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Research Paper

Composting of Cow Dung, Garden Waste, and Market Waste using Local Microorganisms (LMO) through the Takakura Stacking Method

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Abstract
One of the main challenges in agricultural practices is the heavy reliance on chemical fertilizers without being balanced by the use of organic fertilizers. This study aims to analyze the maturity, quality, and quantity of compost produced from a mixture of cow dung, garden waste, and market waste using the Takakura Layered Method with EM4 and Local Microorganisms (LMOs) as activators. The LMOs used included LMO A (tuna fish waste, sugarcane bagasse, and pineapple peel) and LMO B (tuna fish waste, banana peel, and vegetable scraps). Composting was conducted in duplicate with seven treatment variations: (A) cow dung with EM4, (B) cow dung with LMO A, (C) cow dung with LMO B, (D) cow dung mixed with garden waste and LMO A, (E) cow dung mixed with garden waste and LMO B, (F) cow dung mixed with garden and market waste with LMO A, and (G) cow dung mixed with garden and market waste with LMO B. The results showed that all treatments met the composting standards. All variations complied with the Indonesian National Standard (SNI 19-7030-2004) in both maturity parameters (pH, temperature, color, texture, odor, and composting duration) and quality parameters (moisture content, C-organic, nitrogen, C/N ratio, phosphorus, and potassium). The compost quantity was reduced by 27–58%. The best result was observed in variation (D1), which consisted of cow dung, garden waste, and LMO A, achieving a score of 39 with a composting time of only 6 days.

Keywords
Cow Dung Waste, Garden Waste, Market Waste, Local Microorganisms (LMO)

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1. INTRODUCTION

Agriculture plays a crucial role in supporting the economy and ensuring food security in Indonesia, particularly in rural areas. In addition, plantation commodities significantly contribute to the national Gross Domestic Product (GDP), accounting for approximately 3.94% in 2021 (Statistics Indonesia, 2021). The long-term use of chemical fertilizers poses a serious threat to crop productivity and soil quality. Dependence on inorganic inputs can lead to a decline in soil fertility and disruption of the soil ecosystem balance. Organic fertilizers improve soil health and plant growth by enhancing soil organic matter (SOM), soil structure, aggregate stability, nutrient uptake, water holding capacity, cation exchange capacity, nutrient use efficiency, and soil microbial activity (Liu et al., 2024).

The composting process provides a way to convert organic materials into a stabilized product that can be used as a soil amendment (Bernal et al., 2009). Zhao et al. (2025) demonstrated that organic fertilizer application can improve the physicochemical properties of soil and increase cotton yields in Xinjiang, China. Similarly, Zhang et al. (2023a) reported that organic fertilizers promote the growth of soil bacterial populations and enzymatic activities that support plant development.

In Nagari Sirukam, Payung Sekaki District, Solok Regency, the Cerubuih Indah Nan Jaya Farmers Group has established a Compost House Activity Unit (UKRK) to produce organic fertilizer, supported by CO_2 Operate BV and the Rimbo Pangan Lestari Foundation. However, the production remains suboptimal due to limited raw materials sourced exclusively from cow manure. Therefore, utilizing local garden and market waste as supplementary materials presents a promising solution to enhance compost production.

Currently, the Compost House Activity Unit (UKRK) utilizes a combination of cow manure, burnt husks, fine bran, dolomite, *Tithonia leaves*, and the commercial bioactivator EM4. Although EM4 has demonstrated effectiveness, further research is necessary to explore alternative activators known as Local Microorganisms (LMOs). LMOs derived from organic waste represent a cost-effective alternative for biofertilizer production, as they are made from readily available animal and plant-based waste. Their main components microorganisms, carbohydrates, and simple carbon sources such as glucose or molasses play an essential role in enhancing microbial activity during the decomposition process (Kiruba N and Saeid, 2022).

This study developed two types of Local Microorganisms (MOL): MOL A, composed of a mixture of tuna fish waste, sugarcane bagasse, and pineapple peels. These materials have the potential to serve as the base for MOL due to their content of beneficial microorganisms such as *Trichoderma*, *Rhizobium*, *Azospirillum*, *Azotobacter*, and *Pseudomonas* (Saputri et al., 2021). Meanwhile, MOL B consists of tuna fish waste, banana peels, and household vegetable scraps. The aim of this development is to assess the effectiveness of MOL in accelerating the composting process and to provide a more affordable activator alternative for local communities.

Several studies have reported that composting with various organic materials and methods, such as the addition of carbon-rich sources like corn straw and vegetable waste to cow manure, can produce compost that meets SNI 19-7030-2004 standards, with improved nitrogen content and quality (Zakariah et al., 2023). Pajura (2024) found that composting market-like organic waste with animal manure using the open windrow method and EM accelerates decomposition within 4–8 weeks, yielding compost with appropriate nutrient levels and C/N ratios. Additionally, the stacked Takakura method with EM4 produced mature compost within 12 days, with physical and chemical characteristics compliant with SNI, and is suitable for small-scale use due to its efficiency and minimal odor (Riyandini et al., 2023).

This study aims to analyze the maturity, quality, and quantity of compost produced from cow manure, garden waste, and market waste using the stacked Takakura method with EM4 and LMO as bioactivators. It also compares various treatment combinations of raw materials and activators (EM4, LMO A, and LMO B) through a scoring method to determine the most effective variation. This research presents a novel approach by incorporating local waste into the composting process and evaluating two types of LMOs derived from organic waste as affordable alternatives to EM4, an area that remains underexplored. In addition to producing high-quality compost, this study is expected to contribute to reducing the local waste problem in Nagari Sirukam.

2. EXPERIMENTAL SECTION

This study utilized cow manure waste sourced from the Compost House Activity Unit (UKRK) managed by the Rimbo Pangan Lestari Foundation (RPL), as well as garden and market waste collected from the surrounding areas of Nagari Sirukam, Solok Regency. Sample analyses were carried out at the Research Laboratory and Solid Waste Laboratory of the Department of Environmental Engineering, Andalas University, Padang City. The research stages included equipment preparation, material preparation, preliminary testing, compost maturity testing, compost quality evaluation, compost quantity assessment, and data processing and analysis.

2.1 Equipment Preparation

This study employed a Takakura composter as the primary composting unit. The equipment consisted of a perforated basket with a capacity of 40 liters. The essential components of the Takakura composter included the basket, black cloth, cardboard, and a cover (Figure 1). Tools used for assessing compost maturity and quantity included a pH meter, thermometer, and weighing scale. Detailed specifications are presented in Table 1.

Figure 1. Takakura Composter

Table 1. Test Equipment for Compost Maturity and Quantity

Tool	Function
pH meter	Measuring the pH of compost
Thermometer	Measuring compost temperature
Scales	Measuring the weight of the resulting compost

2.2 Material Preparation

Material preparation involved the collection of composting raw materials, which included cow dung, garden waste, and market waste. The ingredients used for preparing the local microorganism (LMO) solution consisted of cob fish waste, sugarcane bagasse, pineapple peel, banana peel, vegetable scraps, and EM4. The required quantities for preparing the LMO solution are listed in Table 2, while the appearance of the LMO and EM4 solutions is shown in Figure 2. The LMO dosage used in composting was determined based on the EM4 dilution guideline, where 1000 mL of EM4 is required for every 1000 kg of bokashi waste. The matured LMO activator needed to be activated before use, which was done by diluting it with clean water at a 1:5 ratio (Aziz et al., 2025). Specifically, 10 mL of LMO was mixed with 50 mL of water, producing 60 mL of activated solution. This activated EM4 or LMO solution was then applied to the compost daily at a volume of 60 mL.

2.3 Composting Process

In field practice, composting is typically carried out using only cow dung waste with the addition of the EM4 bioactivator. This research serves as a development effort by utilizing a combination of organic materials namely cow dung, garden waste, and market waste along with locally produced microbial bioactivators (LMOs). The study consisted of seven different treatment groups, each conducted in duplicate, as follows: A (10 kg cow dung + EM4), B (10 kg cow dung + LMO A), C (10 kg cow dung + LMO B), D (5 kg cow dung + 5 kg garden waste + LMO A), E (5 kg cow dung + 5 kg garden waste + LMO B), F (3.3 kg cow dung + 3.3 kg garden waste + 3.3 kg market waste + LMO A), G (3.3 kg cow dung + 3.3 kg garden waste + 3.3 kg market waste + LMO B). Based on this experimental setup, the hypothesis proposed in this study is that there are significant differences in compost maturity, quality, and quantity among treatments using EM4, LMO A, and LMO B with various combinations of organic waste materials.

The composition of organic materials in each treatment was determined based on the principle of mass equalization, in which the total weight of organic raw materials was standardized to 10 kg per treatment. This approach was adopted to ensure balanced material distribution and to facilitate valid and objective comparative analysis. The composition design also stems from the absence of previous studies that specifically combine cow dung, garden waste, and market waste with LMO bioactivators using the Stacked Takakura Method. The composting process followed the Stacked Takakura Method based on the Operational Guidelines for Small- and Medium-Scale Organic Waste Composting Using the Takakura Method (Hibino et al., 2020). The process began with chopping the garden and market waste, while the cow dung, having been previously dried and mixed with dry additives, required no further size reduction. All materials were then weighed and mixed with either EM4 or LMO bioactivators according to the treatment groups. A 1:1 ratio of organic material and compost starter was placed into 40-liter baskets, resulting in a total of 14 units (two replicates per treatment). Each basket was covered with cloth to prevent contamination and insect infestation. Daily mixing was carried out as part of the decomposition process and to monitor the compost maturity level.

2.4 Compost Maturity Test

The compost maturity test was carried out to assess the maturity level of the resulting compost. The parameters used in this test included composting duration, reduction rate, temperature, pH, color, texture, and odor of the compost. According to the Indonesian National Standard (SNI 19-7030-2004), mature compost is characterized by a temperature of approximately 30°C, a neutral pH range (6.8–7.49), a soil-like texture and color, and an earthy odor.

Figure 2. EM4 and Local Microorganism (LMO)

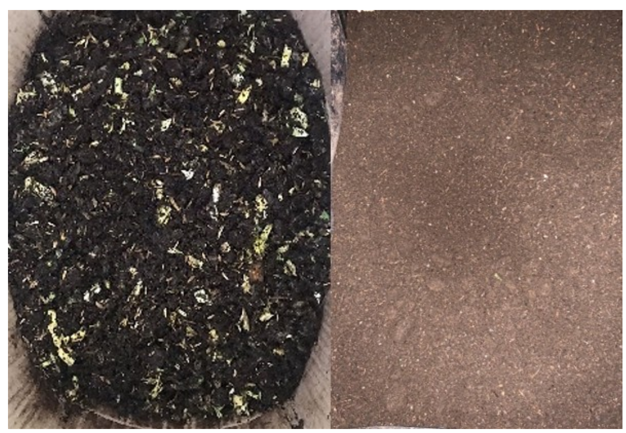

Figure 3. Changes in Color and Texture of Composted Material

2.5 Compost Quality Test

The compost quality test was conducted to evaluate the maturity level, the success of the composting process, and the feasibility of compost as an ameliorant for soil improvement. The parameters analyzed included moisture content, organic carbon (C-organic), total nitrogen (N-total), C/N ratio, phosphorus (P_2O_5), and potassium (K_2O).

Moisture content was determined using the oven-drying method at 105°C until a constant weight was achieved (Sud-

Table 2. Comparison of Local Microorganism Composition

Bioactivator	Raw Materials Comparison		
	Sample (gram)	Aren Sugar (gram)	Rice Washing Water (mL)
Cob fish + (Bagasse + Pineapple peel) = LMO A	50: (50+50)	150	750
Cob fish + (Banana peel + Vegetable scrap) = LMO B	50: (50+50)	150	750

Table 3. Recapitulation of Compost Maturity Process Analysis

Variation	pH	Temperature	Color	Texture	Odor	Time (days)
A1	7	30	Blackish	Like Soil	Odor Soil	7
A2	7	30	Blackish	Like Soil	Odor Soil	7
B1	7	30	Blackish	Like Soil	Odor Soil	7
B2	7	30	Blackish	Like Soil	Odor Soil	7
C1	7	30	Blackish	Like Soil	Odor Soil	7
C2	7	30	Blackish	Like Soil	Odor Soil	6
D1	7	30	Blackish	Like Soil	Odor Soil	6
D2	7	30	Blackish	Like Soil	Odor Soil	6
E1	7	30	Blackish	Like Soil	Odor Soil	8
E2	7	30	Blackish	Like Soil	Odor Soil	8
F1	7	30	Blackish	Like Soil	Odor Soil	7
F2	7	30	Blackish	Like Soil	Odor Soil	7
G1	7	30	Blackish	Like Soil	Odor Soil	7
G2	7	30	Blackish	Like Soil	Odor Soil	8

jadi, 1984). According to SNI 19-7030-2004, mature compost should have a moisture content below 50%. Organic carbon was analyzed using the Walkley and Black method, which involves the oxidation of organic matter by potassium dichromate under acidic conditions (Walkley and Black, 1934). The desired C-organic content for compost ranges from 9.8% to 32%, as specified by SNI 19-7030-2004. Total nitrogen content was measured using the Kjeldahl method, which includes digestion, distillation, and titration steps (AOAC, 2005). Compost should contain a minimum of 0.4% nitrogen to meet the standard. The C/N ratio was calculated from the proportion between C-organic and N-total values. An ideal C/N ratio for mature compost is between 10 and 20, based on SNI 19-7030-2004.

Phosphorus (P_2O_5) was determined using the spectrophotometric method after extraction with sodium bicarbonate solution (Olsen et al., 1954). According to SNI, phosphorus content should exceed 0.1%. Potassium (K_2O) was analyzed using the Atomic Absorption Spectrophotometry (AAS) method after extraction with ammonium acetate solution (Jackson, 1973), with a minimum standard of 0.2% as per SNI 19-7030-2004.

2.6 Compost Quantity Test

The compost quantity test was carried out by weighing the mass of solid compost produced in each treatment. This was done by calculating the difference between the initial weight of organic materials and the final weight of the matured compost. This approach was employed to assess the efficiency of the composting process in producing the final product (Sommer and Dahl, 2004).

2.7 Data Processing and Analysis

The data processing and analysis involved presenting observational data on compost maturity, quality, and quantity, followed by comparisons with the Indonesian National Standard (SNI 19-7030-2004) and relevant previous studies. Statistical analysis was conducted using the Kruskal–Wallis test to determine significant differences among treatments, followed by Dunn's post hoc test to identify specific group differences. The best compost variant was identified using a scoring system based on selected evaluation parameters. This scoring system consisted of two main criteria: (1) a binary scoring method using a value of 1 if the parameter met the quality standard and 0 if it did not; and (2) a ranking approach for parameters without established quality standards, such as composting duration and compost yield, where shorter durations or higher yields received higher scores. The evaluated parameters included physical indicators of compost maturity (temperature, pH, texture, color, odor, moisture content), macro-nutrient content (nitrogen, organic carbon, P_2O_5, K_2O), and the reduction in compost quantity (Zahra et al., 2024).

Table 4. Recapitulation of Compost Quality Analysis

Parameter Standard*	Moisture <50 (%)	C-Organic 9.8–32 (%)	Nitrogen >0.4 (%)	C/N 10–20	Phosphorus >0.1 (%)	Potassium >0.2 (%)
A1	27.552	11.670	0.691	16.90	1.33	5.57
A2	30.766	10.196	0.652	15.63	1.15	5.43
B1	26.654	11.399	0.721	15.82	1.56	6.17
B2	25.519	11.917	0.785	15.19	1.66	5.85
C1	25.299	11.916	0.707	16.84	1.22	6.02
C2	26.833	12.272	0.694	17.69	1.14	5.46
D1	30.111	12.049	0.806	14.94	1.25	5.77
D2	27.690	13.269	0.799	16.61	1.20	5.19
E1	27.358	13.466	0.785	17.15	1.09	5.29
E2	26.086	12.330	0.734	16.80	1.14	4.78
F1	32.411	12.673	0.906	13.98	1.01	5.95
F2	31.385	13.988	0.923	15.15	1.07	6.29
G1	32.547	14.238	0.846	16.83	1.17	4.30
G2	31.550	12.683	0.803	15.80	1.20	4.85

3. RESULTS AND DISCUSSION

The analysis conducted in this study included maturity test analysis, compost quality, compost quantity, and selection of the best compost variation. The variations tested in this study were done in duplicate.

3.1 Analysis of Compost Maturity

Monitoring is carried out every day along with composting starting from the inclusion of waste on the first day until the compost matures. Compost is considered mature when its temperature drops to ≤ 30°C, the pH stabilizes within a neutral range (6.8 - 7.49), the texture and color resemble soil, and the odor resembles that of soil (SNI, 2004).

From day 1 to day 3, all treatment variations exhibited similar pH values, ranging from 5 to 6.5. The initial acidic pH was attributed to the formation of simple organic acids during the early stages of decomposition. All treatments initially showed acidic conditions, which gradually shifted toward neutral pH, with variations across treatments. The increase in pH was associated with protein degradation and ammonia release (Aziz et al., 2025), while the decrease in pH could be due to the accumulation of organic acids, such as lactic and acetic acids, resulting from microbial carbohydrate breakdown (Mengqi et al., 2023). All variations show the pH value at the end of composting is in the range of 6.5 to 7.00, so that all variations of compost tests have met the specified quality standards. The Kruskal-Wallis test showed no significant differences ($p = 0.9997$), indicating stable pH across treatments, likely due to similar materials and buffering capacity. Both EM4 and MOL had minimal impact on pH.

Temperature measurements on day one ranged from 27°C to 35°C across all treatments. Treatment G recorded the highest temperature of 35°C, the peak observed during composting. The temperature gradually decreased from day 7 to ambient temperature (≤ 30°C), meeting the maturity criterion of SNI 19-7030-2004. By the end of the process, temperatures across all treatments were between 27°C and 30°C. None of the treatments reached the thermophilic phase (>40°C), with peak temperatures ranging from 33°C to 35°C. This is likely due to low pile height and a small volume-to-surface area ratio, limiting heat retention (Kalamdhad and Kazmi, 2009). The Kruskal-Wallis test showed a p-value of 0.3681, indicating no significant differences among treatments, suggesting similar temperature patterns due to comparable raw material composition and microbial heat production.

According to Figure 3, the compost color gradually changed, starting from yellowish green, dark brown, and eventually resembling dark soil color. Color observation was stopped when the compost reached a dark color, which met the maturity criteria. This color change was influenced by the mixing materials; materials that were not fully decomposed tended to retain their original color (Aziz et al., 2025). At the early stage of composting, the texture of the compost remained intact as decomposition had not yet occurred. Visual observation was stopped when the compost showed a soil-like appearance, as per the SNI 19-7030-2004 criteria. Variations D and E, a mixture of cow manure and garden waste, showed a soil-like texture within 6 days, the fastest among other variations. On day 2, the compost odor was dominated by the aroma of raw materials, such as cow manure and garden waste. By day 3, an acidic smell began to emerge, and by day 6, variations D1, D2, E1, and E2 emitted an earthy smell. These odor changes indicated the decomposition process, although a slight acidic odor was still detectable in some variations (Aziz et al., 2025).

The Kruskal-Wallis tests conducted for the parameters of color, texture, and odor yielded a p-value of 0.04304, which is below the 0.05 significance threshold. This indicates that

Table 5. Recapitulation of Reduction Rate of Compost Raw Materials

Variations	Raw Material Weight (kg)		Reduction Rate (%)
	Before Composting	After Composting	
A1	10	7.2	28
A2	10	7.0	30
B1	10	7.3	27
B2	10	7.2	28
C1	10	7.1	29
C2	10	7.3	27
D1	10	4.4	57
D2	10	4.3	59
E1	10	4.3	57
E2	10	4.3	57
F1	10	4.5	55
F2	10	4.3	57
G1	10	4.3	57
G2	10	4.4	56

Table 6. Final Compost Yield

Variation	Raw Material Variation (kg)		Compost Seed (kg)	Compost Yield (kg)
	Beginning	End		
A1	10	7.2	10	17.2
A2	10	7.0	10	17.0
B1	10	7.3	10	17.3
B2	10	7.2	10	17.2
C1	10	7.1	10	17.1
C2	10	7.3	10	17.3
D1	10	4.4	10	14.4
D2	10	4.3	10	14.3
E1	10	4.3	10	14.3
E2	10	4.3	10	14.3
F1	10	4.5	10	14.5
F2	10	4.3	10	14.3
G1	10	4.3	10	14.3
G2	10	4.4	10	14.4

there were statistically significant differences between the treatment groups regarding the time required to achieve the characteristics of mature compost. Therefore, it can be concluded that variations in raw material composition and microbial activators significantly influenced the composting rate, as indicated by changes in color, texture, and odor.

The composting duration was determined through daily monitoring of maturity parameters, including pH, temperature, color, texture, and odor. The composting time for each variation was defined as the final day on which all parameters met the maturity criteria according to the Indonesian National Standard (SNI, 2004). Variation D (comprising cow manure, garden waste, and MOL A) and Variation E (containing cow manure, garden waste, and MOL B) exhibited the fastest composting process, reaching maturity in just 6 days. In contrast, Variation F (with added market waste and MOL A) and Variation G (with market waste and MOL B) required the longest duration, taking 8 days to mature. The Kruskal-Wallis test for composting duration produced a p-value of 0.04858. Since this value is below the 0.05 significance level, it suggests a statistically significant difference between the treatment variations in terms of the time required to reach compost maturity. The recapitulation of compost maturity results can be seen in Table 3.

Based on the recapitulation in Table 3, all compost variations met the compost maturity criteria set by SNI 19-7030-2004 in terms of pH, temperature, color, texture, and odor. The Kruskal-Wallis test revealed no significant differences in temperature ($p = 0.3681$) and pH ($p = 0.9997$) among treatments. However, significant differences were found in color, texture, and odor ($p = 0.04304$), as well as composting duration ($p = 0.04858$). These findings support the hypoth-

Table 7. Scoring of Compost Maturity

Variation	pH	Temperature	Color	Texture	Odor	Length of Composting	Total
A1	5	2	2	2	2	1	13
A2	4	2	2	2	2	1	12
B1	4	1	2	2	2	1	11
B2	4	1	2	2	2	1	12
C1	5	1	2	2	2	1	13
C2	4	2	2	2	2	2	14
D1	5	6	3	3	3	3	20
D2	5	5	3	3	3	3	19
E1	5	4	3	3	3	3	18
E2	5	3	3	3	3	3	17
F1	1	2	2	2	2	1	10
F2	1	2	2	2	2	1	10
G1	5	4	2	2	2	2	15
G2	1	2	2	2	2	1	10

Table 8. Scoring of Physical Elements of Compost Quality

Parameter Standard*	Moisture Content <50%	pH 6.8-7.49	Temperature ≤30°C	Color Blackish	Texture Soil	Odor Soil	Total
A1	1	1	1	1	1	1	6
A2	1	1	1	1	1	1	6
B1	1	1	1	1	1	1	6
B2	1	1	1	1	1	1	6
C1	1	1	1	1	1	1	6
C2	1	1	1	1	1	1	6
D1	1	1	1	1	1	1	6
D2	1	1	1	1	1	1	6
E1	1	1	1	1	1	1	6
E2	1	1	1	1	1	1	6
F1	1	1	1	1	1	1	6
F2	1	1	1	1	1	1	6
G1	1	1	1	1	1	1	6
G2	1	1	1	1	1	1	6

esis that variations in organic material composition and microbial activators significantly affect the decomposition rate and compost maturity.

3.2 Analysis of Compost Quality

The compost quality testing was carried out after the compost reached the maturity stage, which involved the composting process, drying, and sieving. The quality analysis refers to SNI 19-7030-2004 on Specifications for Compost from Domestic Organic Waste, encompassing both physical and macro elements.

Each compost treatment exhibited a final moisture content within the acceptable quality range, ranging from 25.30% to 32.55%. The Kruskal-Wallis test for moisture content yielded a p-value of 0.07007, indicating no significant differences among treatments. This suggests that the type of compost material and microbial activator applied had no substantial effect on the final moisture level. These findings are in line with Masowa et al. (2018), who also reported no significant differences, noting that moisture content during composting is more influenced by pile management factors, such as turning frequency, aeration, and pile temperature, than by microbial inoculants. While inoculants may accelerate organic matter decomposition, such as by reducing the C/N ratio more rapidly, they do not directly affect water evaporation or moisture retention.

The lowest organic carbon (C-organic) content was record ed in treatment A2 at 10.196%, while the highest was observed in treatment G1 at 14.238%. According to Masowa et al. (2018), microorganisms such as bacteria and fungi utilize organic carbon derived from food waste as an energy source. During their metabolic processes, carbon compounds

Table 9. Scoring of Macro Elements of Compost Quality

Parameter Standard*	C-Organic 9.8–32 (%)	Nitrogen >0.4 (%)	C/N Ratio 10–20	Phosphorus >0.1 (%)	Potassium >0.2 (%)	Total
A1	1	1	1	1	1	5
A2	1	1	1	1	1	5
B1	1	1	1	1	1	5
B2	1	1	1	1	1	5
C1	1	1	1	1	1	5
C2	1	1	1	1	1	5
D1	1	1	1	1	1	5
D2	1	1	1	1	1	5
E1	1	1	1	1	1	5
E2	1	1	1	1	1	5
F1	1	1	1	1	1	5
F2	1	1	1	1	1	5
G1	1	1	1	1	1	5
G2	1	1	1	1	1	5

are oxidized into carbon dioxide (CO_2), which is released into the atmosphere, thereby reducing the C-organic content in the compost pile. The Kruskal-Wallis test for this parameter yielded a p-value of 0.1372, indicating no significant differences among treatments. This suggests that the combination of composting materials and microbial activators had no significant impact on the final organic carbon content. It is important to note that excessively high carbon levels may hinder decomposition, while low levels can lead to nitrogen imbalance, promote the formation of ammonia (NH_3), and result in nitrogen loss to the atmosphere.

Nitrogen levels varied across treatments, ranging from 0.652% in treatment A2 to 0.923% in treatment F2. Elevated nitrogen content may increase the risk of nitrogen loss through ammonia volatilization, whereas insufficient nitrogen may slow the composting process and limit microbial activity. Low nitrogen levels can be attributed to suboptimal decomposition. The Kruskal-Wallis test for nitrogen content resulted in a p-value of 0.05281, slightly above the 0.05 significance threshold, suggesting no statistically significant differences between treatments. However, the observed trend indicates potential effects from the addition of nutrient-rich materials and microbial activators. Zahra et al. (2024) noted that higher nitrogen levels can enhance the decomposition of organic matter, as nitrogen is essential for microbial development during composting.

The carbon-to-nitrogen (C/N) ratio across treatments ranged from 13.98 to 17.69. According to the Indonesian National Standard (SNI, 2004), the ideal C/N ratio for mature, high-quality compost lies between 10 and 20, which closely resembles the ratio found in natural soil. The Kruskal-Wallis test yielded a p-value of 0.482, indicating no significant differences among treatments. The highest C/N ratio was found in treatment C2 (17.69%), while the lowest was recorded in treatment F1 (13.98%). A lower C/N ratio indicates more advanced decomposition and the formation of humus with relatively higher nitrogen content. In contrast, a higher ratio suggests that the decomposition process is still ongoing due to the greater proportion of carbon in the compost. A C/N ratio approaching that of soil also suggests improved nutrient availability and uptake by plants.

The phosphorus content in the compost samples from all variations ranged from 1.01% to 1.66%, with the highest content found in variation B2 and the lowest in variation F1. The Kruskal-Wallis test yielded a p-value of 0.09699, which exceeds the significance threshold of 0.05, indicating no significant statistical difference in phosphorus content among the different compost treatments. According to (Zhang et al., 2023b), during the maturation phase, the decline in microbial activity and the death of microorganisms lead to the release of phosphorus stored in microbial biomass, which then mixes with the organic material in the compost, thus increasing the total phosphorus content.

The potassium (K_2O) content in the compost samples from all variations ranged from 4.30% to 6.29%, with the highest content observed in variation F2 (6.29%) and the lowest in variation G1 (4.30%). The Kruskal-Wallis test resulted in a p-value of 0.1026, which is above the significance threshold of 0.05, indicating no significant statistical difference in potassium content among the different compost treatments. However, the observed trend suggests a potential influence of the composition of compost materials and microbial activity on the enhancement of nutrients. Tibu et al. (2019) noted that the variation in potassium content during composting is influenced by the additives and microbial activity, where microorganisms contribute to the release of potassium through the mineralization of organic material. The recapitulation of compost quality analysis results can be seen in Table 4.

Based on Table 4, the results of compost quality obser-

Table 10. Scoring of Compost Quantity

Variation	Reduction Rate	Compost Yield	Total
A1	2	6	8
A2	4	4	8
B1	1	7	8
B2	2	6	8
C1	3	5	8
C2	1	7	8
D1	6	2	8
D2	7	1	8
E1	6	2	8
E2	7	1	8
F1	7	1	8
F2	7	1	8
G1	7	1	8
G2	6	2	8

vations for the parameters of moisture content, C-organic, nitrogen, C/N ratio, phosphorus, and potassium showed no statistically significant differences among the treatment groups, as indicated by p-values from the Kruskal-Wallis tests that were all greater than 0.05. These findings suggest that variations in composting materials and types of microbial activators (EM4, MOL A, and MOL B) did not significantly affect the final compost quality. Nevertheless, all measured parameters fell within the acceptable ranges established by the Indonesian National Standard SNI (2004), indicating that the resulting compost meets the quality requirements for use as organic fertilizer.

Compost maturity is accompanied by shrinkage of compost volume or weight. The level of reduction indicates the occurrence of the decomposition process in compost raw materials. The following in Table 5 is a recapitulation of the calculation of the reduction results of raw materials that decompose during composting.

Based on Table 5, it can be seen that the raw materials, which initially had a total weight of 10 kg, experienced weight shrinkage after the compost matured, where each variation became 4.2 kg to 7.3 kg. The reduction rate of each variation is in the range of 27% to 58%. Variations A, B, and C have a small reduction rate because the raw material comes from cow dung, while variations D, E, F, and G have the greatest reduction because the raw material comes from a mixture of cow dung, garden waste, and market waste. The compost must be sieved and air-dried before it can be applied as organic fertilizer. Sifting compost is done to get rid of inorganic materials and organic materials that are not decomposed (Hibino et al., 2020). The following in Table 6 shows the final results of compost after sifting and wind drying.

The composting materials totaled 20 kg, consisting of 10 kg of seed compost and 10 kg of raw materials. Raw materials in the form of cow dung, garden waste, and market waste have decomposed and reduced to 4.2 kg to 7.3 kg, while seed compost is no longer decomposed because it is mature compost, so the compost material becomes 14.3 kg to 17.3 kg. According to Andersen et al. (2011), the decomposition of organic materials by aerobic microorganisms is the primary cause of the reduction in mass and volume. This process involves the breakdown of carbohydrates, proteins, and lipids into simpler compounds such as CO_2, water vapor, and humus. The results of the Kruskal-Wallis test indicated no statistically significant differences in compost weight reduction and final yield among the treatment variations ($p = 0.07943$ and $p = 0.09367$). However, the p-values approaching the significance threshold of 0.05 suggest a moderate trend in the variations among treatments. This indicates that although the combination of composting materials and microbial activators (EM4, MOL A, and MOL B) did not produce statistically significant effects, certain combinations may exhibit higher decomposition efficiency than others.

3.3 Determining the Optimal Compost Variation

The optimal compost variation was identified through a scoring system, with the highest score indicating the best variation. The maturity scoring of the compost is presented in Table 7.

Table 11. Recapitulation of Compost Scoring Results

Variation	Scoring Results			Total Score
	Maturity	Quality	Quantity	
A1	13	11	8	32
A2	12	11	8	31
B1	11	11	8	30
B2	15	11	8	34
C1	12	11	8	31
C2	14	11	8	33
D1	20	11	8	39*
D2	19	11	8	38
E1	18	11	8	37
E2	19	11	8	38
F1	10	11	8	29
F2	10	11	8	29
G1	15	11	8	34
G2	10	11	8	29

*Note: * Variation with the highest score*

Based on Table 7, It can be seen that the highest score is found in variation D1 with a mixture of cow dung, garden waste, and LMO A. Variations with the lowest score are variations F and G. The assessment for the maturity process is given by ranking each variation based on the day when the parameters met the SNI 19-7030-2004 standard. The highest score is given for the fastest time and sorted until the slowest time. The pH parameter was given the highest score of 5 because the variation reached a pH of 6.8-7.49 on day 5. The temperature parameter was given the highest score of 6 because the variation reached a temperature of 27-30°C on day 6. Color, texture, and odor parameters were given the highest score of 3 because the variation reached a blackish color similar to soil on days 6, 7, and 8. The fastest compost maturity time received the highest score of 3. The compost quality scoring can be seen in Table 8 and Table 9.

Based on Table 8 and Table 9, The physical and macro elements of compost are scored as 1 or 0, as these parameters are associated with established quality standards. The parameters of moisture content, temperature, pH, texture, color, and odor in compost maturity have met the criteria outlined in SNI 19-7030-2004, earning a score of 1. Likewise, the macro elements such as C-Organic, Nitrogen, C/N Ratio, P_2O_5, and K_2O have also fulfilled the SNI 19-7030-2004 standards, thus receiving a score of 1. All variations have the same score because each variation has met the quality standards set for compost quality. The scoring of compost quantity can be seen in Table 10.

Based on Table 10, The scoring for the reduction rate and compost yield is done by ranking. The reduction rate and compost yield do not have quality standards, so scoring is done by ranking from the highest to the lowest reduction level and compost yield. The highest score is 7, which is given due to the variation in the resulting numbers, namely the reduction rate (27, 28, 29, 30, 55, 56, 57)% and the weight of the compost, namely (14.3, 14.4, 14.5, 17, 17.1, 17.2, 17.3) kg. The recap of the compost scoring results can be seen in Table 11.

Based on Table 11, the variation with the highest score is variation D1, which consists of a mixture of cow dung, garden waste, and the addition of LMO A, a mixture of cob fish waste, bagasse, and pineapple peel, with a score of 39 and a composting time of 6 days. This D1 variation has met the compost quality standards in SNI 19-7030-2004. Each parameter in variation D1 meets the standard for mature compost with the fastest time, thus receiving the highest score for maturity and quantity. This is followed by variation E, which uses a mixture of cow dung and garden waste, with the addition of LMO B, a mixture of cob fish waste, banana peels, and vegetable scraps, with a score of 38. Variations D and E can accelerate the composting process compared to variation A, which uses the EM4 activator with a score of 32 and a composting time of 8 days. Additionally, it can be concluded that the addition of LMO to composting can replace EM4 in accelerating and improving compost quality.

4. CONCLUSIONS

The findings demonstrated that the compost produced met the standards set by SNI 19-7030-2004 in the maturity tests (pH, temperature, color, texture, odor, and composting duration), as well as in the quality tests, which included physical elements (moisture content, pH, temperature, color, texture) and macro elements (C-Organic, Nitrogen, C/N ratio, P_2O_5, and K_2O). Additionally, the compost yield showed a reduction of 27-58%. The results revealed that variation D1, which involved composting cow dung and garden waste mixed with LMO A (a blend of cob fish waste, bagasse, and pineapple peel), with a score of 39 and a composting period of 6 days, was more effective than using EM4. Consequently, it can be concluded that LMO can substitute EM4 as an activator to accelerate the composting process.

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