Jurnal Teknologi Industri Pertanian 33 (2): 138-147, Agustus 2023
DOI: https://doi.org/10.24961/j.tek.ind.pert.2023.33.2.138
ISSN: 0216-3160 EISSN: 2252-3901

Terakreditasi Peringkat 2
SK Dirjen Pendidikan Tinggi, Riset, dan Teknologi No. 158/E/KPT/2021
Tersedia online http://journal.ipb.ac.id/index.php/jurnaltin

IMPACT OF AERATION ON OIL PALM EMPTY FRUIT BUNCHES DECOMPOSITION

PENGARUH AERASI PADA DEKOMPOSISI TANDAN KOSONG KELAPA SAWIT

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Makalah: Diterima 16 Feb 2023; Diperbaiki 27 Mei 2023; Disetujui 20 Juni 2023

ABSTRAK

Tandan Kosong Kelapa Sawit (TKKS) merupakan salah satu limbah padat besar yang dihasilkan di industri kelapa sawit. Pengolahannya diperlukan suatu teknik pengomposan serat kelapa sawit secara cepat. Penelitian ini bertujuan mengkaji pengaruh aerasi terhadap kadar air, dinamika suhu, pertumbuhan jamur, dan rasio C/N pada serat. Perlakuan yang diuji dalam penelitian ini adalah tiga jenis isolat jamur ligninolitik sebagai dekomposer (Omphalina sp., Pholyota sp., dan Omphalina sp.+Pholyota sp.) dengan perlakuan diberi aerasi dan tanpa aerasi pada tumpukan kompos. Penelitian dilakukan selama tujuh minggu di lahan terbuka. Kadar air tumpukan kompos pada perlakuan aerasi (48,7-53,7%) sedikit lebih tinggi dibandingkan perlakuan tanpa aerasi (37,2-45,56%). Berdasarkan parameter peningkatan suhu, proses dekomposisi serat meningkat dan mencapai maksimum pada minggu kedua kemudian menurun pada periode inkubasi 7 minggu. Pemberian aerasi pada tumpukan serat yang diinokulasi dekomposer tampaknya menghasilkan pertumbuhan miselium yang sedikit lebih baik sebesar 20% dibandingkan tanpa aerasi. Secara umum, nilai rasio C/N lebih rendah pada tumpukan serat aerasi dibandingkan dengan tanpa aerasi. Pengelolaan aerasi seperti mengatur waktu aerasi diperlukan untuk menjaga kelembaban serat agar menjaga kadar air optimum dalam tumpukan pengomposan.

Kata kunci: dekomposer, ligninolitik, Omphalina sp., Pholyota sp

ABSTRACT

Oil Palm Empty Fruit Bunches (OPEFB) is one of the large solid wastes produced in oil palm industries. In this study, a technique of fast composting of oil palm EFB was carried out. This research aims to assess the effect of aeration on water content, the dynamics of temperature, fungal growth, and the carbon-nitrogen ratio of the EFB. Treatments tested in this study were three types of ligninolytic fungal isolates as decomposers (*Omphalina* sp, *Pholyota* sp, and *Omphalina* sp + *Pholyota* sp.) and two types of aeration, i.e., with or without aeration in the composting pile. The study was done for seven weeks on open land. The water content of composting piles on aeration treatments (48.7-53.7%) was slightly higher than treatments without aeration (37.2-45.56%). Based on the parameters of increasing temperature, the EFB decomposition process increased and reached a maximum in the second week and then decreased in the period incubation of 7 weeks. Giving aeration to the EFB pile inoculated with decomposer seems to produce slightly better mycelium growth by about 20% than those without aeration. In general, the values of the C/N ratio were lower in the aerated EFB piles compared to those without aeration. Management of aeration, such as controlling the period of aeration, is needed to maintain EFB moisture in the presence of aeration or add material that keeps the aeration will maintain the optimum water content in a pile.

Keywords: decomposers, ligninolytic, *Omphalina* sp., *Pholyota* sp

INTRODUCTION

In 2022, GAPKI estimated Crude Palm Oil (CPO) production was 49 million tons with this data, if it is assumed that CPO is 25% Empty Fruit Bunches (EFB), then the amount of CPO comes from 200 million tons of EFB, then the amount of EFB produced, assuming 12% is 5.6 million tons. This considerable amount of EFB will significantly contribute if the EFB can be used as organic fertilizer to restore the characteristics of plantation soils induced by a decrease in organic matter content. In the long term, the return of soil characteristics is expected to reduce the consumption of inorganic fertilizers and restore soil health to realize a sustainable palm oil industry.

Oil palm empty fruit bunches contains lignin 22.2%, cellulose 43.07% and hemicellulose 33% (Arisyah *et al*, ,2017). Lignin is recalcitrant and is present on the surface of EFB tissue cells. The C/N ratio of EFB is also very high, so direct application to plants can inhibit plant growth. Therefore, decomposition is needed, which aims to break down lignin and cellulose into simple carbon compounds that plants can use and simultaneously produce macro and micronutrients.

In general, the technology production of organic fertilizer from palm oil mill waste on a semi-

**Penulis Korespondensi*

pilot scale (100 tons of empty fruit bunches/day) and microbial enrichment of palm oil compost have been produced. Fungi are generally considered the main degraders of lignocellulose due to their hyphal growth form, which allows them to redistribute nutrients to nutrient-poor substrates, and their ability to produce extracellular oxidative enzymes (Boer *et al.*, 2005; Baldrian, 2008). Fungi are universally distributed, and they play crucial roles in composting because they can grow under demanding environmental conditions and produce a variety of extracellular enzymes to degrade complex organic substances (Langarica-Fuentes *et al.*, 2014; Ryckeboer *et al.*, 2003).

The most effective decomposition of lignocellulosic material was carried out by fungi due to their production of lignocellulolytic enzymes, at least under a high N supply, which are the main decomposers of polymeric C substrates (Koranda *et al.*, 2014). Fungi have a competitive advantage over bacteria during lignocellulose degradation because of their mycelium structure. However, the decomposition process that occurs by fungi is still not practical due to the fungus growth that has not been maximized to the inside or bottom of the pile of materials. Lack of moisture at the top of the compost pile and lack of oxygen at the bottom causes uneven growth of fungi throughout the compost pile. However, since fungi as decomposers are aerobic, it is hoped that adding aeration in a pile increases the decomposition process, shortening the decomposition time. Microorganisms living in a compost pile need enough moisture to survive. Water is the crucial element that helps transport substances within the compost pile and makes the nutrients in organic material accessible to the microbes. Organic material contains some moisture in varying amounts. The purpose of this study was to reveal the effect of aeration in aerated static piles in the decomposition process of EFB.

MATERIALS AND METHODS

The experiment was conducted in Ciomas, Bogor. The composting material was EFB taken from PKS Kertajaya PTPN VIII. Decomposer used was *Omphalina* sp and *Pholyota* sp. in sawdust media added with 5% *juwawut* and fine peat as a carrier of decomposer isolates. The composting pile was covered with the blue colour of plastic sheet.

Preparation of Decomposer

The decomposers used were two species of white rot fungus (WRF), namely *Omphalina* sp. and *Pholyota* sp. Previously these two WRF species were rejuvenated and then an inoculum was made using a mixture of sawdust enriched with millet seeds. In the formulation of inoculum, sawdust that has been overnight soaked in water was then squeezed to a water content of 50-60% and mixed evenly with 5% of steamed (30 minutes) *juwawut* seeds (30 minutes). The mixture of sawdust and *juwawut* was then put in a jam bottle of as much as 75% of the volume of the bottle, covered with alumunium foil and then sterilized using an autoclave for 15 minutes at a pressure of 1.2 atm. After the media was relatively warm, it was then inoculated with WRF which had been rejuvenated according to the treatment as much as 1x1 cm per bottle and incubated at room temperature until the entire surface of the media was covered by WRF mycelium.

A total of 1 bottle of *Omphalina* sp. and *Pholyota* sp. inoculum was removed from the bottle by stirring using a spoon, then mixed in 1 kg of pasteurized fine peat. Then it is packed in a plastic bag as a decomposer.

EFB Decomposition

In the initial stage, 2.5 kg of decomposer is dissolved in 5 liters of water in a plastic bucket container and stirred until all ingredients are mixed. Furthermore, the decomposer solution is sprinkled evenly onto 1 ton of EFB while stirring until the entire surface of the EFB is wetted. For treatment with two types of decomposer isolates, each isolate was used as 1.25 kg. The pile size of EFB was 1x2x4 m for height, width and length respectively. Cover the pile of organic matter with a plastic sheet, and observe the temperature, water content periodically, and growth of WRF mycelium. The EFB was decomposed for 25 to 53 days and observed the CN ratio.

Aeration Treatment

The schematic of aeration showed in Figure 1. The aeration installation was consisting of a 3-inch in diam of PVC pipe and a blower to circulate the air into the EFB pile. The organic materials to be composted remain static and air is provided through perforated air pipes underneath the materials. The flow rate of air from the pump used in this study was 0.72 m^3/min, 3000 rpm, with continuous aeration during the experiment. Those flow rates are based on the power of the pump specifications.

Treatment assessed

The treatments tested and their code are: *Omphalina* sp. + aeration (O-A), *Pholyota* sp. + aeration (P-A), *Omphalina* sp. + *Pholyota* sp. + aeration (OP-A), control + aeration (C-NA), *Omphalina* sp. – aeration (O-NA), *Pholyota* sp. - aeration (P-NA), *Omphalina* sp. + *Pholyota*-aeration (OP-NA), control-aeration (C-A). There were 8 treatments that were repeated twice for each treatment.

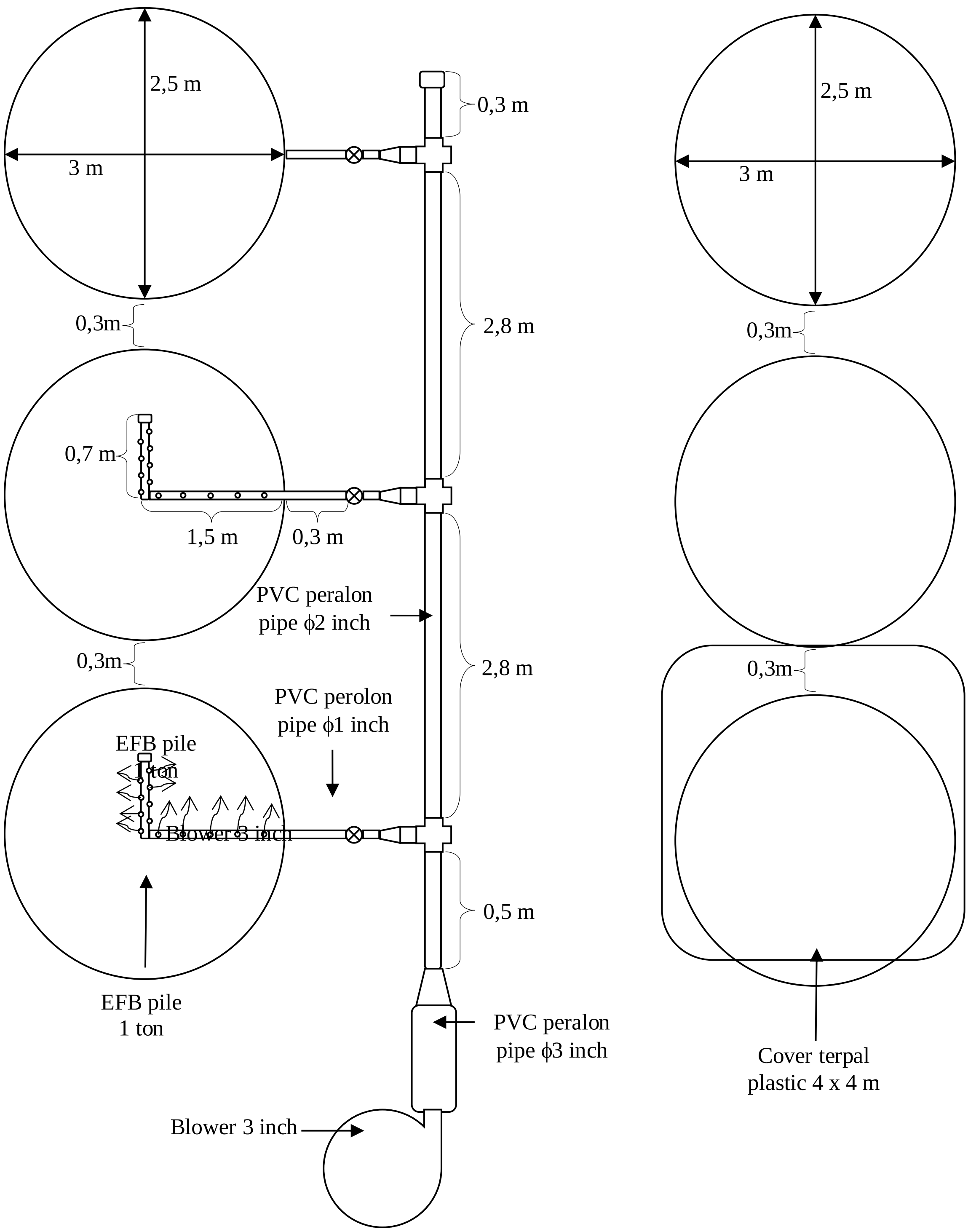


Figure 1. Schematic composting pile with and without aeration

RESULTS AND DISCUSSION

Composting is one of the better-known recycling processes for organic waste to be converted into soil conditioners. The application of compost has been proven to improve soil characteristics and can maintain soil health it can support sustainable land productivity (Agegnehu *et al.*, 2017).

Measuring of the water content of composting pile ~~was~~ ranges from 37.2-53.7% (Figure 2). Addition aeration maintains the water content higher compared to that without aeration. The highest moisture content (53.7%) was in the EFB pile treated with OP and with aeration. While the lowest water content was in the O treatment without aeration i.e. 37.2%. This is probably because white rot fungi are aerobic, so under anaerobic conditions, they cannot grow properly, which results in low water content. The increase in temperature is caused by the degradation of organic matter and the process of mass transfer from the anaerobic to the aerobic area (Jiang *et al*., 2011). However, pH and moisture content are associated with fungal community composition (Siciliano *et al.*, 2014). In general, the water content of all treatment pile support fungal growth. Moisture must usually be controlled because excessive moisture makes maintenance of aerobic conditions difficult, while a dearth of moisture inhibits biological life. A moisture content of 40% to 60% is considered desirable (Ge *et al.,* 2020). Moisture and C:N ratio are two primary characteristics commonly used to determine composting recipes. However, in this research, the moisture level is not optimum since the optimum moisture content is 50-65%. The addition of materials that are able to maintain moisture content is also a solution for optimizing the activity of decomposition by lignolytic microbes (Rynk *et al*., 2022).

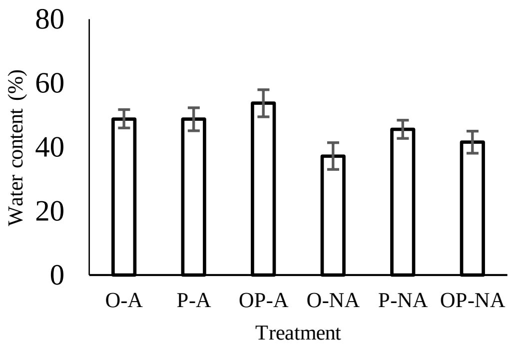


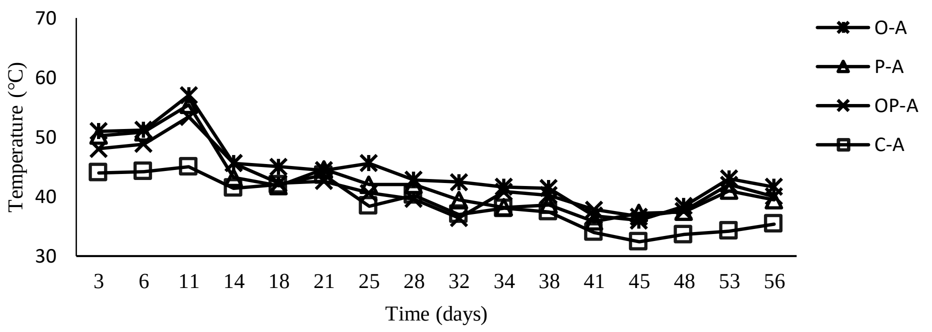
Figure 2. Water content of each treatment tested (O : *Omphalina* sp; P :*Pholyota* sp.; A : with aeration NA: without aeration)

The type of decomposer microbe seems to influence the decomposition activity. In general, lignolytic microbes have laccase, Mn peroxidase and Fe peroxidase activities. However, there are differences in the activity of each ~~of~~ enzyme in each species of lignolytic fungi. It seems that *Omphalina* sp. has an activity that is in accordance with the composition of the media (EFB) so ~~that~~ the activity of this fungus is higher than that of *Pholyota* sp. (Widiastuti *et al.,* 2007) reported that *Omphalina* sp. growth in empty bunches oil palm produces the laccase and Mn peroxidase but not Li peroxidase (Widiastuti *et al*., 2008). In addition, the peak of Mn peroxidase of *Omphalina* sp. was in two weeks after inoculation. The abundant phylla were *Basidiomycota* and *Ascomycota* (Pierce and Vesilind, 1998).

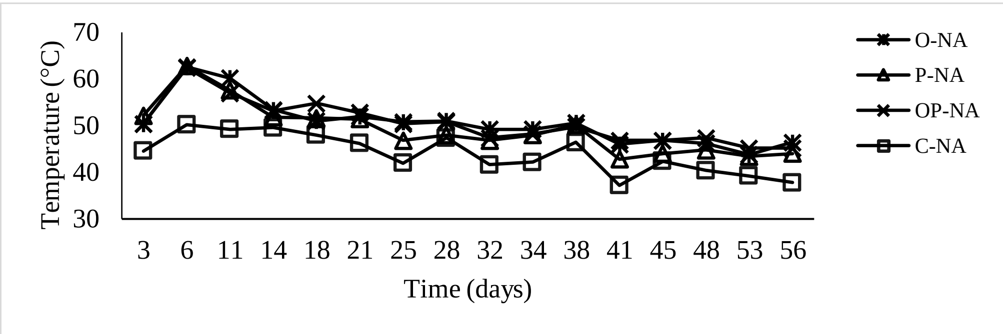
In general, the compost temperature increased from the initial composting to day 11 and then decreased until incubation on day 56 (Figure 3). In the initial incubation the rapid rise of temperature due the biological activities. This temperature increase in the initial 10 days suggests due to biological activity of decomposer of WRF that resulting heat accumulation though after that the temperature ~~was~~ decreased. Giving aeration resulted in a lower temperature of the compost, especially for the O and P lignolytic treatment (Zhang *et al*., 2021). However, the addition of decomposers can increase the temperature of the compost. This is in accordance with the research of (Gong *et al*., 2016) who used white rot fungi *T. versicolor* and *P. chrysosporium* which increased the composting temperature in compost piles, which was caused by the growth of microorganisms and their generation of heat. These results indicate that the decomposition activity is strongly influenced by the presence of decomposers.

The decomposition of lignocellulosic material is strongly influenced by lignocellulolytic microbial activity. The inoculated decomposers were lignolytic fungi, so adding this fungus could increase the decomposition activity observed from the increase in EFB pile temperature. The endpoint of a composting operation is reached when the temperature drops. Once the composting pile is established, requiring about two weeks, the inoculants have not proved to be of any significant value. Among the treatments tested when viewed from the EFB temperature variable, it was shown that the decomposer *Omphalina* sp. with no aeration conditions resulted in higher decomposition activity as indicated by the compost temperature variable. In my opinion, the ~~drop~~ dropping temperature not showed that the decomposition process was stopped—but only decomposer activity was reduced. However, the activities goes too slowly, but the carbon compound's decomposition still happens (Ge *et al.,* 2020). Aeration makes the conditions around the compost pile drier than unaeration area in the compost pile. At the same time, WRF can grow optimally with 50-60% humidity, so that WRF can optimize the decomposition process. Based on the research of Ge *et al.* (2020) the moisture content of the compost pile decreased at high aeration (0.90 L min-1 kg-1) during the compost maturation process.

Adding aeration seems to affect the humidity of the EFB as a medium for fungal growth, namely reducing humidity, thereby, in this case reducing decomposition activity. Since there was an indication that the growth of fungi decreased in areas near aeration and inversely to the area far from the aeration, it seems that we must ~~be~~ manage the flow rate of oxygen in the pile. The oxygen flow must be controlled so the WRF activities are not disturbing. Though aerating the pile allows decomposition to occur faster than in anaerobic conditions, care must be taken. Providing too much oxygen will dry out the pile and impede the composting process. Another treatment ~~sed~~ to improve aeration was turning the pile or including bulking agents such as wood chips and shredded newspaper.



(a)



(b)

Figure 3. EFB pile temperature in each treatment during 56 days incubation; (a) with aeration; (b) without aeration

Lignin decomposition rates are substantially lower in the absence of molecular oxygen (Benner *et al*., 1991), which results in decomposition rates decreasing from the sediment surface through the partially oxygenated rhizosphere to deeper anoxic sediments.

The composting process up to the fourth week (28 days) showed mycelium growth in the pile, especially on the EFB surface, ~~indicate~~d indicating the growth of fungi. In the palm EFB pile, fungal mycelium began to appeared on the 7th day after inoculation (Figure 4). The mycelium growth of *Omphalina* sp (O) is better than that of *Pholyota* sp. (P), as well as the mixture of those two fungi (OP). This is indicated by the denser mycelium growth of *Omphalina* sp. as well as the wider mycelium growth area compared to *Pholyota* sp. and the mixture.

Giving aeration to the EFB pile inoculated with *Omphalina* sp~~.~~ produces slightly better mycelium growth than no aeration. Meanwhile, isolates of *Pholyota* sp. and a mixture of *Omphalina* sp. and *Pholyota* sp. seems to need aeration. This can be seen in the EFB pile without aeration; there was no mycelium growth of those two fungi, while in the EFB pile with aeration, the mycelium growth was seen even though the distribution and density were thin (Figure 3). Aerated composting static pile produces compost relatively quickly (within three to six months). Composting is the aerobic fermentation process of organic waste using of aerobic bacteria under controlled conditions such as pH, air, moisture content, particle size, C: N ratio, etc. Aeration is required to recharge the composting pile with the required oxygen for the microorganisms to grow using natural aeration with a windrow turning machine or passive composting with embedded perforated pipes within the pile or forced aeration assisted with a blower. The main advantages of passive composting are less capital cost than forced aeration, and less running cost than natural aeration.~~.~~ It is odor free because the composting pile can be covered with finished compost to protect the environment. The time required for maturation might be faster in the passive composting technique depending on the environmental factors within and around the composting pile. Maturation or degree of stabilization can be measured by indicators such as decline in temperature, absence of odor, and lack of attraction of insects in the compost pile.

Forced aeration can be conducted in either positive or negative forced aeration. To aerate the pile, layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added so air can pass from the bottom to the top of the pile. There are two principal ways of introducing oxygen in composting, i.e. agitation and forced aeration. The most common composting methods are windrow composting, aerated static pile composting, and in-vessel composting; each composting method employs different ways of introducing oxygen (He *et al.*, 2020).

Figure 4. Mycelium growth on the EFB pile on days 7 after inoculation. (O) Inoculated EFB with *Omphalina* sp., (P) *Pholyota* sp., (OP*) Omphalina* sp. & *Pholyota* sp., (A) with aeration (blower), (NA) without aeration.

Figure 5. Mycelium growth on the EFB pile on days 14 after inoculation. (O) Inoculated EFB with *Omphalina* sp., (P) *Pholyota* sp., (OP) *Omphalina* sp. & *Pholyota* sp., (A) with aeration (blower), (NA) without aeration.

To anticipate the water content evenly throughout the pile ~~in~~ every time, air blowers might be activated by a timer or ~~a~~ temperature sensors. To minimize odors, a harmful aeration method can be used with the exhaust air collected and passing through a biofilter. Oxygen demand is one of the most important parameters affecting composting efficiency.

Generally, insufficient aeration may cause anaerobic conditions, while excessive aeration may lead to extensive moisture and heat losses, as well as gas emissions (Kumar, 2011). The aeration rate has been extensively studied in the literature. Specifically, a study of composting with high aeration (410–547 L air/kg TS/d) showed 60%–100% more moisture and heat losses than with low aeration (74–210 L air/kg TS/d) (Ahn *et al.*, 2007), which was comparable to the above aeration rates tested for micro aeration in anaerobic digestion. Given the same aeration rate, intermittent aeration was ~~shown to be~~ more efficient and economical than continuous aeration (Jiang *et al.*, 2015). Furthermore, using the oxygen uptake rate as the feedback to control intermittent aeration has been shown to induce 30% higher oxygen consumption and save half of the energy compared to using temperature (Puyuelo *et al.*, 2010). A recent study determined that the threshold airflow rate varied among wastes, ranging from 1000 L air/kg TS/d for cow manure to 1600–1850 L air/kg TS/d for anaerobic digestate (Mejias *et al.*, 2017). Since aeration is the main energy input to composting, its optimization is highly recommended.

Mycelium growth continued to develop on days 14 and 25 after inoculation (Figures 5, 6). Mycelium growth of *Omphalina* sp. is better than other fungi as indicated by the density and area of colonization variables. On days 21 and 25, the mycelium growth seemed to penetrate deep into the base of the palm EFB pile (Figures 5 and 7). However, in the treatment with aeration, it turned out that the mycelium on the inside of the palm EFB pile was not as thick and dense as in the treatment without aeration, the palm EFBs on the inside, especially the part closest to the air ducts, seemed dry, so the mycelium growth was fragile and invisible to the eye (Figure 7). Dry EFB is thought to be caused by aeration. In their growth, fungi need sufficient moisture for their activities.

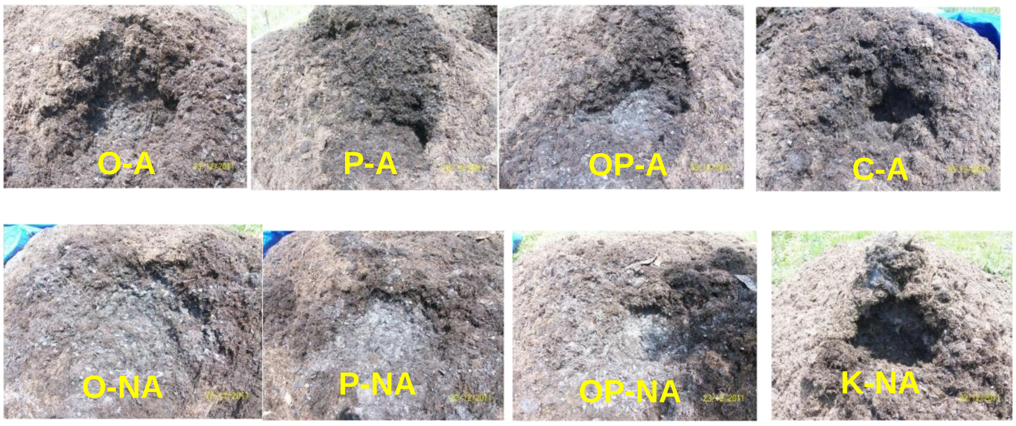


Figure 6. Mycelium growth in side the EFB pile on days 21 after inoculation. (O) Inoculated EFB with *Omphalina* sp., (P) *Pholyota* sp., (OP) *Omphalin*a sp. & *Pholyota* sp., (A) with aeration (blower), (NA) without aeration.

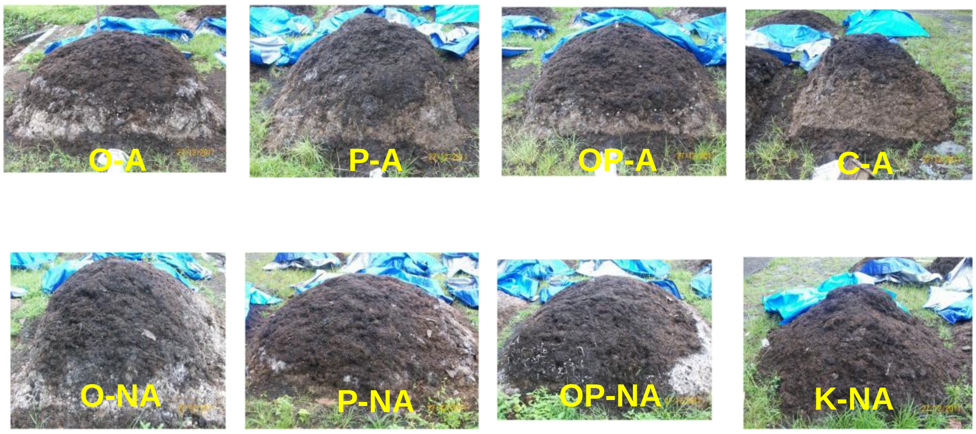


Figure 7. Mycelium growth on the EFB pile on days 25 after inoculation. (O) Inoculated EFB with *Omphalina* sp., (P) *Pholyota* sp., (OP*) Omphalina* sp. & *Pholyota* sp., (A) with aeration (blower), (NA) without aeration.

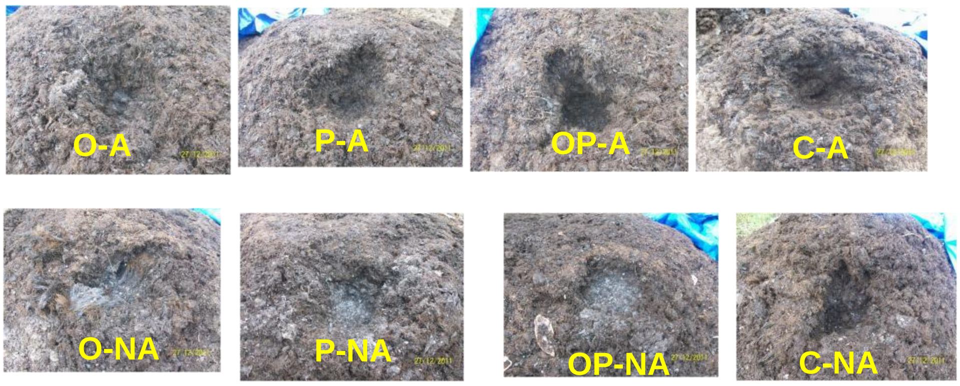


Figure 8. Mycelium growth on the in side EFB pile on days 25 after inoculation. (O) Inoculated EFB with *Omphalina* sp., (P) *Pholyota* sp., (OP) *Omphalina* sp. and *Pholyota* sp., (A) with aeration (blower), (NA) without aeration.

Observation of carbon content showed that in all tested treatments, there was a decrease in carbon content. The decrease occurred continuously up to 53 days of incubation. Analyses of C EFB showed that the rang~~ed~~ was 30 – 35. Adding a decomposer reduces the carbon content in both the aerated and unaerated EFB piles. However, the addition of aeration further reduces the carbon EFB content. The results in EFB added with decomposer OP showed excellent results where there was a decrease in C content with increasing incubation time. The decrease in C is generally due to the reshuffling of C in the respiration reaction by microbial decomposers that produce CO_2. In the aeration treatment, the highest reduction in C was in the treatment of EFB inoculated with OP decomposer. In contrast, the difference was insignificant or minimal with aeration. These results showed that aeration positively affected the process of reducing C content and the best decomposer for composting with aeration was O. However, it did not show much difference compared to the P and OP decomposers since the level of C of the EFB with OP decomposer treatment was slightly different from other decomposers. Carbon content is closely related to lignin content in biomass (Hu *et al.*, 2019). The decrease in C content during 7 weeks of incubation also indicated that the lignin content in the EFB had been degraded. This result, similar to (Jiang *et al.*, 2011) showed that degradation of carbon compounds were degraded in the first two weeks composition. Treatment using WRF showed a lower reduction in C levels when compared to controls. The study of (Lopez *et al.*, 2002) showed that lignin levels continued to decrease with the application of WRF *C. versicolor* and *P. flavidho-alba* for 90 days (Lopez *et al.*, 2002).

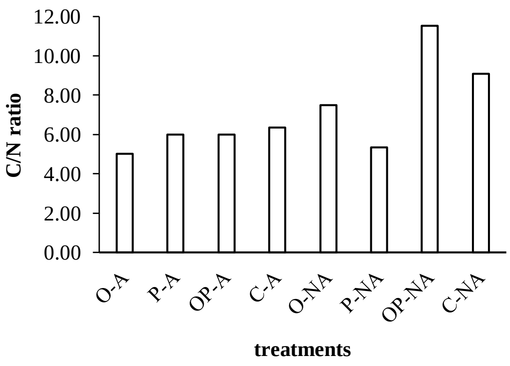


Figure 9. Carbon Nitrogen (C/N) ratio of EFB compost in each treatment during 53 days incubation. (O) Inoculated EFB with *Omphalina* sp., (P) *Pholyota* sp., (OP) *Omphalina* sp. and *Pholyota* sp., (A) with aeration (blower), (NA) without aeration

Giving aeration resulted in higher N EFB content than without aeration, both in the addition of P and OP decomposers. The highest increase in N content for the P decomposer was after 28 days, while for the OP decomposer after, 14 days. The addition of decomposers did not seem to affect on increasing the N content of the EFB except for the O-NA. In general, the N content of EFB decreased on day 53 in all treatments except the EFB added with O in the EFB pile with aeration. (Huang *et al.*, 2004) found similar results after 63 days of composting N content was decreased.

The CN ratio decreased with the increasing incubation time. The highest decline occurred until the fourth week. The treatment with the lowest CN ratio at week 7 was the addition of the decomposer *Omphalina* sp. without aeration and *Omphalina* sp. combined with *Pholyota* sp. both aerated and unaerated. The value of the CN ratio achieved at 4 weeks of incubation was 10. However, giving *Omphalina* sp as a decomposer without aeration also had a low ratio. The achieved CN values are 5 to 7.

In general, the values of the C/N ratio were lower in the aerated EFB pile when compared to those without aeration, except for the P decomposer (Figure 9). The C/N ratio of all treatments in 2nd week was around 15. After the 7th week of incubation, the C/N ratio decreased to 5,02 – 11,52. The aeration control (C-A) treatment had a lower C/N ratio value than the control treatment without aeration (C-NA). This result is in line with (Dissanayaka *et al.*, 2021), who reported that the value of the C/N ratio in composting paddy husks with aeration treatment was lower than without aeration, with the C/N ratio values in 5th week were 6.99 and 8.52, respectively. After 30 days, no more carbon is easily degraded (Pierce & Vesilind, 1998). Generally, microbes have a cellular C:N ratio of approximately 10:1. Narrow C:N ratio, Carbon and energy starvation occur. EFB compost decomposes quickly and releases nitrates readily. The amount of CO_2 released/unit of carbon decomposed is less as more ~~of it~~ is metabolized and converted into microbial tissues. The decomposition rate depends on the technology level used as well as on such physical, chemical, and biological factors as microorganisms, oxygen levels, moisture content, and temperature. Composting works best when these factors are carefully monitored and controlled.

CONCLUSION AND RECOMMENDATION

Conclusion

The effect of aeration on oil palm EFB decomposition resulted in 50-53.7 % water content, a lower temperature of 32-50°C, and a lower C/N ratio of 5-6.35 compared to without aeration treatments. The results of this study also don’t need to turn the compost pile so that it can save costs. Suggestions for the following research are controlling the aeration process, such as the period of aeration and speed of aeration ~~is~~ needed to maintain EFB moisture in the presence of aeration or adding material which keeps the aeration will maintain the optimum water content in a pile.

Recommendation

The airflow rate in this study is still applied according to the pump speed flow rate. It is necessary to vary the air flow rate entering the EFB fruit bunches composting pile. In addition, mathematical modelling also needs to be done to be able to determine the effect of airflow rate on the quality of the compost produced.

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