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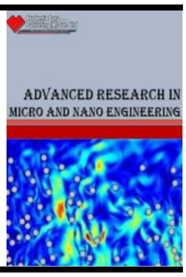

The Influence of Compost Bin Volume and Effective Microorganisms (EM) Quantity for Efficient Food Waste Composting

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ABSTRACT

The utilization of effective microorganisms (EM) in composting has gained substantial prominence since this additional microorganism is believed to overcome natural composting issues, such as slow decomposition and odour generation. However, a lack of awareness and education about proper composting practices involving EM can result in errors that diminish the decomposition process's effectiveness. Thus, this study aims to enhance the decomposition process's efficiency with emphasis on the balance between EM and food waste, as well as the void space within the compost bin. The investigation employed a varying EM quantity ranging from 20 to 100 ml and compost bin volumes of 6, 9, and 21 L. The food waste is mixed with 60% of the volume of each compost bin. The parameters assessed during the composting process include temperature and pH profile. Additionally, the mature sample after 20 days was then examined through the organic matter (OM), total organic carbon (TOC), and nutrient content, including nitrogen (N), phosphorus (P) and potassium (K). A series of controlled experiments found that the 21L compost bin possessing over 65 % free space reached a thermophilic temperature of 51.5°C within a remarkably brief one-day period and attained maturity within seven days, accompanied by a pH level of 7.4. Conversely, the 6L and 9L compost bins did not progress into the thermophilic phase or reach maturity during the seven-day observation period. The findings also indicate that the optimal quantity of EM required to decompose 600 grams of food waste exceeds 80 mL. They reached thermophilic temperature within eight days. These conditions fostered an environment conducive to accelerated decomposition and nutrient preservation. Notably, the final compost produced from these settings met established criteria for high-quality organic compost. This paper provides practical insights into achieving optimal conditions for EM application, thereby maximizing its effectiveness in food waste composting at source. Beyond the technical aspects, the research gives the broader social and environmental effects of home food waste composting, including its contribution to reducing landfill waste, greenhouse gas emissions, and community engagement.

Keywords:
Food waste; effective microorganisms (EM); composting; temperature; pH; nutrient content

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1. Introduction

Municipal solid waste generations have continued to increase in recent years to meet the demands of the burgeoning population and living style [1,2]. This situation has exerted substantial environmental strain and amplified the worldwide financial burdens associated with its effective management [3]. Jeremy *et al.,* [4] and Abd Ghafar [5] stated that the food waste in Malaysia surpassed the generation of other solid wastes, comprising over 40% of the total waste disposed. Among the food waste generated, it was found that households contributed to a greater proportion of food waste compared to other sources [4]. Food waste refers to any edible material discarded, lost, or left uneaten at various points along the food supply chain, including during production, transportation, storage, and retail.

In Malaysia, the prevalent approach for managing food waste is through landfill [3]. The community favors this approach owing to its simplicity, convenience, and cost-effectiveness [1]. However, this approach involves an extensive process and stages like storage, collection and transportation are required before the food waste is finally ended in landfills, and each stage poses an environmental effect [6]. Furthermore, the decomposition of food waste in landfills significantly contributes to global methane emissions, a potent greenhouse gas implicated in climate change [7]. Besides methane, roughly 1% of the gases emitted from landfills consist of odour compound, including S-compound, aromatic, esters, and alkanes [1]. Furthermore, as food waste decomposes in landfills, it can give rise to the production of ammonia and hydrogen sulfide, which exacerbates odour-related concerns. Additionally, the degradation of food waste in landfills has been reported to yield leachate and toxic elements such as aromatic compounds, halogenated compounds, phenols, pesticides, heavy metals [1,8]. The presence of these toxic elements and pollutants can give rise to a range of public health concerns, as they accumulate within aquatic ecosystems, affecting the survival of aquatic life forms and impacting the broader ecological and food chain dynamics [8]. Moreover, it is noteworthy that many landfills in Malaysia are presently being forced to close due to their full capacity [6]. The construction of new landfills can result in deforestation and the destruction of natural habitats due to the requirement for larger construction areas [8].

Composting at the source of food waste generation is a reliable method to reduce the overly dependent on landfill to dispose of the food waste. Food waste composting is an inherently natural process involving the decomposition of organic materials derived from food waste, ultimately yielding nutrient-rich compost [2]. This composting practice can be executed year-round, albeit the decomposition rate is subject to various factors such as temperature, moisture levels, and the composition of materials being composted. Furthermore, adopting this method can effectively mitigate greenhouse gas emissions by eliminating the need for food waste transportation and landfill disposal [1]. Moreover, the final compost or end-product of the composting process contains valuable nutrients that serve as a biofertiliser. This biofertiliser can be directly applied to soils, conferring benefits to agricultural and horticultural activities [8]. Palaniveloo *et al.,* [7] claimed that the biofertiliser is rich in fibre and inorganic nutrients, which positively influence soil quality and environmental aspects. The production of compost material holds the potential to replace reliance on pesticides and synthetic fertilizers, thereby contributing to a reduction in the greenhouse gas footprint [1]. Nonetheless, suboptimal composting practices can also attract pests, such as rodents and flies, giving rise to concerns related to public health and aesthetic aspects. The natural composting process necessitates an extended processing duration before the waste undergoes complete decomposition or attains a mature compost state, typically spanning from 2 to 4 months [8-10]. Besides that, the waste compounds are prone to volatilization during the decomposition process, leading to the emission of an unpleasant odour resulting from the release of trace volatile organic compounds and fine aerosols. This malodor primarily originates from nitrogen compounds, which generate ammonia (NH_3) during the food waste composting due to the lower nitrogen-to-carbon ratio inherent in food waste composition [7]. Regrettably, the end-product of the composting can potentially lead to soil and plant pollution due to the presence of heavy metals [8]. The contamination of soil and plants subsequently becomes part of the food chain, impacting human health through the consumption of these polluted plants.

Thus, to accelerate the decomposition of food waste, there is significant interest in incorporating effective microorganisms (EM) into the composting process [1,8]. In general, EM suspension refers to a group of microorganisms, especially lactic acid bacteria, yeast, and photosynthetic bacteria, that are used mostly in agriculture. These microorganisms play an essential role in promoting the growth of pathogenic microorganisms, lowering pH levels through lactic acid production, and synthesizing a diverse array of biologically active compounds like amino acids and polysaccharides, which nourish other microorganisms [8]. Therefore, besides accelerating decomposition, EM also serves to enhance microbial activity, mitigate odorous emissions, and yield compost with elevated nutrient content [1,12]. However, despite the acknowledged benefits of EM in composting, a degree of skepticism persists among researchers regarding its application. This skepticism, as highlighted by Golec *et al.,* [13], stems from concerns that much of the information regarding EM is unreliable, often driven by commercial interests. In addition, the usage of EM in food waste composting can be attributed to concerns about persistent chemical contaminants [11], limited research [11] and the influence of compost bin design on waste reduction and design preference [32]. Furthermore, it has been reported that the effectiveness of EM in small-scale kitchen waste composting is inconclusive, and the quality of compost cannot be guaranteed, primarily due to unclear or inappropriate handling procedures [1]. This uncertainty arises from the need for more well-defined guidelines provided by suppliers on using effective microorganisms. This includes the absence of standardized application protocols and the absence of precise recommendations regarding the quantity of EM to be employed in relation to a given quantity of food waste [14]. Furthermore, the efficacy of EM may exhibit variability contingent upon the specific composition of the food waste undergoing composting and the prevailing environmental conditions, which can further complicate its application. Moreover, effective management practices are imperative for the successful execution of composting. This encompasses the explicit consideration of factors such as the ratio of food waste to EM and the influence of aeration rate on producing high-quality compost in a short period of time. Thus, this study was undertaken with the aim of examining the influence of compost bin volume and the EM quantity on expediting the decomposition process. This investigation involved monitoring key parameters, including temperature, pH, organic material (OM) content, total organic carbon (TOC), nitrogen (N), phosphorus (P) and potassium (K). The study focuses on providing knowledge and skills to efficiently manage food waste at source (kitchen-scale) using EM through the composting method. This could change households' behaviors towards reducing food waste and supporting sustainable food waste composting practices.

2. Methodology

2.1 Feedstock Preparation

Food waste was obtained from Universiti Tun Hussein Onn Malaysia Pagoh Residential College, mainly composed of rice, vegetables, fruits, meat, and grains. This food waste, representing a single day's accumulation, was chosen to establish a uniform and homogeneous feedstock mixture for this study. The initial moisture content (MC) of the collected sample was 85%, which posed the risk of creating adverse conditions such as waterlogging and anaerobic. To address this concern, the sample was sun-dried for 24 hours to achieve the desired MC falling within the recommended range of 40% to 60%. Then, the collected waste was cut into smaller pieces ranging from 1.5 cm to 4 cm in order to accelerate the decomposition rate of the composting process.

2.2 Activation of Commercial Effective Microorganism (EM)

Commercial Effective Microorganism (EM) called EM-1, and molasses were obtained from EMRO (M) Sdn. Bhd. The EM-1 was activated by combining 20 parts of EM with 20 parts of molasses; the ratio of EM to molasses must be equivalent to 1:1, as recommended by the manufacturer. The EM-molasses mixture was left to undergo storage at room temperature for 5 to 7 days. During this time frame, the pH gradually decreased, eventually falling within the specified range of 4.0 to 3.5. This pH range signified that the EM-1 was now prepared for amalgamation with the fermentation bed for inoculation into the food waste [15,16]. The activation process of EM culminated when the mixture emitted a slightly sweet-sour odour and exhibited the presence of a white bacterial layer on the surface of the solution, in accordance with observations [12].

2.3 Preparation of Compost Bin

The composting process was executed using plastic containers of different sizes, specifically 6, 9, and 21 L, with the primary objective of investigating the impact of compost bin volume on the composting process. The sizes of these container volumes were chosen based on practical considerations, as they are readily available or easily obtained, which can streamline the experimental setup and reduce costs. The selection and preparation of these compost bins adhered to the methodologies outlined by Lew *et al.,* [17] and Guidoni *et al.,* [18]. The schematic diagram of the compost bin is illustrated in Figure 1. Initially, a net was strategically positioned at a height of 3 cm from the base of the compost bins to serve as a barrier in order to retain feedstock and compost medium during composting. The void space beneath this net was intentionally left vacant to collect and retain any leachate generated throughout the composting process. Subsequently, this leachate was removed efficiently via the water trap below the net. A series of holes, each possessing a diameter of 0.07 cm and spaced at intervals of 5 cm between them, were meticulously drilled into the encompassing wall of the compost bin. This measure provided partial aerobic conditions and ensured adequate aeration throughout the composting process.

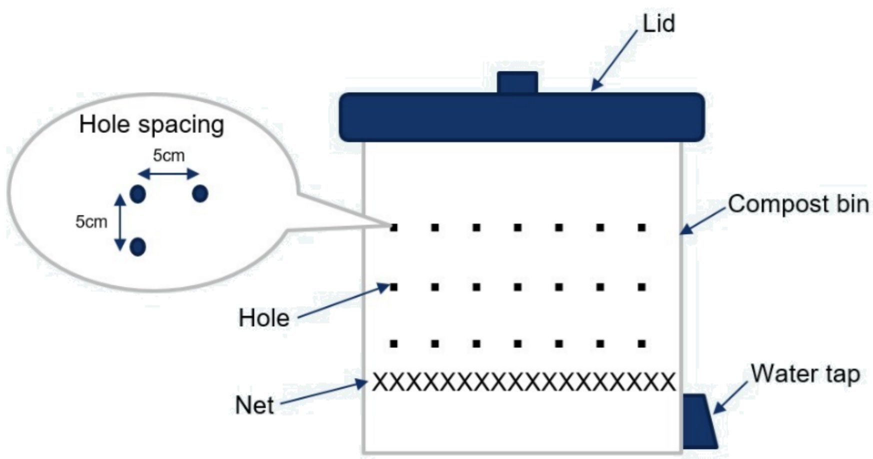

Fig. 1. Schematic diagram of the compost bin

2.4 Preparation of Composting Sample

A total of eight composting samples were meticulously prepared, divided into two distinct observation categories. The first set comprised three (3) samples, intended for scrutinizing the impact of compost bin volumes, which were 6, 9, and 21 L. The second group comprised five (5) samples, designated to assess the influence of varying EM quantities, specifically 20, 40, 60, 80, and 100 mL, on the overall performance of the composting process.

The composting work was carried out in a plastic compost bin equipped with a net at the bottom, and a layer of a newspaper was placed atop the net, serving the purpose of retaining any leachate produced during the decomposition of food waste. Rice husk obtained from Jelapang Selatan Mill Factory Muar served as a fermentation bed (FB) to facilitate aeration and allows microbes to breathe throughout the composting process, aligning with the studies by Chang and Chen [19] and Waqas *et al.,* [2]. Moreover, it also plays a crucial role as an energy source for microbes to enhance the degradation of composting material [20]. Each compost bin was filled with 600 g of FB, 600 g of feedstock, and various quantities of activated EM (ranging from 20 – 100 mL). Distilled water was added to each compost bin to achieve an initial moisture content of 40 to 60 %, as recommended by Adhikari *et al.,* [14] and Van [15]. Prior to commencing the composting process, the FB and feedstock were meticulously mixed by hand to ensure thorough blending. This procedure was replicated across compost bins of different volumes (6, 9, and 21 L) with constants EM quantity (20mL) added each bin and EM quantities (ranging from 20 to 100 mL) to assess their respective effects on the composting process's performance.

2.5 Monitoring of Composting

The monitoring process was carried out in two stages: (1) during the composting process and (2) evaluation of final compost. The temperature and pH of the sample were evaluated daily during the composting process using HI99121 Hanna Direct PH Soil Meter (DPSM) equipped with a temperature probe. The measurements were taken directly in the compost bin at three points within the sample, precisely at a depth of 50% of the mixture feedstock and FB, as suggested by Abdullah *et al.,* [21]. Meanwhile, the moisture content of the samples is being monitored by using a direct moisture content detector equipment which is known as WH0291 Soil Moisture Monitor.

Following the three weeks of the composting process, each final compost was evaluated for organic matter (OM), total organic carbon (TOC), and nutrient contents such as nitrogen (N), phosphorus (P), and potassium (K). The OM content was determined using the loss of ignition (LOI) method, following the procedures outlined in BS 1377-3:1990 [22] and as described by Waqas *et al.,* [2] and Sullivan *et al.,* [23]. Initially, the samples were oven-dried at 105°C for 24 hrs, after which they were cooled in a desiccator and their weights were recorded. Subsequently, the dried samples were burned in a muffle furnace at a temperature of 550 °C for 3 hrs. After 3 hrs, the samples were again cooled in a desiccator, and their weights were determined. The percentage of OM was calculated using Eq. (1), while Eq. (2) was used to estimate TOC. The N, P and K of the samples were directly monitored using Direct Soil Sensor JXBS-3001-SCY-PT. Approximately 60 g of each sample was weighed and placed in a 250 mL beaker. Subsequently, 20 mL distilled water was added into the beaker and shaken for 2 hrs. The direct soil sensor was subsequently inserted into the sample, and the values displayed on the handheld terminal monitoring screen were diligently recorded. The recorded N, P, and K values, initially in mg/kg, were converted into a percentage using Eq. (3)

$$\mathrm{OM}\ (\%) = \frac{\text{oven dry sample weight} - \text{sample weight after burned in furnace}}{\text{oven dry sample weight}} \times 100 \quad (1)$$

$$\text{TOC (\%)} = \frac{\text{OM (\%)}}{1.8} \quad (2)$$

$$\text{NPK substance(\%)} = \frac{\text{Concentration of substance} \left({}^{\text{mg}}/_{\text{kg}} \right)}{\text{mass of sample (mg)}} \times 100 \quad (3)$$

3. Results and Discussion

3.1 Evaluation the Composting Performance at Different Compost Bin Volumes

This study's initial aspects under observation pertained to the compost bin volume on the composting performance, including temperature and pH value. Three distinct compost bin volumes of 6 L, 9 L, and 21 L were employed. Simultaneously, the moisture content of the samples was maintained within the specified range of 40% to 60%.

3.1.1 Temperature evolution during the composting process

Temperature is a crucial parameter to monitor during composting as it significantly influences the performance and the rate of decomposition process. According to Waqas *et al.,* [2], temperature plays a vital role in the succession and evolution of microbiological communities throughout the entire composting process. Figure 2 shows the effect of the compost bin volume on temperature over time compared to the ambient temperature. Initially, all composting samples' temperatures are most similar, ranging from 31 to 32 °C. However, the composting conducted with a 21 L compost bin exhibited notably higher temperatures, reaching 51.5 °C. This is because a larger compost bin will provide more open space, which will increase the rate of composting aeration and boost the temperature [33]. The temperature progression observed in the 21 L compost bin indicates that they entered to the thermophilic temperature of 45.2 °C within the initial days of composting and remained in this phase for three days. Subsequently, the temperatures of the composting samples experienced a sharp decline and returned to ambient temperature on day 7. In contrast, composting performed using 6 and 9 L compost bins shows the lowest temperature profile and failed to reach thermophilic temperature (>45 °C). The compost samples' temperatures were continuously decreased until they reached the ambient temperature by day 7 of composting process. The 21 L compost bin featured a substantial amount of free space, surpassing 65%, to ensure an adequate aeration rate during the composting process. Conversely, the 6 and 9 L compost bins provided a free space of 40 to 65%, resulting in reduced microbial activity [14].

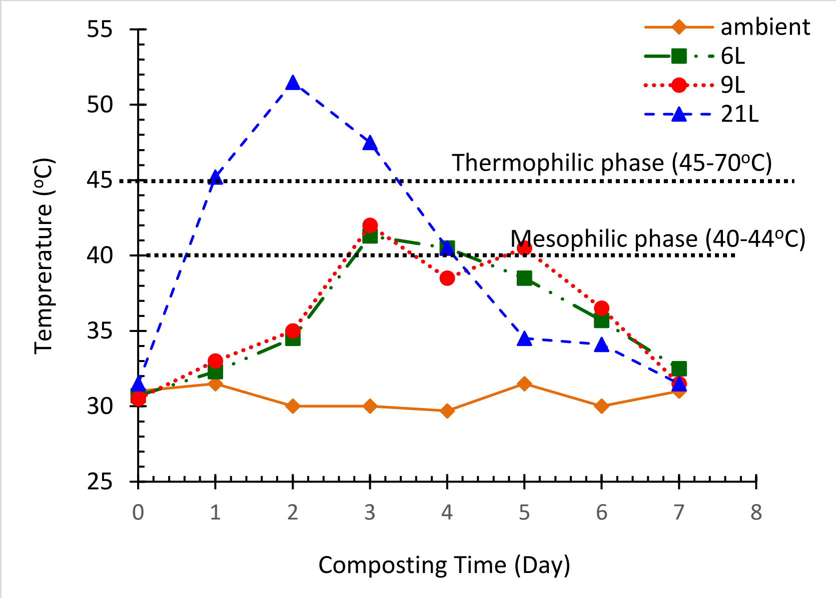

Fig. 2. The temperature evolution throughout the composting process in the various compost bin volumes

3.1.2 pH profile during the composting process over various compost bin volumes

Figure 3 illustrates the pH variations in the various compost bin samples. Each bin was treated with 20 mL of EM, respectively. The 6 L compost bin sample reached a maximum pH of 8.42, the 9 L compost bin reached 8.48, and the sample in 21 L compost bin sample reached a maximum pH of 8.28. Van [15] reported that this phenomenon can be attributed to the production of organic acids and the release of ammonia resulting from the microbial degradation of organic matter. Pan and Sen [24] stated that such conditions indicate organic matter stability. Generally, the ideal pH values for successful composting typically fall within the range of 5.0 to 8.5 [25]. Furthermore, according to Shelley [25], the pH value might drop as low as 5.0 due to the creation of organic acid as a substrate for the subsequent microbial population.

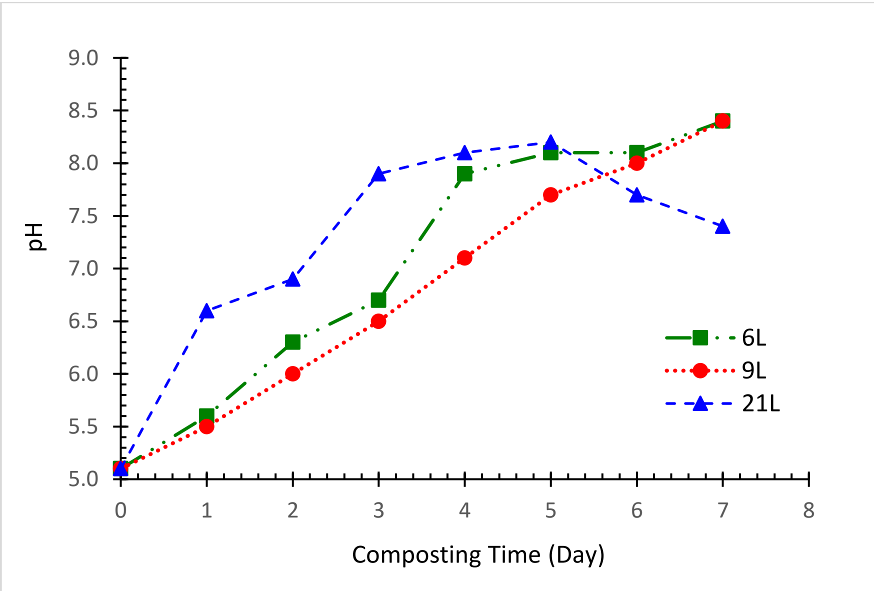

Fig. 3. Effect of the compost bin volume on pH of the sample

The initial pH value for all samples were recorded at 5.05, representing the lowest pH level through the composting. The pH trend for 6 and 9 L compost bin samples gradually increased from the initial day until the 7th day of composting. The compost samples in the 6 and 9 L compost bins did not transition to a neutral state, indicating that these samples did not reach maturity. Interestingly, it was found that the pH value for the 21 L compost bin sample showed a rapid increase, reaching a maximum pH of 8.28 on the fifth day before dropping to 7.4 on the 7th day. The rapid increase of pH may be attributed to the larger compost bin, which tends to have bigger free space for air circulation within compost bin, thereby resulting in elevated oxygen concentrations within the compost container in contrast to smaller composting containers [26]. The compost sample in 21 L bin trend, which is the pH increasing after second day to reach an alkaline level and then gradually declining to weakly neutral state. This indicates the sample in the 21 L compost bin reached the stability phase of composting by 6 days, unlike the sample in the 6 and 9 L compost bins. These observations indicate that the sample in 21 L compost bin shifted from an initially acidic state to a gradually becoming alkaline and nearly neutral state.

3.2 Evaluation of The Composting Performance at Various EM Quantities

In this stage, the composting process was assessed in a 9 L compost bin with varying quantities of effective microorganisms (EM) ranging from 20 to 100 mL mixed with the food waste. The temperature and pH were monitored regularly during the composting process. Meanwhile, the moisture content of compost samples is controlled within the range of 40–60%. Water was added to the sample when the moisture content fell below 45%. Conversely, if the moisture content exceeded 60%, rice husk will be added into the sample. The composting performance was monitored daily.

3.2.1 Effect of effective microorganisms (EM) quantities on temperature

Figure 4 shows the temperature variation of the composting sample across different EM quantities over time. The results reveal that the highest temperature recorded throughout the composting process is 48 °C, attained by the samples treated with 80 and 100 mL of EM on the 9th day of composting. Notably, the higher quantity of EM in the samples treated with 80 and 100 mL is attributed to the increasing population of heterogeneous microorganisms. Conversely, the lowest temperature recorded was 26.3 °C, observed in the sample treated with 20 mL of EM on the third day of composting.

Initially, all samples-maintained temperatures below 40 °C from the 1st to 7th day of the composting process. However, a noteworthy temperature surge exceeding 40°C was observed in the samples treated with 80 and 100 mL of EM on the 8th day, signifying heightened microbial activity [27]. Subsequently, the process transitioned into the mesophilic phase as temperatures continued to rise until the 9th day. This temperature elevation can be attributed to the utilising of nitrogen and carbon organic matter by diverse heterogeneous microbial groups [27]. Both samples treated with 80 and 100 mL of EM reached the thermophilic stage on the 9th day of composting, indicating that EM enhanced microbial population and activity [1,28]. Consequently, heat production occurred due to microbial respiration and the degradation of organic material by these thriving microorganisms [27].

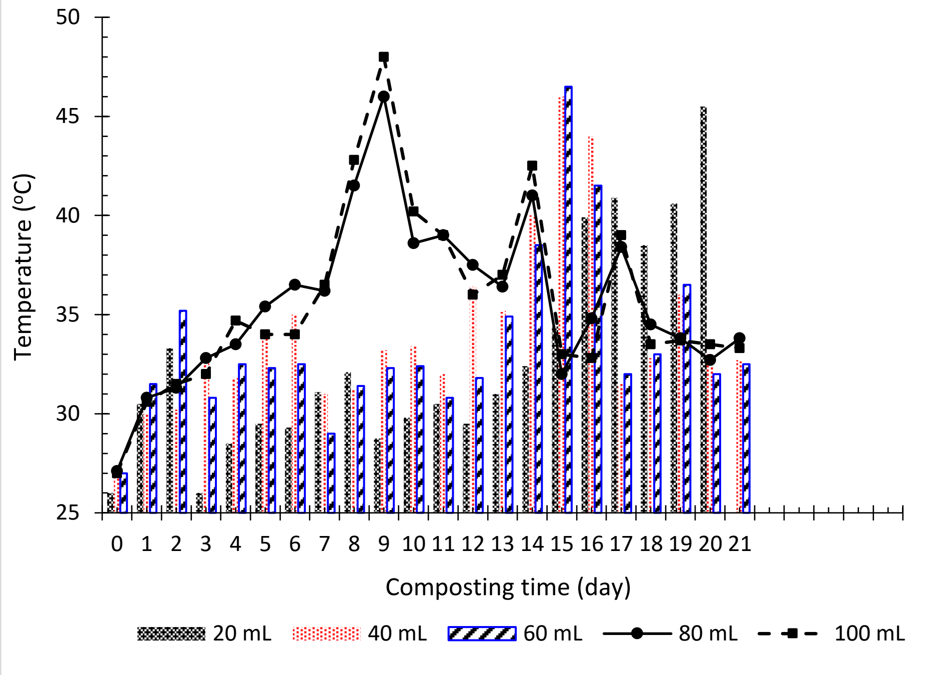

Fig. 4. The effect of the EM quantity on the temperature of the sample

Furthermore, on the 10th day of composting, the temperature for the samples treated with 80 and 100 mL of EM exhibited a decline and entered the thermophilic temperature. During this phase, the compost temperature gradually decreases due to the slower microbial activities and decomposition rate of organic matter [28]. The temperature continued to decrease, nearly reaching 30 °C on the 15th day. Nevertheless, the samples did not fully mature, aligning with findings from a study conducted by Van *et al.,* [1], where the sample will reach full maturity within the fourth week of composting.

On the contrary, the samples treated with 20, 40 and 60 mL of EM exhibited a slower effect on compost temperature than those treated with 80 and 100 mL of EM. This is evident when the samples treated with 40 and 60 mL of EM transitioned into the thermophilic phase on the 15th day of composting. However, the sample treated with 20 mL of EM entered the thermophilic phase after three weeks of composting. This delay in reaching the thermophilic phase might be attributed to slower microbial growth. This can be attributed to the higher initial carbon-to-nitrogen ratio in the feedstock due to a tremendous amount of rice husk compared to the EM concentration [29].

3.2.2 Effect of the effective microorganisms EM quantities on the pH value

Figure 5 shows the pH variations for all samples over time. Initially, the pH value for the sample is 4, indicating that the sample is in the acidic stage. Microorganisms release various organic acids during this acidic stage, leading to sample acidification [27]. The pH value for all samples continued to rise, gradually shifting towards alkalinity until the sample stabilised, indicating that the sample was nearly neutral. An intense odour was emitted during this alkaline stage, primarily attributed to the conversion of ammonium and the hydrolysis of proteins into ammonia. These findings align with studies by Azim *et al.,* [30] and Meena *et al.,* [27].

It was noted that the initial samples to reach the stabilization phase were those containing 80 and 100 mL of EM, accomplishing this on the 9th day of composting, followed by the 60 mL EM sample on the 10th day of composting. During this phase, ammonia was lost through volatilization, and microbes actively synthesized new humic compounds utilizing nitrogen [30]. This observation suggests that the pH of the samples with 60, 80, and 100 mL of EM experienced a more pronounced increase due to the rapid rate of humic compound synthesis. Conversely, the samples containing 20 and 40 mL of EM entered this stage on the 13th day of composting, possibly due to a slower humic compound synthesis rate.

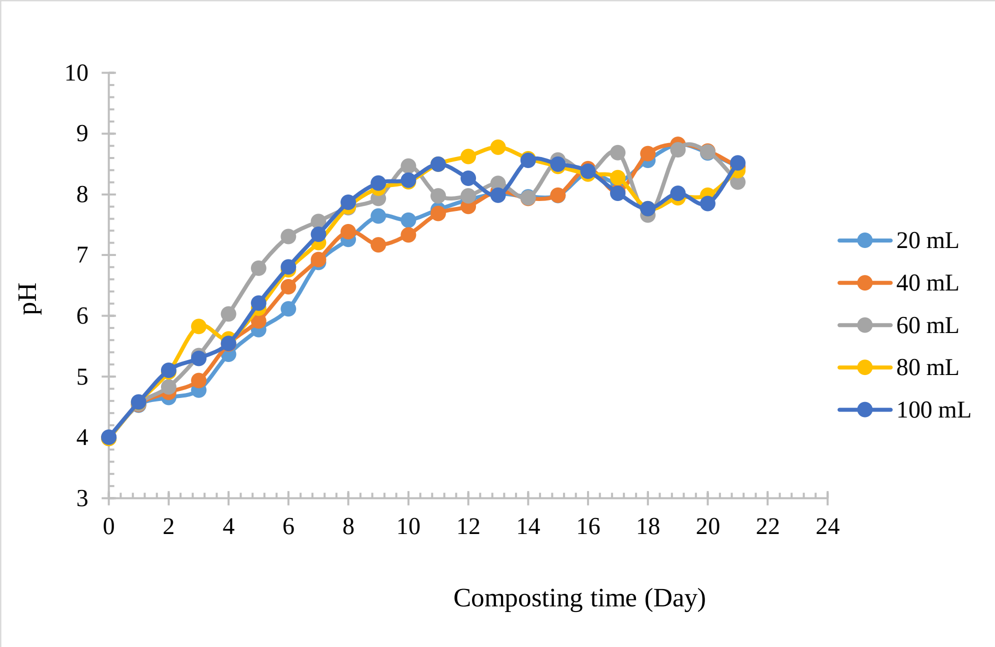

Fig. 5. Effect of the EM quantity on the pH of the sample

The trend of increasing pH aligns with findings in previous studies conducted by Van *et al.,* [1] and Hamid *et al.,* [28]. However, it is noteworthy that in this study, the samples exhibited a more rapid pH shift, transitioning from acidity to a weak alkaline state in less than two weeks of composting. This contrasts with the results reported by Van *et al.,* [1] and Hamid *et al.,* [28], where this pH shift occurred only in the second week of composting. This accelerated pH change could be attributed to the elevated moisture content during the initial week of the composting process, which can lead to reduced oxygen levels [27] and a swift pH increase. Consequently, this can result in nitrogen loss through ammonia volatilization, accompanied by the emission of an unpleasant odour. This may be due to the rise of moisture content in the first week of the composting process, which can cause the replacement of oxygen [27] and rapid increase of pH, then lead to the loss of nitrogen through ammonia volatilisation, which eventually emits the unpleasant odour.

After the 13th day of composting, samples containing 80 and 100 mL of EM experienced a significant decrease in pH, approaching a nearly neutral level. During this phase, a less offensive odour emanated from the samples, signifying their proximity to maturity.

3.3 Evaluation of Final Compost

The final composts or maturity of the sample were assessed by analysing OM, TOC, N, P and K within the third and fourth week of composting. These parameters were examined across various EM quantities and then compared with the final compost without EM.

3.3.1 Organic matter (OM)

Table 1 presents the organic matter and total organic carbon percentages for samples from different compost bin volumes (6, 9 and 21 L) on the second week of the composting process. These compost samples were treated with 20 mL of EM. The findings show that the 21 L compost bin sample has the lower organic matter percentage at 81.52%, in contrast to the 6 and 9 L compost bin samples. Nevertheless, all samples exhibit organic matter percentages exceeding 65%, indicating they have not reached full maturity [23]. This could be attributed to the relatively short duration of composting applied to these samples, potentially resulting in the presence of various unstable organic matter fractions. However, it is worth noting that the total organic carbon (TOC) value for the 21 L sample is slightly lower when compared to the 6 L and 9 L compost bin samples.

Table 1
The percentage of OM and TOC for the sample of different compost bin volume

Bin volume	Quantity of EM (mL)	Organic matter, OM (%)	Total organic carbon, TOC (%)
6 L	20	87.10	43.27
9 L	20	86.54	43.55
21 L	20	81.52	22.10

Based on Table 2, the sample with 60 mL of EM exhibits the highest organic matter percentage during the third week of composting, indicating a comparatively slower rate of organic matter degradation in this sample than the others. Conversely, the sample with 40 mL of EM displays the lowest organic matter percentage among all samples. The samples treated with 80 mL and 100 mL of EM show the second-highest organic matter degradation rates, with an organic matter percentage of 83.09%. In terms of total organic carbon (TOC), the sample with 60 mL of EM records the highest value at approximately 45.78%. the sample with 40 mL of EM has the lowest TOC percentage at about 41.21%. Furthermore, the TOC percentages for the samples with 80 mL and 100 mL of EM are 41.54% and 41.55%, respectively. The organic matter percentage in these samples surpasses the recommended OM range of 25% to 65%, as reported by Sullivan *et al.,* [23]. This indicates that the samples might not be fully composted. Nevertheless, when considering the temperature and pH variations observed in samples with varying EM quantities, it is conceivable that the organic matter percentage in these samples falls within the ideal organic matter range.

Table 2
The percentage of OM and TOC for the sample of different EM quantities

EM quantity	Volume of container (L)	Organic matter (%)	Total organic carbon (TOC) (%)
20	6	83.16	41.58
40	6	82.41	41.21
60	6	91.55	45.78
80	6	83.09	41.54
100	6	83.09	41.55

3.3.2 Nitrogen (N), phosphorous (P) and potassium (K) contents

Table 3 shows the nitrogen (N), phosphorus (P) and potassium (K) contents for the samples at different EM quantities on the third and fourth weeks of composting. This observation was made on the third and fourth week of composting since it is believed that the composting process with the application of EM can shorten the duration to convert the food waste into compost, which is within 45 days compared to the duration taken for the conversion via the normal process of aerobic digestion which took about two months [8]. In addition, this study found that all samples with different quantities of EM were near completing the maturation phase as their color turned dark brown, and an earthy smell was released from the sample on the third week of composting.

Additionally, in the third week of composting, it was observed that the sample with 100 mL of EM exhibited the highest nitrogen content at approximately 0.31%, while the sample containing 60 mL of EM showed the lowest nitrogen percentage, measuring 0.23%. Furthermore, the phosphorus content in all samples ranged from 0.31% to 0.40%, with the highest phosphorus percentages found in the sample with 100 mL of EM and the lowest in the sample containing 60 mL of EM on the third and fourth weeks of composting. Moreover, both the samples containing 80 mL and 100 mL of EM shared the same potassium percentage, which was 0.9%, and this was the highest potassium content among all the samples.

Table 3
N, P and K for the sample at the different EM quantities

Weeks	EM quantity	Nitrogen (N), (%)	Phosphorus (P), (%)	Potassium (K), (%)
Third	20	0.25	0.34	0.8
	40	0.25	0.34	0.8
	60	0.23	0.31	0.7
	80	0.30	0.39	0.9
	100	0.31	0.40	0.9
Fourth	20	0.37	0.49	1.2
	40	0.38	0.49	1.1
	60	0.30	0.39	0.9
	80	0.41	0.51	1.3
	100	0.41	0.56	1.3

On the other hand, it was found that the samples containing 80 and 100 mL of EM displayed the highest nitrogen content, reaching 0.41% on the fourth week of composting. Conversely, the sample treated with 60 mL of EM exhibits the lowest nitrogen percentage, which is 0.30%. Moreover, in the fourth week of composting, the sample with 100 mL of EM showed the highest phosphorus percentage, which was 0.56%, while the sample containing 60 mL of EM had the lowest phosphorus content. Additionally, the samples with 80 mL and 100 mL of EM recorded the highest potassium percentage, which was 1.3%, during the fourth week of composting, whereas the sample with 60 mL of EM displayed the lowest potassium percentage, which is 0.9%.

Based on the previous study, on the third and fourth week of composting, the samples generally exhibited nitrogen content below 0.3% [31], while the phosphorus percentage was less than 0.1% [17,31]. Meanwhile, it was found that the potassium percentage for compost samples without EM is generally found to be less than 0.5%. However, the mature organic fertilizers are considered acceptable when they contain phosphorus levels ranging from 0.30% to 0.90% and potassium levels between 0.5% to 1.5% [23]. Notably, the final compost of all samples met established criteria for high-quality organic compost. However, it was found that the nitrogen percentage for all the samples remained below the minimum threshold for mature compost, which typically ranges from 1% to 2% [23].

4. Conclusion

This study indicates that the compost bin volume and the quantity of the EM significantly impact on the composting process's efficiency. As the compost bin volume increases, the space in the compost bin will increase. This expanded space exerts a direct and pivotal influence on multiple critical factors, including aeration, the population of aerobic microorganisms responsible for the breakdown of organic matter, temperature, and moisture retention. These factors collectively underpin the efficacy of the decomposition process. It can be confidently stated that the 21 L compost bin, boasting a free space in the compost bin exceeding 65% can rapidly reach the desired thermophilic temperature (within one day) and retain the thermophilic phase for longer. The larger compost bins with sufficient space and aeration during composting facilitate the growth and proliferation of beneficial microbes. This catalyzes a more robust and expedited decomposition process. Conversely, the decomposition process within 6 and 9 L compost bins of with less than 65% free space is hindered since they did not reach a thermophilic temperature within the observation for up to 7 days. The limited space may impede proper aeration and the proliferation of the necessary aerobic microorganisms. Moreover, the correlation between temperature, pH, and maturity becomes apparent when assessing compost bin sizes. Notably, only the 21L compost bin reaches near-neutral pH conditions within 7 days, signifying a mature composting phase. In contrast, the 6L and 9L compost bins cannot progress to this mature phase over the same observation period. This divergence in pH trends aligns with the varying temperature profile and decomposition rates observed among different compost bin volumes.

On the other hand, it was found that the EM quantity over 80 mL performed effectively in decomposing 600 g of food waste. It could also potentially speed out the composting process since this sample nearly falls into the ambient temperature and has the optimum temperature and pH performance at the end of the third week. Based on the nutrient contents, the final compost of all samples adhered to prescribed benchmarks for phosphorus levels ranging from 0.30% to 0.90% and potassium levels between 0.5% to 1.5%. However, the percentage of nitrogen is still below the requirement percentage for mature compost. The organic matter (OM) percentage in all the samples consistently falls within the range of 80% to 92%. This indicates that all the samples have yet to reach maturity. In fact, the organic matter percentage in all the samples remains notably higher than the range typically associated with mature compost, which is typically between 25% to 65%. It is recommended to continue the monitoring of the composting process till their temperature is less than 45%. Besides that, it was suggested that air circulation and frequent turning in the compost bin be studied in order to have a better performance.

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