Modification and performance improvement of chopper palm frond (AE03-Type)

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Abstract. A chopper machine has been developed to chop oil palm frond (OPF) for cattle feed in Aceh province. This paper reports the results of the modification of the third generation chopper machine named AE03-type. The purpose of this study is to improve the performance of the chopper machine for OPF through the process of modifying the chopper blade. Modifications made are designing a chopper blade with a plate thickness of 6 mm, a length of 15.5 cm and a width of 4 cm arranged in a spiral around a solid shaft with a diameter of 1 inch with a length of 100 cm, as many as 36 pieces. The parameters measured to show the performance of the chopper machine are dimension average of chopped, the percentage of chopped OPF, chopping efficiency, and capacity of the machine. Three variations of rotation speed are tested on the engine, which is 800 rpm, 1200 rpm, and 1600 rpm, respectively. The results show that modifying the chopper knife can improve the performance of the chopper machine. The best rotation speed for this chopper machine is 1200 rpm with length and width of chopped, OPF percentage of chopped, chopping efficiency, and capacity of the machines are 27.5 mm, 1.5 mm, 86.45%, 98.37%, and 147.85 kg/h, respectively. The size of the chopped is following the dimensions of feed for cattle feed needs, especially those in Aceh Province.

1. Introduction

Palm oil leaves form a compound leaf, even and leafy. The leaves form one oil palm frond (OPF), which reaches more than 7.5 - 9.0 m. The number of sub-leaves in each OPF ranges from 250 to 400 strands [1, 2]. The amount of OPF, the length of OPF, and the number of sub-leaves depends on the age of the plant. Older plants will have more OPF and sub leaves. Similarly, the OPF will be longer than the plants that are still young.

The length of OPF varies depending on the type of variety and fertility of the soil. Leaves reach 9 meters in length in mature plants. The sub-leaves on each side reaches 125-200. The sub-leaves in the middle of the OPF can reach 1.2 meters. OPF weight reaches 4.5 kg dry weight per unit. Palm oil plant is found 40-50 midrib per plant [3-5].

When harvesting, the OPF will be obtained 2.3 tons of dry material per ha. It is equivalent to 22-26 OPF per year with a mean weight of 4-6 kg per OPF. Even the production can reach 40-50 OPF per plant per year with a mass of 4.5 kg per midrib [6-8]. OPF is one of the wastes that is only stacked on field plantations other than empty fruit bunches [1, 9-11]. It makes one lane between the trees impassable because of the OPF stack. Therefore, several practitioners and researchers conducted a
study to process OPF into compost and feed [2, 12] (Figure 1). Both forms of processing require a material size reduction machine called a chopper machine.

![Figure 1. Application of OPF as animal feed [13].](image1)

OPF has parts that are from Initial, middle and edge. Each section of the OPF can be cut using a chopper to reduce its size. One way to reduce the size of the OPF is to use a chopper, but the chopper requires a large amount of power to refine the chopped results. The size of the cuttings can be influenced by various factors such as rotation speed, OPF size, and chopper blade. Each result of the chopper can also be affected by each type of knife used in the chopper machine.

Chopper machines for OPF have been developed by several researchers [14-16]. The design of the chopper machine is shown in Figure 2. This machine has dimensions of length, weight, and width respectively 1964 mm, 1902 mm and 1567 mm. This machine also has a weight and capacity of 500 kg and 1966 kg/hr, respectively. However, the design of the AE01-type OPF counter still has the disadvantage of being too large and not practical/portable to be transported to the plantation or field. On the other hand, it cannot be categorized as affordable, appropriate technology and cheap technology to be obtained by smallholders of palm oil in Indonesia.

![Figure 2. Chopper machine AE01-type.](image2)

The area of oil palm plantations in Aceh Province in 2018 reached 440 thousand ha, of which 64.10% were smallholders [17]. On average each farmer has an area of ±2 ha of plantations. In general, these oil palm farmers do not have enough capital to be able to manage their estates so they can be more environmentally friendly. This makes the application of agricultural technology in the form of large machinery and requires massive investment costs not appropriate in this area. On the one hand, the community's oil palm plantations continue to produce palm fronds during the harvesting and pruning processes. Where the palm fronds are only stacked between oil palm plants which could potentially become a den of plant pests. On the other hand, the ability of farmers to be able to process oil palm fronds is limited because the machines for oil palm plantations available in the market are dominated on a large scale.

To overcome this problem, Bulan et al [18] redesigned the chopper machine. The results of the study showed that the chopper machine had been successfully developed with a capacity of 116.98 kg/hr at a rotation speed of 1600 rpm (Figure 3). This machine has dimensions of length, height, and width of each 880 mm, 572 mm and 919 mm. This machine also weights no more than 100 kg.

![Figure 3. Chopper machine AE02-type.](image3)
However, this design still found disadvantages, namely the largest OPF percentage of chopped was 87.55% at a rotating speed of 1600 rpm. It can even be increased by improvements to the design of the chopper machine. By improving the OPF percentage of chopped, it is expected to strengthen other parameters such as dimension average of chopped, chopping efficiency, and capacity of the machine. Therefore, this study aims to improve the performance of the chopper machine for OPF through the process of modifying the chopper blade.

2. Material and method

2.1. Experiment description

This study uses OPF from oil palm which is ten years old. The composition and distribution in the fields are presented in Figure 4. The OPF were weighed before chopping. The experiment uses three rotational speeds on the chopper blade shaft of 800 rpm, 1200 rpm, and 1600 rpm. Each test will be repeated three times.

2.2. Calculation of parameter performance machine

The capacity of the chopper machine is calculated using Equation 1 [19]. The factors that influence it are the amount of material to be fed and the process time of chopping.

\[ M_C = \frac{W_t}{t} \]  

(1)

Where; \( M_C \) - machine capacity (kg/hr); \( W_t \) - the weight of fed (kg); \( t \) - chopping time (hr).

The machine was evaluated based on two indices that include the percentage of chopped OPF (\( \eta_{oc} \)) and chopping efficiency (\( \eta_c \)) was done by some Researcher [20-23]. These were calculated respectively by using Equations (2-3).

\[ \eta_c = \frac{W_{oc} + W_{noc}}{W_t} \times 100\% \]  

(2)

\[ \eta_{oc} = \frac{W_{oc}}{W_t} \times 100\% \]  

(3)

Where; \( \eta_c \) - chopper efficiency (%); \( W_{oc} \) - weight of OPF chopped (g); \( W_{noc} \) - weight of OPF losses (g); \( \eta_{oc} \) - percentage of chopped OPF (%); \( W_t \) - total weight of OPF put into the machine (g).

This is also referred to as the rate of chopping. The capacity of the machine was evaluated as the quantity of the OPF the machine could process within a recorded time [24-26]. In this case, OPF was introduced into the machine while the time for the chopping operation to complete was recorded. This was calculated using Equation (4).

\[ C_c = \frac{3.6 \times 10^6 \times W_t}{T} \]  

(4)

Where; \( C_c \) - capacity of the chopper machine (kg/h); \( T \) - time (s).
3. Results and discussion

3.1. Machine descriptions
Modification of the chopper machine is taken by adding the number of blades to 36 pieces with the blade angle $\pm 15^\circ$. The shaft used is 25.4 mm in diameter and 1000 mm in length. The blade is welded on a plate with a thickness of 6 mm, 10 cm long, 10 cm wide and given a hole with a diameter of 2.5 cm in the middle. The plate used is nine pieces, where the plate is welded on an iron shaft with a distance of 10 cm. Each plate is welded four blades. On every one plate, there are four pieces. The blade is made using 6 mm thick iron plate, 15.5 cm long and 4 cm wide. The modified chopper machine is presented in Figure 5.

![Figure 5. Chopper machine AE03-type (a) side view of chopper blade (b) chopper machine (c) front view of chopper knife (d) testing of chopper machine.](image)

3.2. Machine capacity
The results of the research on the engine capacity at a different rotating speed of chopper blades are shown in Figure 6. It shows that increasing the rotational speed of the chopper machine will increase the capacity on the middle OPF sample. However, at the initial OPF and edge, the engine capacity decreases on the use of a rotating speed of 1600 rpm. This shows that the chopper AE03-type machine can work with higher capacity at 1200 rpm, i.e., 178.09 kg/h. This chopper machine (AE03-type) capacity has increased by 34.31% from the previous chopper machine generation (116.98 kg/hr)[18].

Machine capacity rises with increasing rotation speed from 800 rpm to 1200 rpm on all parts of the OPF tested. Furthermore, machine capacity will decrease with increasing rotation speed from 1200 rpm to 1600 rpm at the initial OPF, and edge OPF tested. But it is different in the middle OPF that was tested, rising rotation speed from 1200 rpm to 1600 rpm increases machine capacity. It is thought to be caused by the middle OPF having different characteristics from the initial OPF and edge OPF even from the same OPF.

3.3. Chopping of OPF percentage
Data of the chopping of OPF percentage as affected by the different operation variables considered in this study is shown in Figure 7. At given rotation speeds and sections of OPF, the OPF percentage chopping was observed to decrease with increasing the rotation speed. The highest OPF percentage
chopping is at the rotational speed of 1600 rpm in the initial OPF section of 94.64%. This result has been 7.45% higher when compared with the chopper machine AE02 type [18].

Chopping of OPF percentage rises with increasing rotation speed from 800 rpm to 1600 rpm in all parts of the OPF tested. The largest to the smallest chopping of OPF percentage increases sequentially occurred at the initial OPF, edge OPF and middle OPF from rotation speed 800 to 1200 rpm. However, at a rotation speed of 1200 to 1600 rpm, the largest to smallest chopping of OPF percentage increases in the middle OPF, initial OPF and edge OPF. It indicates that low rotation speed is more suitable for softer parts of OPF, and high rotation speed is more efficient for harder parts of OPF.

3.4. Chopping efficiency

The efficiency of the AE03-type chopper machine is shown in Figure 8. The results show that the average chopping efficiency is 97.61% in all variations of the rotational speed experiment and the OPF section. This value has been 1.71% greater than the previous chopper machine [17].

Chopping efficiency rises with increasing rotation speed from 800 rpm to 1200 rpm on edge OPF and middle OPF. Henceforth, increasing rotation speed from 1200 rpm to 1600 rpm causes decreases chopping efficiency in this part. The most considerable decrease in chopping efficiency occurs at the edge OPF. For middle OPF, raised rotation speed from 800 rpm to 1200 rpm causes a reduction in chopping efficiency. However, rising the rotation speed to 1400 rpm can increase chopping efficiency more significant than the edge OPF and middle OPF at a rotation speed of 1600 rpm.

3.5. Dimension of chopped

The measurement of the length and width of the OPF from the chopper machine is presented in Table 1. The results show that the OPF dimension is smaller with increasing rotational speed in all OPF sections. The most considerable length of chopped is found on the edge of OPF with a rotating speed of 800 rpm which is 4.85 mm. The largest width of the OPF chopped is in the initial part of OPF with a rotating speed of 800 rpm which is equal to 5 mm. The smallest length is found in the middle section of OPF with a rotating speed of 1600 rpm which is similar to 20.0 mm. The smallest width is located in the middle part of the OPF with a rotating speed of 1200 rpm which is equal to 1.5 mm.

An increase in rotation speed from 800 rpm to 1600 rpm causes a decrease in the dimension of chopping OPF (length and width) at the initial OPF. An increase in rotation speed from 800 rpm to 1600 rpm also causes a decrease in the chopped dimensions length and not the chopped dimensions width at the middle OPF and edges OPF. In the middle OPF and edge OPF, a rise in rotation speed
from 800 rpm to 1200 rpm causes a decrease in the chopped dimension width. Furthermore, an increase of rotation speed from 1200 rpm to 1600 rpm causes an increase in chopped dimension width at the middle OPF and no change at the edge OPF. At the same rotation speed, the chopped dimensions (length and width) on edge OPF is always smaller than the others. It is due to the characteristics of the edge OPF itself, which has a softer and smaller shape compared to other samples.

![Figure 8](image)

**Figure 8.** Effect of blade rotation speeds and sections of OPF on the chopping efficiency.

| Rotation Speed (rpm) | Initial Length (mm) | Initial Width (mm) | Middle Length (mm) | Middle Width (mm) | Edge Length (mm) | Edge Width (mm) |
|----------------------|---------------------|--------------------|--------------------|-------------------|-----------------|----------------|
| 800                  | 40.00               | 5.00               | 31.00              | 3.00              | 4.85            | 3.00           |
| 1200                 | 35.00               | 3.00               | 27.50              | 1.50              | 2.85            | 2.50           |
| 1600                 | 23.00               | 2.00               | 20.00              | 2.50              | 2.45            | 2.50           |

4. **Conclusions**
Modifications to the chopper machine have been constructed and tested. All parameters tested on the AE-03 type chopper machine were found to have improved performance compared to the previous chopper engine. The machine capacity, chopping of OPF percentage, chopping efficiency of chopper machine increased by 34.31%, 7.45%, 1.71%, respectively. It indicates that the chopper machine modification has been successfully carried out and has been able to improve its performance. The future research from this study is to directly measure the torque load needed to chop OPF to consider the energy consumption of the chopper machine. The next work of this research is to test the results of chopped oil palm frond as feed substitution to be given to cattle.

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