from 29.53-29.94 µm and lumen diameter 20.57-20.77 µm, while the fiber wall thickness is 4.58 µm.

In addition to the morphology of the fiber, the value of the fiber dimension is a requirement to see the feasibility of the material as a pulp material. In addition to Runkel numbers, the Muhlsteph ratio and flexibility ratio must also be a concern. The felting ratio indicates the solubility of fibers in the papermaking process. This parameter affects to breaking length, tearing, bursting, durability and folding endurance. The felting ratio is in the range between 41.65-38.92, which indicated to quality class II. However, Risdianto *et al.* (2016) reported that EFB fiber tip and the end of the part of the EFB stem resulted in felting power 53.00 and 79.95, respectively.

Muhlsteph ratio values depend on the cell wall thickness and it affects to tearing, tensile strength and the density of pulp produced. The comparative value of the Muhlsteph ratio for the inside and outside is relatively the same, namely 51.48-52.17 and belongs to the quality class II. Comparison of the small Muhlsteph value will result in a high pulp sheet density, conversely if a considerable Muhlsteph ratio value, the resulting pulp sheet has a low density with a low pulp strength (Przybysz *et al*., 2018). The higher Muhlsteph ratio has indicated that material is more suitable to produce board and corrugated board rather than paper (Elmas *et al*., 2018).

A comparison of EFB flexibility is a comparison of the diameter of the lumens with the diameter of the outer and inner fibers of class II quality. The flexibility of samples is in the range between 0.69-0.70. A high flexibility comparison value indicates the fiber has a thin wall thickness and is easily deformed. This condition results in better contact between the surface of the fiber and increases the number of bonds (Syafii and Siregar 2006). Also, Risdianto *et al.* (2016) reported that flexibility EFB fiber enhances the burst properties, medium corrugated test, ring crush, tensile and folding endurance.

Oil palm empty fruit bunches fiber wall, including thickness for the inside and outside, seen in the Runkel ratio reached 0.44-0.46, which categorized to quality class II. It calculated by dividing the double cell wall thickness by the lumen width (Elmas *et al*., 2018). Large Runkel numbers will make it difficult in the process of flattening the fibers so that the bond strength between the fibers is not good. Conversely, thin-walled fibers will produce sheets that have low tear strength, but high burst strength (Kiaei *et al*., 2014). It also impacts the strength properties such as tearing, bursting and breaking length.

The rigidity coefficient of the inner and outer part is between the range 0.15-0.16 included in grade III quality. The value of the rigidity coefficient is defined as the ratio of double cell wall thickness to fiber diameter and this indicates an inverse relationship with tensile strength. The higher the rigidity coefficient, the lower the tensile strength of the paper and vice versa (Syafii and Siregar 2006). Lower rigidity ratio results in more fiber collapse and less tendency to aggregate between fiber. Consequently, in the papermaking, it yields paper with lower bulk or higher sheet density (Dutt *et al*., 2004).

Table 2: Morphology of the inner and outer fibers of oil palm empty fruit bunches

Fiber properties	Inner part	Outer part
Fiber length, *mm*	1.27 (0.17)	1.17 (0.18)
Fiber diameter, *µm*	29.94 (3.07)	29.53 (2.83)
Lumen diameter, *µm*	20.77 (3.40)	20.56 (2.45)
Cell wall thickness, *µm*	4.58 (0.47)	4.49 (0.68)
Felting	41.65 (5.90)	38.92 (7.01)
Muhlsteph ratio	52.17 (6.95)	51.48 (5.57)
Flexibility	0.69 (0.05)	0.70 (0.04)
Runkel ratio	0.46 (0.11)	0.44 (0.09)
Rigidity coefficient	0.16 (0.03)	0.15 (0.02)

Table 3: Criteria for the assessment of Indonesian wood for pulp and paper raw materials

	Quality class					
	I		II		III	
Properties	Value	Point	Value	Point	Value	Point
Fiber length	> 2000	100	1000-2000	50	< 1000	25
Runkel ratio	< 0.25	100	0.25-0.50	50	0.5-1	25
Felting power	> 90	100	50-90	50	< 50	25
Muhlsteph ratio	< 30	100	30-60	50	60-80	25
Flexibility ratio	> 0.8	100	0.5-0.8	50	< 0.5	25
Rigidity coefficient	< 0.1	100	0.1-0.15	50	> 0.15	25
Value range	450-600	225-449	< 225			

Source: Pasaribu and Silitonga (1997)

Table 4: Inner and outer chemical components of oil palm empty fruit bunches fibers

Properties	Inner part	Outer part
Ash, %	10.78 (0.07)	9.13 (0.20)
Extractives, %	3.67 (0.31)	4.10 (0.19
Klason lignin, %	12.23 (0.01)	17.08 (0.88)
Acid soluble lignin, %	6.83 (0.08)	5.51 (0.04)
Holocellulose, %	55.77 (0.45)	54.78 (0.14)
Alpha cellulose, %	24.53 (0.57)	19.66 (0.01)
Hemicellulose, %	31.24 (1.01)	35.66 (0.15)

Table 5: Requirements for wood raw materials for pulp

	Quality		
Properties	Good	Enough	Less
Fiber length	> 1,600	0,900-1,600	< 0,900
Holocellulose	> 65%	60-65%	< 60%
Lignin	< 25%	25-30%	> 30%
Extractive	< 5%	5-7%	> 7%

Source: Syafii and Siregar (2006)

Chemical Component Analysis

In general, the EFB fibers most widely contain cellulose, lignin and hemicellulose. The chemical components of EFB from the inner and outer parts are shown in Table 4. The highest content of EFB is the holocellulose group. Based on the requirements of the pulp raw material (Table 5), the holocellulose content in the range of 54.78-55.77% are categorized to the less quality raw materials for pulp and it showed no difference between the inner and outer part of the EFB fiber. In addition, the level of cellulose in the EFB for the inner part around 24.53% and the outer portion around 19.66%. Meanwhile, hemicellulose content for inner and outer parts 31.24% and 35.66%, respectively.

However, a less holocellulose content, it does not mean EFB cannot be made pulp. Alpha cellulose/holocellulose content in EFB fiber material is one indicator to predict the yield of pulp to be produced and the quality of the sheet. The chemical content in EFB varies due to the variation of sources the raw material and the treatment of the material prior to laboratory analysis. Some pretreatments have been reported successful in increasing the alpha-cellulose content in EFB. The pretreatment, such as extensive washing, could improve the solubility in 1% of NaOH (Law *et al*., 2007). Fibers that contain high levels of cellulose will have a greater affinity for water, making it easier to bond between fibers (Hubbe *et al*., 2007).

Besides, ash content for the inner and outer part; 10.78% and 9.13%, respectively, which means it could produce good quality pulp (Table 5). Extractives contents are 3.67% and 4.10% for the inner and outer part of EFB. Klason lignin content for the inner and outer part is 12.23% and 17.08% and acid-soluble lignin around 6.83% and 5.51% for the inner and outer part. According to these results, the EFB fiber is qualified to produce pulp with good quality (lignin content <5%). Lignin content will affect the process of making pulp. Low lignin contents make them easily pulped and produced bleachable-grade pulp; therefore, high brightness pulp can be obtained.

Conclusion

The results of the outer and inner EFB fiber morphology measurement, in general, there were no significant differences in morphology, derivative values of fiber dimensions and chemical components. The value of the length of the fiber and the value of the dimensions of the fiber, including the category II. The amount of holocellulose content is less quality, while the amount of lignin and extractive contents are of good quality. In general, it is not necessary to distinguish between the inside and the outside of the EFB pulping. Pulp making from EFB can be done without sorting the inside and outside parts and has fulfilled the requirements as pulp raw material for paper making

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Author’s Contributions

Ihak Sumardi: Finding an idea for the study, working on collecting data from sources and references, arranging information and sorting data and starting to analyze pulp properties, approving the sturdy results and fully evaluating the subject matter.

Anne Hadiyane: Prepared the material and analysis fiber morphology.

Alfi Rumidatul: Prepared the manuscript.

Lili Melani: Revised it and both the authors approved the manuscript.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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