Effect of the compost mixer machine on the quality of compost made from shredded oil palm fronds (OPF)

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Abstract. In general, the composting process made from oil palm fronds (OPF) is to reduce their size, mixing, and fermentation. One of the essential factors composting process is a mixed uniform between shredded OPF with other raw materials. In this paper, we discuss the quality of compost, which is stirred using a compost mixer machine (drum rotary double helix type). Composting methods chosen are natural inoculum and bokashi inoculum. Rotational speed of the mixer is applied at the levels of 100 rpm, 300 rpm, and 500 rpm. Parameters such as compost mass and temperature are recorded every five days for 60 days of composting duration. The N, P, K content, and C/N ratio were analyzed for 30 days and 60 days of composting duration. A total of 5 kg of mixed raw material was composted. Maximum temperatures recorded during the composting process of natural inoculum and bokashi methods were 35°C, 40°C, respectively. Mass loss of the two composting methods is 75%. A composting method, rotation speed, and composting duration do not significantly affect to achieve the Indonesian National Standard (SNI) quality of composting. Therefore, the use of various types of composting methods, low rotational speed compost mixer machine, and short composting duration can be applied to making compost using this machine.

1. Introduction

Palm oil (Elaeis guineensis JACQ) is a plant with its main products in the form of crude palm oil (CPO) and palm kernel oil (KPO). This product has high economic value and is one of the largest contributors to Indonesia's foreign exchange compared to other plantation commodities [1]. The area of Indonesian oil palm plantations until 2018 is 12.76 million ha with CPO production of 36.59 million tons [2]. However, with the total area and the amount of CPO production, it also produces biomass waste, one of which is oil palm fronds (OPF). The amount of OPF can reach 97 million tons per year [3-5] or 70% of the total residues generated from palm oil industry [6].

Clean production is one of the strategies in the effort to implement Indonesia's national policy on the environment. This policy aims to prevent the occurrence of environmental pollution at the source or reduce environmental pollution by recycling the resulting waste so that the creation of environmental sustainability [7]. Therefore, biomass waste (especially OPF) can be utilized or recycled to reduce environmental pollution. One of the efforts is to make the waste into organic fertilizer. The OPF is a waste material that can be processed into organic fertilizer to reduce the use of anorganic chemical fertilizers [8, 9].

OPF has the potential to be used as raw material for compost because each OPF contain 0.5% nitrogen, 0.1% phosphorus, 0.8% potassium, and 0.1% magnesium [10]. Other studies, Tan, et al. [6]
reported that OPF contained 57.6%, 19.7%, and 5.8% of total structural carbohydrate, total lignin, and ash content. The overall structural carbohydrate consists mainly of 42.8%, 12.5%, and 2.3% of glucan, xylan, and arabian, respectively. It becomes compost very suitable to be processed into organic fertilizer. Organic fertilizer can provide nutrients for the soil and also improve soil structure to reduce erosion [11].

In general, the process of making compost has three stages, namely reducing their size, mixing with other ingredients, and fermentation [9]. Size reduction aims for efficient microbial action during the decomposition process. Reducing this size can be done manually using a knife and or using a chopper machine. Mixing with other ingredients aims to combine some of the compost materials. This mixing can be done manually using a shovel or using a compost mixer [12]. Fermentation aims to provide opportunities for microorganisms to carry out the process of decomposition of the material to be composted. The decomposition process by microorganisms will produce the main nutrient content of compost, which will be more easily uptake by plants.

In recent years, composting equipment technology has continued to develop. Chopping machines with various methods continue to be developed by several researchers and engineers [13-15]. Bulan, et al. [14] conducted developing an integrated palm frond handling machine so that it can chop up palm leaves and pressing the palm frond at the same time. Another paper from Bulan, et al. [12] is reported to develop a compost mixer. However, this research has not evaluated the effect of composting using this mixer machine on the success of compost formation. Therefore, this paper presents a compost quality test which is stirred using a compost mixer machine (double helix rotary drum type).

2. Material and method
The tools used in this study includes equipment for composting, namely OPF chopper machine, compost mixer machine (Figure 1), composting tub, digital vernier caliper (0.01 mm), digital infrared tachometer (0.05% accuracy), thermometer (range measurement 0°C - 110°C), digital stopwatch, and digital scales (accuracy 0.1 g). Materials used in this study include shredded OPF (≤ 2 cm), cow manure, effective microorganism 4 (EM4) and rice husk ash, and glucose. Compost mass loss and compost temperature are measured every five days for 60 days. The treatment in this study consisted of the composting method, the mixer machine rotational speed, and composting duration. This experimental research design uses completely randomized factorial design. Means of the experimental data were compared by Duncan’s multiple range test (DMRT) at 95% confidence of interval.

![Figure 1](image_url) Composting mixer machine (double helix rotary drum type).

The composting method chosen is natural inoculum [16] and bokashi inoculum [17], which are both aerobically fermented. The total weight of compost to be fermented is 5 kg. Each treatment was designed three times. The raw material composition of the natural inoculum composting method consists of 60% cow manure and 40% shredded OPF. The composition of the raw material for the bokashi composting method consists of 16% cow manure, 83% shredded OPF, and 1% other mixed material in the form of EM4 microbial starter, rice husk ash, and glucose.
The compost mixer machine used in this study is the rotary double helix drum-type [12]. Total weight of the compost to be mixed is 5 kg. This mixer machine uses an 8.5 HP diesel engine with a maximum torque of 33.8 Nm. The test of the compost mixer machine is conducted at three stages of rotational speed (100 rpm, 300 rpm, and 500 rpm). The compost mixing duration is 10 minutes. Each treatment level was repeated three times.

The composting duration chosen in this study was 30 days and 60 days. The total weight of fermented compost is 5 kg. The N, P, K content, and the C/N ratio will be analyzed after composting duration finish, and the sample repeated three times. Analysis of compost N content using the Kjeldahl method and titration. Analysis of compost P content using the UV-Vis spectrophotometer method at a maximum wavelength of 400 nm. Analysis of K content using the oxidation method. Analysis of C content using the ash content method.

3. Result and discussion

Status of mass reduction from the composting process is presented in Figure 2. In general, the mass loss of the composting process using both methods is 75%. On one hand, the composting process of the bokashi inoculum method has a more significant mass reduction until the 25th day. However, the mass of both composting methods was the same on the 30th day of composting duration. Furthermore, the mass decrease of the bokashi inoculum method is the smallest between another until the 55th day. However, the mass of both composting methods is the same at the end of the composting duration. On the other hand, in general, composting bokashi inoculum method tends to decrease in mass more significant than the others. This is in line with research Fadzilah, et al. [9] which states that the decrease in mass from composting can be one indicator of the active microorganisms to decompose. The mass reduction model of the two composting methods can be identified using Equation 1 and Equation 2 with the coefficient of determination of 0.9811 and 0.964, respectively. The model was built with the limitation that the process of mixing compost raw material made from OPF was carried out using a mixer composting machine (double helix rotary drum type).

\[
M_{IN} = 0.0012F_r^2 - 0.1392F_r + 5.2191 \quad (1)
\]

\[
M_{IB} = 0.0017F_r^2 - 0.1541F_r + 4.7502 \quad (2)
\]

Where, \(M_{IN}\) - mass natural inoculum compost (kg), \(F_r\) - time of fermentation (day), \(M_{IB}\) - mass compost inoculum bokashi (kg).

The status of the temperature during composting is presented in Figure 3. In general, composting bokashi inoculum method has an average temperature higher than the other methods until the 30th day composting. The highest temperature of composting natural inoculum method and composting bokashi method there are on the same day (after 10 days of composting), the amount of which is 35 °C, 40 °C, respectively. After 10 day of composting, the composting temperature continued to decrease until finally approaching ambient temperature (26 °C). This phenomenon indicates that microorganisms...
from the two composting methods tested have been multiplying to the maximum until the 10th day composting and consume a lot of oxygen to carry out the decomposition process. A decrease in temperature after the 10th day of composting is suspected by the number of microorganisms that cannot multiply anymore and even tend to die. This is in line with the results of research by Bera, et al. [18] who reported that the multiply of microorganisms was determined mainly by the ratio of composting raw material to the number of microorganisms present.

Figure 3. Temperature of compost during the composting process (●-natural inoculum compost; □-bokashi inoculum compost).

The indication of the optimum number of microorganisms in composting can be identified through temperature parameters that occur during the composting process. Based on the temperature tendencies recorded during the composting process, it is known that compost has formed on the 35th day of composting for both composting methods. This is evidenced by the temperature in the compost with the same ambient temperature. The results of Nakasaki and Hirai [19] also stated that when the composting temperature had approached the ambient temperature, the composting process had stopped, and the compost had been decomposed. Besides, rapid decomposition of the composted raw material of compost is suspected by the optimum mixing process between the chopped OPF and other raw materials.

One of the characteristics of the decomposition of compost raw material is the presence of the main elements of a compost, namely N, P, and K. The N content of compost is presented in Figure 4. The rotation speed of the compost mixing machine is identified as affecting the percentage mixing process between raw material that is suspected of having an impact on the formation of N content in the compost. The most significant N content is found to be in the fermentation duration of 60th days composting at all rotational speeds and composting methods. While the smallest N content is found in natural inoculum composting with a fermentation duration of 30th days composting at a rotational speed of 300 rpm. This result also shows that the average percentage difference between the N content in the fermentation duration of 30th days and 60th days of composting is 13.75±0.37%.

Statistical tests showed that the treatment of rotational speed and its interaction with other treatments did not significantly affect the formation of N content. The composting method, the duration of composting, and interaction both gave a real effect on the formation of N content. However, Duncan’s multiple range test (DMRT) at 95% test results revealed that no significant differences were for all treatment.

The P content of compost is presented in Figure 5. The largest P content is known to be in the fermentation duration of 60th days composting at all rotational speeds and composting methods. While the smallest P content is known to be present in the composting method of natural inoculum with a 30th days fermentation duration of composting at a rotational speed of 300 rpm. This result also shows that the average percentage difference between the P content in the fermentation duration of 30th days and 60th days of composting is 0.89±0.69%.
Statistical tests showed that the treatment of rotational speed, composting method, composting duration, and interaction did not significantly affect the formation of P content. Therefore, Duncan’s multiple range test (DMRT) at 95% for all the content parameters was not carried out.

The K content of compost is presented in Figure 6. In general, the most significant K content is known to be in the fermentation duration of 60 days after composting at composting natural inoculum at all rotational speeds. While the smallest K content is found in the composting method of natural inoculum with a fermentation duration of 30th days of composting at a rotational speed of 100 rpm and 300 rpm. It is also found in the composting method of natural inoculum with a fermentation duration of 30th days at a rotational speed of 100 rpm. These results also show the average percentage difference between K content in the fermentation duration of 30th days and 60th days of composting is 2.01±4.73%.

Statistical tests show that the treatment of rotational speed and its interaction with other treatments does not significantly affect the formation of K content. The interaction of the composting method treatment and the duration of composting has a significant influence on the formation of K content. However, Duncan’s multiple range test (DMRT) at 95% test results revealed that no significant differences were for all treatment.

Composting is an effort to reduce the C/N ratio of organic material. The C/N ratio is the ratio of the mass of carbon (C) to the mass of nitrogen (N) in a material. The C/N ratio of fresh organic material tends to be higher compared to after going through the composting process. The higher the C/N ratio of material will cause longer decomposition time. That makes the material more difficult for plants to absorb. The C/N ratio of compost is presented in Figure 7. In general, the most significant C/N ratio is
found to be in the 60th days of composting fermentation duration in all composting methods and the rotational speed. While the smallest C/N ratio is found in the composting method inoculum bokashi at 30th days composting duration, it's also found at a rotational speed of 100 rpm and 300 rpm. This result also shows the average percentage difference between the C/N ratio on the fermentation duration of 30th days and 60th days of composting is 29.76±6.11%.

Statistical tests show that treating the rotational speed, its interaction with the duration of composting, and the interaction of the methods of composting with the duration of composting have no significant effect on the formation of the C/N ratio. The composting method treatment, composting duration, and the interaction between the rotational speed and the composting method have a significant effect on the formation of the C/N ratio. However, Duncan’s multiple range test (DMRT) test results revealed that no significant differences were found at a 5% level for all treatment.

In general, the results of composting using a composting mixer machine (double helix rotary drum type) are capable of producing compost products following SNI 19-7030-2004 standards on the parameters N, P, K, and C/N ratio. The results of statistical tests also showed that the rotational speed, composting method, and composting duration did not have a significant effect. It indicates that this machine can operate even with low rotational speed, on various composting methods and on composting duration (30th days or 60th of days composting duration) to produce compost according to SNI standards.
4. Conclusions
The quality of compost, which is stirred using a compost mixer machine (drum rotary double helix type), has been tested and analyzed. The treatment of the composting method, the rotation speed of the compost mixer machine, and the composting duration are known not to affect the quality of compost to be produced. The quality of compost using a compost mixer machine can still reach the compost quality standard according to the Indonesian National Standard (SNI). This study recommends using a low rotational speed compost mixer machine to minimize engine power. The next activity of this research is to conduct a comparative study between the composting process carried out with and without using a mixer machine.

Acknowledgement
The authors would like to thank the Syiah Kuala University for providing the laboratory facilities for conducting this project. All authors approved the final version of this manuscript. The first and second authors of this paper are the main contributors to this paper.

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