JOURNAL TEKNIK SIPIL DAN LINGKUNGAN| EISSN:2549-1407
https://journal.ipb.ac.id/index.php/jsil

Vol. 10 No. 02 October 2025
DOI: 10.29244/jsil.10.2.327-336

Design and Performance Evaluation of Conventional and Modified Aerobic Composters for Food and Agricultural Waste Management

Rasendriya Arkananta Bhanu Loppies, Joana Febrita*, and Chusnul Arif

Department of Civil and Environmental Engineering, IPB University, Bogor, 16680, Indonesia
***Correspondences: joanafebrita@apps.ipb.ac.id**

Abstract: The management of organic waste, such as food scraps and straw, remains a challenge, particularly in residential areas that produce large amounts of waste but lack effective waste management systems. This study aimed to design and evaluate the performance of two types of aerobic composters: a conventional method and a modified method using a passive aeration system with perforated pipes. Six compost material variations were tested based on different ratios of food waste to straw and observed over an eight-week period using key parameters such as temperature, height, pH, moisture content, organic carbon, nitrogen content, and C/N ratio. The results showed that All compost variations met the compost quality standards of SNI 7763:2024. No significant difference was found between the conventional and modified methods based on ANOVA test results for the C/N ratio and pH. This study concluded that variation B6 was the most favorable, as it produced a C/N ratio closest to the standard value, met the quality standard criteria during the composting process, and reached acceptable pH and carbon levels more quickly than the other variations. Therefore, the compost quality of variation A2 and A3 was superior and reached maturity in a shorter time compared to the other treatments.

Keywords: aerobic; composter; food waste; straw; waste management

Submitted: 07 Oct 2025
Revised: 20 Oct 2025
Accepted: 21 Oct 2025

1. Introduction

The organic waste produced by humans will always have an impact on the environment. Contamination from organic waste can affect the soil and air [1]. One of the main sources of organic waste comes from the agricultural and household sectors. A common example is straw, which is often burned for reasons of time and labor efficiency. Additionally, food waste from households and food processing industries contributes significantly to organic waste, which ultimately ends up in landfills [2].

Composting is an effective solution for reducing the environmental impact of organic waste. Composting is a biological process wherein microorganisms break down organic materials into compost, which can then be used as a medium to enhance soil fertility [3]. This process converts organic materials into simple compounds that can be reused in the environment [4]. Compost produced from food waste contained 15.83% carbon, 0.99% nitrogen, and a C/N ratio of 15.92 [5]. Straw serves as a carbon source that helps balance the C/N ratio in the compost [6]. The combination of straw and nitrogen-rich food waste is believed to produce higher-quality compost.

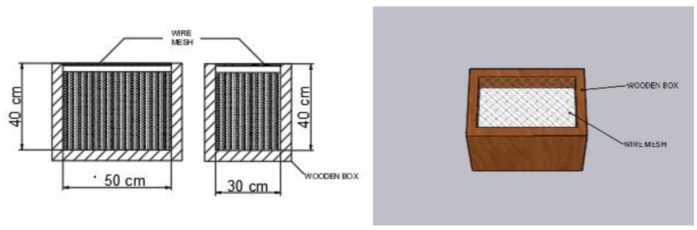
Although there is already an awareness among the public about composting organic waste, more practical, efficient, and easy-to-implement methods are needed. Some studies have indicated that compost activators such as EM4 and MOL can accelerate the decomposition of organic materials [7]. Additionally, the use of technologies such as bioactivators or specific microorganisms has also been proven to enhance the efficiency and quality of compost. Therefore, there is a need to develop a simple, fast, optimally aerated, and economical composting method, so that more people are willing to adopt the habit of composting, thereby reducing waste both locally and independently. This study aims to analyze the characteristics and quality of compost produced from the processing of food and agricultural waste, as well as to compare the results of compost from conventional methods and modified methods with various material compositions.

2. Methods

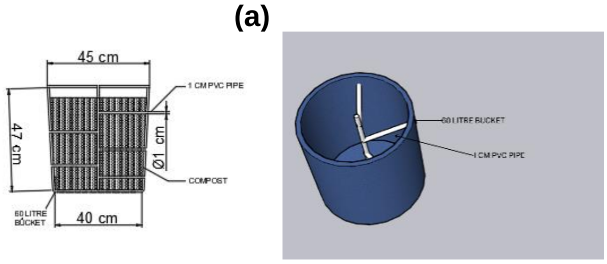
In this study, the equipment used included wooden boxes as composting containers, wire mesh for box covers, buckets, PVC pipes, rulers, thermometers, and soil pH meters for monitoring compost environmental conditions, and digital scales for measuring material mass. Additionally, laboratory equipment such as petri dishes, ovens, furnaces, analytical balances, block digesters, desilator units, Kjeldahl flasks, burettes, Erlenmeyer flasks, pipettes, ball pipettes, measuring flasks, and a laptop equipped with Microsoft Excel, Minitab, and OriginLab software for data processing were also used. The materials used in this study were divided into two categories: field materials and laboratory materials. The main materials used included food waste, straw, EM4 bioactivator, and molasses derived from sugarcane waste. The chemicals used in the laboratory include H_2SO_4, $C_7H_6O_3$, $Na_2S_2O_3$, H_3BO_3, indicator, NaOH, and deionized or distilled water as a solvent and for cleaning equipment.

2.1 *Determination of Design and Variation of Compost Composition*

The compost bin design used is based on conventional and modified methods, but both use a 60-litre container to maintain consistency in volume and composition of materials in each treatment, as shown in **Figure 1**. The 60-litre compost container was chosen because it aligns with the average daily organic waste production of small to medium-sized households, which is approximately 0.62–2 kg per day [8]. The conventional composter used a wooden box-shaped container with dimensions of 50 cm × 30 cm × 40 cm. Meanwhile, the modified composter using a 60-litre plastic bucket with a lid, modified with the installation of 1 cm diameter PVC pipes. These pipes were arranged to form a network inside the container and perforated along their length to enhance air circulation during the composting process. Both types of containers were covered with wire mesh to prevent pest infestation and reduce the risk of contamination from the surrounding environment.



(a)



(b)

Figure 1. Compost Bin Design (a) Conventional and (b) Modified

The variations in this study consist of six variations in the two methods presented in **Table 1.** Each variation was given the same treatment and dosage of EM4 and molasses, in accordance with the recommendations on the EM4 bottle. The moisture content of the compost during the process was maintained by adding water, if necessary. The variation ratios were selected based on previous journal references and then converted using density data into weight to fill a 60 L container, where only 80% will be used, that is, 48 L. The density of the straw used is 0.06 kg/L, and the density of the food waste used is 0.6 kg/L.

Table 1. Variations in Compost Composition

Methods	Variation	Waste (kg)	
		Food Waste	Straw
Conventional	A1	1.25	2.50
	A2	3.45	2.30
	A3	6.00	2.00
	A4	7.40	1.85
	A5	9.60	1.60
	A6	11.20	1.40
Modified	B1	1.25	2.50
	B2	3.45	2.30
	B3	6.00	2.00
	B4	7.40	1.85
	B5	9.60	1.60
	B6	11.20	1.40
Total		77.80	23.30

2.2 Field Data Collection and Laboratory Testing Samples

The physical characteristics observed in this study included temperature, pH, and compost pile height. The pH and temperature measurements were performed daily using measuring instruments. The temperature was measured by inserting a soil thermometer directly into the compost pile to obtain accurate internal temperature data. Meanwhile, other characteristics such as moisture content, carbon (C) content, nitrogen (N) content, and C/N ratio were analyzed through laboratory tests. Samples for carbon and nitrogen content analyses were collected weekly. Moisture content testing was conducted on the 3rd and 7th days of each week to monitor the changes in moisture content during the composting process.

2.3 Moisture and Carbon Content Testing

The moisture content of the compost was calculated based on SNI 7763:2024 [9] using the gravimetric method. The ground sample was weighed and placed in a porcelain dish of known weight. Next, it was placed in an oven and dried at 105 °C for 16 h to remove the moisture content. After the drying process was completed, it was cooled and weighed again to obtain the weight after drying. The moisture content calculation is presented in **Equations (1)** and **(2)**.

$$\text{Moisture Content (\%)} = \left(\frac{W1-W2}{W1}\right) \times 100\% \quad (1)$$

$$\text{fk} = \frac{100}{100-moisture\ content} \quad (2)$$

Explanation:
W1 = sample weight, expressed in g;
W2 = sample weight after drying, expressed in g;
fk = moisture content correction factor.

Carbon content (organic C) was calculated by incineration. After obtaining the dry weight, place the sample in a furnace and perform initial incineration at 300 °C for 1.5 hours, then increase the furnace temperature to the range of 550–600 °C and continue the incineration process for 2.5 hours until the residue is completely burned. After the process was complete, the temperature was allowed to cool naturally. The sample was then transferred to a desiccator for cooling. After cooling, the samples were weighed to obtain the final weight. The calculation of the carbon content is presented in **Equations (3)**, **(4)**, and **(5)**.

$$\text{Ash Content (\%)} = \frac{W3}{W1} \times 100\% \quad (3)$$

$$\text{Organic content (\%)} = 100\% - (\%moisture\ content + \%ash\ content) \quad (4)$$

$$\text{C-organic content (\%)} = \%organic\ content \times 0{,}58 \times fk \quad (5)$$

Explanation:
W3 = ash weight, expressed in g;
W1 = sample weight, expressed in g;
0.58 = conversion factor for organic matter to organic carbon;
fk = moisture content correction factor.

2.4 *Nitrogen Content Testing*

The nitrogen (N-total) content was determined based on SNI 7763:2024. Weigh 0.5 g of ground compost sample was weighed and placed in a Kjeldahl flask. Add 10 ml of salicylic acid sulfuric acid solution, then leave it overnight. Add $Na_2S_2O_3$, then heat at a low temperature until the bubbles disappear. The temperature was gradually increased to 300 °C (approximately 2–3 h) and then allowed to cool. Distil the 100 ml mark with the addition of 10 ml of NaOH solution, 20 ml of H_3BO_3 solution, and three drops of Conway indicator. Titrate with 0.05 N H_2SO_4 solution until the endpoint of titration (the green colour of the solution turns pink) and record the final volume (V1), then repeat the same procedure for the blank solution (V2). The calculation of the nitrogen content is presented in **Equation (6)**.

$$\text{N-Total content (\%)} = \frac{(V1-V2)\times N\times 14{,}008\times 100\times fk}{W} \times 100\% \quad (6)$$

Explanation:
V1 = volume of H_2SO_4 solution used for titration of sample (ml)
V2 = volume of H_2SO_4 solution used for titration of blank (ml)
N = normality of H_2SO_4 solution
14.008 = atomic weight of nitrogen
fk = moisture content correction factor
W = weight of compost sample (mg)

The C/N ratio can be determined based on SNI 7763:2024 using the ratio of carbon and nitrogen content in compost. The calculation of the C/N ratio is presented in **Equation (7).**

$$\text{C/N ratio} = \frac{\%\ C-organic\ content}{\%\ N-total\ content} \quad (7)$$

2.5 Data Analysis

Compost data from field observations and laboratory test results will be used to determine the best method for producing compost from food and agricultural waste in the form of straw. In addition to comparing the compost results with quality standards based on SNI 7763:2024, as presented in **Table 2**, statistical data analysis will also be conducted using ANOVA testing with the assistance of Minitab software to determine the significance of the methods used. The data used included parameters such as the C/N ratio, compost height reduction, and compost moisture content, averaged over an 8-week period.

Table 2. Compost Quality Standards (SNI 7763:2024)

No	Description	Unit	Requirements
1	Moisture	%	8-25
2	C-Organic	%	Minimal 15
3	C/N Ratio	-	Maximal 25
4	pH	-	4-9

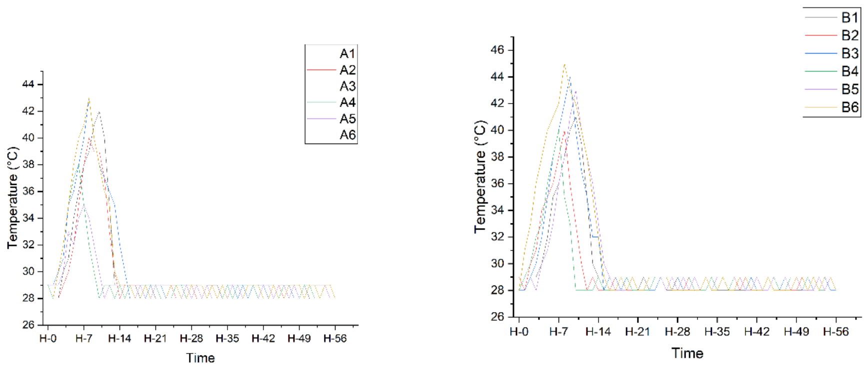
3. Result and Discussion

3.1 Field Observation Results

Documentation of the final composting results is shown in **Figure 2**. Documentation was performed at the end of composting to determine the physical form of compost. The results of the observations of compost temperature are shown in **Figure 3**. At the start of composting, the temperature for all variations was the same at approximately 30°C. During the first few days, there was a significant increase in temperature for each variation, with peak temperatures recorded between 42°C and 45°C on H-7. This increase in temperature was also influenced by a decrease in the pH and C/N ratio, which decreased because microorganisms used carbon as a fuel for decomposition, which generated heat. Variation A6 showed the highest temperature, reaching almost 46°C, which occurred because its composition was very high in nitrogen, while variations A1 and A2 showed lower peak temperatures of approximately 41°C. The higher the compost temperature, the more oxygen is consumed by microorganisms, as more intensive microbial activity increases their metabolic rate, producing more heat [10]. After reaching the peak temperature, all variations experienced a significant temperature drop, stabilizing at approximately 30°C until the end. The method used in this study was aerobic and was conducted in an open environment; the compost temperature influenced by the surrounding environmental temperature.

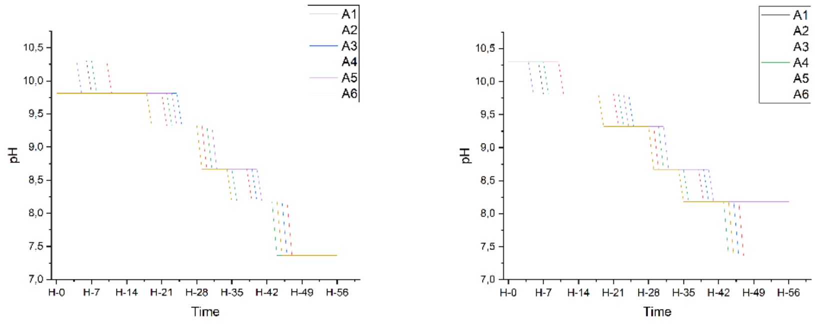
(a) **(b)**

Figure 2. Final Results Compost **(a)** Conventional and **(b)** Modified



(a) **(b)**

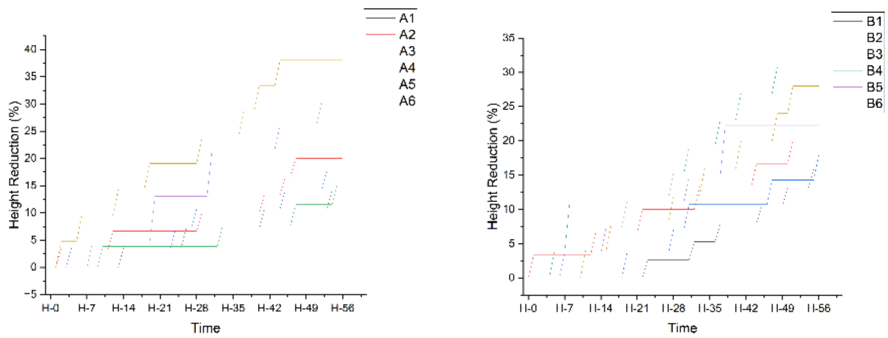
Figure 3. Compost Temperature (a) Conventional and (b) Modified



(a) **(b)**

Figure 4. Compost pH Comparison Chart **(a)** Conventional and **(b)** Modified

Figure 5 shows a gradual decrease in the compost pile height during the composting period. This decrease in compost pile height confirms the degradation of organic material, where the initially porous structure of the compost components undergoes compaction as a result of microbiological decomposition [11]. Each variation experienced a decrease in height with a similar pattern, although at different rates. Variation A1, which had the smallest decrease at the end of the composting period, only experienced a decrease of approximately 14.29%. Meanwhile, variation A6 recorded the highest decrease, reaching 38.1%. The modified method graph shows a similar pattern in terms of the decrease in the compost pile height. However, there were some differences in the rate of decrease between the variations. Variation B1 showed the slowest decrease, with the decrease becoming noticeable on day 22. Over time, variation B1 experienced a smaller decrease compared to the other variations, only approximately 15.79%. Conversely, variations B5 and B6 had faster and more stable decreases (22.22% and 28%, respectively). The faster decrease in these variations indicates that the higher organic matter content in these variations is more easily decomposed by microorganisms.



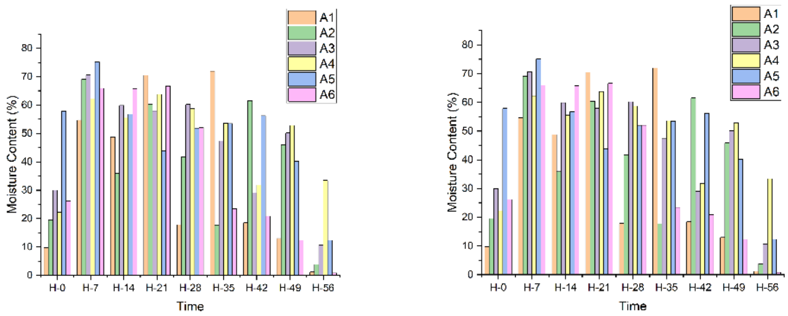
(a) **(b)**

Figure 5. Compost Height Comparison Chart **(a)** Conventional and **(b)** Modified

3.2 Moisture Content Test Results

Moisture content testing of the compost showed a downward trend in moisture content during the composting process, as shown in **Figure 6**. The graph shows that in the early weeks, the moisture content of the compost was still relatively high. However, over time, the moisture content tended to decrease simultaneously, although the decrease was not significant. Some composition variations, such as A1 and A6, showed moisture contents within the standard quality range, that is, 8–25%. By the end of the composting period, most variations stabilized at a moisture content of approximately 30% to 40%, with lower fluctuations compared to the beginning of the period. Some composition variations, such as

A1, A2, A3, A5, A6, and B3, showed moisture contents already within the standard quality range, that is 8–25%. These variations met the quality standards set for mature compost.



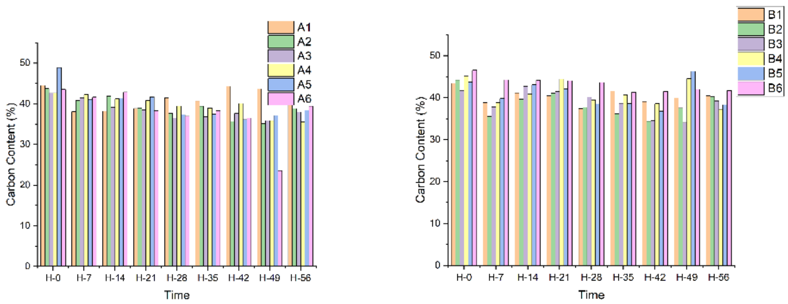
(a) **(b)**

Figure 6. Moisture Content Testing Graph **(a)** Conventional and **(b)** Modified

3.3 C/N Ratio Test Results

The results of the carbon content testing are shown in **Figure 7**. The carbon content graph shows a gradual downward trend each week, with results ranging from 38% to 45%. This decrease indicates that carbon-rich organic materials, such as straw, undergo gradual decomposition during the composting process. Although decreasing, all variations remain above the minimum threshold according to the quality standards, which is 15%; therefore, they are still considered acceptable.

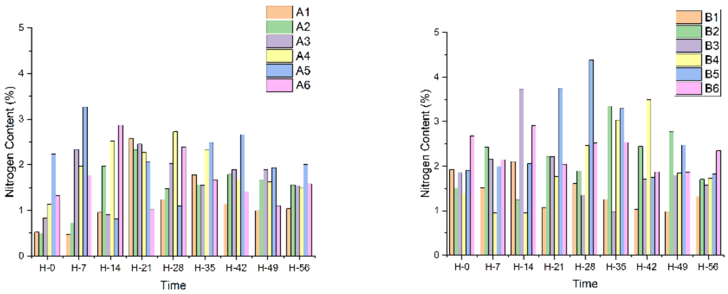
Nitrogen is an element that is very much needed by microorganisms to form enzymes and proteins that are needed in the process of decomposing organic materials [12][13]. For nitrogen levels, as shown in **Figure 8**, the graph shows a relatively stagnant pattern, ranging from 1 to 4%. Some variations showed a slight increase or remained stable from week to week. These values indicate that the nitrogen content, which typically originates from food waste and bioactivators, remains stable throughout the composting process. This consistency is important because sufficient nitrogen levels are required to maintain a balanced C/N ratio and support the decomposition process.



(a) **(b)**

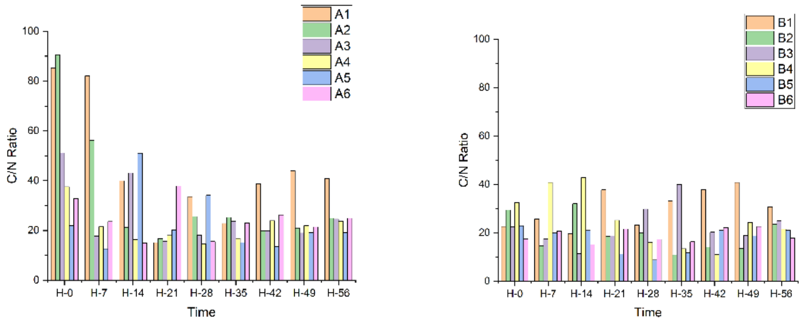
Figure 7. Carbon Content Testing **(a)** Conventional and **(b)** Modified

The C/N ratio, calculated from the ratio of carbon to nitrogen, is shown in **Figure 9**. The graph shows a gradual decrease in the C/N ratio over time during composting. This decrease reflects the active decomposition of the organic material, where carbon continues to decrease at a faster rate than nitrogen. At the end of the composting process, most of the variations met the C/N ratio quality standards based on SNI 7763:2024, which are below 40. However, two variations, A1 and B1, still showed high ratios, remaining at approximately 40, indicating that the carbon decomposition process was not yet optimal. A C/N ratio within the range of 25–35 is known to enhance composting efficiency [14][15]; therefore, variations in ratios within this range indicate better compost quality.



(a) **(b)**

Figure 8. Nitrogen Content Testing **(a)** Conventional and **(b)** Modified

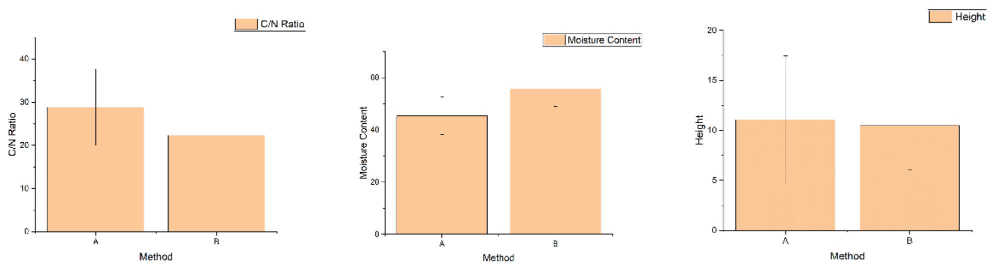


(a) **(b)**

Figure 9. C/N Ratio **(a)** Conventional and **(b)** Modified

3.4 Comparison of Composting Methods

A comparison between the conventional method (A) and the modified method (B) showed that neither method produced a significant difference in the final composting results. Based on the ANOVA test results, the p-values for C/N ratio, moisture content, and compost height were 0.144, 0.028, and 0.864, respectively. Based on the significance level of $p < 0.05$, the C/N ratio and compost height were not significantly different, whereas the moisture content showed a significant difference. The mean and standard deviation of both methods are presented in **Figure 10**. This indicates that, statistically, there is no significant difference between the two methods. In other words, both conventional and modified methods are equally suitable for use and do not negatively impact quality standards.



(a) **(b)** **(c)**

Figure 10. ANOVA Test Barchart **(a)** C/N Ratio **(b)** Moisture Content **(c)** Height Reduction

3.5 Comparison of Composting Composition Variations

During the eight-week composting process, the compost quality parameters were evaluated based on SNI 7763:2024, which includes pH, moisture content, carbon content (organic C), and C/N ratio, as described in **Figure 11**. The results showed that in terms of pH, variation B6 was the fastest to reach the standard range of 4–9. This indicates that the compost in this variation achieved acidity stability earlier, reflecting optimal microbiological activity. For moisture content, which should be within the standard range of 8–25%, only variations A2 and A3 successfully reached this value at exactly week 8. Meanwhile, for organic carbon content, all variations met the quality standard threshold from the beginning and remained within the appropriate range until the end of the period. As for the best composition, as seen in the table, A2 and A3 are the best compositions. This is because, from the best method, no significant differences were found; therefore, the conventional method is more cost-effective and easier to use. The moisture contents of variations A2 and A3 also reached the quality standards the fastest. Additionally, both variations met all the quality standards set by the SNI. Therefore, it can be concluded that variations A2 and A3 excel at the best compost composition.

Parameter	Variation											
	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6
pH	+	+	+	+	+	+	+	+	+	+	+	++
Moisture	+	++	++	-	+	+	-	-	+	-	-	-
Carbon	++	++	++	++	++	++	++	++	++	++	++	++
C/N Ratio	-	+	+	+	+	+	-	+	+	+	++	++

Explanation: ++ = meets the fastest quality standards among all variations
+ = comply with SNI 7763:2024
- = does not comply with SNI 7763:2024

Figure 11. Characteristics of the Best Compost Composition Variations

4. Conclusion

Based on the results of this study, it can be concluded that compost produced from agricultural and food waste with the addition of the EM4 bioactivator has good characteristics and quality. During the composting process, the temperature increased to 40–45°C in the first week, indicating the activity of microorganisms in breaking down organic matter. The initial high pH value gradually decreased and stabilized in the neutral range, between 7 and 8, which meets the compost quality standards according to SNI 7763:2024. Additionally, a decrease in the height of the compost pile indicates gradual degradation of organic material. The moisture content also decreased, although not all variations reached the ideal standard (8–25%). The C/N ratio in most variations successfully decreased to the range of 25–35, indicating that decomposition is proceeding optimally, and the compost can be categorized as suitable. When comparing composting methods, the conventional and modified methods did not show significant differences in the final compost results. The moisture content of the compost showed significant differences when examining the ANOVA test results, with the conventional method being closer to the quality standard. Variations A2 and A3 produced C/N ratios closest to the quality standard and met the quality standard during the composting period. Additionally, pH, moisture content, and carbon content met the quality standard faster than other variations, resulting in superior compost quality and a shorter maturation time compared to other variations.

Based on the results of this study, it is recommended that further research be conducted with a broader scope. This includes variations in the materials used in the composting process and the design of composters. Additionally, modifications to the composter design, such as the addition of an active aeration system, temperature control system, and humidity controller, can significantly impact composting efficiency. However, with the increasing use of compost as an alternative organic fertilizer for plant growth, it is important to test the macro-and micronutrient content of the compost produced. This test aims to assess its impact on plant growth, ensuring that the compost produced is truly effective and meets the needs of the plants.

References

[1] Wang X, Teng Y, Wang X, Xu Y, Li R, Sun Y, et al. Effects of combined pollution of organic pollutants and heavy metals on biodiversity and soil multifunctionality in e-waste contaminated soil. *J Hazard Mater*. 2022;440:129727. https://doi.org/10.1016/j.jhazmat.2022.129727.

[2] FAO. *The State of Food and Agriculture 2020*. Rome: Food and Agriculture Organization of the United Nations; 2020.

[3] Lee H, Kim S, Park J. Microbial dynamics and organic matter decomposition during composting of food waste. *J Environ Manag*. 2019;248:109299. https://doi.org/10.1016/j.jenvman.2019.109299.

[4] Ayumi IDE, Lutfi M, Nugroho A. Efektivitas tipe pengomposan (konvensional, aerasi, dan rak segitiga) terhadap sifat fisik dan kimia kompos dari sludge biogas dan serbuk gergaji. *J Keteknikan Pertanian Tropis dan Biosistem*. 2017;5(3):265–72.

[5] Ariyanti M, Samudro G, Handayani DS. Penentuan rasio bahan sampah organik optimum terhadap kinerja Compost Solid Phase Microbial Fuel Cells (CSMFCs). *J Presipitasi*. 2019;16(1):16–23. https://doi.org/10.14710/presipitasi.v16i1.24-28.

[6] Bernal MP, Alburquerque JA, Moral R. Composting of animal manures and chemical criteria for compost maturity assessment. *Bioresour Technol*. 2008;100(22):5444–53. https://doi.org/10.1016/j.biortech.2008.11.027.

[7] Jassey B, Zaman S, Ceesay B, Touray K, Ngum I, Prakoso H. The effectiveness of EM4 and Local Micro-organisms (LOM) Activators in Organic Waste Processing in Brikama Market West Coast Region, The Gambia. *IOP Conf Ser Earth Environ Sci*. 2022;1098(1):012010. https://doi.org/10.1088/1755-1315/1098/1/012010.

[8] Sarker A, Baul T, Nath T, Karmakar S, Paul A. Household solid waste management in a recently established municipality of Bangladesh: Prevailing practices, residents' perceptions, attitude and awareness. *World Dev Sustain*. 2023;2:100120. https://doi.org/10.1016/j.wds.2023.100120.

[9] [BSN] Badan Standarisasi Nasional. SNI 7763:2024 tentang Pupuk Organik Padat. Jakarta: BSN; 2024.

[10] Herlina F. 2014. Bioactivators effectiveness and utilization in bulking agents of water hyacinth as compost. Jurnal Integrasi Sistem Industri. 1(2): 35-44. doi: 10.24853/jisi.1.2.%25p.

[11] Islam S, Hoque M. 2019. Temporal Changes of Physical Parameters of Solid Waste During Barrel Composting. Journal of Environmental Science and Natural Resources. 11(1):153-157. https://doi.org/10.3329/jesnr.v11i1-2.43382. [12] Qiao C, Penton C, Liu C, Shen Z, Ou Y, Liu Z, et al. Key extracellular enzymes triggered high-efficiency composting associated with bacterial community succession. *Bioresour Technol*. 2019;288:121576. https://doi.org/10.1016/j.biortech.2019.121576.

[12] Widarti BN, Kasran RF, Sarwono E. 2015. Pengaruh ukuran bahan terhadap kompos pada pemanfaatan tandan kosong kelapa sawit. Jukung: Jurnal Teknik Lingkungan. 1(1): 1–7. doi: 10.20527/jukung.v1i1.1034.

[13] Bachtiar B, Ahmad AH. 2019. Analisis kandungan hara kompos johar Cassia siamea dengan penambahan aktivator PROMI. Bioma: Jurnal Biologi Makassar. 4(1): 68-76. https://doi.org/10.20956/bioma.v4i1.6493

[14] Zhang W, Yu C, Wang X, Hai L. Increased abundance of nitrogen transforming bacteria by higher C/N ratio reduces the total losses of N and C in chicken manure and corn stover mix composting. *Bioresour Technol*. 2019;294:122410. https://doi.org/10.1016/j.biortech.2019.122410.

[15] Eiland F, Klamer M, Lind A, Leth M, Bååth E. Influence of initial C/N ratio on chemical and microbial composition during long term composting of straw. *Microb Ecol*. 2001;41:272–80. https://doi.org/10.1007/s002480000071.