Compost Bed Size Influences the Co-Composting of Cow Dung and Spent Mushroom at Mesophilic Stage

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Abstract. Composting is an approach to convert typically organic waste into soil amendment for nutrient enhancement and plant growth. The composting of cow dung and spent mushroom for 13 days to study the potential of degradation of organic matter at different size of laboratory scale. The compost bed size is crucial to study because larger amount of raw materials will reduce the O2 concentration inside the compost bed. In this study, the aerobic compost bed size of 2, 4 and 6 kg were prepared at 60% of initial moisture content, 20 mm particle size and 28:1 of initial C/N ratio. Temperature, moisture content, porosity, pH, C/N ratio and total organic carbon were analysed to evaluate the degradation process. All compost beds recorded the mesophilic phase (>30 ℃) upon composting of initial total organic carbon of 35 to 37%. Moisture content reduced to lower than 43.9%, total organic carbon reduced to less than 25% and compost beds were nearly neutral (pH 7) at the end of composting. The findings show that, all the compost beds follow the first-order kinetic reaction as R² larger than 0.880. The degradation rate constant of 2 kg compost bed showed the largest value, 0.0503 day⁻¹ indicates the best composting process and results the smaller compost bed is preferable for mesophilic phase composting.

1. Introduction
Mushroom medium is readily in bagged and the formulation is consisted of a combination of sawdust, agricultural lime, rice bran and optimum water [1]. After the mushrooms have been harvested for several cycles, the spent mushroom medium (SMM) is necessary to dispose and well managed for sustain the environment quality and better utilization. The conventional disposal management of SMM includes burn and deposit in landfills [2] would lead to environment pollutions; soil contamination and ground water infection. The spent mushroom medium is a by-product contains unstable organic matters and composting is the most feasible method of disposal for the converting into stable and mature compost. Utilization of SMM together with other organic raw materials as a compost is valuable for soil improvement and plant growth.

Some criteria and parameters are controlled, measured and manipulated to analyze the stability of the SMM compost. The physical parameters such as pH, moisture content, temperature, compost bed size and particle size are considered to describe the composting process. In this study, the effect of compost bed size is highlighted by manipulated to 2, 4 and 6 kg. Compost bed size is a crucial physical property as it may affects to other co-operative parameters such as density, porosity, water holding capacity and O2 concentration inside the compost bed [3]. By knowing a suitable compost bed size (and composter), the degradation of organic matter is more efficient. The suitable compost bed size for composting is important to formulate the efficient guideline for researchers that valid to the similar composting waste.

Organic wastes rich in easily biodegradable nitrogen (N) and carbon (C) compounds leads to the formation, accumulation and vaporization through carbon loss and ammonia volatilization. Thus, the
initial C/N ratio for all the composting bed is to be fixed to the optimum condition so that both carbon loss and ammonia volatilization are abridged equally to end of the composting process [4]. The theoretical ratio is 25:1, based on the needed of microbial cellular process [5]. This is the recommended ratio is use to maintain the carbon for energy and nitrogen for protein production. Excess carbon contributes to slow down of decomposition process, while excess nitrogen contributes to the bad odour [4]. The composting process requires four elements; organic material, O₂, moisture and microorganisms. The organic raw material contains macro and micro nutrients which are very essentials for providing a good mineral for plants.

2. Methodology

2.1 Preparation of Raw Materials
Dried cow dung was collected from Veterinar Institute Center, Batu 20, Padang Besar. Spent mushroom medium was collected from the mushroom project developed by staff in Faculty of Chemical Engineering Technology, UniCITI Padang Besar. Tempeh and jagger sugar were obtained from the wet market area Padang Besar, Perlis. The chemical characteristic of dried cow dung and spent mushroom medium are listed in Table 1.

2.2. Preparation of Effective Microorganisms
The microbial inoculant was prepared by 100 g of tempeh were added with 200 g jagger sugar and 3 L distilled water and ferment in the airtight containers for a duration of 7 d. Fermentation process is carried out until a sweet and sour smell with white mold produced on top of the fermented liquid [6]. The tempeh fermented liquid was readily for inoculates with the compost bed.

2.3. Preparation of Compost Bed
Three aerobic compost beds at different size (2, 4 and 6 kg) of dried cow dung and SMM were prepared at 60 % of initial moisture content, 20 mm particle size and 28:1 of initial C/N ratio. The initial total organic carbon of all compost beds was between 35 and 37 %.

2.4. Composting Parameter and Kinetic Modelling
Composting process was carried out for a total of 13 d, with different composting bed size (2, 4, and 6 kg). Temperature of compost beds were measured every day, while pH, organic matter and moisture content of compost beds were measured every 2 d. Each of the data taken was triplicated to increase the accuracy of the result. The composting process follows to the first order kinetic model thus the graph of OM against t was plotted. Decrement of OM exponentially along the composting process indicates that composting process is well fitted to the first order kinetic model [7]. In order to determine the rate of reaction, graph of \( ln\left(\frac{OM}{OM_0}\right)\) against \(t\) (d) was plotted. The slope of the straight line was calculated to determine the \(k\) value. The value of correlation coefficient, \(R^2 > 0.6\) obtained verifies the process to follow to the first order kinetic model [8].

3. Results and Discussion
3.1 Temperature Profile
Temperature plays important role in affecting the composting process. Figure 1 shows the temperature changes during composting period for three different compost bed. The experiment focus on the degradation of the pile at mesophilic phase. For 6 kg compost bed, it reached mesophilic phase earlier compared to 4 kg and 2 kg compost bed. The highest temperature recorded for 6 kg compost bed is 34.0 °C in day 1. The 6 kg of compost bed managed to achieve highest temperature because the heat is more retained in a larger compost bed [9] during the degradation of organic matter by microorganism. Higher temperature also indicates higher microbial activity occurred during the composting process [10].

![Figure 1. Changes in temperature of different compost bed size](image)

The temperature profile for all the compost beds is shown a similar trend. However, the 6 kg compost bed recorded the highest mesophilic temperature at day 1 (>34 °C), while for 2 and 4 kg compost bed, were recorded about 30 °C. The composting process of spent mushroom medium with tempeh fermented liquid was not reach thermophilic phase and shows that the mesophilic phase encountered for the whole composting process. Although the temperature of all composting beds fluctuated due to agitation at day 4 and 8, but after day 10 composting, the temperature reached steady state condition. No more heat gained meaning less microbial activity are occurred due to lack of organic matter [11] (most are being degraded) and indicates the compost bed nearly reached the stable phase.

### 3.2. Moisture Content

Moisture in compost bed avoids dehydration of organic matter. Excessive amount of water accumulated can cause anaerobic conditions that leads to release of high amount of carbon dioxide gas. Figure 2 shows that the initial moisture of compost bed of 2, 4 and 6 kg is 60.02 %, 60.15 % and 59.84 %, respectively. However, if the values greater than 60 %, it generates bad odours and release of greenhouse gases. The recommended that it is important to provide an adequate moisture content between 40 % and 60 % in composting for favourable microbial development. Another research reported that composting quality might be suitable even at high moisture content of 77 % due to its original condition which contained high volume of water [12].
Figure 2. Moisture content changes of different compost bed

Moisture content is linked to the temperature profile of the compost bed. Higher temperature reached during the composting shows higher amount of water vapour released from the compost bed [13]. Comparing the temperature profile of all the compost beds (2, 4 and 6 kg), the compost bed of 6 kg showed the highest temperature through out the composting process. Although the initial moisture content of all the compost beds were same (about 60 %), at the end of the composting process compost bed of 6 kg (37.5 %) showed the lowest moisture content compare to 4 kg (39 %) and 2 kg (49 %).

3.3. Degradation of Total Organic Carbon

In Figure 3, the changes of the degradation of TOC during composting are recorded and showed similar trend for all the compost bed. The initial of TOC were slightly similar due to same raw materials (dried cow dung and spent mushroom medium) chosen for all the compost beds. At day 1 of composting, a significant reduction of TOC was observed. The greater consumption of organic carbon is achieved during the mesophilic phase of the process where there is an intense microbial activity because of readily available organic compounds [14].

Figure 3. TOC changes of different compost bed size

More than 30 % of TOC reduction recorded from the composting of 2, 4 and 6 kg compost bed. The compost bed of 2 kg resulted the highest degradation of TOC which is 42 %, followed by 4 kg (35 %) and 6 kg (31 %). Although 2 kg compost bed showed the lowest mesophilic temperature, the degradation of organic matter contained TOC showed the highest reduction. From the results, it shows that, during mesophilic composting, temperature does not significantly affect the degradation of TOC. However, the
compost bed size does show the significant affect to the composting process. Smaller compost bed size feasible to degrade organic matter even in lower composting temperature (mesophilic temperature).

3.4. Kinetic Modelling

In Figure 4 and Table 2, the graph shows only the successive stages of first-order rate constant for compost bed size 2 kg, 4 kg and 6 kg. For the first-order model, after variable substitution and equation to obtain experimental data for $\ln \left( \frac{TOC}{TOC_0} \right)$ changes over time, the maximum rate constant $k$ was determined. In the first-order model, the horizontal and vertical axis represent composting time (day) and $\ln(\frac{TOC}{TOC_0})$, respectively. Therefore, the slope of the equation expresses the rate constant $k$.

Finally, knowing $k$, the mathematical formula of the first-order model was obtained.

![Figure 4. Degradation constant of different compost bed size](image)

After determination of the TOC rate constant $k$, the highest degradation of compost over time was analysed in Figure 4. Generally, determining the rate constant $k$ for each of the compost bed was successful, but the best fitted results have been found in the compost 2 kg. Compost bed of 2 kg has the highest $k$ value which is 0.0503 compared to compost bed 4 kg and 6 kg which is 0.0204 and 0.0334 respectively. The correlation coefficient ($R^2$) has been used widely to evaluate mathematical models obtained by experimental data. All the correlation coefficient was calculated through Microsoft Excel.

|                | 2 kg | 4 kg | 6 kg |
|----------------|------|------|------|
| $k_{max}$ (day$^{-1}$) | 0.0503 | 0.0204 | 0.0334 |
| $R^2$            | 0.9582 | 0.8759 | 0.8991 |

4. Conclusion

For conclusion, by considering the calculated correlation coefficients of all compost bed size, it was found that compost bed size 2 kg has better dynamic of the composting process which is 0.9582 to fit the first order kinetic model. This value also proves that ($R^2$>0.6) is acceptable for the fitting curve of the first order kinetic modelling analysis. The 2 kg compost bed also showed the highest degradation rate constant ($k_{max}$), 0.0503 that indicates the best compost bed size to compost the dried cow dung and spent mushroom medium with fermented tempeh liquid at stated composting condition.
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