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Research Article

Evaluating floor types during simple composting of leaf wastes

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Abstract

This study aimed to evaluate the type of floor in the composting process of leaf wastes. The waste consisted of cacao leaves (*Theobroma cacao* L.), rubberwood leaves (*Hevea brasiliensis*), teak leaves (*Tectona grandis* L.f), matoa or Fijian longan leaves (*Pometia pinnata*), durian leaves (*Durio zibethinus*), and grass. The research was conducted by composting the leaf mixtures in a composting box sizing 220 cm in length, 180 cm in width, and 100 cm in height. A long box was partitioned by using plastic tarpaulin into four boxes for different floors, namely cement, soil, tarpaulin, and rice husks. A mixture of leaves of 127 kg to 176 kg was introduced in each box and was composted for 145 days. Variables observed were temperature, the height of heap, the mass of material (initial and final), C/N ratio, NPK contents, compost color, odor, pH, and moisture content. The results showed that compost quality fulfilled Indonesian National Standard (SNI 19-7030-2004) regardless of the floor types. However, the type of floors affected the compost process and yield. The composting process with tarpaulin-layered or husk-layered floors produced better compost in terms of N, P, C/N ratio, and color as compared to those resulting from cemented or barely soil floors.

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Introduction

Nutrient requirements during the plant growth process are generally obtained from chemical fertilizers and or organic fertilizers. Chemical fertilizers are farmers' favourite choice because they are easy to use and have high nutrient content. However, chemical fertilizers have disadvantages when used overly for a long time. Plentiful studies reported negative impacts of long-term excessive use of chemical fertilizers, including soil deficiency of potassium (K) and phosphorus (P) (Liu et al., 2010), soil acidification (Matsuyama et al., 2005), decreasing soil organic matter (Ning et al., 2017), increasing soil bulk density (Bitew and Alemayehu, 2017), environmental pollution (Savci, 2012), declining input efficiency (Ge et al., 2018), and reducing food quality and safety (Ye et al., 2020). An alternative way that can be offered to solve this problem is the use of compost. Compost application into the soil is a sustainable way for crop production because it provides various benefits, including supplying organic matter to the soil, improving plant growth, and providing nutrients to crops (Choudhary et al., 2022). Various studies reveal the effectiveness of compost in increasing crop yield, such as rice (Barus, 2016), corn (Naohiro et al., 2016), soybean

(Barus, 2017), cassava (Dermiyati et al., 2016), potato (D'Hose et al., 2012), and so on. Compost is effective not only for improving land and plant productivity but is also suitable as an amendment to rehabilitate degraded land (Zahra et al., 2021), ex-mining land (Paradelo, 2013), critical lands (Nason et al., 2007), and urban lands (Heyman et al., 2019).

Compost is a product resulting from biological processes by microorganisms that separately or collectively break down organic matter into humus. The formed material has a lower weight and volume than the parent material and is stable in its decomposition rate, so it is profitable as a source of organic fertilizer. Various organic wastes such as leaves, livestock waste, agricultural residues, kitchen waste, restaurant waste, etc., can basically be used as raw material for compost. Leaves are one of the most waste produced from gardens or green areas. Generally, leaves are removed by simply burning or throwing them away. In fact, this waste has the potential as a raw material for compost and can be used as a source of biological fertilizer. Leaf litter and twigs that fall from trees and grass in the garden contain macro and micronutrients, making them suitable as compost materials (Parzych, 2022).

Composting is the oldest and easiest way to process organic waste. In fact, composting occurs naturally through the formation of humus which lasts a very long time depending on the presence of decomposing microorganisms and weather conditions. The relatively long formation process for topsoil occurs due to uncontrolled conditions, where aerobic and anaerobic microbes take turns taking roles according to supportive environmental conditions, namely the presence of oxygen (Misra et al., 2003). Composting is implemented to convert organic waste into materials that are more beneficial to the environment and is an affordable process for farmers. Different factors affect the composting process, including C/N, air or oxygen, water, temperature, and pH. Moisture is crucial for bacterial activity during the composting process.

Typically, the highest degradation during composting process occurs when the optimal moisture content in the starting material is around 40-60% by weight (Stentiford, 2007). Although organic matter with a wide range of pH can be composted, compost microorganisms operate best under acidic to neutral conditions, and a maximum decomposition occurs at the optimum pH range between 5.5 and 8.0 (Huang et al., 2006). Oxygen supply is a critical aspect of composting cycle, with a desirable range concentration between 15% and 20% (Rastogi et al., 2020). An inadequate supply of oxygen may reduce organic degradation and cause process instability. Turning compost mass pile is imperative to sustain aeration and provide oxygen. Heat emanated during composting will be transferred to the environment. In this context, composting techniques (including the floor type of the composting box) affect heat transfer. So far, composting has been conducted without considering the type of floor used. Composting at the farm level is generally carried out using soil as the floor, although other floors can be found. The type of floor may have an effect on heat exchange that results in different temperatures in the composting box. The type of floor also affects the mass transfer of water, resulting in differences in moisture content during composting. All of that will indirectly affect the material decomposition process. The effect of floor types on the composting process at the farmer scale has not been widely studied. Therefore, this study was conducted to evaluate the types of floors to determine the appropriate floor in obtaining the optimum conditions for the composting process of leaves.

Materials and Methods

The research was conducted at the Experimental Laboratory of State Polytechnic of Lampung (POLINELA), Indonesia, for 145 days (Latitude: 5°21'26,95" S; Longitude: 105°13'46,88" E; Elevation: 118 m asl). Based on climate data from the climatological station in POLINELA (120 m asl, latitude 5º21'16.1" S, longitude 105º13'7.2" E), the weather conditions at the study site were characterized by annual rainfall of 1847.6 mm with 148 rainy days, the average temperature of 26.7 °C with a range of 25.8-27.5 °C, and average relative humidity of 79.9% with a range of 65-90%.

Cellulose-rich materials require long composting times, up to 140 days for vineyard pruning wastes, as reported by Wang and Schuchardt (2010), or even 180 days for date-palm waste (Mortazavi et al., 2012). The materials used in this study were the mixtures of leaves collected on the experimental farm and consisted of cacao leaves (*Theobroma cacao* L.), rubberwood leaves (*Hevea brasiliensis*), teak leaves (*Tectona grandis* Lf), matoa or Fijian longan leaves (*Pometia pinnata*), durian leaves (*Durio zibethinus*), and mini elephant grass or (*Axonopus compressus*). This material is available throughout the year around the experimental farm and is barely left or destroyed by burning. The leaf mixture had the following characteristics: water content of 11.23%, bulk density of 56.6 kg/m^3, C content of 52.8%, and N content of 1.62%. The mixture of leaves was used as it is without treatment. The fermented bacteria with the brand name EM4 was used to help the composting process.

Treatments

The study was conducted with four types of floors, namely cemented floor, soil floor, tarpaulin-layered floor, and rice husk-layered floor. Four composting boxes were built in an area away from the crowd to avoid environmental pollution such as odors caused by composting. Each composting box sizing 220 cm long and 180 cm wide was separated using a partition of

100 cm height of plastic tarpaulin. All composting boxes were roofed by tarpaulin with a sloped frame made of bamboo. The distance between composting box was 10 cm (Figure 1). This space was provided to avoid heat accumulation for boxes in the middle. The floor of composting boxes consists of a cemented floor (Figure 2a), soil (Figure 2b), tarpaulin (Figure 2c), and rice husks (Figure 2d). The floors were tilted 2% in order to prevent the compost condition from being flooded and to facilitate compost leachate as well as rainwater accidentally entering the box. Composting box with a cemented floor was made of cement-sand mortar with a ratio of 1:5 and a thickness of 10 cm. Meanwhile, composting boxes with soil floors were made barely by compacting the subsoil.

The composting box with a tarp floor was prepared using tarpaulin plastic, which was layered on the ground surface. Composting box with the husk floor was made using rice husks which are stacked on the soil surface with a thickness of 10 cm. Compost raw materials consisting of a mixture of leaves and grass are weighed and put into the composting boxes layer by layer up to a height of 70 cm or a volume of 2.77 m^3.

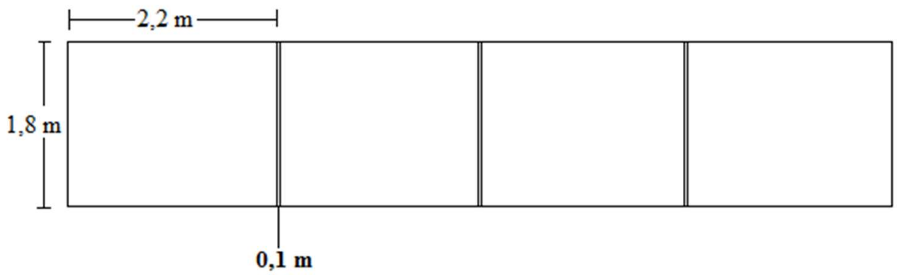


Figure 1. Composting box arrangement with 10 cm spacing.

(a) (b) (c) (d)

Figure 2. Composting box with different floors (a) cemented, (b) soil, (c) tarpaulin-layered, and (d) husk bed.

According to Cromell (2010), the minimum volume to ensure self-insulation so that the composting process runs well on a static pile is about 1 m^3. Compost raw materials were arranged in such a way that the composting process could take place optimally. Effective microorganism EM4 was used as a starter bacterium with an application dose of 300 mL per treatment box. The EM4 was sprayed manually using a hand sprayer onto the material at every 10 cm layer height. In this case, 42.8 mL of EM4 was diluted with water at a volume ratio of 1:5 (EM4: water). The initial mass of compost material put into the box was 136.5 kg, 127 kg, 155 kg, and 176 kg, respectively, for cemented, soil, tarpaulin, and husk-layered boxes. The difference in material mass implied variance of material density due to imperfect mixing. The pile was covered with a plastic tarp made of vinyl to maintain the temperature of the material during the composting process,

The material was turned over after the pile was 10-days old. The turning process was repeated when the pile temperature decreased to around the initial value, namely at 40, 80, and 100 days. Simultaneously with the turning of the pile, water is sprayed to add moisture. After turning it over, the material is covered again. The purpose of turning the pile is to stir and move the materials such that all the materials located at the edges are moved to the center of the pile. Furthermore, the stirring process is a good way to facilitate aeration during the composting process so that the composting process takes place perfectly. At the end of composting (145 days), the mass of the material is reweighed to calculate compost yield.

Analysis and measurements

The composting method was performed through a semi-anaerobically process with several pile turnings. It is important to note that at each turning process, the top compost materials were moved to the bottom of the pile. The variables that were routinely observed include the temperature and height of the compost pile. Compost temperature was measured every two days by sticking a thermometer at half the depth of the piles in three different places. The height of the compost pile was measured and observed once every two weeks. Measurement was made by observing the height of the pile on the measuring tape placed on the side of the box.

Other variables included compost pH, initial and final mass of material, C/N ratio of compost, N-P-K content, compost color, odor, and moisture content. The pH value of compost was measured using a pH meter by dissolving the compost with distilled water and then measuring the pH content. Carbon was measured using the Walkley-Black method, whereas Nitrogen was measured using the Kjeldahl method. Total P was measured using the spectrophotometry method, and potassium was measured using the Atomic absorption spectrometry (AAS) method.

The color of compost was one of the easiest physical properties to observe visually. However, visual observation is subjective and can be biased. The color change of the compost was measured numerically using the Colorimeter AMZ 535 (China) to avoid the resulting bias. CIELab is a method used in color measurement with parameters L^*, a^*, and b^*. The L^* represents the value of brightness (lightness), with 0 representing black and 100 for white. The parameter a^* represents red-green chroma, with the positive (+) value representing red and negative (–) representing green. The b^* represents yellow-blue colors, with the value + representing yellow and – (minus) representing blue. The a^* and b^* values range from +80 (maximum) to -80 (minimum) (Wrolstad and Smith, 2017). Color differences from soils or parent leaves were obtained through the following equations:

$$\Delta \boldsymbol{L}^* = \boldsymbol{L}^*_{compost} - \boldsymbol{L}^*_{o} \quad (1)$$
$$\Delta \boldsymbol{a}^* = \boldsymbol{a}^*_{compost} - \boldsymbol{a}^*_{o} \quad (2)$$
$$\Delta \boldsymbol{b}^* = \boldsymbol{b}^*_{compost} - \boldsymbol{b}^*_{o} \quad (3)$$

where subscript o is for comparators (soils or parent leaves). In addition, positive ΔL means lighter and negative ΔL means darker. Positive Δa means redder or less green, negative Δa means greener or less red. Positive Δb means yellower or less blue, negative Δb means bluer or less yellow.

The odor of compost was observed organoleptically by direct observation and compared with soil. Measurement of the compost moisture content was carried out at the end of the study, where compost samples were weighed (B_I) and oven-dried at 105 °C for 24 hours until the weight of the material was constant (B_F). The water content (KA, %) was calculated using equation (4):

$$\boldsymbol{KA} = \frac{(\boldsymbol{B_I} - \boldsymbol{B_F})}{\boldsymbol{B_I}} * \mathbf{100\%} \quad (4)$$

Results and Discussion

Temperature changes

Monitoring compost temperature regularly will help the composting process because through temperature measurement, it can be observed how fast the composting process occurs and which spot of the pile is too hot or too cold so that it can be handled as early as possible (Bajko et al., 2018). Biomass decomposition consists of two stages of biochemical transformation, namely mineralization and formation of humus. During mineralization, organic substances that are easily fermented, such as carbohydrates (sugars) and amino acids, are degraded by the metabolic activities of microorganisms, producing heat, carbon dioxide, and water (Vigneswaran et al., 2016). The decomposition process will decrease when the bacterial food source is reduced, which is indicated by a decrease in the temperature of the material. Figure 3 portrays temperature development during the composting process for different floor types. It can be observed that the decomposition process of the material began to occur on the 15th day, which was marked by a considerable increase in temperature up to thermophilic conditions for all treatments.

The temperature increased from the initial of 34 °C to different maximum values, namely 52, 48, 54, and 52 °C, respectively, for the cemented floor, ground floor, tarpaulin-layered floor, and husk-layered floor. The low-temperature increase of pile on the soil floor may be related to the higher heat loss as compared to the other floors. The temperature increase causes the decomposing microorganisms to work properly so that the decomposition process can occur quickly. The effective temperature for the composting process ranges from 30-45 °C (Diaz and Savage, 2007). The difference in temperature rise that can be achieved shows the difference in the level of decomposition that occurs in each type of composting floor. The high-temperature rise on the tarpaulin-layered floor and the cemented floor showed a more active decomposition than on the ground floor or rice husk-layered floor. After reaching the highest temperature, the compost temperature will begin to decrease. The temperature of the compost piles was in thermophilic condition for about 2 weeks and then followed by a gradual decrease in temperature to around 35 °C, which signaled the need for returning the pile over.

Figure 3 shows that every time the compost pile was turned over (indicated by the vertical dash line), the temperature raised and was followed by a gradual decrease. This happens because turning adds oxygen which is needed not only to decompose organic material by bacteria but also important to expedite the composting process (Alkoaik, 2019). However, the rise in temperature after turning tended to be lower with increasing composting age. For example, after turning on day 40, the compost pile temperature rose to 40-42 °C. But, after turning on the 100th day, only piles on the cemented floor rose to 38 °C, while other piles were practically stopped. The decrease in temperature indicates that the compost is entering the maturity phase. When harvested on day 145, all compost piles had the same temperature, 30 °C. From Figure 4 can be observed that the composts from all treatments were stable after 105 days, except for the tarpaulin-layered floor, which retarded to 130 days. Based on the temperature development of the compost pile (Figure 3), it can be seen that the decomposition process is initially slow, regardless of the floor types. During the first 12 days, the temperature of the compost heap did not substantially increase. For a comparison, Wang and Schuchardt (2010) reported composting of yard waste that reached maximum temperature after three to four days of composting with an initial C/N ratio variation of 29:1 to 60:1. Some characteristics of compost materials that can inhibit the composting process include the inappropriate initial C/N ratio, bulk density, and particle size. The initial C/N ratio is one of the factors that determine the success of the composting process. A good initial C/N ratio for composting is between 25-30 (Diaz and Savage, 2007). In general, the lower the C/N ratio will result in a higher maximum temperature, and the compost pile will be in a thermophilic condition longer. A high initial C/N ratio value will trigger a slow decomposition process, so composting will take longer (El-mrini et al., 2022). In this work, with an initial C/N ratio of 32.6, it should be a little or no problem for composting the yard and garden waste because, in the range of a C/N ratio of 25:1 to 40:1, it can still take place efficiently (Cromell, 2010). This is also confirmed by the research of Parzych (2022) where leaves substrates with C/N ratio between 20 and 34 degraded rapidly, while the leaves with C/N ratio of 58 to 65 decomposed more slowly.

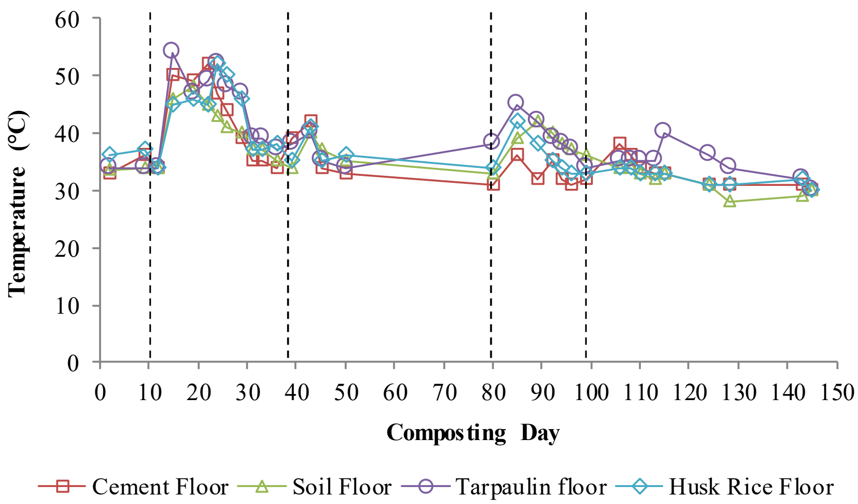


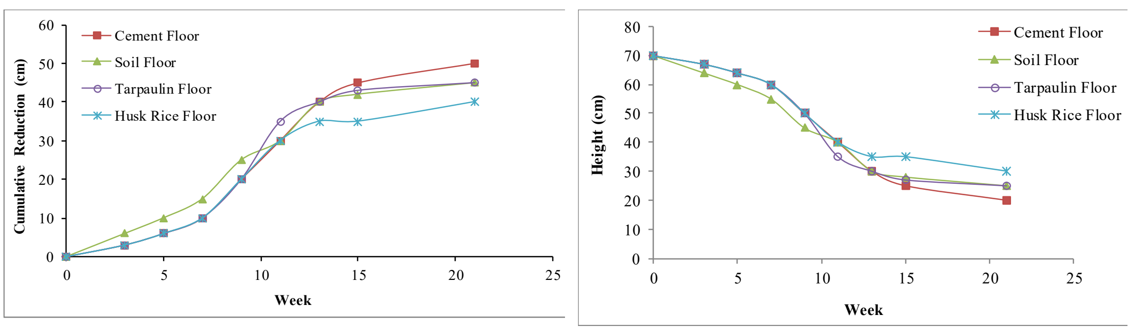
Figure 3. Compost temperature change (vertical dash line indicates turning time).

Another factor that can hinder the composting process is the bulk density of the compost materials. Bulk density affects the porosity of the compost pile, which in turn determines the availability of oxygen needed by bacteria to break down organic matter. In this study, the compost material had a very low bulk density of 53.6 kg/m^3. The ideal composting process requires a bulk density of at least 350 kg/m^3 (Chang et al., 2019). Compost material can be mixed, among other things, with fertile soil or animal manure to increase the bulk density. The bulk density of materials is closely related to particle size, which is also an important factor in composting. In this study, the leaf substrate was not shredded first, so it still had a large particle size. It is worth noting that leaf wastes are quite bulky that must be ground to reduce particle size, increase surface area, and promote microbial activity to expedite the composting process. Fundamentally, the smaller the particle size, the more efficient the decomposition process, so the faster the composting process. For composting using the static pile method, the material has to be ground to a particle size of 3.5-5 cm (Diaz et al., 2007). The particle size must be even finer (10-20 mm) for stronger materials such as date-palm wastes (Mortazavi et al., 2012). Unshredded leaves with a characteristic of large particle size combined with very low bulk density may be the main reason for the slow initial degradation of the leaves in this study. Compost material can be mixed with fertile soil or animal manure to increase bulk density.

Materials losses

The composting process will result in physical, chemical, and biological changes in the compost material. The decomposition of organic matter is followed by the evaporation of C and N. Therefore, one of the physical changes that are easily observed during composting is the reduction of compost material. In this case, composting age affects the characteristics and changes of compost, especially in terms of quantity (Al-Bataina et al., 2016). Decreasing materials indicates that thermophilic bacteria work to decompose compost material. The longer the composting process, the lower the pile height. Figure

4a shows the decrease in the height or volume of compost material during the composting process. The cumulative progression of pile reduction is presented in Figure 4b. Initially, the compost piles have the same height for all floor types of the composting boxes, which is 70 cm. Changes in compost pile height indicate that the material decomposition process occurs which is performed by the microbiological activity of bacteria and fungi in the compost. The type of composting floor did not result in a substantial difference in the decrease in the volume of the compost material. The progress of the volume reduction of compost material shows a sigmoid curve with a rapid phase occurring from week 7 to week 12. This curve shows a slow decomposition process until week 7 and after week 12. Faster decomposition occurs between weeks 7-12. This is related to the growth behavior of living organisms which begins with a slow growth phase (lag phase), followed by rapid growth (log phase), and then ends with a declining growth (stationary phase) (Liu, 2017). Figure 4b shows that the height accumulation of pile reduction was in order (from the highest to the lowest) of the cemented floor, ground floor, tarpaulin-layered floor, and husk-layered floor with, respectively, 71.43, 64.29, 64.29, and 57.14%. The volume reduction in this study was significantly greater than that reported by Breitenbeck and Schellinger (2004), where the average volume reduction for the five substrate compositions was only 40.7% of the initial volume. However, these results are comparable to those reported by (Michel et al., 2004), where volume loss was 74% (range 65-86%) for composting dairy manure mixed with wheat straw. The high volume of reduction in this study was caused by the very bulky starting materials characterized by relatively large particle sizes and very low density. The decrease in compost volume was also followed by the decrease in compost mass. Figure 5 shows the final volume reduction of compost accompanied by a reduction in mass and yield of compost. After composting for 145 days, the compost yield in order from the highest was 35.2% for the cemented floor, followed by 32.5% (soil floor), 27.8% (rice husk floor), and 27.7% (tarpaulin floor).



(a) (b)

Figure 4. (a) development of height of compost piles, and (b) accumulation of height reduction for 21 weeks.

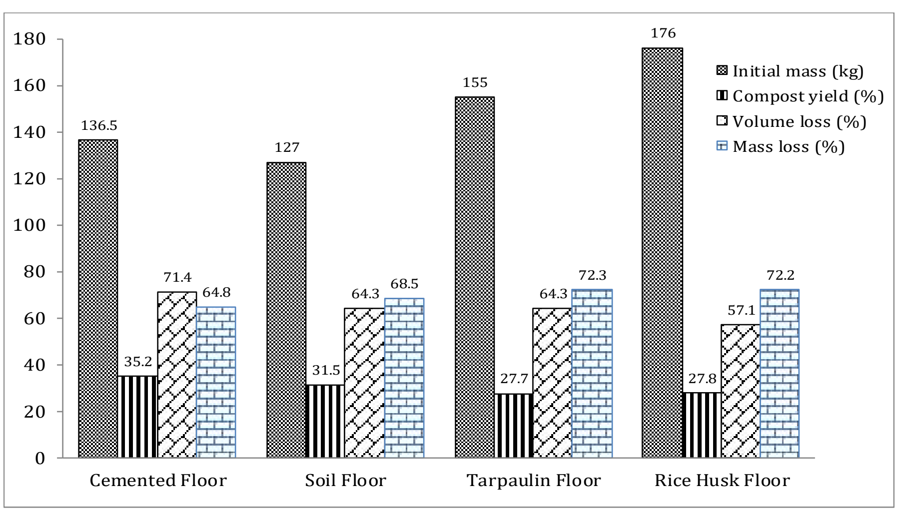


Figure 5. Initial mass (kg), compost yield (kg), volume loss (%), and mass loss (%) at 145 days of composting time.

The percentage of compost yield was in a narrow range (from 27.7 to 35.2%) which indicates that the type of floor had little effect on the compost yield. However, the results showed a very large loss of compost mass, reaching between 64.8% and 72.3% (an average of 69.4%). These results are comparable to those reported by Ajmal et al. (2020) on the in-vessel composting at a thermophilic temperature of 65 ^{o}C with a mixed substrate of poultry, vegetable waste, and rice straw at a ratio of 5.5:3.5:1 where the mass loss reached 78% of the initial mass. Michel et al. (2004) also reported large mass losses of up to 83% for composting dairy manure mixed with sawdust (24%, wet basis) or with wheat straw (31%). The main reasons for this large mass loss are likely due to water loss in the form of evaporation (especially during turning) and C and N loss through gas emissions. A similar reason was given by Tiquia et al. (2002) for composting with a windrow system exposed to the outside environment.

Compost characteristics

Compost characteristics can be observed by determining the quality of the compost, which consists of moisture content, temperature, color, odor, C/N ratio, and N-P-K content. Compost characteristics are presented in Table 1. The final temperature on each floor was 30 °C. This means that the compost quality fulfilled the criteria of these standards with a final temperature close to the water temperature ranging from 25-32 °C. The resulting compost water content in each treatment was different. The highest water content was found in the treatment of rice husk floors with a value of 62%, while the lowest water content was in the cement floor treatment with a value of 35%.

Table 1. Compost characteristics resulted from various floor treatments.

Parameters	SNI 19-7030-2004	Cemented Floor	Soil Floor	Tarpaulin Floor	Rice Husk Floor
Water Content (%)	50 (max)	35	56	42	62
Bulk density (kg/L)	-	0.061	0.040	0.043	0.041
Temperature (°C)	25-32	30	30	30	30
Smell*	soil odor	++	++	++	+
pH	6.8-7.49	7.4	7.3	7.5	7.1
Carbon (%)	9.8-32%	9.76	11.24	15.01	22.48
Nitrogen (%)	0.4 (min)	0.669	0.801	0.852	1.31
Potassium (K_2O) (%)	0.2 (min)	0.768	1.4	0.593	0.432
Phosphorus (P_2O_5) (%)	0.1 (min)	0.12	0.10	0.21	0.21
C/N ratio	10-20	14.6	14	17.6	17.2

*Description: + soil odor; ++ very soil odor.

Based on the regulations in the Indonesian National Standard regarding the specification of compost from domestic materials, the maximum moisture content allowed in compost is 50% (BSN, 2004). From the data obtained, the maximum water content exceeds the SNI standard water content data; this is due to high rainfall on the last day of observation. The high water content of the compost can be decreased by drying. From the odor parameter, compost that has an odor close to the soil is the treatment on cement floors, soil, and tarpaulins which are shown with a double plus (++) sign. The pH value of compost resulted using cement floors, soil, tarpaulin, and rice husks ranges from 7.1 to 7.5, which means that it is in accordance with the provisions of the Indonesian National Standard SNI 19-7030-2004 (BSN, 2004). The pH value is influenced by the presence of N in the compost materials. The highest N content was produced in compost with rice husk floor treatment. The decomposition of organic matter affects the N levels in organic matter. The highest value of potassium is produced by composting boxes with soil floor treatment. This can be due to the direct contact between the material and the soil, which causes a high value of K compared to other flooring treatments. The resulting C/N ratio fulfilled the established standards, which ranged from 10 to 20. The decrease in C/N ratio was influenced by microbial activity that decomposed leaves.

Compost color

Compost color is one of the physical parameters that is easily perceived by the eyes that can be used to determine the maturity level of compost. So far, the comparison observations between compost and soil color are observed by using the eye senses. In this study, compost color was measured using a colorimeter according to IE (Commission Internationale de l'Eclairage) method. The method has been used to determine composting process (Khan et al., 2009a) and the level of compost maturity (Wichuk and McCartney, 2010). The CIELab colorimeter is also used to evaluate compost stability (Khan et al., 2009b), organic matter content of compost (Palechor-Tróchez et al., 2018), and compost quality (Rashwan et al., 2020). The color of the compost can be visually seen in Figures 6a, 6b, 6c and 6d. As a comparison, the color of long no-till soil (6e), intensively cultivated soil (6f), and dry leaves parent (6g) are also presented. The values of L^*, a^*, and b^* are included in Figure 6. Visually, the compost produced from the four floor types had a darker color when compared to the color of the parent leaves or the color of the soil (no-till soil and intensively tillage soil). In addition, the compost produced from floors covered with tarpaulin or husks has a darker color than those produced from cemented floors or ground floors. The L^* of compost resulting from tarpaulin floor (11.7) or husk floor (12.3) is significantly lower than that of compost produced from the cemented floor (23.3) or soil floor (28.3). The parent leaf has L^* value of 29.7. According to Khan et al. (2009b), the lightness value L^* of compost has a good positive correlation with the C/N ratio and can be used as a criterion for determining the degree of maturity of compost. In general, compost material will turn darker due to the evolution of humus material produced by the decomposition of organic matter. Therefore, the value of L^* will decrease with composting time (Khan et al., 2009b). Results of this study indicated that the tarpaulin and husk-layered floors produced better compost than the other two floors. This is also reflected in the nutrient content of compost produced from tarpaulin-coated floors or husks which have higher N, P, and C/N ratio values than the compost produced on cemented floors or soil floors (Table 1).

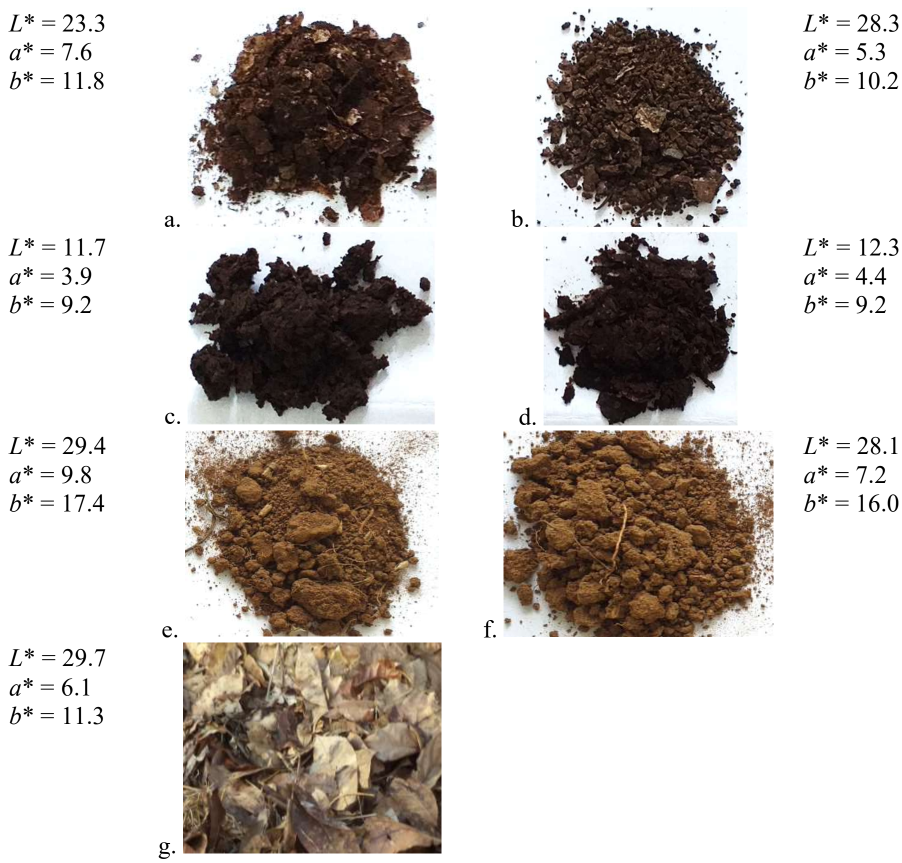


Figure 6 Compost color: (a) Cemented floor, (b) Soil floor, (c) Tarpaulin floor, (d) Rice husk floor, (e) No-till soil, (f) Intensively cultivated soil, and (g) Dry leaves before composting.

In comparison with the comparator (parent leaves, no-till soil, or intensively cultivated soil), the values of ΔL^*, Δa^*, and Δb^* were calculated and presented in Table 2. The value of ΔL^* is the difference in brightness between the compost and the color of the comparator. All floor types produced compost with a negative value of ΔL^*, meaning that the color of the resulting compost is visually darker than the comparators, and this is a good sign because good compost has a darker color (dark brown). Compost produced from cemented floors or soil floors had narrower ΔL^* values. This indicates that the color of the compost resembles the color of the soil. However, this does not mean that the compost produced from these two floors is better because the soil in Lampung is dominated by infertile podzolic soil with a yellowish-brown color. Compost produced from tarpaulin-layered or husk-layered floors had wider

ΔL^*, meaning that the compost is substantially darker than the comparators. Compost color in this work is in accordance with a study by Zahrim et al. (2016) which reported that compost darkened, implying the degree of lightness (L^*) declined during the composting process.

As shown in Table 2, all composts have negative differences in chroma color Δa^* and Δb^* when compared to the color of the parent raw material and the color of the soil. This shows that the compost has a greener and bluer chroma than the color of the raw material and the color of the soil. One exception occurs in the compost produced from cement-floored boxes which have positive Δa^* and Δb^*, which means less green and less blue when compared to the original leaf color. Palechor-Tróchez et al. (2018) concluded that chroma a^* and b^* have the potential to be used to predict carbon content in compost with a high correlation value, namely r = – 99% for a^* and r = 97% for b^*, respectively.

Table 2. Compost color difference as compared to parent leaves, no-till soil, and intensively tilled soil.

Parameters	Cemented Floor			Soil Floor			Tarpaulin Floor			Rice Husk Floor		
	D	TS	TM	D	TS	TM	D	TS	TM	D	TS	TM
ΔL^*	-6.5	-6.2	-4.8	-1.5	-1.2	0.2	-18.0	-17.7	-16.4	-17.4	-17.1	-15.8
Δa^*	1.5	-2.3	0.4	-0.8	-4.5	-1.9	-2.2	-5.9	-3.3	-1.7	-5.4	-2.8
Δb^*	0.5	-5.6	-4.2	-1.1	-7.2	-5.8	-2.1	-8.2	-6.8	-2.1	-8.2	-6.8

Description: D = Dry leaves, TS = No till soil, TM = Intensively cultivated soil.

Conclusion

Research on the evaluation of floor types (cemented floors, soil, tarpaulins, and rice husks) has been carried out in making leaves compost. Generally, the compost produced from all composting floor treatments has fulfilled the SNI 19-7030-2004 standards and is suitable for use. The results showed that compost that has been composted for 145 days resulted in a C/N ratio ranging from 14.0-17.6, which complies with national standard SNI 19-7030-2004 values between 10 and 20. The tarpaulin-layered floor or husk-layered floor produces better compost with higher N, P, and C/N ratios and darker color than those produced from cemented-floor or soil floor. This research indicates that producing compost from leaves can barely use the soil floor. But, tarpaulin or husk can be used to layer the ground to get better compost. However, some treatments for composting materials need to be performed to optimize further the decomposition process, including size reduction (chopping) and adding materials to increase bulk density and adjust the initial C/N ratio between 25:1 and 30:1.

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References

Ajmal, M., Aiping, S., Awais, M., Ullah, M.S., Saeed, R., Uddin, S., Ahmad, I., Zhou, B. and Zihao, X. 2020. Optimization of pilot-scale in-vessel composting process for various agricultural wastes on elevated temperature by using Taguchi technique and compost quality assessment. *Process Safety and Environmental Protection* 140:34-45, doi:10.1016/j.psep.2020.05.001.

Al-Bataina, B.B., Young, T.M. and Ranieri, E. 2016. Effects of compost age on the release of nutrients. *International Soil and Water Conservation Research* 4:230-236, doi:10.1016/j.iswcr.2016.07.003.

Alkoaik, F.N. 2019. Integrating aeration and rotation processes to accelerate composting of agricultural residues. *PLOS ONE* 14:e0220343, doi:10.1371/journal.pone.0220343.

Bajko, J., Fišer, J. and Jícha, M. 2018. Temperature measurement and performance assessment of the experimental composting bioreactor. *EPJ Web of Conferences* 180:02003, doi:10.1051/epjconf/201818002003.

Barus, J. 2016. Utilization of crop residues as compost and biochar for improving soil physical properties and upland rice productivity. *Journal of Degraded and Mining Lands Management* 3(4):631-637, doi:10.15243/jdmlm.2016.034.63.

Barus, J. 2017. Soil chemical properties and soybean yield due to the application of biochar and compost of plant waste. *Journal of Tropical Soils* 21:1-7, doi:10.5400/jts.2016.v21i1.1-7.

Bitew, Y. and Alemayehu, M. 2017. Impact of crop production inputs on soil health: A review. *Asian Journal of Plant Sciences* 16:109-131, doi:10.3923/ajps.2017.109.131.

Breitenbeck, G.A. and Schellinger, D. 2004. Calculating the reduction in material mass and volume during composting. *Compost Science & Utilization* 12:365-371, doi:10.1080/1065657X.2004.10702206.

BSN. 2004. SNI 19-7030-2004: Specifications of Compost from Domestic Organic Waste. National Standardization Agency, Jakarta (*in Indonesian*).

Chang, R., Guo, Q., Chen, Q., Bernal, M.P., Wang, Q. and Li, Y. 2019. Effect of initial material bulk density and easily-degraded organic matter content on temperature changes during composting of cucumber stalk. *Journal of Environmental Sciences* 80:306-315, doi:10.1016/j.jes.2017.10.004.

Choudhary, R.C., Bairwa, H.L., Kumar, U., Javed, T., Asad, M., Lal, K., Mahawer, L.N., Sharma, S.K., Singh, P., Hassan, M.M., Abo-Shosha, A.A., Rajagopal, R. and

Abdelsalam, N.R. 2022. Influence of organic manures on soil nutrient content, microbial population, yield and quality parameters of pomegranate (*Punica granatum* L.) cv. Bhagwa. *PLOS ONE* 17:e0266675, doi:10.1371/journal.pone.0266675.

Cromell, C. 2010. *Composting for Dummies*. Wiley, Hoboken, NJ.

D'Hose, T., Cougnon, M., De Vliegher, A., Willekens, K., Van Bockstaele, E. and Reheul, D. 2012. Farm compost application: Effects on crop performance. *Compost Science & Utilization* 20:49-56, doi:10.1080/1065657X.2012.10737022.

Dermiyati, Lumbanraja, J., Banuwa, I.S., Triyono, S., Maulida, O. and Agsari, D. 2016. Application of organonitrofos and inorganic fertiliser on cassava (*Manihot esculenta* Crantz) in Ultisol soil. *Journal of Tropical Soils* 20:167-172.

Diaz, L.F. and Savage, G.M. 2007. Factors that affect the process. In: Diaz, L.F., de Bertoldi, M., Bidlingmaier, W. and Stentiford, E. (eds.), *Compost Science and Technology*, Elsevier, pp. 49-65, doi:10.1016/S1478-7482(07)80007-8.

Diaz, L.F., Savage, G.M., Eggerth, L.L. and Chiumenti, A. 2007. Systems used in composting. In: Diaz, L.F., de Bertoldi, M., Bidlingmaier, W. and Stentiford, E. (eds.), *Compost Science and Technology*, Elsevier, pp. 67-87, doi:10.1016/S1478-7482(07)80008-X.

El-mrini, S., Aboutayeb, R. and Zouhri, A. 2022. Effect of initial C/N ratio and turning frequency on quality of final compost of turkey manure and olive pomace. *Journal of Engineering and Applied Science* 69:37, doi:10.1186/s44147-022-00092-6.

Ge, S., Zhu, Z., Jiang, Y., Ge, S., Zhu, Z. and Jiang, Y. 2018. Long-term impact of fertilization on soil pH and fertility in an apple production system. *Journal of Soil Science and Plant Nutrition* 18:282-293, doi:10.4067/S0718-95162018005001002.

Heyman, H., Bassuk, N., Bonhotal, J. and Walter, T. 2019. Compost quality recommendations for remediating urban soils. *International Journal of Environmental Research and Public Health* 16:3191, doi:10.3390/ijerph16173191.

Huang, G.F., Wu, Q.T., Wong, J.W.C. and Nagar, B.B. 2006. Transformation of organic matter during co-composting of pig manure with sawdust. *Bioresource Technology* 97:1834-1842, doi:10.1016/j.biortech.2005.08.024.

Khan, M.A.I., Ueno, K., Horimoto, S., Komai, F., Tanaka, K. and Ono, Y. 2009a. Physicochemical, including spectroscopic, and biological analyses during composting of green tea waste and rice bran. *Biology and Fertility of Soils* 45:305-313, doi:10.1007/s00374-008-0335-x.

Khan, M.A.I., Ueno, K., Horimoto, S., Komai, F., Someya, T., Inoue, K., Tanaka, K. and Ono, Y. 2009b. CIELAB color variables as indicators of compost stability. *Waste Management* 29:2969-2975; doi:10.1016/j.wasman.2009.06.021.

Liu, E., Yan, C., Mei, X., He, W., Bing, S.H., Ding, L., Liu, Q., Liu, S. and Fan, T. 2010. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma* 158:173-180, doi:10.1016/j.geoderma.2010.04.029.

Liu, S. 2017. Chapter 11 - How Cells Grow. In: Liu, S. (Ed.), *Bioprocess Engineering (Second Edition),* Elsevier, pp. 629-697, doi:10.1016/B978-0-444-63783-3.00011-3

Matsuyama, N., Saigusa, M., Sakaiya, E., Tamakawa, K., Oyamada, Z. and Kudo, K. 2005. Acidification and soil productivity of allophanic Andosols affected by heavy application of fertilizers. *Soil Science and Plant Nutrition* 51:117-123, doi:10.1111/j.1747-0765.2005.tb00014.x.

Michel, F.C., Pecchia, J.A., Rigot, J. and Keener, H.M. 2004. Mass and nutrient losses during the composting of dairy manure amended with sawdust or straw. *Compost Science & Utilization* 12:323-334, doi:10.1080/1065657X.2004.10702201.

Misra, R.V., Roy, R.N. and Hiraoka, H. 2003. On-Farm Composting Methods. Food and Agriculture Organization, Rome.

Mortazavi, M., Ghehsareh, A.M. and Kalbasi, M. 2012. The effect of particle size and composting period on (C/N) ratio of date-palm waste. *The 1st International and The 4th National Congress on Recycling of Organic Waste in Agriculture*, Isfahan, Iran, 26-27 April 2012.

Naohiro, M., Koji, N., Chisambi, C. and Moyo, M. 2016. Improvement of maize yield and soil fertility by 2-years compost application in Malawi's northern districts. *African Journal of Agricultural Research* 11:2708-2719, doi:10.5897/AJAR2016.10884.

Nason, M.A., Healey, J., Tandy, S., Christou, M., Jones, D. and Healey, J. 2007. Using Organic Wastes and Composts to Remediate and Restore Land: Best Practice Manual. School of the Environment and Natural Resources, Bangor University, Bangor, Wales.

Ning, C., Gao, P., Wang, B., Lin, W., Jiang, N. and Cai, K. 2017. Impacts of chemical fertilizer reduction and organic amendments supplementation on soil nutrient, enzyme activity and heavy metal content. *Journal of Integrative Agriculture* 16:1819-1831, doi:10.1016/S2095-3119(16)61476-4.

Palechor-Tróchez, J.J., Ordoñez Santos, L.E. and Villada-Castillo, H.S. 2018. Relationship between color CIE L*a*b* and total organic carbon in compost. *Advances in Materials Science and Engineering* 2018:1-6, doi:10.1155/2018/5474239.

Paradelo, R. 2013. Use of compost for the restoration of mine wastes and mine soils. *Boletin Geologico y Minero* 124:405-419, doi:10.12911/22998993/146327.

Parzych, A. 2022. Urban leaf litters as a potential compost component. *Journal of Ecological Engineering* 23:250-260.

Rashwan, M., Alkoaik, F., Abdel-Razzak, H., Ibrahim, M., Fulleros, R., Shady, M. and Abdel-Ghany, A. 2020. Evaluation of tomato waste compost stability and maturity using CIELAB color indicator. *Journal of Plant Nutrition* 43:1427-1437, doi:10.1080/01904167.2020.1739301.

Rastogi, M., Nandal, M. and Khosla, B. 2020. Microbes as vital additives for solid waste composting. *Heliyon* 6:e03343, doi:10.1016/j.heliyon.2020.e03343.

Savci, S. 2012. Investigation of effect of chemical fertilizers on environment. *APCBEE Procedia* 1:287-292, doi:10.1016/j.apcbee.2012.03.047.

Stentiford, E.I. 2007. Composting control: Principles and practice. In: Diaz, L.F., De Bertoldi, M. and Bidlingmaier, W. (eds.), *Compost Science and Technology*, Elsevier, Amsterdam, pp. 49-59, doi:10.1007/978-94-009-1569-5_6.

Tiquia, S.M., Richard, T.L. and Honeyman, M.S. 2002. Carbon, nutrient, and mass loss during composting.

Nutrient Cycling in Agroecosystems 62:15-24, doi:10.1023/A:1015137922816.

Vigneswaran, S., Kandasamy, J. and Johir, M.A.H. 2016. Sustainable operation of composting in solid waste management. *Procedia Environmental Sciences* 35:408-415, doi:10.1016/j.proenv.2016.07.022.

Wang, Y.Q. and Schuchardt, F. 2010. Effect of C/N ratio on the composting of vineyard pruning residues. *Landbauforschung Volkenrode (Agriculture and Forestry Research)* 60:131-138.

Wichuk, K.M. and McCartney, D. 2010. Compost stability and maturity evaluation-a literature review. *Canadian Journal of Civil Engineering* 37:1505-1523, doi:10.1139/L10-101.

Wrolstad, R.E. and Smith, D.E. 2017. Color Analysis. In: Nielsen, S.S. (ed.), *Food Analysis*, Springer International Publishing, Cham, Food Science Text Series. pp. 545-555, doi:10.1007/978-3-319-45776-5_31.

Ye, L., Zhao, X., Bao, E., Li, J., Zou, Z. and Cao, K. 2020. Bio-organic fertilizer with reduced rates of chemical fertilization improves soil fertility and enhances tomato yield and quality. *Scientific Reports* 10:177, doi:10.1038/s41598-019-56954-2.

Zahra, M.B., Fayyaz, B., Aftab, Z.E.H. and Haider, M.S. 2021. Mitigation of degraded soils by using biochar and compost: A systematic review. *Journal of Soil Science and Plant Nutrition* 21:2718-2738, doi:10.1007/s42729-021-00558-1.

Zahrim, A.Y., Leong, P.S., Ayisah, S.R., Janaun, J., Chong, K.P., Cooke, F.M. and Haywood, S.K. 2016. Composting paper and grass clippings with anaerobically treated palm oil mill effluent. *International Journal of Recycling of Organic Waste in Agriculture* 5:221-230, doi:10.1007/s40093-016-0131-9.