Performance Evaluation of Composter Bins for Food Waste at the Universiti Kebangsaan Malaysia

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Abstract: Food waste generated from cafeterias in Universiti Kebangsaan Malaysia (UKM) was evaluated using composter bin system. The aim of the study was to determine if all of the cafeteria food waste in UKM could be composted using this system. The mixes of food waste and saw dust was evaluated in composition ratio of 0.5 kg of sawdust to 10 kg of food waste. Three composter bins were used, namely Bin 1, Bin 2 and Bin 3. Bin 1 consisted of uncooked waste, Bin 2 of uncooked waste and effective microorganism and Bin 3 of cooked waste and effective microorganism. Temperature, moisture content, pH value, Carbon to Nitrogen (C:N) ratio, Phosphorus (P) and Potassium (K) were monitored during the composting process. The moisture content dropped from the initial range of 87.38% to 51.15% with a final temperature varies between 32.3°C and 34.5°C. After 12 weeks, the C:N ratio dropped from 14 to 12 for Bin 1, 14 to 9 for Bin 2 and 8 to 6 for Bin 3 with the pH values ranging from 7-8. The concentrations of nutrients were within the standard limit.

Key words: Food waste, composter bin, composting, effective microorganism

INTRODUCTION

Food waste accounts for 43.16 % (Tiew et al. 2009) of the total solid waste generated in Universiti Kebangsaan Malaysia (UKM). Therefore, an effective system is required for the treatment of the food waste from all cafeterias in the campus. Food waste is suitable for biological treatment such as composting method, as this will help to reduce the volume of waste and also stabilize it (Huang et al. 2000).

Composting is considered as a biological transformation process in which municipal solid waste (MSW) is converted into a product, compost, which can be beneficially used as fertiliser or as a soil conditioner (Tchobanoglous et al. 1993). For composting to be accepted as a viable alternative to landfilling and to other methods of MSW treatment such as incineration, effective separation of the organic fraction needs to be achieved. It is possible to practice the separation of the degradable material at the source of generation, i.e., the individual cafeteria in UKM campus. Moreover, early separation of the waste flows and their decentralised recycling could contribute to reduce the waste quantities to be transported by the contractor and to free capacities which can be used elsewhere (Zurbrugg et al. 2004).

Food waste is defined as all food produced or purchased that is discarded by humans (Gallo 1980). Food waste occurs during the food system stages of production, processing, distribution, acquisition, preparation, and consumption (Sobal 1999, 2004). A 2006 study carried out by Japan International Corporation Agency shows that 45% of Malaysian MSW consists of food waste. Food waste consists of uneaten portion of meals, leftover and trimmings from food preparation from restaurants, kitchens and cafeterias (Chua et al. 2008). For this case study, composting using the composter bin method was used to compost the food waste. The effective microorganism (EM) was added to treat the food waste. EM consists of mixed cultures of beneficial and naturally occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plants (Higa and Parr 1994). EM can enhance decomposition of organic matter (Sekeran et al. 2007).

The main factors in the control of composting include: (i) environmental parameters (temperature, moisture content, pH, aeration) and (ii) substrate nature parameters (C/N ratio, particle size and nutrient content). Among environmental parameters, temperature is a key factor in composting, which has frequently been used to judge
the efficiency and degree of stabilisation of the treatment process (Jeris and Regan, 1973; Diaz et al. 2003).
Moisture is an important factor to be controlled during composting as it influences the structural and thermal properties of the material, as well as the rate of biodegradation and metabolic process of the microbes (Young et al 2005).

Carbon, nitrogen, phosphorus and potassium are the primary nutrients required by microorganisms involved in composting, as well as the primary nutrients for plants, influencing the value of compost (Dick and McCoy 1993; Wilkinson et al 2005). Almost all organic materials used for composting contain all of these nutrients at various levels which microorganisms use for energy and growth. An insufficient or excessive supply of nutrients may result in low quality compost (Sandra and Tirado 2008).

For this study, three composter bins were used, whereby Bin 1 and Bin 2 were dedicated for uncooked waste (consisting of fruits and vegetables waste), while Bin 3 was dedicated for cooked waste (leftover meal). The effective microorganism was added in Bin 2 and Bin 3. The rationale of using three bins is to evaluate the performance of composter bins in composting the uncooked waste and cooked waste in UKM, and to evaluate the effectiveness of adding the effective microorganism towards uncooked and cooked waste.

**MATERIALS AND METHODS**

**Composter bin:**
A composter bin with 325 liter capacity was used. The dimension of the bin is 735 x 735 x 820 mm and it is made up of an ultra violet stabilized polypropylene material. The bin cover is half-side lid with two adjacent opening at sides of bin to take out compost. The bottom of the bin was designed to be uncovered to drain off excess water to the ground. Figure 1 shows the composter bin.

![Composter bin](image)

**Fig. 1:** Composter bin

**Feedstock:**
Food waste was collected from four residential college cafeteria at UKM campus, namely Dato’ Onn College Cafeteria, Rahim Kajai College Cafeteria, Keris Mas College Cafeteria and Ibu Zain College Cafeteria, and brought to the compost site located at Dato’ Onn College. Daily collections of food waste from four cafes were variable. The quantity of food waste collected from four college cafeterias are shown in Table 1. The food waste was first separated from inorganic waste, grinded using a food processor and then weighed and loaded into the three composter bins. All the three bins were filled up with food wastes up to half of the bin which took about 4 weeks, and further monitoring up to 12 weeks. During the study, only food waste (consisting of fruit, vegetables and leftover food), sawdust, and soil were being used. The EM was used to enhance the process. A solution for EM was prepared by mixing 1.5 liters water to 3 ml EM. The compost was prepared with four different proportions of feedstock as detailed in Table 2.
Table 1: Quantity of food waste collected in various cafeterias

<table>
<thead>
<tr>
<th>College cafeterias</th>
<th>Quantity (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dato’ Onn</td>
<td>232.2</td>
</tr>
<tr>
<td>Keris Mas</td>
<td>128.8</td>
</tr>
<tr>
<td>Ibu Zain</td>
<td>60.7*</td>
</tr>
<tr>
<td>Rahim Kajai</td>
<td>8.3*</td>
</tr>
<tr>
<td>Total</td>
<td>430.0</td>
</tr>
</tbody>
</table>

*The quantity of food waste from these two cafeterias was low due to poor cooperation from operators.

Table 2: Initial composition of compost feedstock

<table>
<thead>
<tr>
<th>Feedstock material</th>
<th>Bin 1</th>
<th>Bin 2</th>
<th>Bin 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight of mixture (kg)</td>
<td>248.03</td>
<td>201.2</td>
<td>152.27</td>
</tr>
<tr>
<td>Food waste (uncooked) (kg)</td>
<td>188.13</td>
<td>144.0</td>
<td>-</td>
</tr>
<tr>
<td>Food waste (cooked) (kg)</td>
<td>-</td>
<td>-</td>
<td>97.4</td>
</tr>
<tr>
<td>Soil (kg)</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Saw dust (kg)</td>
<td>9.4</td>
<td>7.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Dried leaves (kg)</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Process and Operation:

Prior to the composting process, the food waste was first separated from inorganic waste such as aluminium cans, plastics and polystyrene. Then the food waste was chopped and grounded to reduce the particle size ranging from 1.3 cm and 7.6 cm in order to provide better aeration and moisture control (Eng 2005). Initial input in the composter bins were dried leaves and then followed by a layer of soil. The average weight of food waste loaded in each bin was 5-12 kg at a time. For every loading of food waste, sawdust and soil were put in layers. Then the EM was sprayed over this layer. The ratio of the sawdust to food waste used was 0.5 kg of sawdust to 10 kg of food waste. The piles were turned manually using a digging fork on a daily basis and samples were taken weekly for laboratory analysis. The lid was opened for 10 minutes after the loading to provide aeration in the bins.

Sampling and Analysis:

Each sample consisted of five subsamples, taken after turning the piles. All grab samples were mixed together to achieve a representative sample (Kalamdhad et al. 2008). Measurement of the total N and the total C in compost were carried out on the dried sample by catalytic tube combustion using Thermo Finnigan EA112 Elemental Analyser. The C:N (carbon to nitrogen ratio) was calculated as the quotient of total C over total N (Iqbal et al. 2010). Fresh samples were determined by stirring the samples with distilled water at a solid-to-water ratio of 1:10 (w/v) (Rasapoor et al. 2009) for pH values and measured by using the pH electrode meter. Moisture contents were determined gravimetrically by heating to constant weight at 105 °C in an oven for 24 h (Bueno et al. 2008). Temperature was measured five times per week with a mercury thermometer 50 cm long. In order to determine the P and K, samples were digested with nitric acid and then analyzed using inductively coupled plasma mass spectrometry (ICPMS) (Stoffella and Kahn 2001). The mass of the final compost was weighed to get the reduction in weight.

RESULTS AND DISCUSSIONS

Waste characteristics such as moisture content, pH value, temperature, C: N ratio, Phosphorus and Potassium were evaluated. The composting process can reduce the weight of food waste depending on the initial feedstock. Some research has shown that the percentage of weight reduction in compost ranges between 80% to 90% (Iyengar and Bhave 2006). Table 3 shows the final characteristics of compost feedstock.

Table 3: Characteristics of final compost

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bin 1</th>
<th>Bin 2</th>
<th>Bin 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight reduction, %</td>
<td>74.05</td>
<td>81.26</td>
<td>68.66</td>
</tr>
<tr>
<td>Moisture content, %</td>
<td>51.15</td>
<td>52.16</td>
<td>52.51</td>
</tr>
<tr>
<td>pH</td>
<td>7.99</td>
<td>7.67</td>
<td>8.53</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td>30</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Total Carbon, mg/g</td>
<td>6.17</td>
<td>4.31</td>
<td>3.18</td>
</tr>
<tr>
<td>Total Nitrogen, mg/g</td>
<td>0.53</td>
<td>0.48</td>
<td>0.52</td>
</tr>
<tr>
<td>C:N</td>
<td>12.1</td>
<td>9.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Phosphorus, ppm</td>
<td>0.156</td>
<td>0.159</td>
<td>0.194</td>
</tr>
<tr>
<td>Potassium, ppm</td>
<td>0.403</td>
<td>0.425</td>
<td>0.478</td>
</tr>
</tbody>
</table>
Moisture Content:

The maximum permissible moisture content is a function of the structural strength of the particle that makes up the materials to be composted (Diaz et al. 2007). Regan et al. (1973) and Murwira et al. (1990) reported that the optimum moisture content for compost is between 50%-70%. Figure 2 shows the moisture content during the composting process, whereby the initial moisture content of the feedstock is 87.38% for uncooked waste and 74.53% for cooked waste as suggested by Thakur (2006).

Generally the moisture content for three bins decreased towards the end of the process. Initial moisture in Bin 1 and Bin 2 were slightly decreased in week 3 and 1 respectively. The initial moisture reduction for Bin 1 and Bin 2 were in a range of 34.79% - 20.58%. The reduction was due to proper mixing of food waste and sawdust. However, the moisture in Bin 1 and Bin 2 rose abruptly after week 3 and week 1 due to slow absorption of excess water from the compost mass and rain to the ground. From the physical observation, the ground was rigid. Modification has been made to ensure the stagnant water absorbed to the ground. The moisture in Bin 3 decreased 22.02% during the composting process. The moisture content for all three bins were in a range of 51.15% - 52.51%.

Temperature:

Changes in temperature are commonly used as a measure of microbiological activity underlying the composting process. Thus, the temperature profile of the composting process can be used to determine the stability of organic material (Fogarty and Tuovine 1991). Temperature observations were taken at five different locations in the composter bins; i.e. at their four corners and one at the centre by using a mercury thermometer. At the beginning of this study, after the formation of the piles, a rapid increase in temperature was observed in all piles, indicating a marked increase in microbial activity (Rasapoor et al. 2009). Variations of the compost temperature, plotted in Figure 3, shows that under the experimental conditions, the compost temperature increases rapidly to reach its maximum temperature on week 3 for Bin 1 (38.6°C) and Bin 3 (52.8°C), whereas in Bin 2, the maximum temperature of the mixture attained 37.0°C on week 2. Bin 2 reached its maximum temperature earlier due to less waste content inside the bin, allowing faster microbial activity on the pile. With decreased microbial activity, the temperature may then stabilised. During this period, the temperatures in all 3 bins were found to vary from 32.3°C to 34.5°C, indicating normal composting conditions.

Fig. 2: Moisture content of compost during composting period.

Fig. 3: Temperature pattern during composting process.
2.2 pH Value:
The pH of the composting material initially increased and then suddenly dropped during the initial weeks of composting due to the formation of organic acids, i.e., amino acids and other volatile fatty acids (Hagerty et al. 1973). It then increased and became alkaline and finally dropped back to near neutral as a result of humus formation (Poincelot 1974). During the maturation phase, the pH settled down to 7.99 for Bin 1, 7.67 for Bin 2 and 8.53 for Bin 3 (See Figure 4).

![Fig. 4: pH value during composting process](image)

**Nutrient Contents:**

**C:n Ratio:**
Nutrient balance is very much dependent on the type of feed material being processed. Carbon provides the preliminary energy source and nitrogen quantity determines the microbial population growth. Hence, maintaining the correct C:N ratio is important to obtain good quality compost (Young et al 2005). The optimum C:N ratio to begin composting of food waste is 15:1 (Thakur 2006). From the study, the initial C:N ratio is 14:1 for uncooked waste and 6:1 for cooked waste. The decomposition of organic matter was due to the usage of carbon by microorganisms as the energy resource and nitrogen for building the cell structure (Miller et al. 1995; Kalamdhad et al. 2009). The C:N ratio is an important index to evaluate the degree of compost maturity. It is normally expected that compost should have a C:N value of less than 12 (Jimenez and Garcia 1992). The C:N value usually has a decreasing tendency as the composting process progresses (Lin 2008). Based on Table 3, the C:N ratio for the final compost decreased for Bin 1, Bin 2 and Bin 3 which were 12:1, 9:1 and 6:1 respectively.

**Phosphorus and Potassium:**
Levels of Phosphorus along with Nitrogen and Potassium are important to determine the quality of compost since Phosphorus is also one of the essential nutrients for plant growth (Young et al 2005). Phosphorus is not lost by volatilization or lixiviation during the composting process, rather its concentration might increase as composting process proceeds (Warman and Termeer 1996). It was found that Phosphorus content during the last study was 0.156 ppm for Bin 1, 0.159 ppm for Bin 2 and 0.194 ppm for Bin 3. Potassium content in Bin 1 was 0.403 ppm, Bin 2 was 0.425 ppm and Bin 3 was 0.478 ppm. According to Polprasert (1989), Potassium is the element that is present in leachate. The value of Potassium recommended by Yusof (2007) is 1%. The result shows that the value of potassium is less than the recommended value. This is due to leachate production from the food waste being absorbed by the saw dust, whereby this bulking agent has potential to hold the structure of the food waste and keep the Potassium from leaching.

**Conclusion:**
Close monitoring and analysis of the aerobic composting process of food wastes were carried out. The final compost had a dark colour, earthlike odour and a particle size of less than 15 mm. Qualitative and quantitative data for nearly all parameters monitored were within their normal range. In practice, using the composter bins to treat food wastes in UKM’s cafeterias is not the best solution because this system needs intensive proper care and takes a longer period to achieve its maturity, i.e. more than 12 weeks. If this has to be applied, then there will be a lot of waiting time to mature the food waste in bins outside UKM cafeterias, and thus requiring larger areas.
The effective microorganism applied in Bin 2 and Bin 3 did not turn out a good result. From the comparison made with Bin 1, which no effective microorganism added, the parameters and time taken to compost food waste were nearly the same. The effective microorganism need to be improved to suit the UKM food waste characteristic, so that the food wastes mature faster. The temperature in the bins reached a maximum of 42.3°C on average. It shows that the waste was composted in the mesophilic range.

However, this research on composting of food waste using composter bin is a good start for UKM to discover better control of composting system which suits the campus environment and surroundings. All data gathered from this research are useful as base line information for future research on composting systems in the UKM campus

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