Research Article *Science, Engineering and Health Studies 2020, 14(2), 132-140*

Performance analysis of effective microorganisms on chicken manure composting

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Received: March 11, 2020; Revised: July 21, 2020; Accepted: July 30, 2020

ABSTRACT

Effective microorganisms (EM) in organic waste management converts poultry manure into high-quality biofertilizer. However, the production of biofertilizer is limited by the high price of imported EMs that are currently used in the poultry industry. Untreated manure will attract flies that will cause environmental problems. Therefore, it is necessary to find effective, locally available, and affordable alternatives to the current imported EMs. This study aimed to determine suitable local EMs based on cost and compost quality. Specifically, in terms of nitrogen (N), phosphorus (P), potassium (K), sodium (Na) and magnesium (Mg) composition. Five batches of chicken manure were prepared with two control setups of manure only and manure with sawdust (at carbon to nitrogen ratio, C/N of 30:1). The remaining batches of manure treated with different commercial EMs. Temperature and pH values were measured every 3 days for 45 days. The highest temperature recorded was 45°C and the measure pH was between 4.0 to 6.5. Composts matured after 24, 27 and 45 days for EM1 (local), EM3 (imported) and EM2 (local), respectively. The highest values obtained for K (412 ppm), Na (233 ppm) and Mg (54 ppm) with low energy (11.7 kJ/g) and application cost (RM 171/tonne manure) suggest that EM3 was the best option. However, the higher NPK values of EM2 and faster maturation of EM1 also make them promising local substitutes. Future work should investigate the potential mixture of these EMs for optimum composting time and quality.

Keywords: biofertilizer; chicken manure; composting; effective microorganisms; EM; NPK

1. INTRODUCTION

Malaysia consumes a high amount of poultry products and is estimated to have a per capita consumption of 49 kilograms annually (Organisation for Economic Co-operation and Development, 2020). In 2018, Annual Economic Statistics reported the gross output of the livestock industry reached 15.2 billion Malaysian Ringgit (Department of Statistics Malaysia, 2019). The large amount of chicken manure produced by the industry has created environmental problems such as air, water, and land pollution (Peigné and Girardin, 2004). It also attracts flies since the nutrients found in the manure serve as a perfect breeding ground for fly larvae (Hulley, 1983). Therefore, there is a need to

ISSN Online 2630-0087

manage poultry waste effectively using treatment processes or by turning it into value-added products.

Chicken manure is usually sold untreated as fertilizer. This practice has contributed to a wide spread fly problem that has affected the local livelihoods and living conditions. Alternative manure treatment methods such as using pesticide, daily collection for disposal and anaerobic digestion could be successful but incur high operational costs. The use of pesticide can also induce algae blooms and endangers aquatic lives in water bodies (Khan and Ansari, 2005) while anaerobic digestion requires a large footprint (Gujer and Zehnder, 1983). Composting is a proven treatment process to convert manure into a soil-friendly fertilizer (Chan et al., 2011).

Poultry farmers often overfeed the chickens to meet a minimum weight of 2 kg prior to entering the market. This practice has resulted in a large daily manure generation with a high protein content along with other nutrients such as carbohydrates and minerals (Singh et al., 2018). These nutrients can be converted into a high-quality organic fertilizer via a composting process. Composting uses microbial activity to stabilize organic wastes under controlled pH, temperature, and humidity. During the process, aerobic microorganisms decompose the biodegradable organic materials to produce a stable end product known as compost that is rich in humic acid-like substances (Rupani et al., 2010). Generally, manure composting takes a long time such as 40 days for cow manure (Qian et al., 2016), 90 days for goat manure (Jusoh et al., 2013) and 45 days for chicken manure (Li et al., 2017). The process can be enhanced by adding composting agents such as composting worms and effective microorganism (EMs). EMs are a mixture of microorganisms first developed in 1982 to enhance specific natural processes such as the digestion system (Côté et al., 2006) and composting (Van Fan et al., 2018). This study aimed to determine suitable local EMs based on cost and compost quality.

2. MATERIALS AND METHODS

2.1 Materials

Chicken manure was obtained as an in-kind Manjung. Local EMs, EM1 and EM2, were purchased from a local agriculture supplies store while imported EM3 (currently used by Dindings Poultry) was supplied by Dindings Poultry (Malaysia). Sawdust was obtained from Wan Sang Sawmill Enterprise Sdn. Bhd. (Malaysia) as an in-kind contribution.

2.2 Feedstock preparation

Two control batches consisting of chicken manure alone (EM0) and chicken manure with sawdust (CM30) were prepared. Sawdust was used as a carbon adjuster to produce compost feedstock at carbon to nitrogen (C/N) ratio of 30:1. C/N ratio range of 20-30 is widely accepted as the ideal balance between carbon and nitrogen materials in composting pile with C/N 30 being the optimum (Hau et al., 2020).

EM1 was activated prior to application according to the method outlined by Jusoh et al. (2013) and Mandalaywala et al., 2017. One part of EM1 was mixed with 20 parts of a mixture containing molasses and water. The EM1 solution was set to ferment for three days. EM2 was a ready-to-use product that required no activation. It was diluted at a ratio of one part of EM2 to 20 parts of water similar to EM1. The imported EM3 was used directly in its solid form as per application instruction from the manufacturer. All EMs were stored away from sunlight to avoid bacterial contamination. Table 1 summarizes the characteristics of all EMs used in this study.

2.3 Aerobic composting

A 30-L HDPE multipurpose container was modified into a composting bin. Adequate aeration holes were installed in the bin with a plastic mesh cover to protect from insects. The bins were located on an outdoor rack under shelter for composting activity. The composting setup is illustrated in Figure 1. Five batches of compost were prepared according to Table 1. A weekly addition of EM solution was given at 5% of initial weight of compost until maturation was reached. Every 3 days, the temperature and pH of the compost were recorded in triplicate using a GoerTek digital soil multimeter and the pile was re-mixed. The composting method and analysis were conducted according to the method outlined by Hau et al. (2020).

Table 1 List of compost composition, C/N ratio and comparison of EMs used

Name	Composition	Composition (%)		Theoretical	EM Characteristics		
		C	N	C/N	Appearance	Activation	Odor
EM0	Chicken manure (4 kg)	21.12	5.52	3.826	-	-	-
EM1	Chicken manure (4 kg) + EM1 (20-25 mL)	21.12	5.52	3.826	Viscous liquid	Yes	Molasses-like
EM2	Chicken manure (4 kg) + EM2 (20-25 mL)	21.12	5.52	3.826	Liquid	No	Manure-like
EM3	Chicken manure (4 kg) + EM3 (3.0 grams)	21.12	5.52	3.826	Cornmeal-like	No	Hay-like
CM30	Chicken manure (1.4 kg)	21.12	5.52	30	-	-	-
	Sawdust (2.6 kg)	45.93	0.125				

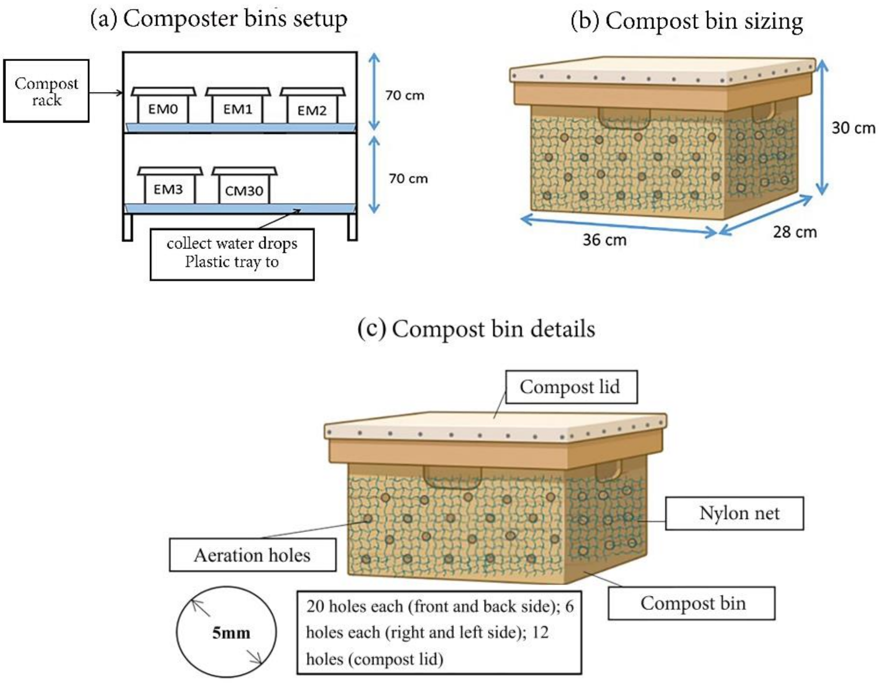

Figure 1 Compost bin illustration of (a) outdoor rack setup, (b) dimension and (c) design features

Composting requires moisture content to allow optimum biodegradation. A range of 50-70% on wet basis is frequently used. Some suggested moisture contents are 65-75% by Guo et al. (2012) and 50-60% by Jusoh et al. (2013). In this study, moisture content was maintained between 60-70% during composting.

Richard et al. (2002) explained that moisture content outside the mentioned range causes a significant reduction in biodegradation rate, thus adding water over time can compensate the loss of moisture to maintain the biological activity. To determine the moisture content, samples were taken and dried at 105ºC for 24 hours followed by an hour storage in a desiccator. The moisture content is then determined using Equation 1.

$$MC\ (\%) = \frac{W_w - W_d}{W_w} \times 100 \qquad (1)$$

where MC is the moisture content of the materials (%), W_w is the wet weight of sample before drying (g) and W_d is the dry weight of sample after drying (g).

3. RESULTS AND DISCUSSION

3.1 Profile of temperature and pH

Measurements of temperature and pH were used to determine the maturation period of the composts. Result variation was expected as the experiment was conducted outdoors under a covered shelter. Triplicate readings were done to minimize this variation. All composts reached maturity at the end of 45 days as can be seen from the constant values of pH and temperature in Figure 2. Similar trends of temperature and pH profiles are also found by Jusoh et al. (2013) and Lew et al. (2020).

Composting parameters such as temperature and pH have a direct impact on composting maturity. Temperature recordings in Figure 2 suggested that the temperatures were in the mesophilic range with the highest and lowest temperature recorded at 45ºC and 27ºC, respectively. The highest temperature recorded was obtained by CM30 due to the addition of sawdust that contained the heat inside the composting system. Troy et al. (2013) stated that the addition of sawdust increase the net energy yield of the compost system. However, with increasing sawdust dosage, the net energy yield decreased, indicating the importance of materials balance for carbon to nitrogen sources within the composting pile. Fluctuating pH was caused by the acids produced during the degradation and nitrification process (Oliveira et al., 2018). Towards the end of the composting process, the fluctuation reduces and eventually stabilizes. Compost is considered matured when the temperature of the compost pile reaches near-ambient levels (Cooperband, 2000).

Comparing EM-treated composts with the control batches (EM0 and CM30), composts without EM displayed a more irregular pattern of temperature and pH. This may be because EM addition counterbalanced the temperature and pH effect due to enhanced microbial activity in the piles. EMs are a group of good bacteria assisting the composting process, therefore, various species may be able to provide checks and balances of the composting system (Cooperband, 2000).

During the initial stage of composting (Figure 2), a release of hydrogen ions during the nitrification process in the composting cause the pH to decrease (Cáceres et al., 2016; Cáceres et al., 2018). The lowest pH recorded during composting process was pH 4.8 for EM3. All composting piles experienced temperature and pH fluctuations as the result of weather and acid accumulation until the maturation period. Generally, composting can tolerate a wide pH range but extreme acidic conditions can affect the process and produce an unhealthy compost that is detrimental to soil (Sánchez et al., 2017). From the temperature and pH profiles, this study revealed the maturation period to be at 24, 27 and 45 days for EM1, EM3 and EM2, respectively.

3.2 Compost characterization

Figure 3 shows the K, Mg and Na content in the samples. A sharp peak in K value of 412 ppm concentration was found for EM1 as the highest amongst all samples, followed by EM2 and EM3 at 213 and 276 ppm, respectively. Na concentration was the highest for EM2 and EM3 at about 51 ppm, which was double than EM1 at 27 ppm. Mg showed a similar trend with EM2 and EM3, having the highest content at about 230 ppm, followed EM1 at 198 ppm. Similar results were reported by Jusoh et al. (2013) and Hau et al. (2020).

Commercial inorganic fertilizers generally have higher NPK values compared to organic fertilizers. The NPK content of inorganic fertilizers can be enhanced directly with the addition of specific chemical additives that contain a high concentration of N, P and K, whereas the organic fertilizers have limitations in this respect due to green certification requirements. Organic additives such as fish meal, bone meal and palm oil bunch ash can be used to improve the final compost's NPK (Hau et al., 2020). Composting agents such as EMs can potentially increase the NPK content of the compost as demonstrated in this study.

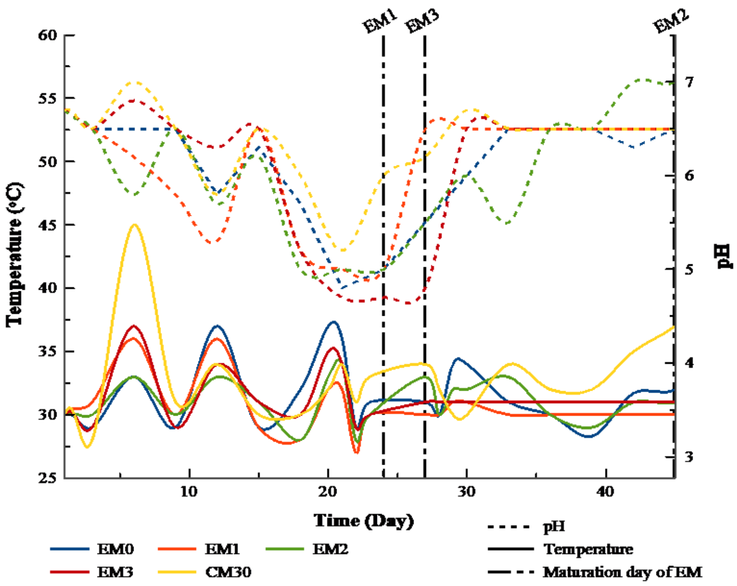

Figure 2 Temperature and pH profiles of composting (lines indicate maturation periods)

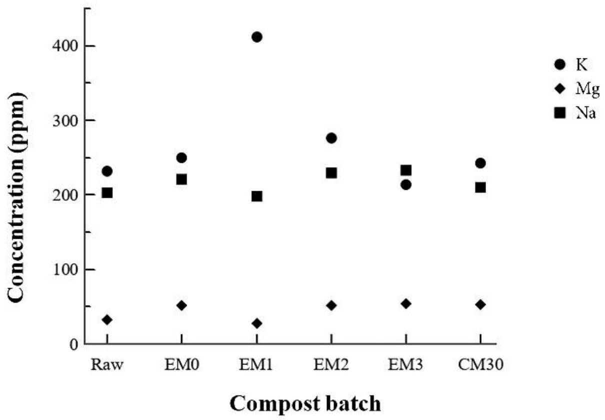

Figure 3 Potassium, magnesium and sodium concentration in final compost products

The NPK values recorded in this work were 3:4:9 (local EM1), 4:5:3 (local EM2) and 3:3:3 (imported EM3), in comparison to control batches of EM0 at 1:1:3 and CM30 at 3:3:6. Although the values were far less than typical NPK values of 10:10:10 for commercial chemical fertilizers, organic fertilizers offered balanced nutrient contents for plants with no environmental side effects. Furthermore, organic fertilizers are rich in micronutrients and humic acid, which acts as a plant's growth promoter (Khiew et al., 2020).

According to Figure 4, EM1 was a better option to increase N and P values whereas K values can be enhanced by EM2. EM1 was also found to have the fastest maturation period. Combination of local EMs (EM1 and EM2) could potentially improve the NPK content and maturation period of a composting pile. Further work is needed to prove this hypothesis.

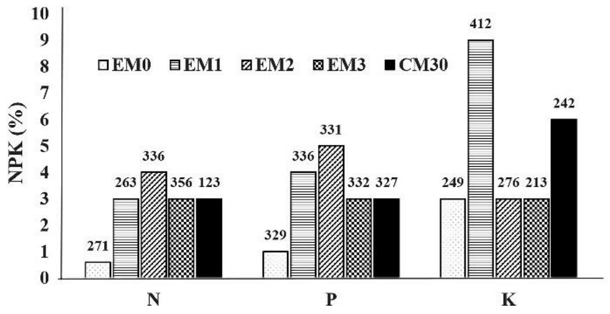

Figure 4 NPK of compost with EMs

Note: NPK values of control setups (EM0 at 1:1:3 and CM30 at 3:3:6) were taken from previous work; numbers on bar graphs indicate the values in ppm.

Carbon has been used by the microorganisms as a source of energy to perform decomposition (Elango et al., 2009). This can be seen in Figure 5 where the energy content of all EM-treated composts decreased throughout the composting period except for CM30 compost. This setup contained sawdust as the carbon adjuster (to reach a C/N ratio of 30:1), which increased the energy value. Naturally, matured compost should have a lower energy content due to carbohydrate decomposition. However, compost that is rich in fiber such as from cow and horse manure could still possess a high energy content due to its cellulosic content that is not easily degradable (Hubbe et al., 2010). With sufficiently low moisture content, such composts can be used as a solid fuel for heating purposes (Irvine et al., 2010).

3.3 Cost analysis

Based on the cost calculation in Table 2, the lowest application cost (171 Malaysian Ringgit) is obtained by EM3 followed by EM2 (547 Malaysian Ringgit) and EM1 (656 Malaysian Ringgit). The calculation was done based on treating 1 tonne of manure according to the application dosage suggested by the manufacturers. Since EM3 was purchased in bulk quantity (tonnes), it has resulted in the lowest cost as compared to EM1 and EM2 that were estimated based on off-the-shelf price. The local EMs used in this study were sold for household composting usage in 1L volumes rather than tonnes. This uneven pricing comparison has contributed to a wide variation in the cost analysis. Some strategies to reduce the error were by obtaining the bulk purchase of EM1 and EM2 as well as applying EM dosage according to bacterial concentration rather than recommended dosage. These two methods were, however, beyond the scope of this study due to the commercial sensitivities of the EM producers.

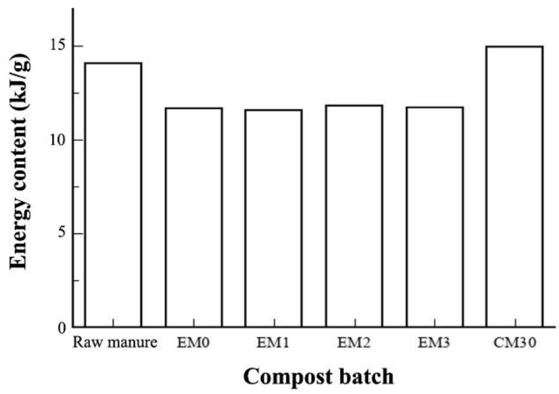

Figure 5 Energy content (kJ/g) of composts

The NPK increment content was found in the order of EM1 (3:4:9), EM2 (4:5:3) and EM3 (3:3:3). Compost with a higher NPK content such as the ones produced with EM1 and EM2 can be sold at a higher price compared to compost of EM3. This profit margin can offset the relatively higher cost for the EM purchase. Future research should explore the possibility of growing in house EMs by utilizing poultry biomass waste. Using this approach, the poultry industry could reduce the cost of EMs significantly and could promote circular economic activities from conversion of biomass waste into value-added products which could further increase the overall business profit.

Table 2 Cost analysis of effective microorganisms

	EM 1	**EM 2**	**EM 3**
Initial cost of EM	Malaysian Ringgit 35/1 L EM + 1 L Molasses	Malaysian Ringgit 25 / 1 L EM	Malaysian Ringgit 57/kg
Cost per usage time	25 mL EM + 25 mL Molasses	25 mL EM	3 grams EM
Cost per tonne of manure (Malaysian Ringgit)	656	547	171

4. CONCLUSION

Local and imported EMs were investigated for effectiveness in composting poultry manure. Compost maturation was obtained at day 24, 27 and 45 for EM1 (local), EM3 (imported) and EM2 (local), respectively. The highest temperature recorded was 45ºC for CM30 compost (control batch containing manure and sawdust) and the pH was between 5.0 and 6.5 for all setups. The highest values obtained for K (412 ppm), Na (233 ppm) and Mg (54 ppm) with low energy (11.7 kJ/kg) and application cost (171 Malaysian Ringgit/tonne manure) suggested EM3 was the best option. High NPK values of EM2 and faster maturation of EM1 could make both local EMs as a promising local substitute. Future work should investigate the potential mixture of these EMs for optimizing composting time and quality. The potential application of various farm litters and biomass waste as growth media for in-house EM breeding should be investigated. Apart from promoting a circular economy, poultry biomass utilization will benefit the environment and could alleviate the regional fly problem caused by improper poultry waste disposal.

ACKNOWLEDGMENT

The authors would like to acknowledge Dr. Aaron Low of Ligar LP New Zealand for the technical advice, the Ministry of Higher Education Malaysia for the financial support via research grant of FRGS (015MA0-093) and HICoE to CBBR as well as the in-kind contribution from Dindings Poultry Sdn. Bhd. (Malaysia).

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