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Optimizing household waste composting: A comparative study of activators in rotary communal composters for sustainable waste management

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ABSTRACT

Indonesian landfills have a shorter lifespan due to the burgeoning amounts of mixed waste. The government should apply locally adaptable, simple, and affordable techniques for waste recycling. This study aimed to optimize the performance of community composters based on the various activators used. Within such a context, the systems will be designed to cope with household waste, mainly dominated by organic biodegradable waste. In the research, testing was done on three activators: mature compost, effective microorganism 4 (EM-4), and Promi. The last two are commercial compost activators. This research is a follow-up to the earlier studies that used the best rotary communal composter design: compact, space- and area-saving, mobile, odourless, and pleasurable. The testing comprised analyses of the compost maturity, quantity, and quality. Accordingly, it showed that the best quality compost was obtained with an activator of EM-4 within only 16 days. Interestingly, the inclusion of mature compost as an activator gave a relatively short duration of 18 days, therefore displaying competitive performance in terms of EM-4. This study shows that the application of EM-4 in rotary communal composter is the most preferred technique for the management of biodegradable waste at a community level.

Keywords: communal composter, household waste, activator, compost maturity, compost quality, compost quantity.

INTRODUCTION

Rapid population growth in urban areas has led to a significant increase in waste generation, particularly organic waste (Ray et al., 2021). In Padang City, West Sumatra, Indonesia, recycling potential of organic biodegradable waste makes up 59.42% of domestic waste (Raharjo et al., 2019). The average water content of domestic waste in this city was 54.02% (Maryanti, 2010), and the C/N ratio was approximately 27 (Azkha, 2006). This data indicates that urban domestic waste is easily decomposed, which correlates with the high population of flies found in the waste (Hayati, 2010). Poor waste management can result in various environmental issues, such as disease spread and flooding due to clogged waterways (Das et al., 2019; Ferronato and Torretta, 2019; Abubakar et al., 2022; Somani, 2023). Composting has been identified as a plausible approach in the management of organic wastes (Vimieiro et al., 2015; Lin et al., 2018; Ayilara et al., 2019; Bilkiewicz-Kubarek et al., 2024), and this means of disposal is useful in waste volume reduction with an added advantage of providing an organic fertilizer through the compost product (Hassan et al., 2023; Yin et al., 2024). Previous research has focused on improving communal composters, a simple technology used at the community level to process organic waste (Raharjo et al., 2021). A compact, space-saving, mobile, odourless, and beautifully designed communal composter is the rotary drum composter method with mechanical blower application. This design will hasten the composting process and greatly improve aeration. In using a communal stirring composter and adding a blower to it, previous research has proven that it can produce good quality compost, but still leaves much to be desired in terms of composting time.

Our research aims to enhance the performance of communal composters by studying the impact of different activators on the composting process. The activators used in this research are mature compost, effective microorganism 4 (EM-4), and Promi, a commercially available microbial inoculant with a mixed culture of beneficial microorganisms, and Promi, a commercial compost activator containing Trichoderma sp. and cellulolytic bacteria (Resman et al., 2023). These activators were selected because of their wide availability and low cost. Using activators can accelerate the composting process and improve the compost quality (Zhou et al., 2022). This research employs an experimental method to test the performance of the communal composter using the three variations of activators. The parameters tested include compost maturity, quantity, and quality of the compost produced. By testing different activator variations, this research seeks to find the best combination that can be widely applied by the community to process household waste.

This research is significant as it offers practical solutions for urban communities to manage their organic biodegradable waste. As reported by IGES Centre Collaborating with UNEP on Environmental Technology (CCET) and United Nations Environment Programme – International Environmental Technology Centre (UNEP – IETC), Padang City Government should apply locally adaptable, simple, and affordable techniques in waste recycling in order to increase the lifespan of landfill (Hayashi et al., 2022). Additionally, using communal composters, which are easy to operate, can encourage community participation in waste management, reduce negative environmental impacts, and produce beneficial products. The results of this research can serve as a reference for developing composting technology in the future and make a tangible contribution to sustainable waste management efforts in Indonesia.

MATERIALS AND METHODS

In this regard, the study assessed the different activators that directly influenced the performance of communal composters in handling biodegradable wastes. The research applied three types of variations: mature compost, variation A; effective microorganism 4 (EM-4), variation B, and variation C (Promi). Each activator was to undergo similar conditions so as to establish its efficacy in terms of speeding up decomposition and improving the quality of the compost. Here, the dosage of mature compost as the activator is used in the Takakura method, with the dosage of mature compost 20% of the capacity of the composter. While in the case of EM-4, the dosage used is according to the instructions on its usage; that is, in the ratio of 1:1:50, 59 ml of the EM-4 activator is added to 59 g sugar and 2.9 L of water. On the dosage of Promi, according to its usage instructions, 1 kg of the Promi activator can decompose 500 kg of wastes.

For the current process, the communal composter designed in our previous study was used, with a capacity of 150 L, a diameter of 50 cm, and a height of 76 cm. It is a rotary drum composter combined with a mechanical blower and air channel drainage, inclusive of a vent. It serves around 49 families and has a capacity for raw materials of 59 kg with bulking agents of 0.8 kg, hence giving a total capacity of 59.8 kg. The mechanical blower is used to pump in air while mixing the compost pile for extra aeration. The vent allows for the natural flow of air into the composter. The design also incorporates aeration holes to control the internal temperature and wheels on the bottom frame for easy mobility. The outlet at the bottom permits liquid compost drainage. Manual stirring is performed by rotating the drum to maximise contact between the ingredients. Figures 1 and 2 demonstrate the image, plans, and sections of communal composter design.

The food waste composition from domestic sources, organic waste generation, composition, and recycling potential were referenced by Alhusna, 2009 and Maryanti, 2010. The materials used included wastes that were biodegradable of domestic origin in Padang City, West Sumatera, Indonesia: food waste – vegetable scraps and remains of fruit, rice, and side dishes – and yard trimmings – leaves. They were then chopped into small pieces using a chopping machine. The bulking materials were sawdust, rice husk ash, bran, and dolomite. Food waste, yard waste and bulking agents are put in a rotary drum that stirs and aerates the compost. Composting was done by stirring three times a day, morning, afternoon, and evening, manually, with aeration using a blower for 2 minutes after each stirring. The study design is presented in Table 1.

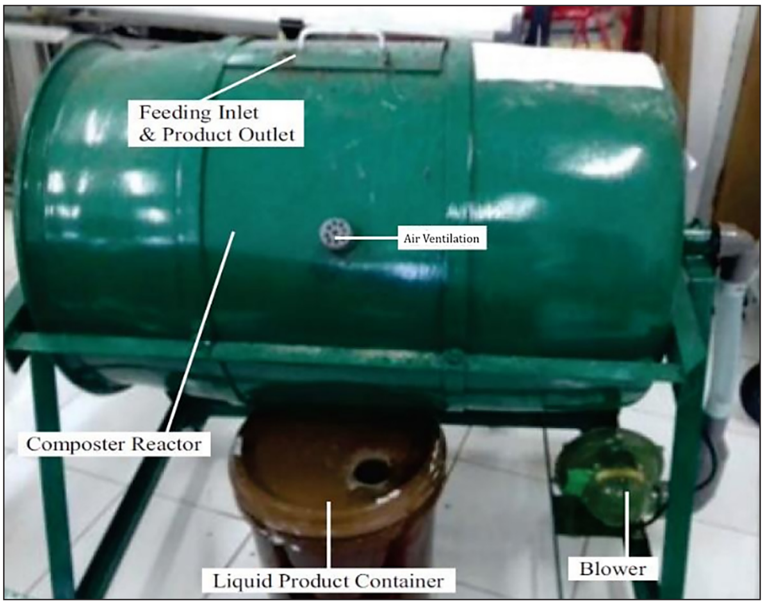

Figure 1. The communal composter (Raharjo et al., 2021)

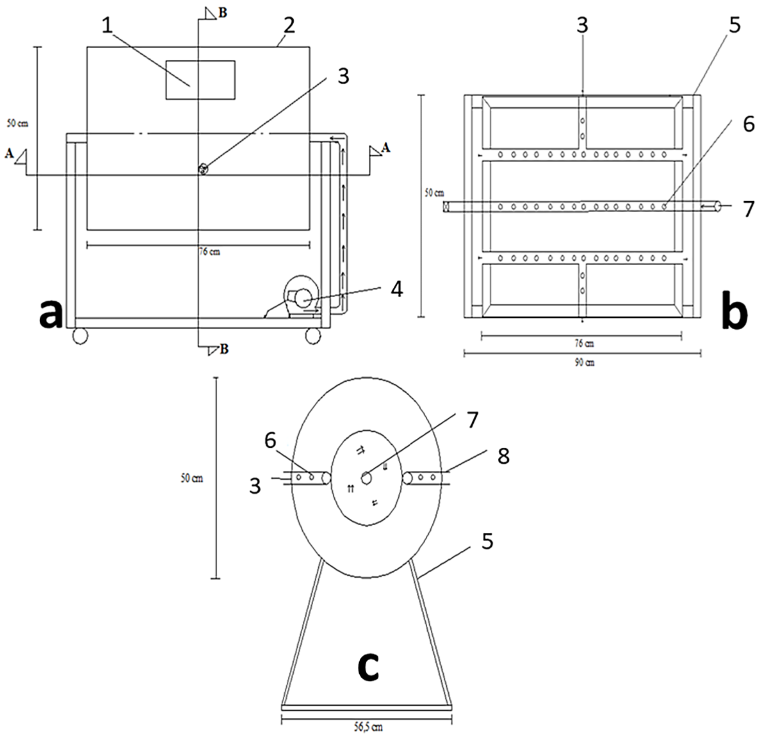

Figure 2. Communal composter design (a) floor plan (b) pieces A-A (c) pieces B-B) 1 – hole for inserting or taking out composting material; 2 – compost tube; 3 – vent; 4 – blower; 5 – frame; 6 – aeration holes; 7 – pipe to supply air to the blower; 8 – drive frame

Measurements and analysis involve evaluating compost maturity, quantity, and quality. Compost maturity is assessed based on temperature, pH, texture, colour, and odour. Temperature and pH are recorded thrice daily using a thermometer and pH paper. Texture and colour are observed visually, while odour is assessed by smell. Compost quantity is determined by weighing the solid compost and measuring the volume of liquid compost after the composting process. Solid compost is sifted using a sieving machine (7.5 mm), while liquid compost is measured by volume. Compost quality is tested in the laboratory according to Indonesian National Standard Number 19-7030-2004 and Indonesian

Table 1. Composting materials

Variations	Activators	Materials	Bulking	Treatments
A	Mature compost (11.8 kg)	91.25% Food waste 8.75% Yard waste	50% sawdust 20% rice husk ash 25% bran 5% dolomite	Stirring (thrice a day) Blower (2 min after stirring) Vent
B	EM-4 (59 mL)			
C	Promi (0.1 kg)			

Minister of Agriculture Regulation Number 70 of 2011, including C-organic, nitrogen, phosphorus, and potassium levels.

The data collected is analysed to assess the effectiveness of each activator in accelerating the composting process and improving compost quality. The analysis involves calculating the compost's maturity level, quantity, and quality for each activator variation (Raharjo et al., 2021).

In this research, the types of waste processed were still limited to household waste. However, even though the waste samples came from housing in Padang City, the results of this study can also be applied in other cities in Indonesia because their wastes have generally similar characteristics. In addition, the activators used are those that are easily available in agricultural markets in Indonesia, which may not be available in other countries.

RESULTS AND DISCUSSIONS

Compost maturity

Temperature

Figure 3 illustrates that all three variations reached the maximum temperature on the third composting day. The highest maximum temperature was recorded for variation B at a temperature of 47 °C; the lowest was in variation C, at a temperature of 44 °C. This was an indication that it was in a mesophilic phase rather than a thermophilic phase, where it is supposed to have a maximum temperature of 50 °C. EM-4 led to an increase in temperature towards the mesophilic phase, thus depicting a high level of microbial activity and, hence, efficiency in decomposing organic matter (Biyada et al., 2021).

pH

The activator significantly influenced the pH change process. In variation A, the pH drastically increased to 8 on the 9th day, then decreased to 5 before rising to a neutral pH on the 18th. In variation B, the pH gradually moved towards neutral by the 14th day, with the neutralization process occurring faster than in variation A. Meanwhile, variation C reached a neutral pH by the 24th day (Figure 4). Bacteria in variation B with the EM-4 activator worked more effectively than in variations A and C. The higher temperature in variation B accelerated the decomposition of organic material, increasing the pH value. Compost using EM-4 achieved pH stability more quickly toward neutral, indicating optimal decomposition and a supportive microbial environment (Rastogi et al., 2020).

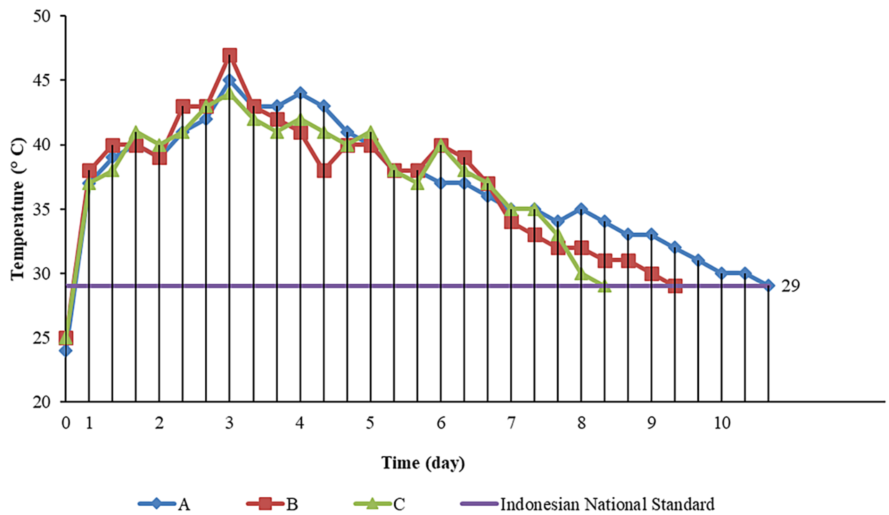

Figure 3. Changed temperature during composting for each variation of activator

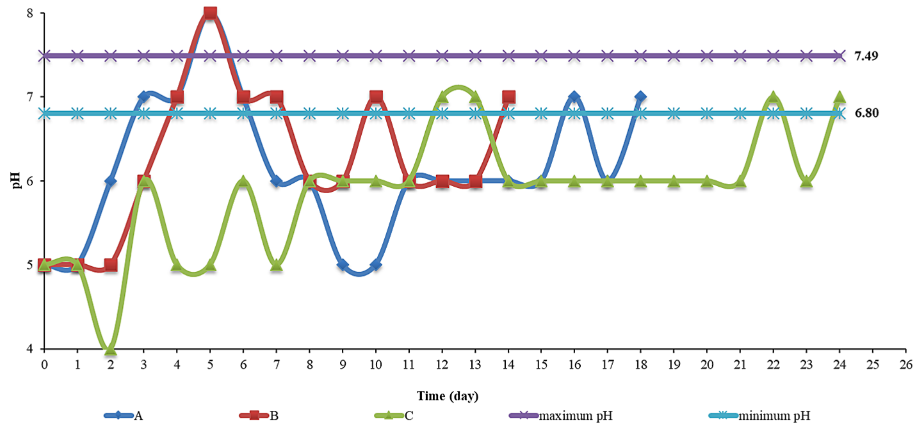

Figure 4. Changed pH during composting for each variation of activator. Maximum and minimum pH based on Indonesian National Standard No. 19-7030-2004

Texture and colour

According to the Indonesian National Standard (SNI 19-7030-2004), compost is considered mature when its texture and colour resemble that of soil. In this study, the texture and colour of the compost in each variation met the standard values. More detailed information can be found in Figures 5 and 6.

Odour

According to Figure 7, at the start of the composting process in each variation, there was a strong smell of food waste, particularly vegetable waste. This strong odour started to decrease between the 2nd and 4th day. The odour is caused by the presence of anaerobic conditions. It is due to the formation of ammonia (NH_3), hydrogen sulphide (H_2S), volatile organic acids, mercaptans, and metal sulphides under anaerobic conditions (Andraskar et al., 2020). Composting in variations A, B, and C produced an earthy smell on days 13, 11, and 17, respectively.

The composting time is determined by the time it matures based on specific parameters (SNI 19-7030-2004). Compost is considered mature when it reaches groundwater temperature (below 30 °C), has a pH between 6.80 and 7.49, and exhibits soil-like texture, colour, and temperature. Variation A (mature compost) reaches maturity in 18 days, variation B (EM-4) in 16 days, and variation C (Promi) in 28 days. Variation B (EM-4) has the fastest composting time and the highest quality maturity, as indicated by its temperature, pH, texture, colour, and smell. This suggests that the microorganisms in EM-4 are more efficient in breaking down organic material, resulting in quicker and higher-quality mature compost.

Interestingly, the addition of mature compost as an activator gave a relatively short period of 18 days, thus showing competitive performance with regard to EM-4. This agrees with previous studies (Zhou et

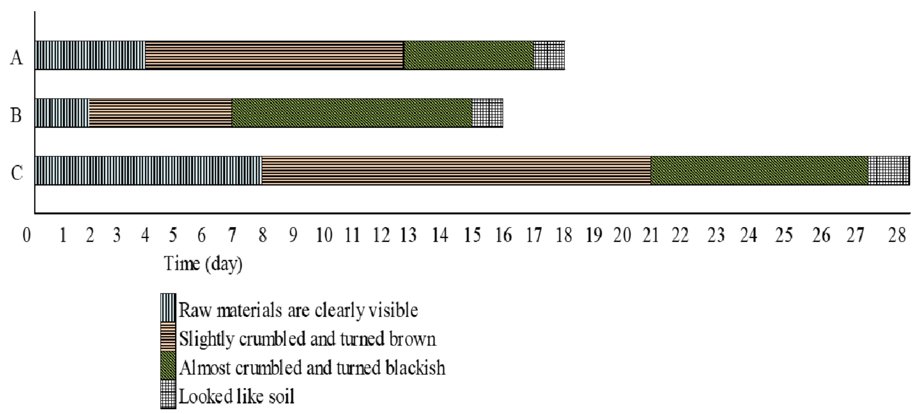

Figure 5. Changed texture and colour during composting for each variation of activator

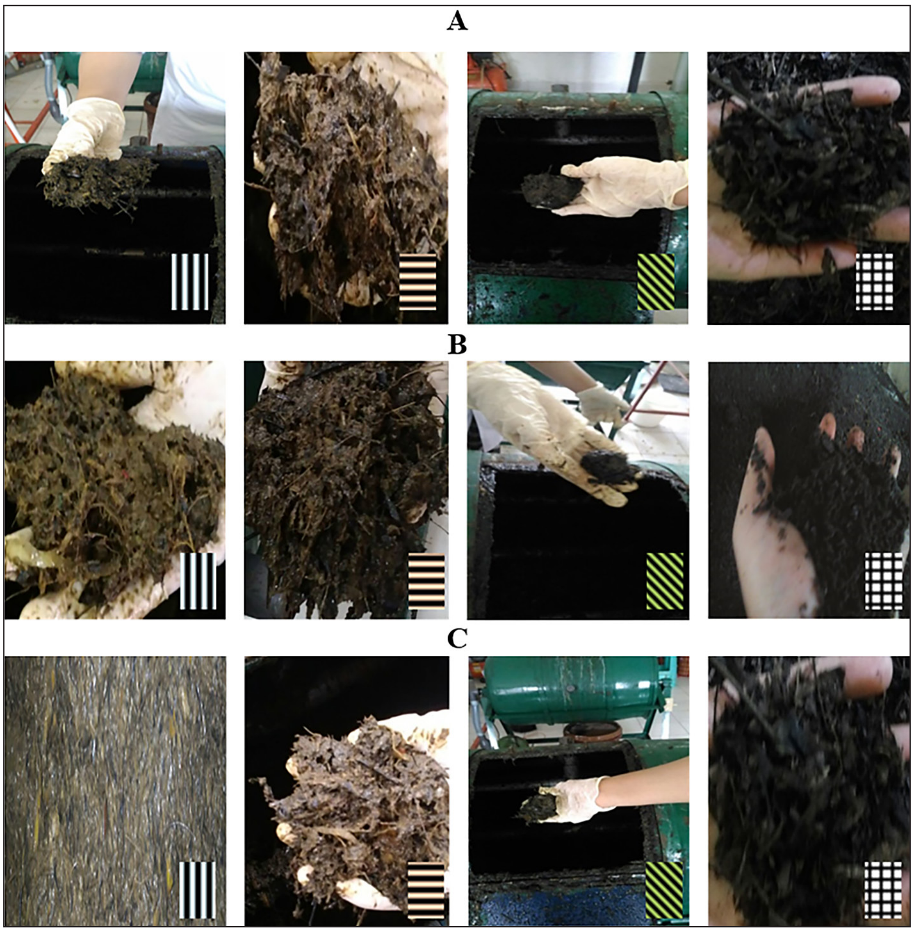

Figure 6. Photographs of texture and color changes in compost. Shading symbols correspond to those in Figure 5

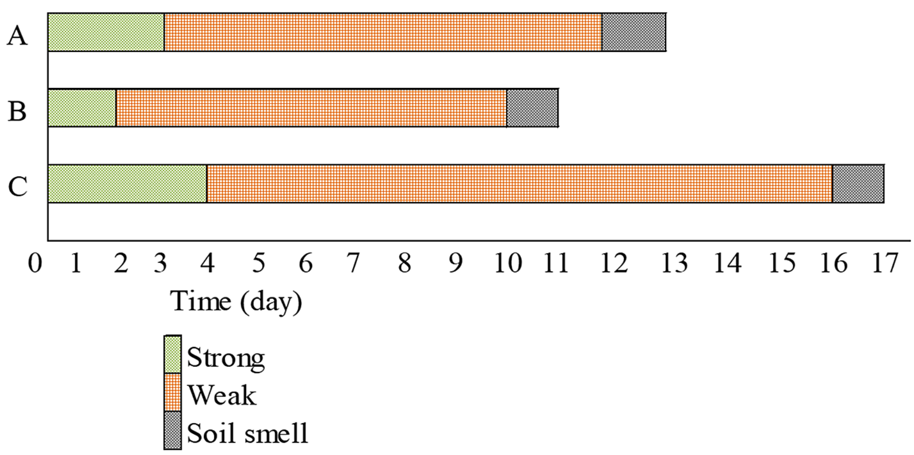

Figure 7. Changed odour during composting for each variation of activator

al., 2022) that have also documented the effectiveness of mature compost in accelerating this process and enhancing the quality of compost due to its complete content of microbes and nutrient profile. Moreover, while Promi is a commercially available product, the time it took to mature was the longest, at 28 days. This could be due to the fact that it is especially formulated for agricultural wastes with high lignin content and therefore might differ in both composition and degradability compared with the household wastes this research made use of, which are mainly composed of food scraps and yard waste. The complex organic matter in agricultural waste, like lignin, may break down easily and would not require more time for composting for Promi to effectively decompose (Indrayani et al., 2021).

Compost quantity

In this study, we presented the total amount of produced compost in both solid and liquid forms. The solid forms of compost produced from the three activator variations differed: the most was given by variation B (EM-4), at 36 kg; the variation with mature compost (variation A) was 35.5 kg; the variation with Promi was the least, at 34.5 kg, due to the fact that *Lactobacillus* sp. is not very available. It means that bacteria in EM-4 accelerated decomposition of organic materials. On the other hand, yard waste itself, especially lignin in fallen leaves, was recalcitrant to decomposition.

The quantity of liquid compost, collected from the outlet pipe after the temperature of the compost fell to less than 30 °C, also differed among the types of activators. Variation B, with EM-4, yielded 20 L; variation C with Promi, yielded 17 L; while variation A, with mature compost, yielded the least at 16 L. A greater yield in variation B indicates that the type of activator, that is, EM-4, utilizes available water more efficiently during the process of composting.

The reduction level in the study was also assessed as a parameter for the extent of decomposition of the compost. An ideal reduction level for composting would range between 20–40%. The reduction level obtained in all three variations fell within 34–37%. Variation B showed a higher reduction level due to the better performance of the EM-4 microorganisms on the decomposition of the organic matter. The recapitulation is available in Table 2.

Further, the mass balance analysis, as depicted in Figure 8, revealed that the initial composition of the compost was 100% and it degraded to solid compost, residue, and liquid compost, in percentages of 58–60, 3–8, and 27–33, correspondingly, while the balance amount evaporated.

Compost quality

The compost quality is assessed based on C-organic, nitrogen, phosphorus, and potassium levels. All variations must meet the standards of SNI 19-7030-2004 and Minister of Agriculture Regulation Number 70 of 2011. The macro elements of solid compost in each variation must comply with SNI 19-7030-2004 regarding Compost Specifications from Domestic Organic Waste. Tables 3 and 4 present a summary of solid and liquid compost quality in this study, indicating that it meets all compost quality parameters per Minister of Agriculture Regulation 70 of 2011, except for nitrogen and potassium

Table 2. Assessment of compost quantity

Variations	Total raw (kg)	Solid compost (kg)	Residue (kg)	Liquid compost (L)	Reduction rate (%)
A	59.8	35.5	3	16	36
B		36	1.5	20	37
C		34.5	5	17	34

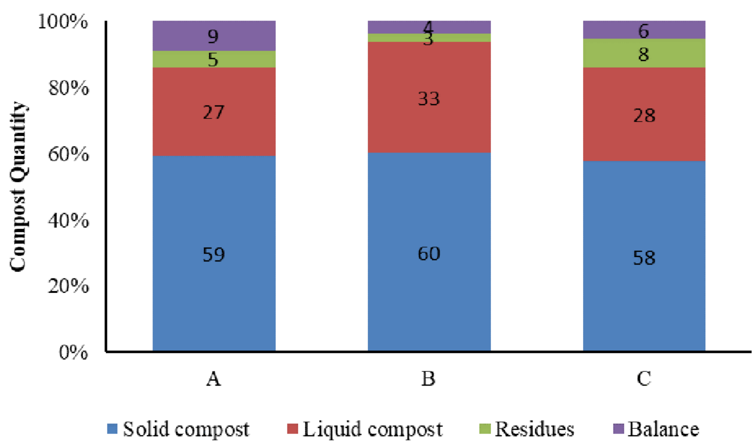

Figure 8. The percentage composition of compost

Table 3. Solid compost quality

Variations	Water content (< 50%)	C-Organic (9.8–32)	Nitrogen (> 0.4%)	C/N (10–20)	Phosphorus (> 0.1%)	Potassium (> 0.2%)
A	47.75	15.69	1.00	15.69	12.21	5.62
B	45.85	13.83	1.06	13.05	19.56	6.52
C	49.99	17.31	0.98	17.67	4.85	2.38

Tabel 4. Liquid compost quality

Variations	C-Organik (min 6%)	Nitrogen (3–6%)	Phosphorus (3–6%)	Potassium (3–6%)
A	7.39	0.56*	10.37	4.16
B	6.10	0.60*	10.96	4.66
C	7.94	0.46*	3.90	1.91*

Note: * non-conformance with the Indonesian Minister of Agriculture Regulation No. 70 of 2011.

levels in variation C (liquid). The low levels of nitrogen and potassium in variation C are a result of the small amount of these elements released in the liquid. As a result, the potassium content in the solid is still high. This indicates that the quality of the solid compost is better than that of the liquid compost. For optimal application, it is necessary to combine the use of both solid and liquid compost.

Variation B (EM-4) yielded the most favourable results in terms of nutritional balance, followed by variation A (mature compost) and variation C (Promi). The optimal levels of organic carbon, nitrogen, phosphorus, and potassium in EM-4 compost indicate that this compost has the potential to enhance soil fertility and support sustainable agriculture significantly.

CONCLUSIONS

The research findings indicated that communal composters performed better in processing organic waste using an EM-4 activator. It expedited the composting process by up to 16 days, producing the largest quantity of solid and liquid compost. It improved the quality of the compost through the optimization of its nutritional elements. Compared with mature compost and Promi, EM-4 yielded better results across all parameters measured.

These results indicate that EM-4 represents a pragmatic and effective choice for communal composters, offering the effective way of solving the problems of managing organic wastes by urban communities. With an equipped communal composter using EM-4, refuse sent to landfills is reduced in volume, high-quality compost produced for use as an organic fertilizer, and fosters sustainable agriculture.

Specifically, this study offers significant contributions to waste management and composting technology. Such results will foster the use of more effective and more environmentally friendly composting technology within communities, bring awareness to all about the need for practicing sustainable waste management, and further drive the said-AIP implementation in the community for sustainable waste management.

To sum up, EM-4 application as an activator in a rotary communal composter provides the best performance whether for compost maturity, quantity, and quality. These results indicate that the best remedy in boosting the performance of communal composters is EM-4. This technology is not labor-intensive and easy to adopt; hence, in most cases, it will be applicable to urban communities desiring a practical solution to their problems in organic waste management, providing community-based technology option that can be implemented by local governments. Besides reducing wastes, high quality organic fertilizer can be produced with communal composters through an EM-4 activator, thus helping to support more sustainable waste management.

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