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# The Effectiveness of Bio Activator of Phosphate Solubilizing Bacteria Consortium on Composting Bag-log Waste Incorporated with Cow Dung

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**Abstract:** Bag-log waste is an organic material that is difficult to decompose. This is due to the bag log's high content of lignin compounds. Therefore, to speed up the composting process, it is necessary to include other organic materials and bio activators. This study aims to analyze the effectiveness of the bio-activator consortium of Phosphate Dissolving Bacteria (KBPF) in composting bag-log waste mixed with cow dung. The experiment consisted of 5 treatments with three replications, namely (T1) bag-log waste, (T2) a mixture of bag-log waste and cow manure with a composition of 1:2 (wt/wt), (T3) a mixture of bag-log waste and cow manure with 2:1 ( wt/wt), (T4) a mixture of bag-log waste and cow manure with a composition of 1:2 (wt/wt) plus KBPF (200 ml) with a density of $10^8$ CFU/ml (T5) a mixture of bag-log waste and cow manure with a composition of 2:1 (wt/wt) plus KBPF (200 ml) with a density of 108 CFU/ml. The experiment was created as - Completely Randomized Design (CRD). The experimental results show that bag-log waste cannot be decomposed fastly without cow dung and bio activators. The treatments of T2, T3, T4 and T5 produced compost with quality not significantly different from one another. Under these treatments, the temperature was controlled in the mesophilic stage, and the composting pH was returned to neutral, while the moisture content and C/N ratio decreased to almost half of their original levels at the end of the composting period. It seems that inoculation of KBPF into the mixture of cow dung and bag-log waste has no role in accelerating the composting process. The mix of Bag-log and cow dung, with a minimal proportion of 2:1 without inoculation KBPF, was the recommended combination in composting bag-log in which the final product (compost) could fulfil its pH (neutral), the threshold of temperature and water content. The C/N ratio of the treatment was close C/N ratio of mature compost, and total N and total P contents were more than the standard of SNI 19-7030-2004.

**Keywords:** Bio activator; Bag-log waste; Composting moisture; Composting pH; Composting temperature; Cow dung; Mature Compost.

## Introduction

Bag-log is becoming a popular medium for oyster mushroom cultivation elsewhere. However, in long run, its unused materials will become unexpected waste in environments. It is fortunately, bag-log waste can be recycled into organic fertilizer through composting (Siregar & Idris, 2018). The oyster mushroom growing medium is composed of three main ingredients: sawdust, and organic materials containing carbohydrates, such as corn flour, rice bran, agricultural lime and other materials. The lime is added to control acidity level during the mushroom cultivation process (Siregar et al., 2018), while water content in the growing media is preserved at 60%-70% (wt/wt).

Recycling bag-log waste into organic (compost) fertilizer is beneficial for maintaining environmental sanitation and the source of organic fertilizers for crops. Incorporating organic fertilizers into soils increase soil fertility through various mechanisms. First, the growth and activity of soil microbes increase because of the increased availability of energy sources (Lazcano et al., 2013). Second, the soil's ability increased to hold nutrients from being washed away by percolation water

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flows. Silber et al. (2010) reported that the organic fertilizer application resulted in an increased pH-dependent cation exchange capacity which has a significant role in providing nutrient availability in the soil during plant growth. Third, soil physical properties such as aggregation, aeration, and drainage are better (Devi et al., 2019). Therefore, the change in the soil environment due to the input of organic fertilizers makes plants grow healthy with relatively high productivity.

Regarding composting bag-log waste, bag-log waste has several limiting factors that cause composting to take a relatively long time. Therefore, human intervention is needed to obtain compost in a short time and meet the standards of SNI 19-7030-2004 . One of the limiting factors is that bag-log waste has a relatively high C/N ratio (more than 80). In addition, bag-log waste also contains high lignin compounds. According to SNI 19-7030-2004, the minimum technical requirements for organic fertilizers must have a C/N ratio of 20, and an acidity level (pH) of organic fertilizers ranging from 6.8 to 7.49.

The strategy for accelerating bag-log waste composting is to add organic material with a low C/N ratio (C/N less than 40), such as cow dung (Sunarya & Wardhana, 2020) and legume plant litter (Kohmann et al., 2018). In addition, it is necessary to use bio activators to decompose organic matter (Wang et al., 2020; Susilowati et al., 2021). One of the bio activators introduced is the bio activator of phosphate solubilizing bacteria consortium (KBPF), the result of a national research scheme for Applied Research from 2017 to 2019, and is currently in the process of filing a simple patent with No. Application SID201902856. This bio activator has multi-functional advantages, namely solubilizing phosphate, producing IAA, controlling diseases caused by the fungus *Sclerotium rolfsii* and decomposing organic matter rich in cellulose (Susilowati et al., 2019). Regarding the effectiveness of KBPF as a bio activator in composting organic waste with a high C/N ratio, this has never been evaluated.

This study aims to analyze the effect of adding cow dung on composting of bag-log waste and the effectiveness of the bio activator consortium of phosphate solubilizing bacteria in bag-log waste composting by adding cow dung.

## Method

The research was carried out in a composting house belonging to the Women Farmer Group (PaManSam) in Narmada Village, West Lombok Regency. Several parameters of the experiment were measured at the Laboratory of Chemistry and Soil Fertility, Faculty of Agriculture, University of Mataram.

The compost materials consisted of mushroom bag-log waste with a C/N ratio of 70, cow dung with a C/N ratio of 25, and a KBPF bio activator. The tools used in this research were composting pit, shovel and hoe, and some laboratory equipment, such as a thermometer, pH meter, and oven.

The experiment was set up as -Completely Randomized Design (CRD) with five treatments and three replications for each treatment. Thus, there were 15 composting pits containing 20 kg respectively. Compost materials consisted of bag-log waste and cow dung arranged according to treatments

The treatments were as follows:

(T1) bag-log waste

(T2) mixture of bag-log waste and cow dung with a composition of 1:2 (wt/wt)

(T3) mixture of bag-log waste andcow dung with a composition of 2:1(wt/wt

(T4) mixture of bag-log waste and cow dung with a composition of 1: 2 (wt/wt) plus KBPF (200 ml) with a density of $10^8$ CFU/ml

(T5) mixture of bag-log waste and cow dung with a composition of 2: 1 (wt/wt) plus KBPF (200 ml) with a density of $10^8$ CFU/ml.

*The research stages*

The experiment began with the preparation stage (collection of experimental material, proliferation of a consortium of phosphate-dissolving bacteria), followed by composting, harvesting of the compost, and analyzing the quality of the compost in the laboratory. Figure 1 shows the flowchart of the research activities.

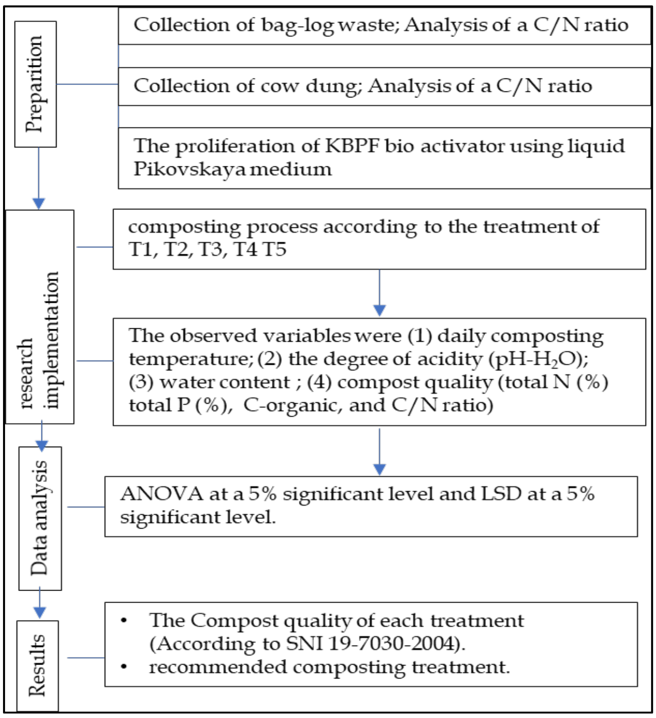



**Figure 1**. The flowchart of the research activities

The observed-variables were (1) daily composting temperature which was measured by using a thermometer carried out every day; (2) the degree of acidity (pH-$H_2O$); -using a pH meter (glass electrode), with a ratio of compost and water = 1:1; (3) water content was -determined by - the oven method (AOAC 2005); (4) total N (%) was determined by Kjeldahl method; (5) total P (%) was determined by Olsen method, C-organic was determined by Walkey and Black method and C/N ratio.

Data were analysed by ANOVA at a confidence level of 5%. -The difference between treatments was tested by a least significant difference test, LSD at a 5% significant level Research design and method should be clearly defined.

## Result and Discussion

*Composting -Temperature*

Temperature is one of the determining factors for the continuity of the composting process of organic matter (Cooperband, 2002). The aerobic composting process produces energy, simple organic compounds, water vapour, carbon dioxide, and small amounts of other gases (Ahn, 2011). Energy is released as heat so that during the composting process, it must pass through the temperature dynamics stage. The variation of temperature change is well correlated with the characteristic of compost materials and the rate of microbial activity (Ahn et al., 2011). In this study the composting temperature was measured every day for 36 days of composting time, and the results are shown in Figure 2.

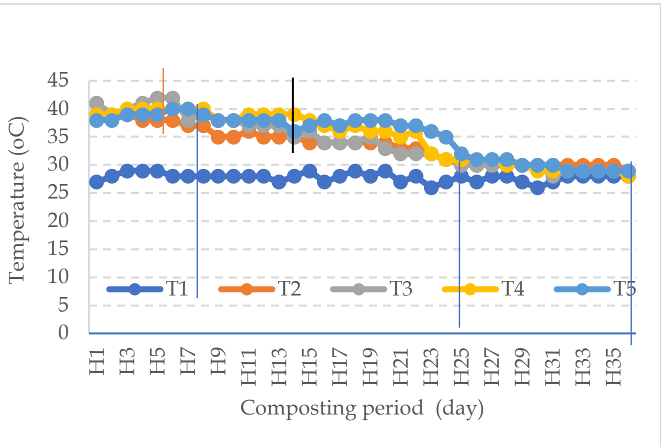



**Figure 2**. Changes in temperature during composting

Figure 2 above shows that temperature in the T1 treatment was relatively constant and fluctuated within an interval of 27 – 29$^{o}$C in 36 days of composting time. This was in the mesophilic phase. The temperature change in treatment T2 to T5 was significantly different from that in treatment T1. The temperature of T2, T3, T4 and T5 treatments increased gradually from the first day to the 9$^{th}$ day of composting time and reached the maximum temperature on the 6$^{th}$ day. From the day 6$^{th}$ to the 9$^{th}$, the composting temperature was in the thermophilic phase in which temperatures ranged from 39-44$^{o}$C. The increase in temperature in the early stages of composting indicates that the decomposition of compost material by mesophilic microbes has begun to take place at that time and generates heat.

Next, it can be seen in Figure 1 that the temperature in the T4 and T5 treatments was higher than in the T2 and T3 treatments for the composting period from the 9$^{th}$ to the 15$^{th}$ days. The ambient temperature in the T4 and T5 treatments ranged from 39 to 40$^{o}$C. The temperature was in the thermophilic phase. The composting temperature in the T2 and T3 treatment was in the mesophilic phase in the temperature range of 30-32$^{0}$C. These results indicate that the thermophilic phase of the composting treatment with the addition of bio activator lasted six days longer than the without-bio activator. One of the advantages of composting with a relatively long thermophilic phase is the death of weed seeds and ant pathogenic microbes (Insam & De Bertoldi, 2007). It means the addition of bio activator to the compost materials can help improve the quality of the compost where produced compost is free from weed seeds and pathogenic microbes.

Furthermore, Figure 2 shows that the composting temperature of treatments T2 to T5 slowly decreased from the 15$^{th}$ to the 25$^{th}$ day of the composting, and was in the cooling temperature phase. After the 25$^{th}$ day, the composting process of the T2 to T5 treatments entered the maturation phase, and the temperature was relatively constant at 30$^{o}$C. Thus, during the composting period of 36 days, there have been four stages of temperature changes (mesophilic, thermophilic, cooling and maturity phases) in treatments T2 to T5. It means that the composting process of a mixture of bag-log waste and cow dung takes at least 36 days. Zhou et al., (2015) states that an indicator of the progress of composting is a change in temperature in four stages, namely the mesophilic phase, the thermophilic phase, the cooling phase, and the maturity phase.

For the T1 treatment, where it was only bag-log waste, there were no significant changes in temperature during the composting time. A relatively constant temperature during composting (mesophilic phase) in 36 days indicates that bag-log waste in T1 treatment was not actively decomposed by microbes during the composting period. The causative factor may be that the bag-log waste does not carry decomposer microbes due to the sterilization process during the preparation of the bag-log. Another factor may be because of the contents of low nitrogen and high carbon in bag-log waste. So, it did not meet the amount of N required by microbes to start their activities. Composting of material with high C/N requires - input of N - as a starter element to stimulate the activity of decomposers (Sutanto, Widowati, Achyani, Hendri, Rifai, & Yulistiana (2020). The dominant component in bag-logs is dust-saw which contains relatively high lignin-cellulose compounds which it difficult to decompose. Therefore, accelerating the composting process of bag-log waste need the incorporation of N-source and bio-activator inoculation.

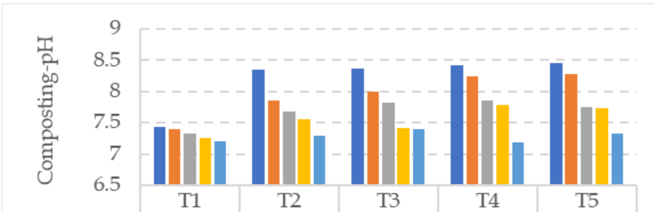
Temperature changes in T2, T3, T4 and T5 treatments, (Figure 1) was associated with microbial response to ambient temperature. Temperature had increased from the mesophilic phase (35°C) to the thermophilic phase (39°C to 44°C). Mesophilic microbial groups have started to decompose the materials since the beginning of the composting time. Increased activities of mesophilic microbial groups increased $CO_2$ released from composted materials which could increase composting temperature. Cooperband (2002) reported that the temperature increases due to heat energy released from the metabolic activities of decomposers intercepted by – the accumulation of $CO_2$ in moist air. Isroi & Yuliarti, (2009) stated that the increase in composting temperature from the beginning of composting to reaching the maximum temperature (thermophilic) was caused by the heat generated by mesophilic microbial activity in the decomposition of compost materials. Furthermore, Cooperband (2002) emphasized that the effect of warm air and organic compounds could accelerate the proliferation of mesophilic microbes so that the temperature could increase rapidly.

Regarding the acceleration of the bag-log waste composting process, it should be recommended that other organic matter with a low C/N ratio must be added to the bag-log waste. The results of this study show that compost materials containing cow dung are faster than those without cow dung. Animal manure in composting organic matter presents several decomposer and provides the source of energy for other microbial life involved in composting ((Teo & Teoh, 2011). Previous research revealed that manure with a C/N ratio of 25 added to straw with a C/N ratio of 80 could speed up the composting of rice straw up to 5 times faster than without manure (Setyorini, Saraswati & Anwar, 2019). Cow dung added to composting can help the decomposition of organic solids by aerobic bacteria (Erickson et al., 2014).

*Changing in composting-pH*

During the composting process, the pH of the compost will change and the pattern of change will depend on the microbial group that is actively decomposing the organic matter at that time. Figure 2 presents the results of weekly composting pH measurements over a 5-week composting period. Figure 3 shows that the composting pH in the T1 treatment was not significantly different during the five weeks of composting. The composting pH ranging was from 7.43 to 7.25 and decreased slowly. In contrast, the pH in the T2, T3, T4 and T5 treatments increased and were higher than in the T1 treatment at the beginning of composting (the first week). The composting pH in the four treatments ranged from 8.35 to 8.46. Furthermore, the composting pH in the T2, T3, T4 and T5 treatments gradually decreased from weeks 2 to 5. In addition, Figure 2 shows the pH decrease sharply to a level neutral in bag-log waste incorporated with cow dung with a ratio of 1:2. The pattern of changes in composting pH in this study is similar to the results of previous research. Azizah et al. (2017) reported that the incorporation of cow and goat manure into plant litter with a C/N ratio of 68 resulted in the composting pH increasing at the beginning of the composting period and reaching a slightly alkaline pH (pH 8.45) on day 14. After that, the composting pH began to decrease towards the pH requirements for mature compost (pH 6.80 - 7.49) according to SNI 19-7030-2004 standards.

Next, a test of the regression coefficient was carried out to determine the decreased rate of pH as a function of time during composting from T2 to T5 treatments. Decreasing rate of pH in the T2 treatment was 0.245 week$^{-1}$ ($p=0.265$), in the T3 was 0.252 week$^{-1}$ ($p=0.262$), in the T4 was 0.294 week$^{-1}$ ($p=0.264$) and in the T5 was 0.283 week$^{-1}$ ($p=0.280$). It is clear from these results that pH insignificantly decreased in all four treatments ($p>0.05$). It seems that bag-log waste and cow dung were determinant factors in affecting pH. However, the KBPF bio activator did not affect the pH change, although the KBPF was mixed in bag-log waste and cow dung.




| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| week 1 | 7.43 | 8.35 | 8.36 | 8.42 | 8.46 |
| week 2 | 7.4 | 7.85 | 7.99 | 8.24 | 8.28 |
| week 3 | 7.32 | 7.68 | 7.82 | 7.86 | 7.75 |
| week 4 | 7.25 | 7.56 | 7.41 | 7.78 | 7.73 |
| week 5 | 7.20 | 7.29 | 7.39 | 7.18 | 7.32 |

**Figure 3**. Changes in composting pH during the composting period of 5 weeks

An increase in pH at the beginning of composting in the T2, T3, T4 and T5 treatments may be caused by increasing the activity of the proteolytic decomposer carried in cow dung. As a result of stirring the compost heap, there provides more aeration. More aeration in the composting process promotes faster proteolytic microbial activity and growth. As a result, the composting pH increases rapidly. Setyorini et al., (2019) stated that at low aeration rates, the pH did not increase, and in some cases it even decreased, whereas high aeration rates gave increased pH as well as faster decomposition and more stable products.

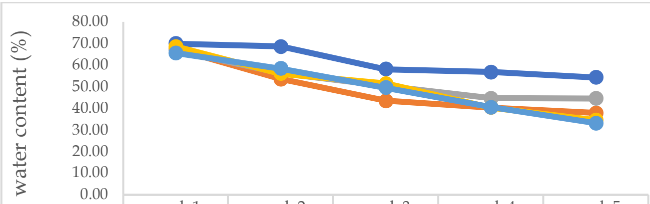
At the beginning of the composting process, the decomposer actively decay protein compounds to produce nitrogen and energy source for other mesophilic microbes. The decomposition of protein compounds produces amino acids. Then, it is mineralized to $NH_3^+$(ammonia). Ammonia reacts with $H_20$ to produce $NH_4OH$ which it dissociates into $NH_4^+$ and $OH^-$. The presence of $OH^-$ in high concentrations causes the composting pH of bag-log waste incorporated with cow dung to reach a pH greater than 8 in the beginning stage, viz at week $1^{st}$ to week $2^{nd}$. Setyorini et al. (2019) stated that the ammonia production at the initial phase of cow dung composting resulted in the composting pH is being alkaline (pH 8-9). Azim, Saudi, Bhoukhari, Perissol, Roussos & Alami (2018) stated that the pH of compost increases due to the mineralization of organic compounds which increases the number of basic cations, such as potassium, calcium and magnesium, and the breakdown of proteins. On the other hand, Azim et al., (2018) stated that an alkaline composting environment would facilitate the breakdown of lignin-cellulose bonds by enzymes produced by cellulolytic microbes.

In contrast, pH decreased after stirring the compost in the last of the second week. It may be because of input -oxygen after the stirring process which stimulates the activity of decomposer that produce organic acids. Increasing the concentration of organic acids causes the pH to decrease (Azim et al., 2018). Source of $H^+$ ions in this composting process comes from (1) organic acids resulting released from the decomposition of organic matter by mesophilic decomposers, and (2) an increase in concentration of $H_2CO_3$ compounds which is produced from the reaction $CO_2$ and $H_2O$ (Azim et al., 2018; Setyorini et al., 2019).

Based on the results of this study, it seems that the inoculated KBPF at the beginning of composting has no significant effect on the dynamics of changes in composting pH from a mixture of wood bag waste and cow dung. In this case, it could be because the bacterial agent in the KBPF bio activator is not from a group of thermophilic bacteria. These bacteria are unable to survive when the composting temperature reaches the thermophilic phase. It is also possible that the microbial agents in KBPF cannot develop because they are unable to compete with the inherent decomposers of cow dung. Another factor is that the bacterial agent in KBPF is not a microbial group that produces ligninase enzymes, enzymes decomposing lignin-cellulose compounds, so the composting pH in the treatments with and without inoculation KBPF did not show a significant difference.

*Water Content During Composting*

The water content in the composting process is one of the factors to be maintained during the composting process. Aerobic microbial metabolism requires a balanced availability of water and oxygen to be able to do optimal activities in breaking down compost materials. The efficiency of the aerobic composting process occurs in an environment with a moisture content of 60%-40% (Setyorini et al., 2019). If the moisture content exceeds 60 %, then the air volume is reduced, an odour will be produced (due to anaerobic conditions), and the decomposition of compost material takes place slowly. In this study, the moisture content in compost was measured once a week from the first week to the fifth week, and the Figure 4 shows the measurement results




| | week 1 | week 2 | week 3 | week 4 | week 5 |
|---|---|---|---|---|---|
| T1 | 69.87 | 68.57 | 58.15 | 56.84 | 54.26 |
| T2 | 67.50 | 53.50 | 43.49 | 40.40 | 37.9 |
| T3 | 66.82 | 56.27 | 50.29 | 44.67 | 44.54 |
| T4 | 68.62 | 56.1 | 51.41 | 40.32 | 34.55 |
| T5 | 65.59 | 58.4 | 49.48 | 40.61 | 33.17 |

**Figure 4**. Water content (%) in each treatment during the composting period

Figure 4 shows that water content tended to decrease in all treatments (T1, T2, T3, T4 and T5) during the composting period. The compost water content was in the range of 65.59 - 69.87 % (wt/wt) in all treatments at the beginning of the composting process (at week 1). Figure 3 shows that water loss in the T1 treatment was lower than in the other four treatments. Water content decreased from 68.62% at the beginning of composting (week 1) to 54.26% at the end of composting (week 5) in the T1 treatment. While in the other four treatments (T2, T3, T4 and T5) decreased the water content from about 65.59 – 68.62% (wt/wt) in week 1 to 33.17-44.54% in week 5. Next, the average decrease of moisture content was by 3.08% $week^{-1}$ at T1, 10.6% $week^{-1}$ at T2, 8.6% $week^{-1}$ at T3, 11.3% week-1 at T4 and 8.4% $week^{-1}$ at T5. These results illustrate that composting that takes place intensively will lose more water.

Water loss was mainly due to evaporation triggered by increasing temperature during composting. The correlation rate between water loss and the composting temperature reached r= 0.92 in this study. Increasing the composting temperature is followed by increasing water loss in the compost material in the form of water vapour which is released into the atmosphere during the mixing and turning in the compost. Setyorini et al. (2019) reported that the decrease in water content in aerobic composting occurs because the water in the compost material evaporates due to the heat that occurs during composting.

The degree of correlation between water loss and the composting temperature was r = 0.92 in this study. The rate of water loss during the composting process is in line with the increase in composting temperature. Increasing the composting temperature accelerates the change of water into water vapour which is then released into the atmosphere when the compost is stirred and turned over.

Furthermore, Figure 3 shows that the water loss in the T1 treatment was relatively low, from 69.87% (wt/wt) in the first week to 54.26% in the fifth week. In contrast, water loss at the treatment of T2, T3, T4 and T5 was relatively high, from 65.59 – 68.62% (wt/wt) in week 1 to 33.17-44.54% in week 5. These results indicate that the microbial activity in the four treatments was very intensive in breaking down the compost material to produce water vapour, heat, $CO_2$ and simple organic compounds. Setyorini et al. (2019) explained that the amount of water loss in the aerobically composting describes the intensity level of microbes in decomposing compost material. The optimal moisture content in compost material decomposition process by aerobic microbes was about 40–60 % (wt/wt) (Insam & De Bertoldi, 2007). A composting process would be hampered when the moisture content of the compost is less than 40% or more than 60%. The results of this study indicate that the water con tent in the four treatments was slightly below the optimal moisture content for the composting process within 36 days. This result illustrates that adding or mixing cow dung into bag-log waste has an important role in maintaining the water content so that the composting process takes place intensively.

*Compost chemical characteristics*

According to SNI 19-7030-2004, the minimum requirements for compost quality standards contain 0.4% nitrogen, 0.10% phosphorus ($P_2O_5$), 0.20% potassium ($K_2O$) and a 20 C/N ratio. Table 1 present the results of the analysis of the chemical quality of the compost in each treatment.

**Table 1.** The content of total N, total P, C-organic and C/N ratio in each treatment at the end of composting (in the fifth week of composting)

| Treatment | Total N (%) ± SE | Total P (%) ± SE | C-organic (%) ± SE | C/N ratio |
|---|---|---|---|---|
| T1 | 0.89 c ± 0.030 | 0.20 e ± 0.007 | 50.12 a ± 2.07 | 56.31 |
| T2 | 1., 20 a ± 0.015 | 0.45 a ±0.021 | 26.04 d ± 1.76 | 21.79 |
| T3 | 1.12 b ± 0.020 | 0.38 c ± 0.021 | 28.37c ± 1.76 | 25.33 |
| T4 | 1.17 a ± 0.030 | 0.41 b ± 0.014 | 26.45 d ± 3.06 | 22.60 |
| T5 | 1.17 a ± 0.020 | 0.33 d ± 0.021 | 31.22 b ± 2.03 | 26.68 |

Note: numbers followed by the same letter in the same column are not significantly different

Table 1 shows that within 36 days of the composting period, the bag-log waste composting process cannot produce mature compost. C/N ratio of bag- log waste was still high (C/N ratio of 56.31). The total N and total P contents were also relatively low compared to the other four treatments. Meanwhile, the treatments of T2, T3, T4, and T5 produce compost with C/N ratio close with C/N ratio in mature compost. These results prove that adding cow dung to bag-log waste can speed up the composting process of bag-log waste. Therefore, it is necessary to add cow dung or other organic matter with a low C/N ratio to accelerate and obtain high-quality compost into the compost material with a high C/N ratio, such as bag-log waste. In addition, adding cow dung to the bag-log waste can increase the N and P content in the mature compost. Mirwan, (2015) reported that the input of compost from cow manure to teak leaf litter - Tectona grandis - produced compost with higher N, P and K content than compost without cow manure. Furthermore, it can be shown that the compost quality of the treatments of T2 and T4 insignificantly different, as weel as the treatments of T3 and T5. It means that inoculation of KBPF bio-activator into a mixture of cow dung and bag-log waste has no role in accelerating composting

## Conclusion

Composting bag-log waste with a C/N ratio of >69 seems to take a relatively long time. The C/N ratio of bag-log was still relatively high (C/N ratio = 56. 50%) on the 36$^{th}$ day of the composting period. Meanwhile, the C/N ratio of compost of the treatments of T2, T3, T4 and T5 had closed to the C/N ratio of mature compost. These results indicate that adding cow manure to bag-log waste can shorten the composting period, with a minimum proportion of 2 parts bag-log waste and one part cow manure (wt/wt). The inoculation of KBPF into bag-log waste mixed with cow dung does not show its role as a bio activator which can speed up the composting process or improve the compost quality. The compost quality in the treatments of T2 and T4 was insignificantly different, as well as the treatments of T3 and T5. The mix of bag-log waste and cow dung, with a minimal proportion of 2:1 without inoculation KBPF, was the recommended combination in composting bag-log waste in which the final product (compost) could fulfil its pH (neutral), the threshold of temperature and water content. The C/N ratio of the treatment was close C/N ratio of mature compost, and total N and total P contents were more than the standard of SNI 19-7030-2004.

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