

# Chemical composition, fiber morphology, and kraft pulping of empty fruit bunch of dura variety (*Elaies guineensis* Jack)

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## Chemical composition, fiber morphology, and kraft pulping of empty fruit bunch of dura variety (*Elaeis guineensis* Jack)

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**Abstract.** Fiber dimension, chemical component and pulp properties of biomaterial will directly affect the process, cost and quality of the paper produced, unfortunately until now it is very difficult to find information regarding these traits for Dura varieties. This study aims to examine the suitability of OPEFB of dura variety as paper raw materials based on those properties. Measurement of fiber dimension was carried out on maceration preparation made using Fraklin solution. Chemical components were determined by following the Tappi test method procedure. Pulp was made by the kraft method, then the properties were analyzed using Tappi test method and Scan. The results showed that this material had thin-walled fibers ( $2.79 \pm 0.84\mu\text{m}$ ) with a medium length ( $1073.81 \pm 373.63 \mu\text{m}$ ). This material contained extractive (7.19%) and holocellulose (67.69%) which were categorized high, and low in lignin (21.08%). The pulp produced yield (39.7%) and a high-categorized kappa number (23.3) and low alkali consumption (9.4%). Based on those values, OPEFB of dura variety was suitable as raw material for paper manufacture, although more efforts are still needed to increase the pulp yield value, due to the high value of "uncooked" pulp (32.43%).

### 1. Introduction

Indonesia has become one of the strong competitors in pulp and paper exports in the world. Pulp and paper are one of the mainstay products of national exports. The source of the main raw material for the pulp and paper manufacture is wood from the industrial timber plantation (HTI) program. With the realization of HTI which has only reached 40% as raw material for pulp & paper, Indonesia is in the 9<sup>th</sup> place as pulp manufacturer and No. 12 as the largest paper manufacturer in the world. The Chairman of the Indonesian Pulp and Paper Association said that if HTI had been realized 100%, or if there are other sources of raw materials, then the position could be raised to No. 03 and 04 in the world [1]. Unfortunately until 2013, Forest Watch Indonesia reported that the realization of HTI until the period 2009 - 2013 only reached 1,842,688 ha or has increased 428,359 ha from period 2002 - 2008 [2], so that it could be said that HTI realization has not met the expectation [3].

Nationally, oil palm empty fruit bunches (OPEFB) waste in Indonesia are very abundant. OPEFB waste ranges from 20 - 23% of total fresh fruit bunch (FFB)[4]. In 2010, the oil palm empty fruit



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bunch waste reached 20.2 - 25.2 million tons [5]. This number will continue to increase along with the increase of palm oil production in Indonesia. The production of crude palm oil (CPO) increased from around 700 thousand tons in 1980 to 31 million tons in 2015 [6]. OPEFB waste contains lignocellulose [5]. One requirement for raw materials that can be used as paper is contain lignocellulose [7]

Oil palm has three varieties, namely dura, pisifera and tenera [8, 9]. Dura variety has thick shell and thin fruit flesh than tenera variety [10]. The fruits of pisifera variety are shell-less and the female flowers are sterile so they rarely produce fruit.

Unfortunately, based on the maximum search we have conducted on various literature, it is difficult to find publication on basic properties and the quality of pulp from the dura variety as a raw material for paper manufacture. It is unfortunate since it has been known that the basic properties of the material, namely the fiber dimension and chemical component and pulp quality directly affect the process, cost and quality of the paper produced [11, 12, 7]. This research aims to assess the suitability of the OPEFB of dura variety as raw material of paper manufacture based on the fiber dimension, chemical component and the pulp quality.

## 2. Materials and Methods

### 2.1 Research sample

The fiber dimension, chemical component and pulp properties of OPEFB samples obtained from two palm trees of dura variety as replication would be observed. The two palm trees were randomly selected from 40 dura palm trees. The 40 palm trees were selected purposively with the criteria of having FFB and ripe characterized by the amount of kernel around 15-20 grains and uniformity of bunch size and originated from oil palm plants with the same age and land class [13].

From each palm tree, two OPEFB were taken. Then the first OPEFB was divided into three, 1/3 part in the middle was used for observing the fiber dimension and chemical component analysis. The second OPEFB and the remainder of the first OPEFB were used as sample for pulping.

### 2.2 Fiber maceration and measurement

OPEFB samples for the measurement of fiber dimension was firstly cut into sticks of 1 mm x 1 mm x 20 mm. The sticks collection then was macerated using Franklin's solution, which was 60% glacial acetic acid and 40% hydrogen peroxide at 60 °C for 48 hours [14].

The separated fibers obtained from the maceration then was put into bottles and colored with two drops of safranin. The bottle was then slowly shaken so that safranin was evenly distributed to all parts of the fiber. The colored fibers were then rinsed with distilled water and sterilized with alcohol rinse in 30%, 50%, 70% and 90% in sequence [15].

Measurement of fiber dimension was conducted using a microscope equipped with a micrometer. The dimension measured included fiber length and diameter, and lumen diameter. Fiber length was measured at 10 x 10 magnification, and the diameter and lumen at 10 x 40 magnification. Fiber wall thickness values were calculated by reducing the fiber diameter value with lumen diameter then divided by two [14]. The dimension of the amount of fiber observed was 40. Determination of the amount of measured fiber was carried out after the preliminary measurement of 100 fibers.

### 2.3 Analysis of chemical components

OPEFB samples were first made into 40 mesh size powder. The powder was then analyzed for its chemical components following the procedures of the Technical Association Pulp and Paper Industry (Tappi) standard Test Methods. The analysis and determination of extractive content used Tappi Test Method [16]. For analysis and determination of holocellulose and lignin from extractive free powder respectively used chloride method [17] and Tappi Test Method [18]. Tappi Test Method [19] was used to determination of  $\alpha$ -cellulose content from the holocellulose powder.

## 2.4 Pulping

All OPEFB samples for pulping were then made chip with size of  $\pm 15 - 25$  mm X  $15 - 25$  mm X  $2 - 4$  mm (L x W x H). The resulting chips were then filtered using Williams's chip classifier type filter to avoid chips that were too large or small. The selected chips were those that passed through the sieve with the cavity diameter of  $5/8$  "and were left in the sieve with the cavity diameter of  $3/8$ " [20].

The selected chips were then pulped using the kraft method with cooking condition of 22% active alkali, 25% sulfidity and 5:1 of chemical and chip scale ratio. The cooking time from room temperature to maximum temperature ( $170$  °C) was 90 minutes. Then cooking was continued at the maximum temperature for 90 minutes.

At the end of the pulping period, representative samples of the black liquor were analyzed to determine the value of alkali consumption [21]. The pulp obtained, then was washed and disintegrated to avoid fiber bundles. The pulp then was filtered and pressed, next the yield was calculated and the value of the kappa number was determined by applying the Tappi Test Method Standard [22] procedure.

## 2.5 Data analysis

The data obtained was tabulated. This data compared with fiber dimensions, chemical component and pulp properties of wood as raw material for the paper manufacture. This comparison aims to predict the paper properties to be produced. Comparison was performed with wood, since wood is the dominant raw material for paper nowadays, while the fibers from this OPEFB would also be designated as paper raw material in this research.

The dimension and derivative values of fiber were compared with fiber classifications according to the International Association of Wood Anatomists (IAWA) [23]. The chemical component values of OPEFB tenera variety were compared with chemical component classification for hardwood (Appendix 1). The pulp properties produced were compared to the quality of the tropical hardwood as raw material of sulfate pulp for paper (Appendix 2).

## 3. Results and Discussion

### 3.1 Fiber dimension

The average of fiber length and wall thickness of OPEFB dura variety was  $1073.81 \pm 373.63$  and  $2.79 \pm 0.84$   $\mu\text{m}$ , respectively (Table 1). When compared with fiber of mangium (*Acacia mangium* Willd) as the main raw material for the pulp and paper manufacture in Indonesia, it had an average length of  $982$   $\mu\text{m}$  [7] and an average wall thickness of  $3.33$   $\mu\text{m}$  [14], while the average of the OPEFB fiber was longer and thinner. Hardwood fiber with a length between  $901$  to  $1600$   $\mu\text{m}$  was categorized as medium length fiber according to IAWA classification [23]. The fiber length is directly proportional to the tensile and bursting strength of the paper produced [24, 25].

**Table 1.** Dimension of palm oil empty bunches fiber of dura variety

Fiber dimension	Value ( $\mu$ )
Fiber length	$1073.81 \pm 373.63$
Fiber dimension	$28.15 \pm 6.05$
Lumen diameter	$22.57 \pm 5.81$
Fiber wall thickness	$2.79 \pm 0.84$

IAWA categorizes fiber wall thickness in three groups: very thin, thin to thick and very thick. It is categorized very thin if the of wall thickness is six or more times wider than the double wall thickness. Fiber is categorized as thin to thick if the value is less than three times the double wall thickness. Last,

fiber has thick wall if the lumen is almost covered all [23]. As six times the fiber wall ( $2.79 \mu\text{m}$ ) is  $16.74 \mu\text{m}$ , it turned out that it was still smaller than the lumen diameter ( $22.57 \mu\text{m}$ ), so the OPEFB fiber of the dura variety was very thin. Paper made of thick-walled fibers will produce paper with low tear strength [12, 25] and tensile strength [12] and folding endurance [20].

### 3.2 Chemical Component

The chemical component of a material is an important factor that determines pulp yield and paper quality. Data on the results of research on the chemical components of OPEFB fibers of dura variety are presented in Table 2.

**Table 2.** Chemical components of oil palm empty bunches of dura variety

Chemical Component	Content (%)
Extractives	7.19
Lignin	21.08
Holocellulose	67.69
$\alpha$ -cellulose	40.27

Extractive content of OPEFB of dura variety (7.19%) was high if it was based on the classification of hard wood extractive content (Appendix 1). The pulp yield was affected by the extractive content of material. Materials with low extractive content are preferred as pulp raw materials [26]. The extractive presence in plant cells in the form of pits will inhibit the penetration of cooking solutions into chip in pulping [27]. The consequence of such constraints is the large opportunity for "uncooked pulp" or it will require more chemicals to convert the chips into pulp. Fifty persen of resin is left in sulfite pulp [28].

The average of lignin content of OPEFB of dura variety was 21.1% (Table 2). The lignin content of this variety was middle classified according to the classification of chemical components for hardwood (Appendix 1). Material for pulp raw material is expected to have low lignin content, because it will produce high pulp yield [12] and consume fewer chemicals [29, 26].

The  $\alpha$ -cellulose OPEFB of dura variety (40.27%) was considered moderate based on those classification (Table 2), but the holocellulose content (67.69%), which was a combination of hemi and  $\alpha$ -cellulose was higher than the total holocellulose of *Pinus merkusii* Jungh et De Vries (61.7%) [30]. *P. merkusii* has been used as raw material for making cement bag. High holocellulose content will produce high pulp yield [11, 31], while high  $\alpha$ -cellulose content is associated with greater affinity for water, making it easier to form bonds between fibers and the color of paper becomes whiter [32]. With the value of holocellulose and  $\alpha$ -cellulose content, it is assumed that the OPEFB of tenera variety will produce high pulp yield but it still requires bleaching chemicals to increase the brightness level of paper produced.

### 3.3 Pulp Properties

The average screened pulp yield obtained from OPEFB of dura variety was 39.7% (Table 3). Kraft pulp yield of mangium is 44.06 % [33]. Mangium trees are the most dominant species planted in HTI [34, 35], with the main goal as the main raw material for the pulp and paper industry as well as other wood products [36, 37].

**Table 3.** Pulp properties of oil palm empty fruit bunch of tenera variety

Pulp Properties	Value
Yield (%)	39.7
Kappa number	23.3
Alkali consumption (%)	9.4

This pulp yield value can be categorized as second class, or good based on the quality class of hardwood pulp for paper, in appendix 2 [38]. The cause of the yield value was due to the high level of holocellulose content (67.69%) and the level of lignin content (21.08%) which was classified as moderate as described previously (Table 2). The pulp yield is directly proportional to the holocellulose content [11] and inversely proportional to the lignin content [12] of the raw materials.

The average of kappa number of OPEFB of dura variety was 23.3 (Table 3). Based on the quality class of hardwood pulp for paper [38] in Appendix 2. The kappa number of this material was still relatively high because it was categorized into third class. A high kappa number indicated that there was still a lot of lignin left in the pulp after pulping, and this was proved by the percentage of uncooked pulp that was still high (24.00%). Future research will be directed at efforts that can simultaneously decrease the value of the kappa number and increase the pulp yield value.

The average of alkali consumption of the OPEFB of dura variety was 9.4% (Table 3). Alkali consumption can be interpreted as the amount of chemicals used to convert chip into pulp. The amount of chemicals used is expressed in percent to the oven dry weight of the cooked chips.

Based on the quality class of hardwood pulp for paper [38] in Appendix 2, the chemicals used to convert chip into pulp were very little, therefore the alkali consumption was classified as first class. However, the reason why the amount of chemicals used were very little, because there were still quite a number of uncooked chips as stated above.

#### 4. Conclusion

In general, OPEFB of dura variety was suitable as raw material for paper manufacture. This assessment is based on the value of the fiber dimension, chemical component and pulp properties. OPEFB fiber of dura variety was categorized as medium in length and thin in wall thickness according to IAWA classification, so it is expected to produce paper with relatively high mechanical strength. Yield and alkali consumption of pulp were classified as second and first class, respectively, based on the quality class of hardwood pulp for paper. This pulp yield value is still possible to be improved, because there is a "pulp uncook" (32.43%), which is also indicated by a high kappa number (23.3). A high Kappa number indicates that the amount of lignin left in the pulp is still relatively high, even though the material actually has moderate lignin content (21.08%) and high holocellulose content (67.69%).

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## Appendix 1. Chemical component classification for hardwood

Chemical Component (%)	Component class		
	High	Moderate	Low
Hardwood			
Cellulose content	> 45	40 - 45	< 40
Lignin content	> 33	18 - 33	< 18
Pentosan content	> 24	21 - 24	< 21
Extractives content	> 4	2- 4	< 2
Ash content	> 6	0,2 - 2	< 0,2

Source [39]

## Appendix 2. The quality of the tropical hardwood as raw material of sulfate pulp for paper

Properties	I	II	Quality					
			III	IV				
					120-			
Wood density, g/cm <sup>3</sup>	>200	100	150-200	50		25	<120	12,5
Screened pulp yield, %	>44	100	40-44	50	35-40	25	<35	12,5
Alkali consumption, %	<18	100	18-20	50	20-22	25	>22	12,5
Felting power, l/d	>100	100	50-100	50	30-50	25	<30	12,5
Permanganat/kappa number	<18	100	18-20	50	22-30	25	>30	12,5
Breaking length, Km	>5	25	3,5-5	12,5	2,5-3,5	6,25	<2	3,13
Burst factor	>25	25	20-25	12,5	15-20	6,25	<15	3,13
Streth, %	>2,5	25	1,5-2,5	12,5	1-1,5	6,25	<1	3,13
Folding endurance	>25	25	20-25	12,5	10-20	6,25	<10	3,13
Brightness, °GE	>80	100	75-80	50	65-75	25	<65	12,5
<i>total value</i>	700		400		250		175	
<i>Value range</i>	>700		400-699		250-399		175-249	

Source [38]

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