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Effect of Compost Maker on Composting and Compost Quality

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Compost and its liquid product can be used as an organic fertiliser. Bulking agent, microbial inoculants or compost maker can be added to improve the composting process. Compost maker is an organic substance that speeds up the composting process. It contains microorganisms that can speed up the degradation process and reduce the odour emitted during composting. Limited studies have reported the effect of compost maker on composting and its end quality. The aim of the study is to characterise the nutrient characteristics of the food waste compost treated with compost maker. The correlation between the nutrients in compost and its bio-liquid was investigated. A two-stage composting system, i.e. facultative and aerobic system, will be used. The raw materials used for composting included the post-consumed food waste, shredded palm leaves as the bulking agent and matured compost as the compost maker. Two formulations were conducted: (i) food waste composted with the shredded palm leaves and compost maker using the ratio of 2:1:1 and (ii) food waste composted with the shredded palm leaves (1:1) without the presence of compost maker as the control. The results showed that the first formulation reported the higher contents in nitrogen and potassium as compared to the control. The macronutrients of the solid compost are positively correlated with the respective bio-liquid fertiliser. The use of compost maker is recommended as a supplement to improve the quality of both the solid and liquid compost product.

1. Introduction

The average amount of municipal solid waste (MSW) generated in Malaysia is 0.5 – 0.8 kg/person/d and most of it is food waste (Manaf et al., 2009). Diverting food waste from the landfill reduces the land requirement and greenhouse gases (Sagnak et al., 2011). Compost is formed where organic compounds are naturally degraded into nutrient-rich products. Food waste contains a high proportion of biodegradable organic compounds suitable for composting (He et al., 2018). However, food waste composting emits hazardous odours such as ammonia (NH_3), trimethylamine, dimethyl sulphide and dimethyl disulphide contribute to the environmental impact (Cerda et al., 2018). It is desirable to add compost maker, an organic substance which acts as compost amendments. Compost maker consists of matured compost rich in beneficial microorganisms, to enhance the composting process by reducing the odour and assimilation of nutrients. Yang et al. (2019) reported that by mixing the matured compost with the fresh organic waste can reduce the emission of NH_3 by 58.0 %, CH_4 by 44.8 %, N_2O by 73.6 %.

The positive effect of compost maker on reducing the gaseous emission is clear; the overall effect of compost maker on the composting performance, notably on compost quality remained unclear. Detail effects of compost maker on composting in terms of physical performance such as organic matter degradation rate,

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moisture content level, temperature profile and pH profile are also unclear. The aim of this study is to investigate the effect of compost maker on the physical performance of food waste composting and the quality of the end products, namely the solid compost and bio-liquid fertilizer, also known as compost leachate (CL). The outcome of this study is to validate the use of matured compost as a viable compost maker.

2. Materials and methods

2.1 Composting materials and treatment

A two-stage home composting system, comprised of a facultative stage (first stage) and aerobic stage (second stage), was conducted this study. The food waste (FW) was collected from three caféterias at Universiti Teknologi Malaysia (UTM), Johor Bahru campus. Dried leaves (DL) from shredded palm oil tree (average size of 4 - 5 cm) was used as a bulking agent for the composting process. DL and matured compost fertilizer (CF) from FW were collected from a local composting site at Layang - Layang, Johor. The raw materials for composting were layered in a homemade compost bin (50 L) according to the formulation shown in Table 1. The bin featured a modified pipe fixed on the bin body, about 4 cm from the bin bottom, to collect the CL released from the composting materials. The bottom layer of the bin was covered with 2 L of DL to trap the FW residue and to prevent the blockage of the water pipe outlet. FW was added to this bottom layer followed by CF and DL. For each layer of FW, 200 mL of 4 % activated solution of effective microorganism (EM) supplied by EMRO Sdn. Bhd., Johor, Malaysia was added as a microbial inoculant. Upon completion of layering the raw materials, the layers were mixed using a stick to homogenize the materials. The layering step was repeated until the bin was about 80 % full. At the top final layer, 2 L of DL was layered to cover the entire contents in the compost bin.

Table 1: Formulation and volume of compost materials in each layer

Treatment	Formulation	Formula ratio (v:v)	Volume of FW per layer (L)	Volume of DL per layer (L)	Volume of CF per layer (L)
A	FW:DL	50:50	2	2	-
B	FW:DL:CF	50:25:25	2	1	1

The raw materials were left in the compost bin for five weeks of first-stage composting. CL was collected from each bin once per week during the first stage. The CL samples were stored at 4°C and analysed within 3-5 d. The volume of the CL was recorded. After five weeks, the partially composted material was mixed briefly using a spade on the ground, piled at 60 cm height, 40 cm width and 50 cm length and covered with a canvas sheet. The compost pile was turned once a week and composted for five weeks in the second stage of composting. For each pile, 200 g of solid compost was sampled every week and stored at 4 °C.

2.2 Sample analysis

The temperature was recorded every other day in both composting stages using a digital thermometer. The CL collected weekly during first stage composting were analysed for pH and chemical oxygen demand (COD). The pH of CL was measured using a portable meter (HandyLab 680, SI Analytics, Germany). For COD analysis, the CL was diluted by 100 times as instructed in the Spectrodirect Instruction Manual and measured by SpectroDirect COD pack (MERCK, Germany). The CL collected at the 5th week of first-stage composting were analysed for nitrogen (N), phosphate (P) and potassium (K) content. The CL samples were diluted at a dilution range of 50 - 1,000 factors and measured by SpectroDirect nutrient analysis pack (MERCK, Germany).

For the second stage composting, the solid samples were collected weekly and analysed for organic matter (OM), moisture content (MC), and pH. For pH analysis, the solid samples were mixed with water at 1:10 w/v ratio and shaken by the shaker (ST-250D, SastecTM, Malaysia) for 1 h (Karnchanawong and Suriyanon, 2011) before measured using a portable meter (HandyLab 680, SI Analytics, Germany). OM was determined by the % loss of dried sample weighed after furnace ignition (ELF 11/6, Carbolite, UK) at 550 °C for 3 h (Xu et al., 2019). MC was measured from the % loss of weight after heated at 105 °C for 24 h in an oven (Memmert 100, Memmert, Germany) (Zhou et al., 2018). N, P, K content was analysed for the end compost following second-stage composting. KCL extraction method (for N analysis) (Jones and Willett, 2006) and calcium acetate and calcium lactate mixture extraction method (for P and K analysis) (Wong, 2017) was used. The extracted samples were analysed using SpectroDirect nutrient analysis pack (MERCK, Germany).

3. Results and discussions

3.1 First-stage composting

Common composting parameters such as temperature, COD and the volume of bio-liquid produced during composting could be used as indicators to determine the stability of the end compost; whereas pH determines the maturity of the compost (Oviedo Ocana et al., 2015). Figure 1 shows the temperature profile during the first-stage composting for sample A (with compost maker) and B (without compost maker) as the control.

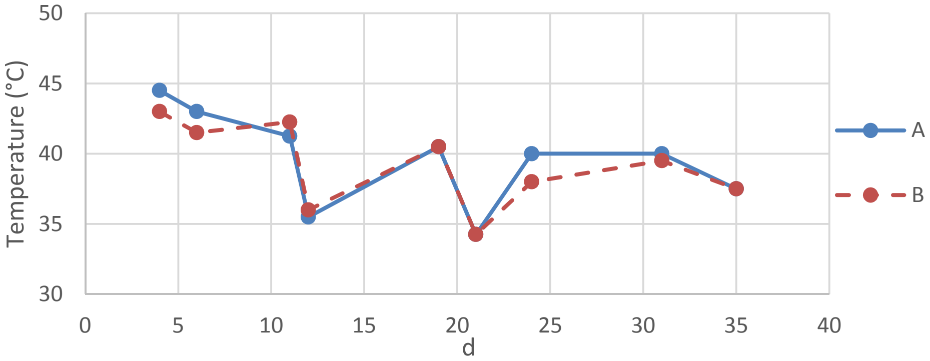

Figure 1: Temperature profile for both the compost bin during first-stage of composting: with compost maker (A) and B as control (without compost maker).

Sample A and B show similar temperature profile and both composts reached the highest temperature on day 6th and decreased gradually thereafter. Guidoni et al. (2018) recorded the same temperature profile during small-scale composting with the highest temperature recorded on day 10 within the range of 38 °C to 41 °C. Small compost pile of about 50 L did not reach a temperature as high as 55 °C as an indicator of sanitation during composting (Jurado et al., 2014). The low temperature of the compost is due to lack of aeration in the compost bin. Lack of contact between the composting material and the atmospheric air contributes to the low-temperature profile (Guidoni et al., 2018). However, the compost will be further matured during the second stage outside the bin. Table 2 shows the pH, colour, odour and COD of the CL recorded during first-stage composting.

Table 2: The pH, volume and COD of the bio-liquid recorded from both bins during first-stage composting

Week	COD (g/L)		Cumulative volume of CL (mL)		pH	
	A	B	A	B	A	B
1	163 ± 6.5	70 ± 20.5	1,000 ± 275	250 ± 50	4.09 ± 0.17	3.74 ± 0.05
2	151 ± 11	91 ± 22	1,800 ± 235	550 ± 300	4.31 ± 0.22	3.83 ± 0.01
3	150 ± 8.5	139 ± 48.5	2,550 ± 95	800 ± 260	4.65 ± 0.15	4.35 ± 0.03
4	189 ± 3.9	123 ± 42.4	3,200 ± 135	1,010 ± 140	4.65 ± 0.34	3.67 ± 0.04
5	163 ± 6.5	70 ± 20.5	1,000 ± 275	250 ± 50	4.09 ± 0.17	3.74 ± 0.05

Bin B showed a lower pH range indicating that the degradation rate was lower with the addition of compost maker compared to bin A. Low pH at the beginning of kitchen waste composting is likely due to the production of organic acids, such as acetic acid and butyric acid (Yang et al., 2019) and carbonic acid due to release of CO_2 (Komilis and Tziouvaras, 2009). Over the first three weeks, the pH of the CL from bin B increased by 15.25 % when the pH of CL from bin A increased by 13.57 %. It was likely due to the release of ammonium following degradation of acids and nitrogen-containing matters (Lim and Wu, 2016). However, the CL from both bins was too acidic and may damage the crops and soil. The recommended pH of soil enhancer is 5.5 – 6.5 (Yaseer et al., 2014). The CL in bin B (with compost maker) showed a lower range of COD over the first five weeks of composting, indicating a higher level of initial degradation compared to the control (Bin A). From week 0 to 5, the COD from bin B increased by 53 % and 8 % for bin A. The increased of COD is due to the assimilation of organic matter content in the liquid (Mokhtarani et al., 2012). The dissolution of some organic content from the CF may contribute to the rapid increased of COD in bin B. At the 5th week of composting, the COD of the CL from bin B is 15 % lower than the CL in bin A. Due to the microbial diversity in CF (bin B), the degradation rate of organic carbon was higher, and reduction of the total organic content in bin B was higher compared to bin A. It was a likely and higher level of organic contents dissolution. For the cumulative volume of the CL collected, bin A released a higher volume compared to that from bin B. The low volume of CL collected indicated that CF has a high absorption capacity. The brown colour of the CL from bin B is due to the residue of the CF in the CL. The colour intensity of the CL from both bins becomes darker as the first stage composting progress. The CL from bin B emitted a sour-like odour, whereas the CL from bin A emitted a strong-pungent smell. CF have a capacity to control odour emission such as NH_3, CH_4 and N_2O (Yang et al., 2019), avoiding attraction of pests at the compost site. The colour of the CL from Bin B is slightly darker compared to the CL from Bin A. The CL from Bin emits a sour-like smell, whereas the CL from bin A emits a strong, pungent smell.

3.2 Second-stage composting

Figure 2 shows the temperature profile of the two compost piles during the second-stage composting on the floor.

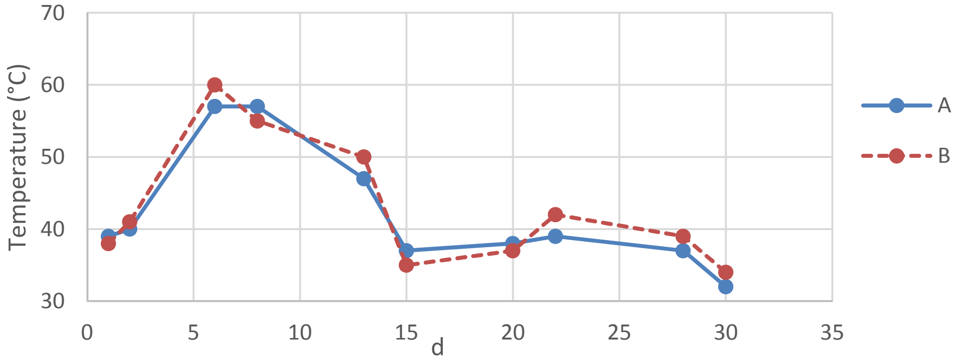

Figure 2: Temperature profile of two compost piles during the second-stage composting

The temperature of both piles increases due to the high microbial activity to degrade organic matter. With the presence of excess oxygen, both compost piles reached a thermophilic phase on the fifth day, i.e. from 40 to 65 °C. After 6 d, the temperature decreased due to the exhaustion of organic matter, which lead to the reduction of microbial activity. It is important for the compost to reach the temperature as high as 55 °C as an indicator of sanitation and improve the quality of the compost (Jurado et al., 2014). However, the temperature should not exceed 60 °C as it may eliminate micro-fungi and actinomycetes that may slow down the degradation of lignin (Tuomela et al., 2000). Table 3 shows the list of parameters during the second-stage composting.

Table 3: List of parameters during second-stage composting

Week	pH		OM (%)		MC (%)	
	A	B	A	B	A	B
0	4.97 ± 0.81	5.00 ± 0.01	73.62 ± 12.47	67.11 ± 5.39	59.48 ± 1.67	64.82 ± 3.93
1	6.95 ± 0.83	7.46 ± 0.06	74.54 ± 7.68	64.20 ± 3.89	52.33 ± 4.66	57.58 ± 8.12
2	7.40 ± 0.24	7.50 ± 0.07	72.90 ± 13.50	67.31 ± 0.64	51.14 ± 5.56	49.05 ± 18.90
3	7.37 ± 0.15	7.18 ± 0.22	73.05 ± 6.55	66.44 ± 9.71	55.26 ±7.96	45.43 ± 11.31
4	6.85 ± 0.10	7.31 ± 0.39	62.50 ± 2.71	61.76 ± 6.67	55.01 ± 5.06	58.38 ± 8.16
5	6.85 ± 0.13	7.39 ± 0.09	65.44 ± 0.44	56.52 ± 1.47	52.33 ± 5.52	57.60 ± 7.78

In terms of pH, both pile A and B increased to the neutral state over the 5 weeks. The organic acids from the initial decomposition of the organic waste had been neutralized and stabilised (Karnchanawong and Suriyanon, 2011) indicating a maturing process (Adhikari et al., 2009). In terms of MC, both pile A and B reported MC above 50 % at week 0. High MC was due to the high moisture content of the FW. Margaritis et al. (2017) reported that FW from MSW in South European countries exhibited MC of 70 % or more, due to high water content by fruits and vegetables. MC between 55 and 60 % creates a suitable condition for microbial activity and higher mineralization of organic matter during the composting (Jurado et al. 2014). The MC significantly decreased from week 0 to week 2, with pile B reported a higher degree of reduction (24 %) compared to pile A (14 %). High temperature during the thermophilic stage (week 0 to week 1) led to the loss of water through evaporation. The MC continues to decrease until week 5. Rainwater was added at week 4 to maintain the MC above 40 % to promote microbial activities. At week 5, compost from pile B have a higher MC than pile A. CF has a high water absorption capacity; the compost in pile B could maintain its water content.

In terms of OM profile, the initial OM from pile B is lower compared to pile A. The OM profile of both pile A and B slowly decreased from week 1 to week 3 and rapidly decreased to week 5. The OM reduction was higher in pile B (15.8 %) compared to pile A (11.1 %) from week 0 to week 5. Rich et al. (2018) reported a similar OM profile during compost using a different bulking agent with the OM reduction range of 16 – 22 %. The microorganism in CF (bin B) served as a microbial inoculant to speed up the degradation of organic matter. Yang et al. (2019) reported the reduction of total organic carbon of mixed kitchen waste treated with mature compost is about 5 % higher than the mixed kitchen waste without the mature compost. Mixing matured compost as compost maker improved the physical performance of the composting process. CF has a high water absorption rate, which ensures the MC content is at the optimum range (55 - 60 %) for microbial growth. CF contains microorganism that can speed up the composting process, resulting in the higher organic carbon degradation rate and higher stabilizing rate for the compost pH.

3.3 Nutrient composition of solid compost and CL

Table 4 shows the nutrient composition of compost and bio-liquid from treatment A and B. The average N, P, K content of compost and CL in treatment B is higher compared to treatment A (control). The high N composition of the compost in bin B is due to the high adsorptive capacity of CF. Matured CF have a physiochemical absorption of NH_4^+, urea and uric acid, reducing the NH_3 production and volatilization (He et al., 2018). P and K are not volatile,and the increase of P and K composition is due to the increase of biodegradation rate of organic compound (Zhou et al., 2018). Zhang and Sun (2016) reported that adding composted green waste with waste input could increase the mineralization of waste input, enhancing the release of nutrients by 90 %. The nutrient composition in CL is almost similar to that obtained by Kucbel et al. (2019) (N = 374 - 745.0 mg/L, P = 42 - 206.0 mg/L, K = 235 – 1,545.5 mg/L) except for N which is higher than the value reported in the literature. During the first-stage composting, most of the organic N in FW was degraded and transform into mineral N. The mineral N may have leached in the form of NO_3-N causing high N content in the bio-liquid. N content in the solid compost has reduced. Despite the low N content, the nutrient contents of compost from treatment B meets the standard value set by the Philippines National Standard (25 – 50 g/kg of total N, P, K) (Philippines National Standard, 2013). Mixing compost raw materials with CF has improved the quality of compost and bio-liquid.

Table 4: Nutrient content of compost and CL from treatment A and B.

Treatment	Nutrient composition in CL (mg/L)			Nutrient composition in compost (g/kg)		
	N	P	K	N	P	K
A	1,800 ± 282	594 ± 93	2350 ± 212	4.69 ± 0.78	9.47 ± 0.63	5.96 ± 0.79
B	2,400 ± 849	596 ± 140	2750 ± 636	6.64 ± 1.36	11.64 ± 3.71	6.80 ± 1.13

4. Conclusion

Composting of food waste added with CF (treatment B) has significantly enhanced the physical performance in both the first and second stage of composting. The enhanced temperature profile was also observed for both the first and second stage of composting, allowing the compost to reach the optimum temperature range. The CL obtained from treatment B showed a low COD due to the rapid degradation of organic content in the CF. However, the CL from both treatments has a low pH where treatment or dilution is needed to increase the pH to the recommended range (pH 5.5-6.5). In the first-stage composting, compost under treatment B has a higher OM degradation rate, due to the presence of the microorganism in the CF. It also has a high MC due to the higher water absorption capacity of the CF. In terms of nutrient contents, the compost and CL produced from treatment B are 20 – 50 % higher compared to that from treatment A. This indicates the addition of CF to composting has enhanced the nutrient composition of the end compost products. Addition of about 25 % of matured compost as compost maker to the composting raw materials is significant to promote the composting performance. A future study could investigate the effect of compost maker on other physical parameters such as porosity, aeration, C/N ratio, germination index and micronutrient content of the compost products.

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