Rapid composting of food waste and yard waste with effective microorganisms (EM)

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Abstract. Rapid composting is an alternative method to reduce highly generated food waste and yard waste discarded to the landfill. This study aims to determine the effect of effective microorganisms (EM) application on the chemical and physical properties and to determine the performance and factors affecting the rapid composting process. The chemical and physical properties such as pH, temperature, moisture content, carbon-to-nitrogen (C/N) ratio and Nitrogen (N), phosphorus (P) and Potassium (K) nutrient are examined over rapid composting period in order to assess the performance of compost and effectiveness of EM in enhancing the degradation process of organic waste. There are three compost prepared which are A, B and C that received different ratio of EM which 1 L, 2 L and 3 L respectively. Based on the result obtained from the 54 days of composting conducted, compost A, B and C show no significance differences on parameters tested. The temperature obtained mostly within the range 35-38 °C, pH values are 5-9, moisture content are 20-60 % and for NPK nutrient, Total Nitrogen content are 1.3 % to 1.4 %, Total Phosphorus are within 0.10 ppm to 0.45 ppm and Potassium are within 0.8 ppm to 6.7 ppm.

1. Introduction
Waste generation is an influential global problem and exacerbated through the years. According to statistical survey by Ministry of Housing and Local Government in 2012, waste generation of Malaysia for the whole is approximately 33,000 tonnes per day are currently produced, with per capita waste generation ranging from 1 to 1.33 kg/person/day across the strata and housing type, with an average of 1.17 kg/capita/day [1]. Malaysia wastes enough food and the country’s population bins up Food waste is the biggest component in the national waste composition that constituted about 44.5 % as Malaysia wastes enough food and the country’s population bins up to 16,667.5 tonnes food per day. The amount rises during festive seasons such as Ramadan that caused the food waste as severe issue in Malaysia. Due to improper separation with municipal solid waste, food waste attributes to the production of greenhouse gases in landfills [2]. Typically, food waste and yard waste highly involved in conventional disposal practice in Malaysia such as land filling. Thus, a proper management of organic waste such as composting contributes to divert these organic wastes from landfills and treats the problems. Composting is an initiative to turn the food waste and materials scrap into compost that can be used as organic fertilizer. In order to efficiently produce high quality product in a short period, Effective
Microorganisms (EM) application is discovered rapidly decomposed the organic materials. During decomposition process, the chemical and physical properties of compost are evaluated so that the factors influenced the performances is optimizing.

Rapid composting of food waste with yard waste and effective microorganisms are related to accelerate the period of composting process. The degradation process of organic products into a stable material product causes by microbial activity that act as composters on the organic matter with the presence of oxygen (O\textsubscript{2}) to encourage naturally composting occurs\cite{3}. The breakdown of organic matter produced final product consists of carbon dioxide (CO\textsubscript{2}), ammonia gas (NH\textsubscript{3}), water, heat and humus. Humus commonly known as compost that was useful to the nature as it returned the organic matter to soil. The application of effective microorganisms (EM) in the compost enhanced the decomposition process as it has major influence on the process because its ability to change the chemical structure of organic waste while producing high quality compost\cite{4}\cite{5}.

An aerobic rapid composting conducted used food waste, yard waste, goat dung and EM as the main components of compost medium. Food waste collected from the food stall near Unimap Dragon. The rice husk was used as yard waste. Goat dung acts as sources of nitrogen and EM concentrated solution as sources of bacteria reproduction. The optimization conditions are required for the growth of aerobic microbes. The microbes demand enough oxygen, food and water for the decomposition process to occur. Thus, the important parameters included moisture content, temperature, pH, C/N ratio must be controlled to maximize the compost quality.

The goal of the study were to analyze the effective rapid composting method of organic waste such as food waste and yard waste with the aid of microbes that functioning in accelerated the decomposition process by using three horizontal rotary drum shaped compost bins. Compost A, B and C received 1 L, 2L and 3L of EM respectively and were placed at Wang Ulu students’ residential college. Besides that, the performance of the compost and its factors that influenced the composting process is evaluated.

2. Materials and Methods

2.1. Compost Bin Fabrication

The compost bins used in this study were horizontal drum shaped bins to mix, aerate and move the compost medium. The bins consist of holes for aeration during the turning process and consists a door that open and closed to facilitate the roll up and down during the turning process and for entrance of organic waste composition. Figure 1 shows the schematic diagram of compost bin while Figure 2 shows the bin that was fabricated in this study. The dimensions of compost bin were 490 mm x 270 mm height with the capacity 50 Litres.

![Figure 1. The schematic diagram of compost bin for aerobic composting process.](image-url)
2.2. Mixtures Preparation

For the preparation of the compost mixtures 3 ratio, the composition of food waste, yard waste, goat dung and effective microorganisms (FW: YW: GD: EM) were fixed except for the EM. Table 1 shows the composition of raw organic waste for composting process.

| Table 1. Compositions of raw organic materials. |
|-----------------------------------------------|
| Compost A                                      |
| 2 kg of food waste                            |
| 3 kg of yard waste                            |
| 1 kg of goat dung                             |
| 1 litre of EM                                 |
| Compost B                                      |
| 2 kg of food waste                            |
| 3 kg of yard waste                            |
| 1 kg of goat dung                             |
| 2 litre of EM                                 |
| Compost C                                      |
| 2 kg of food waste                            |
| 3 kg of yard waste                            |
| 1 kg of goat dung                             |
| 3 litre of EM                                 |

2.3. Source Materials

EM is prepared by adding 500 g of brown sugar into 2 pieces of ‘tempe’ and 6 L of tap water that is added into the mixtures Tempe need to be chopped into small pieces before added into the mixture. The mixtures were then transferred into clean air tight container and avoid exposure to the sunlight at ambient temperature for 7 days. EM applied directly into compost.

The amount of 3 kg goat dung was prepared for the compost mixtures. The goat dung is collected from villagers at Kampung Wang Ulu. Goat dung is one of the some animal products can be used as organic sources of nitrogen including livestock manures from plant-eating animals. For example cow, sheep, goat, rabbits and chicken. Herbivore manures compost quite quickly.

The collections of food waste were taken from the stalls near Unimap Dragon and most of the food waste collected kitchen waste and spoilage food due to expiry. Rice husk that being used as yard wastes were collected for about 9 kg. The food waste collected must rinsed using tap water before blended. It was collected around 6 kg.

2.4. Compost Laboratory Analysis

At the early stage of the compost, the initial parameters were recorded such as temperature, pH and also moisture content each compost bin received 8 times of turning process to control the temperature and provide some aeration. The temperature was measured by using the mercury thermometer after the turning process at several points to obtain the average temperature. In the case of a rotary drum shaped compost bin that horizontally lie down and the access was only available from the top. Three sampling sites of compost in the bin were standardized and sampling is done every 3 days The sample of compost were collected was in the centre, back and at the front of the bin to record accurate data during composting period.
pH compost was analyzed by grinded and weighed about 10 g. The deionized water was added at ratio 1:10. The sample was stirred for 5s and let it sit for 15 min. After 15 min, the sample was stirred again and recorded the pH by using pH meter.

Moisture content was measured by using the oven-dry method (ASTM 2974-87)[6]. The sample weighed about 13 g as wet weight and kept into oven for 16 hours at 105 °C. Then, dry weight sample was recorded again.

The nutrient content of compost; Nitrogen (N), Phosphorus (P) and Potassium (K) were examined. Total N was measured by Total Kjeldahl Nitrogen (TKN) method. The testing consists of digestion, titration and distillation process on a diluted sample using Boric acid solution to determine the existence of Nitrogen in the sample. The carbon was determined by Loss-on-Ignition Method according to ASTM 2974-87 that quantified the amount of oxidizable organic matter which estimated organic matter based on gravimetric weight change associated with high temperature oxidation of organic matter. After initial oven drying at 105°C the samples was ignited in furnace for 2 hours at 750°C. The total organic carbon was calculated according to the following equation C=OM/1.84[7]. Then, C/N ratio was determined by the values obtained.

The concentration of K was determined by wet acid digestion in an open system run on the sample before continued with Hach Method (Tetraphenylborate Method) while P concentration was determined by Nitric-perchloric-sulphuric digestion. Then, continued the Hach method PhosVer3 to examine the nutrients contained in the compost. Both concentrations were examined by using Spectrophotometer to analyze the nutrient content.

3. Result and Discussions

3.1. Effect on Temperature

Figure 3 shows the effect of rapid composting process on the temperature over the period.

![Figure 3. The effect of rapid composting process on temperature.](image)

Compost A, B and C has slightly different temperatures at initial. Compost A, B and C has initial temperature of 36.7 °C, 36.6 °C and 37.6 °C respectively. Temperature of A, B and C started to rise on day 3 which A recorded the value 40 °C, 43 °C and 42 °C. On day 6, compost A and C has slightly increased in temperature which recorded the values 41 °C and 43 °C before it decreased slowly. The temperature of compost B slightly decreased to 41 °C on day 6. The temperature recorded the same change pattern during composting process which it increased and decreased within the range 35-37 °C at ambient temperature. The compost of rapid process supposedly reached the optimum temperature range which 40 – 50 °C[8].

Somehow, the rises on temperature only happened the first few days of composting process. It caused by microbial activity on the organic waste. This condition can be seen when the food waste was added...
on the setting day and the temperature arise on the next 6 days before it slowly declined. The change on temperature indicates the microbial activity on organic materials. Less availability of nutrients dropped the temperature due to microbial activity slow down [9][10].

The decreased and increased in temperature indicates that the microbial activity on organic materials. As the temperature increased, it encouraged microbes to actively breakdown the organic materials[11]. During the initial stage of composting, the mesophilic bacteria live at low temperature between 20 – 45 °C characteristically predominant at the start and early stage of composting process. It can be seen through the temperature increased on day 3 to day 6. The thermophilic bacteria take place to continue breakdown the organic materials in high temperature about 45 °C and above.

However, the thermophilic phase in this study not occurred due to low moisture content and the environment factors around the compost bins that influenced the compost temperature. Low outside temperature slows down the decomposition process due to slow microbial actions on organic materials while warmer temperature encouraged the decomposition process. According to Khalib et al.[12], temperature is considered ideal between 55 °C to 65 °C because at this temperature range, most pathogens are killed. The high temperature also affected the moisture content of compost [9].

3.2. Effect on pH

Figure 4 shows the effect of rapid composting on pH over the period. The pH values of compost A, B and C obtained during rapid composting period as shown in Figure 4.

![Figure 4. The effect of rapid composting on pH.](image)

The pH varied at initial stage of the composting. Compost A and C were recorded pH 6.7 and 5.1 respectively on setting day. A increased on day 3 which 7.5 and 7.8 on day 6. Compost C has initial pH 5.1 and the reading increased to 8.5 on day 3 and on day 6 the pH 8.3 was recorded. The usual initial pH that consisted mixed of vegetable, food waste likely to be more acidic and possibly reached the pH value 5 to 7 [13]. Compost microorganisms grew and multiplied within the pH range of 5.5 to 8. The pH slowly decreased throughout the time within the range of 7.3 on day 15. The pH values of compost A and C changed significantly from slightly acidic to alkali.

The formation of organic acids at initial stage of aerobic decomposition favours the growth of fungi and breakdown of cellulose and lignin[9]. Increase in pH also resulted from high volume of ammonia produced due to degradation of protein [10]. pH level should not exceed 8.0 because at high pH level generated more ammonia gas and caused it lost to atmosphere [14].

Compost B has initial pH of 8.3 and it decreased to 7.8 on day 9 and lower pH obtained on day 15 which 7.1. Compost B not reached acidic condition as it constantly obtained the pH within the range of 7.1 to 8.3. This condition may caused by the fungi and bacteria digested the organic matter released organic acids and it encouraged the growth of fungi and breakdown of lignin [9][15]
recorded alkali pH as organic materials in the compost contained significant proportion of goat manure during sampling which increased the pH. Its neutral pH was beneficial to composting process [16].

The initial pH that slightly acidic remained constant because of composting microorganisms reacted and increased the temperature for few days and pH began to rise as organic acids were neutralized. Alkaline pH was the best for composting because acidic pH slow down the process due to destruction of microorganisms [4]. Acidic pH affected the rate of microbes respiration and decreases the rate of degradation [17]. Mature compost generally recorded pH between 6 to 8. The alkaline pH indicates compost maturity and stability [10]. The alkaline pH recorded throughout and end of composting day for compost A, B and C were 8.0, 8.1 and 8.4 respectively.

pH values related to ammonia emissions and microbial activity on the organic matter. The composting process considered successful when the pH value between 8.0 and 9.0 [12]. Thus, it were supported that the pH of organic materials composted were affected the composting rate.

3.3. Effect on Moisture Content

Figure 5 shows the effect of rapid composting on moisture content.

The percentage of moisture content in the compost as shown in Figure 5 were recorded that A, B and C had the initial reading 44.77 %, 51.54 % and 60.77 % respectively on setting day. The moisture percentage was dominant factor in composting. It provided better degradation and maintained the temperature for longer period [17]. Moisture content percentage of A, B and C were observed where it decreased and increased in the time interval. Moisture of A, B and C dropped to the lowest reading on day 12 which the reading of moisture content was recorded about 15 % to 20 %. However, the moisture content started to increase on day 15. The water was added to control the moisture until it reached optimum moisture range. The low moisture content of compost may due to high amount of rice husk and limited of food waste. Food waste typically consisted high moisture content which able to control the moisture of compost.

Ideal moisture content that should be maintained between 40 % to 60 % during composting process as it supported the growth of composting microorganisms. Excess water in compost medium lead to diffusions of oxygen then reduced the metabolic activities of organisms. Too dry or too much moisture of compost medium inhibited and slowed down the degradation process of organic matter.

Moisture content was inversely proportional to temperature and microbial activity on the organic matter. Moisture related to temperature as during the decomposition process the water loss through microbial activity was high which increased the temperature of compost [12]. Moisture content affected by the temperature distributions of compost medium and the factor of moisture lost due to rising in
compost temperature [9]. Most of the moisture percentage of A, b and C observed shows no significant differences throughout the composting period.

3.4. Effect on C/N Ratio

C/N ratio was mandatory requirement in obtained best quality compost. Compost A, B and C recorded different values of C/N ratio on day 48 as shown in Table 2.

| Table 2. The C/N ratio of compost A, B and C. |
|-----------------------------------------------|
| C/N ratio | A   | B   | C   |
|------------|-----|-----|-----|
| 10:1       |     |     |     |
| 9:1        |     |     |     |
| 14:1       |     |     |     |

Table 2 shows the C/N ratio obtained from compost A, B and C on day 48. The C/N ratio of compost A, B and C recorded the values less than 20. Thus, the compost concluded in their mature phase. Typically, the reduction in C/N values along the decomposition period was due to mineralization of organic matter. The values of C/N ratio less than 20 can be considered as mature compost [12].

Although the C/N ratio within range of 10 to 20 was considered in mature level. However, these claims contended by Che Jusoh et al. [18] in their previous study indicated that it cannot be concluded as mature because higher in C/N ratio may occur due to carbon sometimes were not in available state form. Generally, moist and green organic materials had high nitrogen content. For example, vegetable scraps, grass clippings and manures. While for high carbon organic materials included straw, saw dust, bark and leaves.

Initial C/N ratio for raw organic materials used in composting is referred to previous study by Khalib et al. [19] which food waste and goat dung has initial C/N ratio of 16.00 and 18.63 respectively. Rice husk has initial C/N ratio of 18.63. In this study, the goat dung and rice husk were used as source of nitrogen and carbon to be used by microbes in decomposition process. The suitable C/N ratio to optimize the composting should be 20 to 30 [20]. Low C/N ratio caused excess in nitrogen and loss as ammonia gas meanwhile high C/N ratio caused unsufficient nitrogen to support microbial growth [15].

The C/N ratio of compost decreased along the rapid composting period. This due to microbes activity that converted the carbon to CO₂ gases and it also being used by the microbes to build their cellular components. According to Bhatia et al. microorganisms used and converted 60 % to 70 % carbon to CO₂ and the remaining 30 % to 40 % was utilized as cellular components in the body while degraded organic compounds [10]. Thus, the mix of organic materials need proper C/N ratio and can be consumed for rapid composting process as microbial systems primarily responded to available nutrients readily for decomposition of organic matter.

3.5. Effect on Nutrient Content

3.5.1. Phosphorus (P). Table 3 shows the phosphorus content obtained in compost A, B and C that were recorded on day 0 and day 12 of composting process.

| Table 3. The Phosphorus content of compost A, B and C. |
|-------------------------------------------------------|
| Nutrient | Time (day) | Compost |
|-----------|------------|---------|
| Phosphorus, ppm | 0 | A | B | C |
|             | 12 | 0.10 | 0.10 | 0.10 |
|             |     | 0.45 | 0.10 | 0.40 |

The compost products show that phosphorus content in A, B and C in Table 3 that were measured during composting. Initial samples recorded the same concentration of A, B and C which 0.10 ppm. The
phosphorus concentration of A and C increased on day 12 which 0.45 ppm and 0.40 ppm respectively. Compost B on day 12 remained the same as initial concentration which 0.10 ppm. The result obtained shown a very little amount of P and may caused by composting process that possibly leaching out P in soluble organic solute. Compost has lower concentration of phosphorus content indicates characteristics of compost that were made using green wastes. The values of phosphorus obtained also similar to the compost that used vegetable waste and manures.[7][18].

Available phosphorus in organic waste was released through mineralization process caused the phosphorus content to increase during composting process. Phosphorus content increased slightly week by week due to the rate of carbon loss was high that occurs when organic matter decomposed [21].

3.5.2. Nitrogen (N). Table 4 shows the nitrogen percentage obtained on day 48.

| Table 4. Percentage of Nitrogen content |
|----------------------------------------|
| Nutrient | Compost |              |
|          | A       | B       | C       |
| Nitrogen, % | 1.4     | 1.3     | 1.4     |

The N content on day 48 of composting process recorded 1.4 % for compost A and C while compost B recorded the value of N 1.3 % that slightly lower than A and C. The standard of N in organic fertilizer stated that N content should not less than 1 % [3]

Compost recorded the increased percentage in N at the end of composting process due to the dry mass net loss as the loss of organic carbon converted as CO₂ during composting process and total N might also increased due to nitrogen-fixing bacteria that typically occur at the end of composting. In addition, N was used by the composting microorganisms to build up their cells and some of microorganisms that eventually died during composting process were recycled as N. Thus it contributed in increased of N value [18].

3.5.3. Potassium (K). The potassium (K) content measured in compost A, B and C along rapid composting period as shown in Figure 6.

![Figure 6. The concentration of potassium nutrient over rapid composting period](image)

Initial concentration of K in compost A, B and C as shown in Figure 6 slightly varied which it recorded the value of 1.5 ppm, 1.0 ppm and 0.8 ppm respectively. Initial concentration of compost A shows higher concentration compared to B and C. The unstable K concentration of compost A, B and C that increased constantly and it slowly decreased after day 24. However, the K content increased to the highest
concentration at the end of composting day. Compost A was recorded the K value of 6.7 ppm while B and C 4.2 ppm and 4.4 ppm on day 54.

In overall, compost A has highest reading of potassium (K) content at initial and final reading compared to B and C. The K values might increased by week but not constant. Increased and decreased of potassium occurs on weekly basis and unstable potassium content in compost due to the microbes’ activity that need the nutrients on certain time which caused the potassium content declined and unstable over the rapid composting period. In addition, higher microbial activity on organic matter increased K which consequently promoted high rate of mineralization [21] 

Che jusoh et al. [18] stated K element that easily leached out. This might caused the increased and decreased of K content in compost during decomposition period. K very soluble in water and rain that could easily leached potassium out of compost before it was finished. Therefore, covered up the compost bins help to maintained K in compost. In addition, increased in K content also caused by rice husk that being used as one of the main ingredient of compost medium. It inhibited the loss of K since its structural integrity and porosity maintained.

4. Conclusion

During 54 days of composting, the chemical and physical properties of compost such as pH, temperature, moisture content, C/N ratio and NPK nutrient were examined to measure the quality of compost which necessary to established the quality of product. Besides, the factors influenced the performance of rapid composting of compost A, B and C can be optimized and controlled so composting process were in the best condition resulting in produced effective composting method. Based on the result obtained, there were no significant changes in physical appearances of compost A, B and C even though different volumes of Effective microorganisms (EM) applied on composting process of food waste and yard waste that might affect the performance of compost as it enhanced the degradation process of organic matter. Somehow, most of the parameters tested on compost A, B and C showed same pattern of performance. Frequent testing on compost essentially required to identify the characteristics of compost.

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