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(RESEARCH ARTICLE)

The effect of lignocellulolytic bacteria consortium on composting empty oil palm fruit bunches

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Abstract

Oil palm empty fruit bunches (OPEFB) are waste produced by palm oil mills from processing fresh fruit bunches into oil. For every 1 tonne of fresh fruit bunch (FFB) processing, 21–23% EFB will be produced. EFB can be used as compost. OPEFB compost has considerable potential because it contains complex nutrients (macro and micro). The OPEFB composting process has problems because of the lignin content which causes the decomposition process to take a long time so that microorganisms are needed that can accelerate the OPEFB decomposition rate. This study aimed to test the ability of lignolytic bacteria from larvae of Oryctes rhinoceros L. plus cellulolytic bacteria from organic waste that have the potential to decompose OPEFB. This research was conducted experimentally using a non-factorial Completely Randomized Design (CRD) consisting of eight treatments. The results showed that the administration of cellulolytic bacterial isolates had a significant effect on water content, compost weight loss, pH, C-Organic, C/N ratio and P nutrient content, but had no significant effect on N and K nutrient levels. Treatment of lignocellulolytic bacteria ORL9 and ORL6 and a consortium of cellulolytic bacteria showed good compost quality, which could be seen from the parameters of weight loss of compost, pH, N nutrient content and reduced C/N ratio.

Keywords: Compost; Oil palm empty fruit bunches (OPEFB); Lignocellulolytic bacteria; Consortium of cellulolytic bacteria

1. Introduction

Oil palm empty fruit bunches (OPEFB) are a type of solid waste produced in the palm oil industry. The number of empty palm oil bunches is quite large because it is almost the same as the amount of crude palm oil production. The waste has not been used optimally. The largest component of oil palm empty fruit bunches is cellulose (40-60%), in addition to other smaller components such as hemicellulose (20-30%), and lignin (15-30%). One alternative to using empty oil palm fruit bunches is as organic fertilizer by composting [1]. Nutrient content of OPEFB compost: C 35%, N 2.34%, C/N 15, P 0.31%, K 5.53%, Ca 1.46%, Mg 0.96%, and Water 52% [2].

Compost is a type of fertilizer that comes from the final result of the decomposition of animal and plant remains that function as a supplier of soil nutrients so that it can be used to improve soil physically, chemically, and biologically. Physically, compost is able to stabilize soil aggregates, improve soil aeration and drainage, and increase the ability of the soil to hold water. Chemically, compost can increase macro and micro soil nutrients and increase the efficiency of soil nutrient uptake. While biologically, compost can be a source of energy for soil microorganisms that are able to release nutrients for plants [3].

The horn beetle (Oryctes rhinoceros L.) is a major pest in oil palm plantations. Horn beetle larvae dung is one of the organic fertilizers obtained from the defecation of horn beetle larvae (Oryctes rhinoceros L.) which feed on organic

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waste such as empty fruit bunches of oil palm (OPEFB). Pulungan et al [4] stated that the horn beetle has the ability to degrade oil palm empty fruit bunches (OPEFB).

Lignocellolytic bacteria are microorganisms that have an important role in the fermentation process of lignocellulosic components. The reshuffle of lignocellulosic components involves the activity of enzymes such as peroxidase, phenol, oxidase, cellulase, hemicellulase, and sugar oxidase [5]. Various groups of microbes from fungi, bacteria and actinomycetes can produce lignolytic enzymes. Microbes such as Clostridium, Penicillium, Cellulomonas, Thricoderma, Basidiomycetes, Fusarium, Aspergillus, and Neuspora have high lignolytic, cellulolytic and hemicellulolytic activities [6].

Bacterial consortium is a collection of a number of similar organisms to form a community of a number of different populations. Microorganisms can associate with other organisms physically through two mechanisms, namely the presence of an organism that generally has a smaller size (as an ectosymbiont) on the surface of another organism that is generally larger in size, this is commonly known as ectosymbiosis. Another mechanism is the presence of an organism (endosymbiont) in another organism, which is known as endosymbiosis [7].

2. Methodology

2.1. Research Site

The research has been carried out at the Soil Science Laboratory, Faculty of Agriculture, Riau University, Kampus Binawidya KM12,5, Pekanbaru, Riau, Indonesia.

2.2. Research Method

This research was conducted experimentally, using a non-factorial completely randomized design (CRD) with the following treatments:

- B0: Consortium (a mixture of 6 bacteria from organic matter)
- B1 : Consortium (mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 19)
- B2 : Consortium (mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 6)
- B3 : Consortium (a mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 19 + ORL 6)
- B4 : Consortium (a mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 19 + ORL 6 + ORL 1)
- B5 : Consortium (a mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 19 + ORL 6 + ORL 1 + ORL 2)
- B6 : Consortium (a mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 19 + ORL 6 + ORL 1 + ORL 2 + ORL 4)
- B7 : Consortium (a mixture of 6 bacteria from organic matter + lignocellulolytic bacteria ORL 19 + ORL 6 + ORL 1 + ORL 2 + ORL 4 + ORL 7)

There were 8 treatments and 3 replications, so there were 24 experimental units. Each experimental unit is used as a sample. Observation parameters observed were compost organoleptic test (color and smell), moisture content, weight loss of compost, C-organic content, CN ratio, pH, 3.7. nutrient content of compost.

2.3. Data Analysis

The data obtained were analyzed statistically using analysis of variance (Analysis of Variance). The nonfactorial RAL linear model is as follows:

$$\mathbf{Yij} = \boldsymbol{\mu} + \boldsymbol{\tau}\mathbf{i} + \boldsymbol{\varepsilon}\mathbf{ij}$$

Information:

Yij : Observation results from the consortium treatment of lignocellulolytic bacteria in treatment i repetition and j
$\boldsymbol{\mu}$: General mean
τ_i : Effect of consortium of i-th lignocellulolytic bacteria
ε_{ij} : Effect of lignocellulolytic bacterial consortium error based on treatment i-th and j-th test.

3. Results

3.1. Color

Table 1 Compost color in OPEFB

Treatment	Color
B0	2/2 10 YR Very dark brown
B1	2/2 10 YR Very dark brown
B2	2/1 10 YR Black
B3	2/1 10 YR Black
B4	2/2 10 YR Very dark brown
B5	2/2 10 YR Very dark brown
B6	2/2 10 YR Very dark brown
B7	2/2 10 YR Very dark brown

3.2. Moisture Content

The results of the analysis of variance showed that the application of lignocellulolytic bacteria in the manufacture of OPEFB compost had a significant effect on the water content. The results of the further test of compost material shrinkage with Duncan's multiple spacing test at the 5% level can be seen in Table 2.

Table 2 Moisture content in OPEFB compost

Treatment	Moisture Content (%)
B0	71.82 ab
B1	74.90 ab
B2	77.10 a
B3	74.47 ab
B4	69.53 b
B5	72.17 ab
B6	72.40 ab
B7	73.66 ab

3.3. Weight Loss of Compost

The results of the analysis of variance showed that the application of lignocellulolytic bacteria in the composting of OPEFB had a significant effect on the weight loss of the compost material. The results of the further test of compost material shrinkage with Duncan's multiple spacing test at the 5% level can be seen in Table 3.

Table 3 Weight loss of EPEFB compost material

Treatment	Weight Loss of Compost (%)
B0	16.66 c
B1	21.66 bc
B2	23.3 ab
B3	28.33 a

B4	20, 00 bc
B5	23.33 ab
B6	23.33 ab
B7	20,00 bc

3.4. C-Organic Content

The results of the analysis of variance showed that the application of lignocellulolytic bacteria in the manufacture of OPEFB compost had a significant effect on the C-Organic content. The results of the further test of compost material shrinkage with Duncan's multiple spacing test at the 5% level can be seen in Table 4.

Table 4 Content of C-Organic OPEFB compost

Treatment	C-Organic Content (%)
B0	42.5 b
B1	44.54 a
B2	42.24 b
B3	42.26 b
B4	42.48 b
B5	43.46 ab
B6	44.64 a
B7	42.97 ab

3.5. C/N Ratio

The results of the analysis of variance showed that the application of lignocellulolytic bacteria in the manufacture of OPEFB compost had a significant effect on the C/N ratio. The results of the further test of compost material shrinkage with Duncan's multiple spacing test at the 5% level can be seen in Table 5.

Table 5 C/N ratio of OPEFB compost with the provision of a consortium of lignocellulolytic bacteria

Treatment	C/N (%)
B0	24.90 ab
B1	25.90 a
B2	24.67 ab
B3	24.28 b
B4	24.51 ab
B5	25.45 ab
B6	25.89 a
B7	24.82 ab

3.6. pH

The results of the analysis of variance showed that the application of lignocellulolytic bacteria in the manufacture of OPEFB compost had a significant effect on the pH of the compost. The results of further tests for shrinkage of compost material with Duncan's multiple spacing test at a level of 5% can be seen in Table 6.

Table 6 pH of OPEFB compost with the provision of a consortium of lignocellulolytic bacteria

Treatment	pH
B0	7.93 ab
B1	7.95 ab
B2	7.97 ab
B3	8.16 a
B4	7.47 c
B5	7.59 abc
B6	7.85 ab
B7	8.10 a

3.7. Nutrient Content of Compost

The results of the analysis of variance showed that the application of lignocellulolytic bacteria in the manufacture of OPEFB compost had a significant effect on the P nutrient content and did not significantly affect the N and K nutrient content in the compost. The results of the further test of compost material shrinkage with Duncan's multiple spacing test at the 5% level can be seen in Table 7.

Table 7 Nutrient content of OPEFB compost by giving a consortium of lignocellulolytic bacteria

Treatment	N	P_2O_5	K_2O
B0	1.7 a	0.24abc	4.36 a
B1	1.72a	0.24abc	4.49 a
B2	1.71a	0.26 a	4.32 a
B3	1.74 a	0.25abc	4.38 a
B4	1.73 a	0.25 ab	4.62 a
B5	1.7 a	0.23 bc	4.46 a
B6	1.72 a	0.22 c	4.56 a
B7	1.73 a	0.26 a	4.3 a

4. Discussion

4.1. Color

In this study, all treatments produced compost colors between very dark brown and black. The two colors of the compost indicate that the OPEFB organic matter has undergone a physical change to mature compost. Based on the SNI compost standard number 19-730-2004, that the mature compost is black in color and has a soil-like texture. This is in accordance with the results of research Okalia et al [8], which reported that mature compost will experience a darker color change.

The results of the study indicate that treatments B2 and B3 are treatments that have met the standard. Color changes in compost occur due to the loss of color pigments in organic matter due to the decomposition process carried out by microorganisms [9]. Mustika et al (2012) added that the color change of OPEFB compost occurs due to the CO_2 content or volatile organic acids in the compost.

4.2. Smell

All treatments given in the study produced odorless compost. This indicates that the OPEFB added to the bacteria in each treatment has undergone a composting process. So that at the end of composting there is no odor. These results are in accordance with the criteria for mature compost according to SNI 197030-2004, namely compost is said to be ripe if there is no pungent odor or the same as the typical soil odor. This is in accordance with the results of research Haq et al [11], which states that mature compost has the same odor as soil, because the material it contains already resembles soil material. The results of the study of Anif et al [12] stated that the odor produced after the composting process was earthy.

The smell of compost is caused by organic material that is too alkaline and is not turned over [13]. Maurer et al [14] added that the smell of compost is caused by the presence of hydrogen sulfide compounds during composting. The smell of compost will disappear due to the oxidation of sulfur to sulfuric acid by bacteria during the composting process.

4.3. Moisture Content

The results of the water content analysis in Table 2 show that the average water content value is 69.53%-77.1%. The highest percentage of OPEFB compost moisture content was found in treatment B2 (consortium bacteria + ORL6 bacteria) which was 77.1% and the lowest percentage of OPEFB compost moisture content was found in B4 treatment (Consortium bacteria + ORL9, ORL6, and ORL1) bacteria, which was 69.53%. These results are not in accordance with the criteria for mature compost according to SNI 197030-2004, namely <50%.

Baharuddin et al [15] stated that the range of 60-75% is the range of water content where the activity of microorganisms is maximum. The recommended water content is generally in the range of 50-60%. The water content in the compost should not be too little or too much. When the water content is too little, it is feared that it will interfere with the growth and metabolism of microorganisms so that it affects the decomposition process. Water content that is too high will also have a negative impact on compost, especially compost with an aerobic process.

4.4. Weight Loss of Compost

In Table 3 it can be seen that the percentage of weight loss of OPEFB compost in treatment B3 (consortium bacteria + bacteria ORL9 and ORL6) was significantly different from treatments B0, B1, B4 and B7, but not significantly different from treatments B2, B5 and B6. This indicates that the addition of lignocellulolytic bacteria with isolate codes ORL9 and ORL6 is thought to be able to optimize the composting process so as to produce the highest percentage of shrinkage of compost material. This is in accordance with the opinion of Ayunin [16] which states that the shrinkage of compost material occurs due to gases from decomposition by microbes that are wasted into the air, such as ammonia, causing the weight of the final material to be reduced.

During the fermentation process, the weight of the compost shrinks. According to Amalia and Widiyaningrum [17], shrinkage occurs due to the activity of microorganisms that decompose compost material. The degradation process becomes faster due to the addition of bioactivator as a source of decomposing microorganisms and as a result the organic matter is quickly weathered and the volume decreases.

4.5. C-Organic Content

Based on the results of the C-Organic analysis in Table 4, it can be seen that the OPEFB compost in treatment B6 (consortium bacteria + bacteria ORL9, ORL6, ORL1, ORL2 and ORL4) was significantly different from treatment B0, B2, B3 and B4, but not significantly different from treatment B1, B5 and B7. The average percentage value of C-Organic EFB compost is 42.97-44.64%. The highest percentage of C-Organic EFB compost was found in treatment B6 (Bacteria consortium + bacteria ORL9, ORL6, ORL1, ORL2 and ORL4) which was 44.64% and the lowest C-Organic percentage of EPEFB compost was found in treatment B7 (Bacteria consortium + bacteria ORL9, ORL6, ORL1, ORL2, ORL4 and ORL7) is 42.97%. These results are in accordance with the criteria for mature compost according to SNI 197030-2004, namely 27-58%. This is in accordance with research Ratrinia et al [18], which states that the decrease in C-organic concentration is due to the use of carbon by microorganisms as an energy source to decompose organic matter.

According to Suwoyo et al [19], the provision of several sources of organic activator has a statistically significant effect in reducing organic C-organic compost. This is due to the decomposition process caused by microorganisms where carbon is consumed as an energy source by liberating CO_2 and H_2O for aerobic processes so that the carbon concentration is reduced.

4.6. C/N Ratio

The results of the C/N analysis in Table 5 show that the value of the C/N ratio has decreased from the analysis of the initial C/N ratio of compost, which is 46.11. This indicates that the use of lignocellulolytic bacteria as decomposers in OPEFB compost can reduce the C/N ratio of OPEFB compost. Based on the results of the analysis of the C/N ratio of EFB compost in Table 7, it can be seen that the C/N ratio of EFB compost is on average 24.28-25.9. The value of the C/N ratio of EFB compost in each treatment was not in accordance with the criteria for mature compost according to SNI 197030-2004, namely 10-20.

In research Mustika et al [10] it was explained that the carbon content in oil palm empty fruit bunches compost was 42.8% and the C/N ratio of compost was 53. The high C/N ratio was due to the compost of oil palm empty fruit bunches containing many ingredients. which are difficult to decompose such as lignin and cellulose. The higher the C/N value of the compost indicates that the organic matter has not been completely decomposed. On the other hand, the lower C/N value of the compost indicates that the organic matter has been decomposed and is almost into compost.

4.7. pH

Based on the results of the pH analysis in Table 6, it can be seen that the average pH value of the compost is 7.47-8.16. The results of Duncan's follow-up test 5% showed that the treatments B3, B4, B5, and B7 were significantly different from treatment B0, but treatments B1, B2 and B6 were not significantly different from treatment B0. The highest pH value was found in the treatment of B3 compost (Bacteria consortium + bacteria ORL9 and ORL6) with a pH of 8.16. Meanwhile, the lowest pH value was found in treatment B4 (Bacteria consortium + bacteria ORL9, ORL6 and ORL1) with a pH of 7.47. The pH of OPEFB compost increased for each treatment.

Based on SNI compost number 19-730-2004 treatment B4 has a pH value according to the criteria, where the criteria for good compost is to have a pH of 6.8-7.49. It means that the compost treatment B4 by giving a consortium of bacteria + bacteria ORL9, ORL6 and ORL1 has met the criteria for good compost, while the pH value of the compost treatment B1, B2, B3, B4, B6 and B7 has not met the criteria of SNI. According to Manuputty et al [20], the increase in pH that occurs is thought to be due to the reaction of basic cations, especially potassium and sodium which are alkali metals that form strong bases, in addition to calcium and magnesium which are released during the decomposition process.

4.8. Nutrient Content of Compost

The results of the analysis in Table 7 show that the total N content has increased, but still has a low status. In the initial analysis, the N-total of OPEFB compost is 1.05 and the results of the final N-total analysis in table 9 can be seen that the N-total value of OPEFB compost is on average 1.7-1.74. This is in accordance with the SNI Compost Quality Standard: 19–7030–2004. The results of Duncan's 5% follow-up test showed that the treatment of B1, B2, B3, B4, B5, B6 and B7 was not significantly different from the treatment of B0. The highest N-total value was found in the B3 compost treatment (Bacteria consortium + bacteria ORL9 and ORL6), namely 1.74. Meanwhile, the lowest N-total value was found in the treatment B0 (Bacteria consortium) and B5 (Bacteria consortium + bacteria ORL9, ORL6, ORL 1 and ORL2), namely 1.7. The low total N content in OPEFB compost is thought to be because the compost has not been completely decomposed, this is indicated by the C/N ratio which is still > 20 which indicates an immobilization process. According to Ratna et al [21], the high and low levels of N compost are closely related to the presence of microorganisms. N-total increases due to the increased activity of microorganisms that are able to utilize N as a building block for their cells.

The results of the research on the total P_2O_5 content of OPEFB compost with lignocellulolytic bacteria are presented in Table 7. In Table 7 it shows that the P2O5 content has increased, the initial analysis of P_2O_5 in OPEFB compost is 0.14% and the results of the final P2O5 analysis in Table 7 can be seen that the N value -Total OPEFB compost is on average 0.22-0.26 %. This is in accordance with the SNI Compost Quality Standard: 19–7030–2004. The highest P2O5 value was found in the compost treatment B2 (Bacteria consortium + ORL6) and B7 (Bacteria consortium + bacteria ORL9, ORL6, ORL1, ORL2, ORL4 and ORL7) which was 0.26%. Meanwhile, the lowest P2O5 value was found in treatment B6 (Bacteria consortium + bacteria ORL9, ORL6, ORL1, ORL2, and ORL4), which was 0.22%. Arbi et al [22] (2019) explained that in the composting process, some of the phosphorus is absorbed by microorganisms to form egg white substances in the body. The more microorganisms will make the compost ripen faster so that the microorganisms have the opportunity to absorb phosphorus in the ripe compost.

The results of the research on the total K2O content of OPEFB compost with lignocellulolytic bacteria are presented in Table 7. In Table 7 it shows that the K_2O content has increased, the initial analysis of K_2O in OPEFB compost is 1.97 and the results of the final K_2O analysis in Table 9 can be seen that the N- the total OPEFB compost is on average 4.3-4.62. This is in accordance with the SNI Compost Quality Standard: 19–7030–2004. The results of Duncan's 5% follow-up test showed that the treatment of B1, B2, B3, B4, B5, B6 and B7 was not significantly different from the treatment of B0. The highest K2O value was found in the B4 compost treatment (Bacteria consortium + ORL9 + ORL6 and ORL1), which was 4.62. Meanwhile, the lowest K_2O value was found in B7 treatment (Bacteria consortium + ORL9, ORL6, ORL1, ORL2, ORL4 and ORL7) treatment, which was 4.3. According to Ayunin [16], potassium is used by microorganisms in the substrate as a catalyst. Microbial activity will affect the increase in potassium content.

5. Conclusion

Based on the results of the study, it can be concluded that the administration of lignocellulolytic bacterial isolates can accelerate the process of weight loss of compost material, increase the pH of the compost, decrease the water content, decrease the organic C, reduce the C/N ratio of the compost and increase the nutrient content of N, P and K. Treatment of lignocellulolytic bacteria ORL9 and ORL6 and a consortium of cellulolytic bacteria showed good compost quality, which could be seen from the parameters of weight loss of compost, pH, N nutrient content and reduced C/N ratio.

Compliance with ethical standards

Disclosure of conflict of interest

All authors declare there is no conflict of interest in this paper.

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