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Physical and Mechanical Properties of Palm Frond for the Development of Palm Oil Waste Chopper and Pressing Machine Design

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Abstract— Physical and mechanical properties of palm oil frond are very important factor for the development of palm oil waste utilization technology. The objective of this research was to determine the maximum pressure to break off palm oil tissue for mulch processing. The average dimension of palm frond is also needs to be determined in order to design pressing machine as well as leaflet and frond chopper machine. The result found that the average length of palm oil frond was 675.89 cm, average leaflet length at the palm frond base was 103.89 cm and average leaflet length at palm frond tip was 23.83 cm. Based on the experiment, the maximum compression strength at the 20 years-palm frond base was 443.78 kgf and at the 5 years-palm midrib base was 287.56 kgf. This finding suggests that pressure of machine should be designed above 443.78 kgf.

Index Terms— Palm Frond, maxsimum pressure, chopper machine, mulch, compost

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1 INTRODUCTION

Palm oil frond is produced during plants maintenance through pruning, fruit harvesting and plant rejuvenation by cutting trunk and frond from the plants. Each tree has more than 60 fronds with 120 cm of length per frond (Aholoukpe, *et al*., 2013).

With average economic life of palm oil trees that reaches up to 20-25 years (Rupani *et al*., 2010), the frond will accumulate in considerable amounts as waste biomass in palm oil plantations if there is no recovery. Husin *et al*. (1986) reported that the whole process starting from pruning, harvesting until rejuvenation for 25 years will produce 16 tons / ha of oil palm frond. Frond as palm oil waste can be processed into organic mulch and compost.

Organic mulch can be used for land conservation and compost can be used as a substitute for chemical fertilizer during palm oil plant growth and development (Sarwono, 2008).

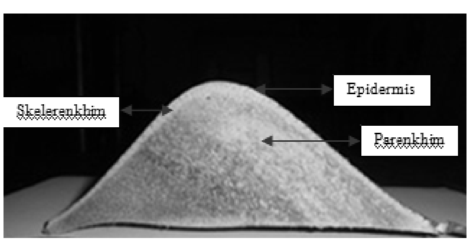

Figure 1. Cross-sectional view of palm frond

Palm frond generally consists of 3 parts: leaflet, rachis and petiole. The leaflets are attached to the frond and can be used as raw material for compost and mulch. Size reduction of leaflet is carried out through chopping and pressing. Rachis and petiole on palm frond can be used as an organic mulch. Biomass waste in the form of trunk and frond is generated during palm oil plant production (Wanzari, 2002).

Compression breaks rachis and petiole connective tissue. Broken rachis and petiole makes them degraded easier on the ground and optimize plants nutrient uptake. Compression up to a certain level may cause physical damage on frond especially rachis and petiole. Damaged rachis and petiole can be applied to palm oil plantation as mulch. This study aimed to determine the physical and mechanical properties of palm frond to design palm oil chopper and pressing machine.

2 RESEARCH METHOD

2.1 Time and Location

Research was carried out from January to December 2014. Location of the research was Cikabayan palm oil plantation of Department of Agronomy and Horticulture, Bogor Agricultural University, palm oil plantation of PTPN I Langsa Aceh and Laboratory of Forest Product, Bogor Agricultural University.

2.2 Material and Equipment

Research used 25 of palm oil frond and aluminum foil. Equipments used in this research were Instron machine type 3369P7905, oven, desiccator, tray, knife, cutter grinder, saw, gauge, caliper, digital weighing scale, palm chisel harvester and markers.

2.3 Research Procedure

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Research was initially started by measuring the length of palm leaflet and frond. Palm frond was then stored for 9, 7, 5, 3 and 0 days and cut at the base, middle and tip of the frond. Every parts were then measured in term of moisture content and compression strength.

Moisture content measurement was carried out by weighing 5 gram of every part of frond in which pericarp and parenchyma had been separated before. Aluminum foil paper was cut into smaller size to contain samples and then put together into oven which set at temperature 105^{o}C for 24 hours. After oven drying, sample and the container were then placed into desiccator before weighing. Weighing was conducted to obtain the final mass of material after oven drying.

Compression test was carried out using Instron machine for every storage period and at every part of frond. Instron machine automatically recorded the magnitude of force applied during compression test.

3 RESULT AND DISCUSSION

3.1 Physical Properties of Palm Frond

Based on the physical properties measurement, the average length of palm frond was 675.89 cm, the average length of palm leaflet at the base side was 103.89 cm and the average length of leaflet at the tip side was 23.83 cm. The average weight of leaflet per frond was 3 kg and the average weight of frond was 9.5 kg. The average width of frond base was 17 cm and the average height of frond base was 6 cm. The length comparison of palm leaflet and palm frond are shown in Figure 2.

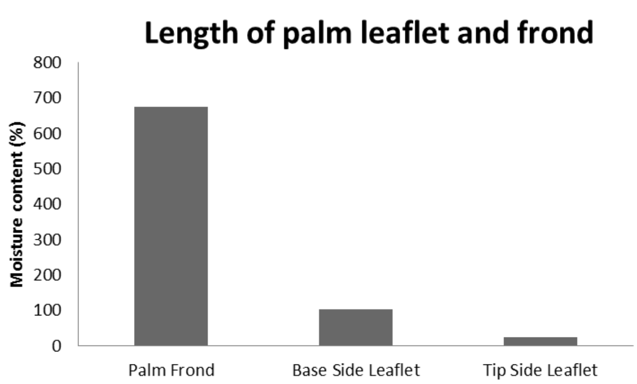

Figure 2. Length of palm leaflet and frond

3.2 Moisture Content of Palm Leaflet and Frond

High moisture content contained in the frond causes the firmness level of the material. Moisture content testing of palm frond was carried out at 5 and 20 years old plant with 9 days storage period. Table 1 shows the result of moisture content test.

Table 1. The average moisture content of parenchyma and pericarp at different storage period

Storage period (days)	Moisture content (% wet basis)			
	Parenchyma		Pericarp (skin)	
	5 years old	20 years old	5 years old	20 years old
0	80.127	78.037	60.502	58.465
3	71.587	70.504	54.758	49.822
5	66.912	72.783	48.888	51.606
7	68.809	64.515	55.906	47.229
9	66.769	62.197	52.637	46.717

According to Table 1, it can be seen that pericarp had lower moisture content compared to parenchyma. This could be due to the structure of pericarp fiber was more compact than parenchyma. Thus pericarp was only able to store lower water than parenchyma.

Pericarp at 20 years old plant-frond had lower moisture content compared to 5 years old plant due to more compact fiber structure. Research also resulted that there was a decreasing moisture content along increasing storage period both for 5 years and 20 years old plant.

In order to measure the moisture content, palm frond was chopped into 2, 4 and 6 cm of size as shown in Figure 4.

(a) (b) (c)

Figure 3. Palm frond chopping size a) 2 cm, b) 4 cm, c) 6 cm

The moisture content of palm frond is shown in Figure 4.

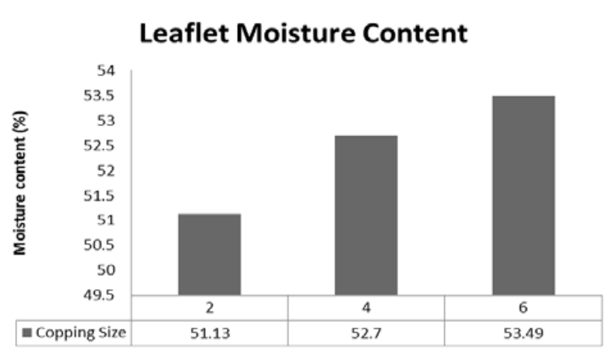

Figure 4. Fresh palm frond moisture content

Based on the figure above, it can be seen that longer leaflet chopping size resulted in higher moisture content. This was due to smaller leaflet surface area which led to higher evaporation.

3.2 Mechanical Properties of Palm Frond

Figure 5 shows cross-sectional and surface area of palm frond prior compression test.

Figure 5. Palm frond prior compression test

An illustration of compression test using Instron machine type 3369P7905 is shown in Figure 7.

Figure 6. Palm frond compression test

Cross-sectional and surface area of palm frond after compression test is shown in Figure 8.

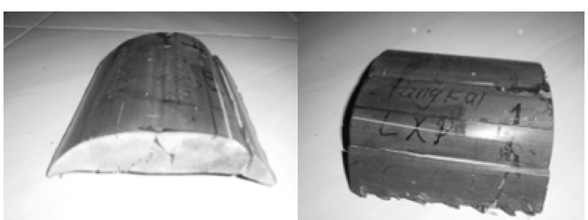

Figure 7. Palm frond after compression test

Compression test on palm frond caused damage to the vertical direction which changed the shape to be more flattened. More flattened shape caused pericarp and parenchyma damage.

Compression test result of palm frond at 5 and 20 years old plant under different storage period is shown in Figure 8 and 9.

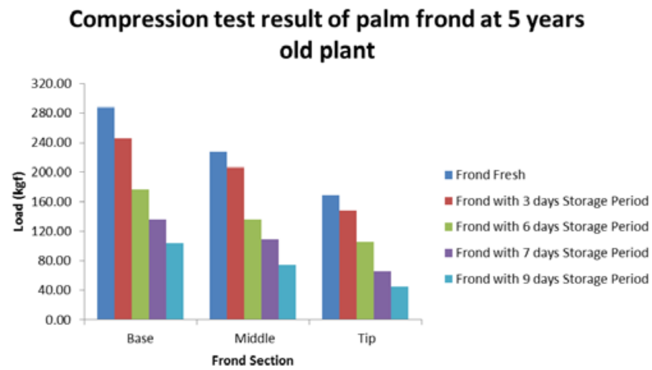

Figure 8. Compression test result of palm midrib at 5 years old under different ripening period

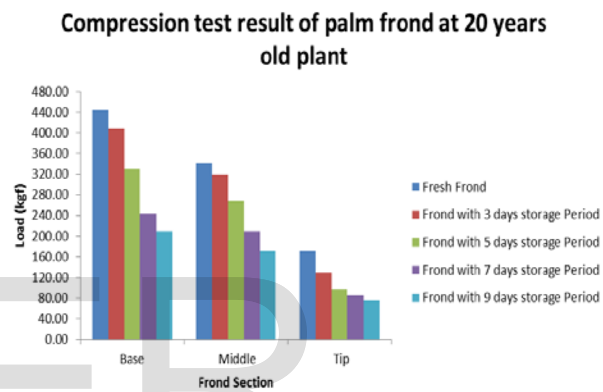

Figure 9. Compression test result of palm frond at 20 years old under different storage period

Figure 8 and 9 show decreasing compression strength at increasing storage period. Fresh palm frond (0 day storage period) had the highest compression strength compared to others both at the tip, middle and base section. This indicated that base side had more compact fiber structure and needed higher compression strength.

The highest compression strength of 5 year old plant occurred at the base side i.e. 287.56 kgf. Similar condition also found that the highest compression strength of 20 years old plant occurred at the base side i.e. 443.87 kgf.

The compression strength of 20 years old plants was higher than 5 years old plants. Therefore, this condition can be used as a reference to design the power of a palm oil waste chopper and pressing machine.

CONCLUSION

1. The average length of palm frond was 675.89 cm, average length of leaflet at base side was 23.83 cm, average weight of leaflet per frond was 3 kg, average weight of palm frond was 9.5 kg, average width of

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frond base side was 17 cm and average height of frond base side was 6 cm.

2. Pericarp had more compact fiber structure compared to parenchyma. The moisture content of parenchyma and pericarp of 5 and 20 years old were decreasing along with the increasing storage period.
3. Compression strength of 5 and 20 years old of palm frond was 287.56 and 443.78 kgf, respectively. Palm frond base had larger compression strength compared to middle and tip side. Therefore, the machine should be designed with higher compression strength than 443.78 kgf.
4. Compression strength of 5 and 20 years old plant was decreasing along with the increasing storage period.

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