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Acceleration of Organic Waste Decomposition: A Comparative Study of ASEM-7 Decomposer Efficiency on Several Organic Wastes

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Abstract. *Effective organic waste decomposition is vital for sustainable waste management and agricultural productivity. This study investigates the efficacy of ASEM-7—a newly developed decomposer comprising a consortium of seven microorganisms—in accelerating the composting process and enhancing compost quality across various types of organic waste. Five treatment groups were evaluated: paddy straw; animal manure; fruit and vegetable waste; a mixture of fruit and vegetable waste with straw; and a combination of fruit, vegetable waste, straw, and manure. During the decomposition process, key physicochemical parameters— including pH, temperature, moisture content, organic carbon (C-organic), total nitrogen (N-total), and the carbon-to-nitrogen (C/N) ratio—were systematically monitored. The results demonstrated that ASEM-7 significantly enhanced composting efficiency compared to both EM-4 and control (no-decomposer) treatments, achieving optimal pH stabilization (7–8) at a faster rate. Additionally, ASEM-7 reduced moisture content and C/N ratios more effectively, indicating a higher degree of compost maturity. Compost treated with ASEM-7 also exhibited the lowest levels of organic carbon, reflecting superior decomposition efficiency. Although temperature levels remained below the threshold required for effective pathogen elimination, microbial activity successfully facilitated nutrient recycling. The microbial consortium—comprising Bacillus sp., Lactobacillus sp., and Trichoderma sp.—demonstrated high efficacy in degrading recalcitrant organic materials such as straw and manure, thereby improving the compost's nutrient composition. By meeting key compost quality standards—organic carbon (≥15%), total nitrogen (≥0.5%), and a C/N ratio of 15–25—ASEM-7 effectively converts organic waste into high-quality compost. These findings underscore the importance of tailored microbial consortia in advancing sustainable waste management practices and enhancing soil fertility.*

Keywords: *ASEM-7 decomposer; compost quality; organic waste; composting.*

Type of the Paper: Regular Article.

1. Introduction

Organic waste refers to biodegradable materials that can be decomposed by microbial activity into simpler compounds. Common sources include household waste (e.g., vegetable and fruit scraps), agricultural residues (e.g., straw and plant matter), and livestock waste (e.g., animal manure) [1]. Improper management of organic waste can result in environmental contamination and significant public health risks [2]. The accumulation of decomposing organic matter attracts

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pests—such as rodents and flies—that act as vectors for diseases including dysentery, cholera, and typhoid fever [3–10]. Uncontrolled decomposition of organic waste results in the emission of harmful gases—such as methane and ammonia [2]—which contribute to air pollution and respiratory health problems. Therefore, proper management and treatment of organic waste are imperative to mitigate these environmental and public health risks.

Organic waste possesses significant potential for utilization, particularly as organic fertilizer. The conversion of organic waste into fertilizer occurs through microbial activity in a process commonly referred to as composting [5–7,11]. The microorganisms involved in this process—commonly termed decomposing microorganisms or bio-decomposers—are capable of degrading organic and inorganic materials [6,8,9]. These decomposers, comprising fungi and bacteria, exhibit catalytic activity during decomposition and function efficiently under both aerobic and anaerobic conditions. In addition to decomposing waste into simpler compounds, decomposer microorganisms enhance nutrient content in the resulting organic fertilizer through nitrogen fixation, phosphorus solubilization, and cellulose degradation [10].

Microorganisms play a pivotal role in the decomposing organic matter by converting complex compounds into simpler forms readily assimilable by plants [12]. Prominent fungal decomposers include *Humicola*, *Trichoderma*, and *Penicillium* and *aspergillus* species, which facilitate the degradation of lignocellulosic materials, thereby accelerating the composting process. In addition to fungi, several bacterial species—such as *Bacillus*, *Flavobacterium*, *Microbacterium*, and *Pseudoxanthomonas*—serve as effective decomposers [13–15]. These microorganisms act synergistically to degrade organic waste, thereby enhancing the release of essential nutrients and promoting soil microbial diversity.

The application of organic fertilizer derived from decomposed waste represents a sustainable strategy to enhance soil fertility and mitigate the detrimental impacts of excessive synthetic fertilizer use. Prolonged use of chemical fertilizers has been linked to soil degradation, nutrient imbalances, and diminished microbial biodiversity, contributing to long-term soil infertility [16,17]. Studies have demonstrated that the incorporation of decomposer microorganisms into organic fertilizers not only enhances soil fertility but also indirectly promotes crop productivity by improving nutrient availability and soil structure [18–21]. This approach supports environmentally sustainable agricultural practices and reduces reliance on synthetic fertilizers, presenting a viable solution for long-term sustainable farming systems.

Although commercial decomposer products such as EM-4 are available, many existing bio-decomposers remain limited in terms of efficiency, microbial stability, and decomposition rate. The effectiveness of a decomposer is largely influenced by microbial diversity [22], population density, and the specificity of the microorganisms in degrading complex organic substrates [23].

ASEM-7 is an advanced decomposer formulation designed with a high microbial load and selective bacterial strains capable of accelerating the decomposition of organic waste more efficiently than conventional decomposers. Moreover, ASEM-7 is engineered to maintain microbial viability over time, addressing a prevalent limitation of commercial decomposers, which often lose efficacy due to microbial decline during storage.

This study evaluated the effectiveness of ASEM-7 on various types of organic waste. ASEM-7 is a newly developed decomposer formulated from a consortium of seven distinct microbial strains. It is designed to enhance composting efficiency and produce high-quality compost. This study utilized various types of organic waste, including paddy straw, animal manure, fruit and vegetable residues, a mixture of fruit and vegetable waste with straw, and a combination of fruit, vegetable, straw, and manure.

2. Materials and Methods

2.1. Experimental setup

The study was conducted in a controlled greenhouse environment at the Faculty of Agriculture, Universitas Padjadjaran, to minimize external variables. The experimental period spanned two months, encompassing all stages from material preparation to the completion of the decomposition process. To evaluate the effects of two treatment factors, the study employed a factorial design nested within a Randomized Complete Block Design (RCBD). The RCBD was selected to control for environmental variability among experimental blocks within the greenhouse setting.

The experiment involved two treatment factors. The first factor was the type of decomposer, with three levels: D1 = ASEM-7, D2 = EM-4, and D3 = no decomposer. The second factor was the type of organic waste, comprising five levels: L1 = paddy straw, L2 = animal manure, L3 = fruit and vegetable waste, L4 = a mixture of fruit and vegetable waste with paddy straw, and L5 = a mixture of fruit and vegetable waste, paddy straw, and animal manure. Each treatment combination was replicated three times, resulting in a total of 45 experimental units. The units were randomly arranged within the greenhouse to minimize positional bias.

The observed parameters included a preliminary analysis of the decomposers prior to application to assess the initial characteristics of ASEM-7 and EM-4, with a focus on their microbial composition. The physical parameters measured during the study included pH, monitored weekly with a pH meter to track acidity changes during fermentation; temperature, recorded daily using a thermometer to evaluate microbial activity; and moisture content, measured using a moisture meter to maintain optimal fermentation conditions. The chemical parameters analyzed comprised total nitrogen (N-total), determined by the Kjeldahl method; moisture content, measured gravimetrically; organic carbon (C-Organic), analyzed via the Walkley-Black method; and the carbon-to-nitrogen (C/N) ratio, calculated from the C-Organic and N-Total values as an indicator of compost maturity.

2.2. Material and Equipment Preparation

The materials used in this study included organic waste (paddy straw, animal manure, and fruit and vegetable waste), decomposers (ASEM-7 and EM4), and water. Organic waste was collected from the surrounding area and finely chopped to a maximum size of approximately 1 cm to ensure material homogeneity and increase the surface area for microbial activity. The equipment used included airtight plastic buckets, a pH meter (Hanna Basic pH/ORP Benchtop Meter - PH21-02), a soil tester (Aventru 4 in 1) to measure temperature and moisture, an analytical balance, and laboratory instruments for chemical analysis, such as the Kjeldahl method for nitrogen determination, the Walkley-Black method for organic carbon determination, and an oven (Memmert series-902619) for gravimetric moisture content analysis. The organic waste was separated according to the treatment combinations, with mixed treatments prepared in specific ratios to ensure consistency. The waste materials were placed into 10-liter fermentation containers for each experimental unit.

2.3. Application of Decomposers

Each experimental unit was treated with decomposers at a standard dosage recommended by the manufacturer, 20 ml per liter (ASEM-7 and EM-4). The decomposer was evenly mixed with the organic waste using a manual stirrer. The fermentation containers were then sealed and stored in a greenhouse under controlled environmental conditions.

2.4. Maintenance and Monitoring

During the fermentation process, the contents of each container were stirred twice a week to ensure the uniform distribution of the decomposers. Physical parameters, including temperature, moisture content, and pH, were monitored to observe changes throughout the decomposition process. This methodology ensured reliable data collection for evaluating the effectiveness of ASEM-7 compared to EM4 on different types of organic waste.

3. Results and Discussion

Several factors, including particle size, pH, temperature, moisture content, and the carbon-to-nitrogen ratio (C/N ratio) of organic waste, significantly impact the composting process [24]. This study observed a wide range of initial pH values [5–7,9,10] among different organic waste materials (Fig. 1). The use of ASEM-7 effectively increased the pH of the organic waste from the second day onwards, stabilizing between 7 and 8 in subsequent observations. Both ASEM-7 and the treatment without decomposers stabilized the pH within the 7-8 range from day 27, followed by EM-4 on day 37. The lowest final pH was observed in the treatment without decomposers, while treatments with decomposers achieved higher final pH values (above 8). According to prior research by Zhou et al. [25], monitoring pH changes during composting can provide valuable insight into the progression of the process. Generally, the initial and cooling phases are characterized by slightly acidic pH, whereas the heating and thermophilic phases exhibit an increase in pH. The composting rate is significantly influenced by pH, with alkaline conditions generally being most favorable. In contrast, acidic conditions can inhibit composting by adversely affecting microbial activity [2].

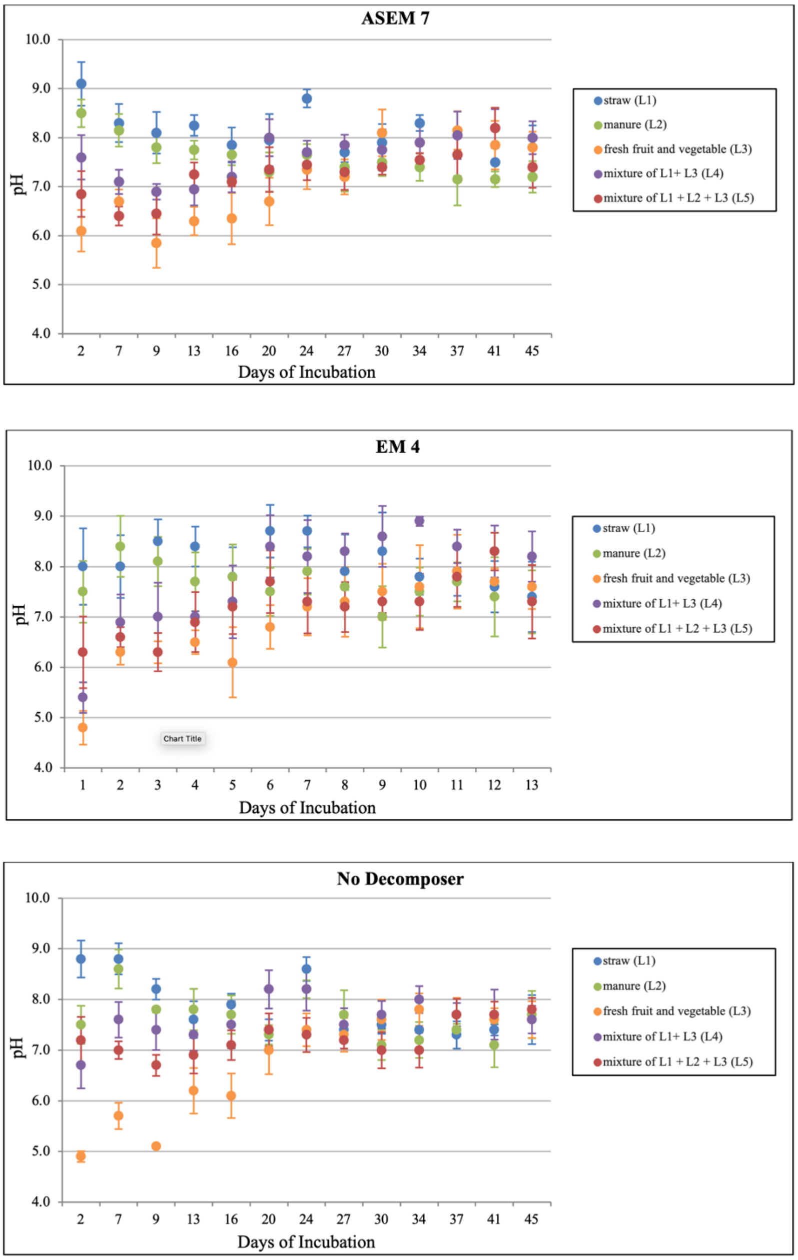

Fig. 1. Changes in pH of organic waste during composting

As composting is an aerobic process, proper aeration and adequate moisture are crucial factors [26]. Moisture plays a critical factor in decomposition, significantly impacting oxygen uptake, temperature, and microbial activity [27]. In this study, organic waste materials derived from animal manure and paddy straw exhibited high moisture content at the end of the observation period, with an increase observed from day 27 onward (Fig. 2). This elevated moisture content may have slowed down the composting process for these materials. According to Mohammad et al. [28], increased moisture content can reduce the rate of gas diffusion, potentially limiting oxygen availability and shifting the process towards anaerobic conditions due to restricted microbial activity. This is likely because paddy straw and animal manure contain more recalcitrant (i.e., resistant to decomposition) components compared to fruit and vegetable waste, which decomposes more readily.

Paddy straw primarily comprises cellulose, hemicellulose, and lignin [29,30], making it more resistant to decomposition. The texture of manure also impacts its degradability, with excessively liquid manure posing challenges for aerobic decomposition. Generally, moisture content decreases throughout the composting process, which includes the mesophilic, thermophilic, cooling, and maturation stages [25].

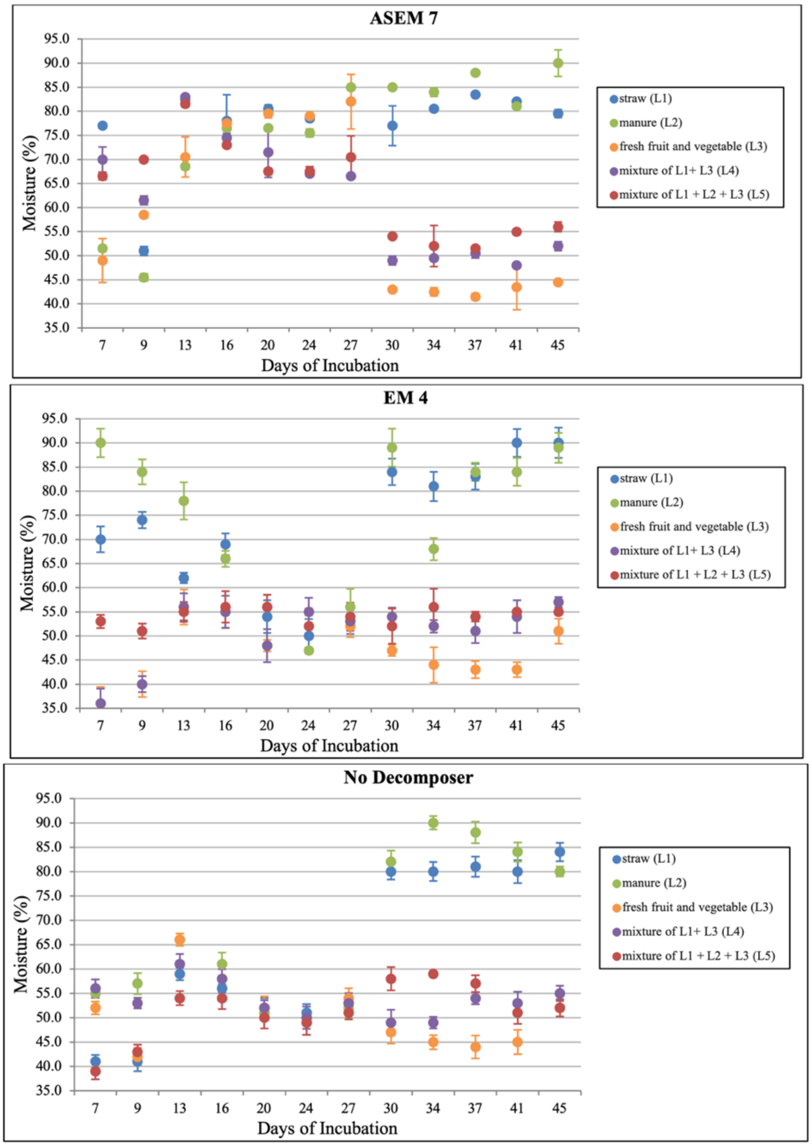

Fig. 2. Changes in moisture content of organic waste during composting

Temperature is a crucial factor in the composting process, which is typically divided into mesophilic, thermophilic, cooling, and maturation stages [26]. The temperature of organic waste treated with various decomposers exhibited significant fluctuations throughout the observation period (day 7 to 45) (Fig. 3), reflecting variations in microbial activity and the degradation of organic matter [31]. High temperatures generally occur during the thermophilic stage, driven by the activity of heat-loving (thermophilic) microorganisms. Conversely, lower temperatures are generally observed during the initial (mesophilic) and maturation stages, where different microbial communities (mesophilic microorganisms) are active.

The highest average temperature (31°C) was observed in the ASEM-7 and EM-4 treatments, while the treatment without decomposers reached a maximum temperature of 30°C. The ASEM-7 treatment maintained the highest final temperature (31°C), followed by EM-4 and the treatment without decomposers (28-29°C). However, this temperature range does not align with several studies reporting a suitable composting temperature range of 40-65°C [32].

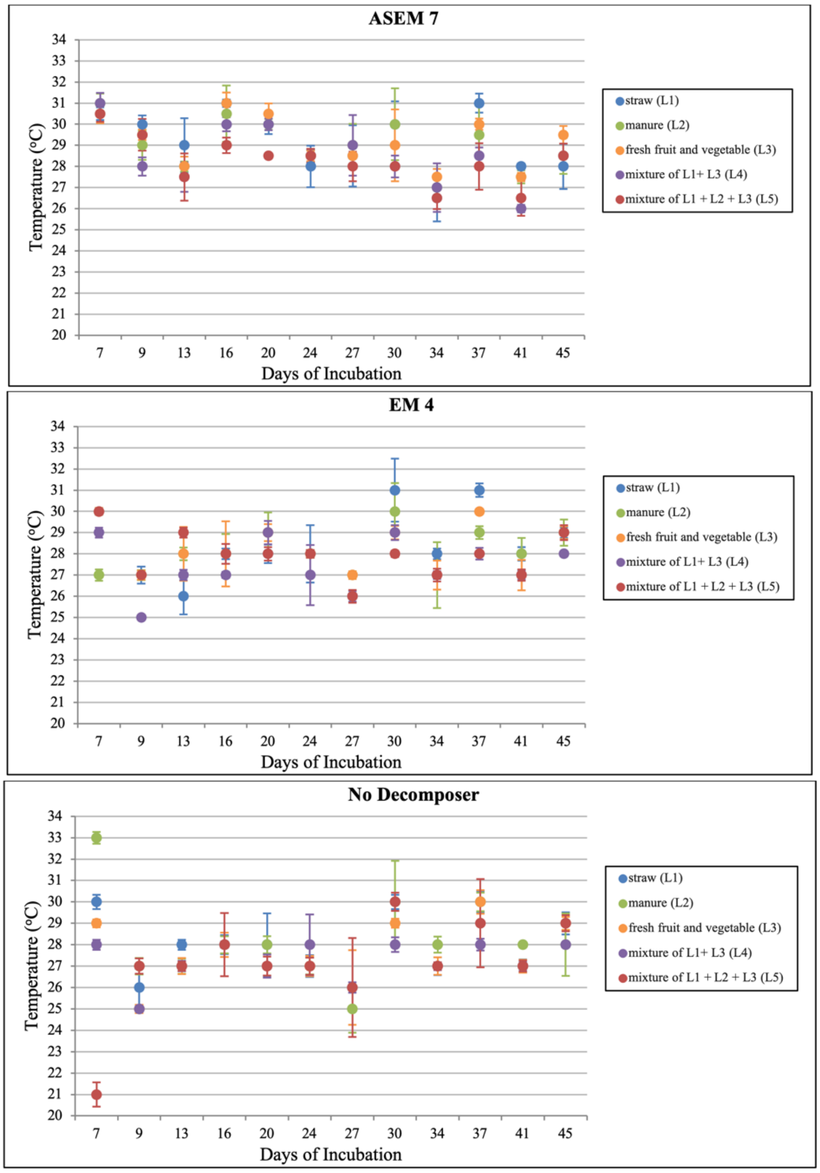

Fig. 3. Changes in temperature of organic waste during composting

Additionally, temperatures below 55°C are insufficient to eliminate parasites and pathogens, which is crucial for ensuring optimal sanitary conditions [33]. Nevertheless, other research suggests that sometimes composting temperatures may not always reach 45°C; studies have shown that pathogens can be eliminated even at lower temperatures due to factors such as nutrient depletion and the activity of competitive organisms that produce enzymes capable of destroying them [2].

Microorganisms require nitrogen (N), carbon (C), and potassium (K) nutrients during composting to break down organic matter. Furthermore, they produce these nutrients as a byproduct of organic matter decomposition [34]. Laboratory analysis (Table 1) revealed that the D1 (ASEM-7) treatment resulted in lower organic C content compared to the EM4 decomposer and no decomposer treatments, with the lowest value reaching 18.95%. The highest value was observed in the D2 (EM4) treatment, particularly in L5 (a combination of paddy straw, animal manure, and fruit and vegetable waste), which reached 32.38%. The highest average C-organic content was found in D2 (EM4) at 30.17%, followed by D3 (no decomposer) at 31.88%.

Table 1. Effect of decomposers on several organic waste

Decomposer	Organic waste										Average
	L1		L2		L3		L4		L5		
C-organic (%)											
D1	28.01±0.45	f	25.97±0.12	e	18.95±0.34	a	22.23±0.29	bc	21.61±0.22	b	23.35
D2	31.42±0.67	h	28.66±1.10	f	18.07±1.88	a	23.32±1.05	cd	23.81±0.91	d	30.17
D3	30.06±0.30	g	38.59±0.57	i	28.30±0.87	f	30.08±0.38	g	32.38±0.51	h	31.88
Average	29.83		31.07		25.18		27.46		28.79		(+)
N-Total (%)											
D1	1.43±0.01	b	1.65±0.03	d	1.54±0.03	c	1.88±0.03	f	1.54±0.02	c	1.61
D2	1.53±0.02	c	2.31±0.03	h	1.74±0.03	e	1.99±0.03	g	2.51±0.03	i	2.02
D3	1.17±0.04	a	1.62±0.03	d	1.64±0.01	d	1.92±0.03	f	1.89±0.05	f	1.65
Average	1.38		1.86		1.64		1.93		1.98		(+)
C/N Ratio											
D1	19.59±0.46	j	15.77±0.25	h	10.62±1.00	b	11.73±0.18	cd	13.46±1.11	ef	12.06
D2	18.34±0.51	i	11.23±0.11	bc	10.91±0.17	bc	11.20±0.22	bc	8.60±0.16	a	14.23
D3	26.94±0.94	k	14.93±0.58	gh	11.06±1.19	bc	14.38±0.81	fg	12.61±0.69	de	15.98
Average	21.62		13.98		10.86		12.44		11.56		(+)
Water Content (%)											
D1	31.57±0.57	a	33.66±1.74	b	39.33±0.87	e	37.19±0.80	cd	36.18±0.44	cd	35.59
D2	32.43±1.74	ab	33.97±1.19	b	41.41±0.70	f	37.62±0.90	d	35.96±1.30	c	36.28
D3	33.97±1.15	b	39.76±0.69	e	43.28±1.01	g	43.03±1.14	g	44.12±0.62	g	40.83
Average	32.66		35.80		41.34		39.28		38.75		(+)

Note: Values within the same column followed by the same letter are not statistically different according to the DMRT test at the 5% significance level. D1 = ASEM-7, D2 = EM4, D3 = no decomposer. L1 = paddy straw, L2 = animal manure, L3 = fruit and vegetable waste, L4 = L1+L3, L5 = L1+L2+L3.

This observation suggests an inverse relationship between the effectiveness of organic waste decomposition and organic carbon content. The persistently high organic carbon content after decomposition indicates that the decomposer's activity was not fully effective. An efficient decomposition process should reduce organic carbon content, as decomposers convert carbon into simpler compounds, such as carbon dioxide (CO_2), which is released into the atmosphere. This result aligns with the findings of Zhu et al. [35], who reported an 8% reduction in total organic carbon by the 49th day of the composting process. The results also show that the treatment without decomposers had the highest water content in almost all types of waste, with the highest level observed in L5 waste at 44.12%. In contrast, paddy straw waste treated with ASEM-7 had the lowest water content, at 31.57%. Based on the average values, the best performance was demonstrated by the ASEM7 decomposer, which reduced water content by the greatest amount, specifically 35.59%.

EM4 produces a higher N-total content in almost all types of waste, especially in L5, with the highest value of 2.51%. The no decomposer and ASEM-7 treatments produce lower N content, although ASEM-7 shows fairly good results in L1 (paddy straw) and L2 (animal manure). The highest average N-total content is found in EM4, at 2.02%. The no decomposer treatment has the highest C/N ratio in almost all types of waste, indicating that carbon remains more dominant than nitrogen in these wastes. EM4 produces a lower C/N ratio, especially in L5, with a ratio of 8.60, indicating a better balance between carbon and nitrogen. ASEM-7 provides a higher C/N ratio compared to EM4, but still lower than the treatment without decomposer. The highest average C/N ratio was observed in the no decomposer treatment, with a value of 21.62, while EM4 showed the lowest C/N ratio. However, a good C/N ratio is not necessarily the lowest; there is an acceptable range. According to the Ministry of Agriculture of Indonesia, high-quality compost should have a C/N ratio between 15 and 25%. Based on this range, the lowest C/N ratio of 8.60, produced by EM4, is considered too low. Treatments that result in C/N ratios within the acceptable range include ASEM-7 with L1 and L2 waste, and EM4 with L1 waste.

The C/N ratio, representing the ratio of total organic carbon to total organic nitrogen, is a critical factor in nutrient availability during composting. Carbon serves as the primary energy source for microorganisms, while nitrogen is essential for cell structure [26,36]. Consequently, nitrogen deficiency limits microbial growth and slows down carbon decomposition [37]. Conversely, excessive nitrogen can cause other issues. Optimal C/N ratios for composting are generally reported to be around 20-30 [38]. A low C/N ratio can result in the release of ammonia gas, causing unpleasant odors, and the accumulation of soluble basic salts, which can adversely affect soil conditions and hinder plant growth [39]. In contrast, a high C/N ratio indicates insufficient nitrogen for microbial growth, slowing the composting process [26]. The judicious combination of composting materials is crucial to optimize the C/N ratio, thereby ensuring efficient and effective microbial decomposition.

Based on the analysis (Table 1), all treatments met the minimum requirements for C-organic (≥15%) and N-total (≥0.5%) as stipulated by the Indonesian Ministry of Agriculture, with C-organic ranging from 18.95% (ASEM-7 + fresh fruit and vegetable waste) to 38.59% (EM4 + animal manure), and N-total ranging from 1.17% (EM4 + animal manure) to 2.51% (EM4 + mixed waste of fruit, vegetables, straw, and animal manure). However, only some treatments achieved a C/N ratio within the standard range (15–25), while others, such as EM4 + mixed waste, exhibited low C/N ratios (8.60), indicating that the compost was not fully matured. Additionally, the water content in all treatments exceeded the maximum allowable limit (≤25%), ranging from 31.57% (ASEM-7 + straw) to 44.12% (EM4 + complete mixed waste). These indicate that ASEM-7 exhibited better performance than EM4 in producing well-matured compost with more efficient decomposition, as evidenced by lower C/N ratios and more optimal water content.

The use of specific decomposing agents has been widely demonstrated to improve composting effectiveness. A study from Lasmini et al. [40] revealed that applying decomposers containing *Trichoderma sp.* in the composting of goat manure and vegetable waste significantly improved compost quality, as evidenced by changes in C content, N content, C/N ratio [41], temperature [42], and pH [43]. Furthermore, variations in decomposing agents affected C-organic content in cattle manure compost [9], N-total content, and the C/N ratio [44], which are critical indicators of compost maturity and quality. Another study [45] showed that inoculation with an effective microbial consortium (*Bacillus sp.*, *Actinomycetes sp.*, *Lactobacillus sp.*, *Saccharomyces sp.*, and *Trichoderma sp.*) enhanced the nutrient content of the compost. Research Monica et al. [46] also found that an effective microbial consortium consisting of *Lactobacillus*, *Pseudomonas*, *Aspergillus*, *Saccharomyces*, and *Streptomyces*, isolated from various sources, significantly improved waste treatment efficiency.

4. Conclusions

In conclusion, ASEM-7, a newly formulated decomposer containing seven different microbes, significantly improved the composting process by optimizing key factors such as pH stabilization, moisture content reduction, and C/N ratio. Compared to EM-4 and no-decomposer treatments, ASEM-7 demonstrated superior performance in promoting efficient decomposition, which is crucial for producing high-quality compost. These findings suggest that ASEM-7 has the potential to enhance the composting process and produce compost that meets quality standards, including C-organic ≥15%, N-total ≥0.5%, and a final C/N ratio of 15–25%, in accordance with the criteria of the Ministry of Agriculture of Indonesia.

Abbreviations

RCBD Randomized Complete Block Design

Data availability statement

Data will be shared upon request by the readers.

CRediT authorship contribution statement

Ana Khalisha: Conceptualization, Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing – original draft, Writing – review and editing. **Dwi Novanda Sari**: Conceptualization, Project administration, Resources, Writing – review and editing. **Stefina Liana Sari**: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. **Rani Sukmadewi**: Conceptualization, Project administration, Resources, Writing – review and editing. **Adi Surya Pradipta**: Investigation, Methodology, Validation, Writing – review and editing. **Astri Nur Istyami**: Data curation, Investigation, Methodology, Validation, Writing – review and editing.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest or competing interest.

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References

[1] Gonawala SS, Jardosh H. Organic Waste in Composting: A brief review. International Journal of Current Engineering and Technology 2018;8. https://doi.org/10.14741/ijcet.v8i01.10884.
[2] Ayilara M, Olanrewaju O, Babalola O, Odeyemi O. Waste Management through Composting: Challenges and Potentials. Sustainability 2020;12:4456. https://doi.org/10.3390/su12114456.
[3] Wondimu H. The Impact of Poor Waste Management Practice on The Campus Students: The Case of Gondar University of "Tewodros" Campus, Ethiopia. International Journal of New Economics and Social Sciences 2020;12:45–58. https://doi.org/10.5604/01.3001.0014.6881.
[4] Gashaw T, Jambo A. Typhoid in Less Developed Countries: A Major Public Health Concern. Hygiene and Health in Developing Countries - Recent Advances, IntechOpen; 2022. https://doi.org/10.5772/intechopen.108109.
[5] Cai Q-Y, Mo C-H, Wu Q-T, Zeng Q-Y, Katsoyiannis A. Concentration and speciation of heavy metals in six different sewage sludge-composts. J Hazard Mater 2007;147:1063–72. https://doi.org/10.1016/j.jhazmat.2007.01.142.
[6] Toledo M, Siles JA, Gutiérrez MC, Martín MA. Monitoring of the composting process of different agroindustrial waste: Influence of the operational variables on the odorous impact. Waste Management 2018;76:266–74. https://doi.org/10.1016/j.wasman.2018.03.042.
[7] Yu H, Xie B, Khan R, Shen G. The changes in carbon, nitrogen components and humic substances during organic-inorganic aerobic co-composting. Bioresour Technol 2019;271:228–35. https://doi.org/10.1016/j.biortech.2018.09.088.

[8] Berg B, McClaugherty C. Decomposer Organisms. Plant Litter, Cham: Springer International Publishing; 2020, p. 45–65. https://doi.org/10.1007/978-3-030-59631-6_3.

[9] Wang X, Wang X, Geng P, Yang Q, Chen K, Liu N, et al. Effects of different returning method combined with decomposer on decomposition of organic components of straw and soil fertility. Sci Rep 2021;11:15495. https://doi.org/10.1038/s41598-021-95015-5.

[10] Iqbal N, Agrawal A, Dubey S, Kumar J. Role of Decomposers in Agricultural Waste Management. Biotechnological Applications of Biomass, IntechOpen; 2021. https://doi.org/10.5772/intechopen.93816.

[11] Bai J, Shen H, Dong S. Study on eco-utilization and treatments of highway greening waste. Procedia Environ Sci 2010;2:25–31. https://doi.org/10.1016/j.proenv.2010.10.005.

[12] Shahid MJ, AL-surhanee AA, Kouadri F, Ali S, Nawaz N, Afzal M, et al. Role of Microorganisms in the Remediation of Wastewater in Floating Treatment Wetlands: A Review. Sustainability 2020;12:5559. https://doi.org/10.3390/su12145559.

[13] Evans R, Alessi AM, Bird S, McQueen-Mason SJ, Bruce NC, Brockhurst MA. Defining the functional traits that drive bacterial decomposer community productivity. ISME J 2017;11:1680–7. https://doi.org/10.1038/ismej.2017.22.

[14] Floudas D, Bentzer J, Ahrén D, Johansson T, Persson P, Tunlid A. Uncovering the hidden diversity of litter-decomposition mechanisms in mushroom-forming fungi. ISME J 2020;14:2046–59. https://doi.org/10.1038/s41396-020-0667-6.

[15] Purahong W, Wubet T, Lentendu G, Schloter M, Pecyna MJ, Kapturska D, et al. Life in leaf litter: novel insights into community dynamics of bacteria and fungi during litter decomposition. Mol Ecol 2016;25:4059–74. https://doi.org/10.1111/mec.13739.

[16] Kai T, Kumano M, Tamaki M. A Study on Rice Growth and Soil Environments in Paddy Fields Using Different Organic and Chemical Fertilizers. J Agric Chem Environ 2020;09:331–42. https://doi.org/10.4236/jacen.2020.94024.

[17] Qin S, Jiao K, Lyu D, Shi L, Liu L. Effects of maize residue and cellulose-decomposing bacteria inocula on soil microbial community, functional diversity, organic fractions, and growth of *Malus hupehensis* Rehd. Arch Agron Soil Sci 2015;61:173–84. https://doi.org/10.1080/03650340.2014.928927.

[18] Khalisha A, Widyastuti R, Chaniago IA. Use of phosphorus- and potassium-solubilizing multifunctional microbes to support maize growth and yield. SAINS TANAH - Journal of Soil Science and Agroclimatology 2022;19:91. https://doi.org/10.20961/stjssa.v19i1.57816.

[19] Chen M, Xu P, Zeng G, Yang C, Huang D, Zhang J. Bioremediation of soils contaminated with polycyclic aromatic hydrocarbons, petroleum, pesticides, chlorophenols and heavy metals by composting: Applications, microbes and future research needs. Biotechnol Adv 2015;33:745–55. https://doi.org/10.1016/j.biotechadv.2015.05.003.

[20] Adhikari D, Yudha Perwira I, S. Araki K, Kubo M. Stimulation of soil microorganisms in pesticide-contaminated soil using organic materials. AIMS Bioeng 2016;3:379–88. https://doi.org/10.3934/bioeng.2016.3.379.

[21] Singh JS, Pandey VC, Singh DP. Efficient soil microorganisms: A new dimension for sustainable agriculture and environmental development. Agric Ecosyst Environ 2011;140:339–53. https://doi.org/10.1016/j.agee.2011.01.017.

[22] Maron P-A, Sarr A, Kaisermann A, Lévêque J, Mathieu O, Guigue J, et al. High Microbial Diversity Promotes Soil Ecosystem Functioning. Appl Environ Microbiol 2018;84. https://doi.org/10.1128/AEM.02738-17.

[23] Semchenko M, Barry KE, de Vries FT, Mommer L, Moora M, Maciá-Vicente JG. Deciphering the role of specialist and generalist plant–microbial interactions as drivers of plant–soil feedback. New Phytologist 2022;234:1929–44. https://doi.org/10.1111/nph.18118.

[24] Fernández-Delgado Juárez M, Prähauser B, Walter A, Insam H, Franke-Whittle IH. Co-composting of biowaste and wood ash, influence on a microbially driven-process. Waste Management 2015;46:155–64. https://doi.org/10.1016/j.wasman.2015.09.015.

[25] Zhou X, Yang J, Xu S, Wang J, Zhou Q, Li Y, et al. Rapid in-situ composting of household food waste. Process Safety and Environmental Protection 2020;141:259–66. https://doi.org/10.1016/j.psep.2020.05.039.

[26] Chen Z, Zhang S, Wen Q, Zheng J. Effect of aeration rate on composting of penicillin mycelial dreg. Journal of Environmental Sciences 2015;37:172–8. https://doi.org/10.1016/j.jes.2015.03.020.

[27] Chen T, Zhang S, Yuan Z. Adoption of solid organic waste composting products: A critical review. J Clean Prod 2020;272:122712. https://doi.org/10.1016/j.jclepro.2020.122712.

[28] Mohammad N, Alam MdZ, Kabbashi NA, Ahsan A. Effective composting of oil palm industrial waste by filamentous fungi: A review. Resour Conserv Recycl 2012;58:69–78. https://doi.org/10.1016/j.resconrec.2011.10.009.

[29] Wu W, Wang Z, Jin Y, Matsumoto Y, Zhai H. Effects of LiCl/DMSO dissolution and enzymatic hydrolysis on the chemical composition and lignin structure of rice straw. Biomass Bioenergy 2014;71:357–62. https://doi.org/10.1016/j.biombioe.2014.09.021.

[30] Pan M, Gan X, Mei C, Liang Y. Structural analysis and transformation of biosilica during lignocellulose fractionation of rice straw. J Mol Struct 2017;1127:575–82. https://doi.org/10.1016/j.molstruc.2016.08.002.

[31] Li H, Li J, Jiao X, Jiang H, Liu Y, Wang X, et al. The Fate and Challenges of the Main Nutrients in Returned Straw: A Basic Review. Agronomy 2024;14:698. https://doi.org/10.3390/agronomy14040698.

[32] Rigby H, Clarke BO, Pritchard DL, Meehan B, Beshah F, Smith SR, et al. A critical review of nitrogen mineralization in biosolids-amended soil, the associated fertilizer value for crop production and potential for emissions to the environment. Science of The Total Environment 2016;541:1310–38. https://doi.org/10.1016/j.scitotenv.2015.08.089.

[33] Ravindran B, Sekaran G. Bacterial composting of animal fleshing generated from tannery industries. Waste Management 2010;30:2622–30. https://doi.org/10.1016/j.wasman.2010.07.013.

[34] Darby I, Xu C-Y, Wallace HM, Joseph S, Pace B, Bai SH. Short-term dynamics of carbon and nitrogen using compost, compost-biochar mixture and organo-mineral biochar. Environmental Science and Pollution Research 2016;23:11267–78. https://doi.org/10.1007/s11356-016-6336-7.

[35] Zhu N, Zhu Y, Kan Z, Li B, Cao Y, Jin H. Effects of two-stage microbial inoculation on organic carbon turnover and fungal community succession during co-composting of cattle manure and rice straw. Bioresour Technol 2021;341:125842. https://doi.org/10.1016/j.biortech.2021.125842.

[36] Iqbal MK, Nadeem A, Sherazi F, Khan RA. Optimization of process parameters for kitchen waste composting by response surface methodology. International Journal of Environmental Science and Technology 2015;12:1759–68. https://doi.org/10.1007/s13762-014-0543-x.

[37] Hilkiah Igoni A, Ayotamuno MJ, Eze CL, Ogaji SOT, Probert SD. Designs of anaerobic digesters for producing biogas from municipal solid-waste. Appl Energy 2008;85:430–8. https://doi.org/10.1016/j.apenergy.2007.07.013.

[38] Yan C, Yan S-S, Jia T-Y, Dong S-K, Ma C-M, Gong Z-P. Decomposition characteristics of rice straw returned to the soil in northeast China. Nutr Cycl Agroecosyst 2019;114:211–24. https://doi.org/10.1007/s10705-019-09999-8.

[39] Awasthi MK, Pandey AK, Khan J, Bundela PS, Wong JWC, Selvam A. Evaluation of thermophilic fungal consortium for organic municipal solid waste composting. Bioresour Technol 2014;168:214–21. https://doi.org/10.1016/j.biortech.2014.01.048.

[40] Lasmini SA, Edy N, Yunus M, Haji Nasir B, Khasanah N. Effect of the combined application of manure compost and trichoderma sp. On production parameters and stem rot disease incidence of shallot. Chilean Journal of Agricultural & Animal Sciences 2022;38:335–44. https://doi.org/10.29393/CHJAA38-31OHVL10031.

[41] Ramadan LMAH, Alim N, Tala S, Debora M, Barus B. Differences in C/N ratios and nutrient content of N, P, and K, in Making Compost from Rice Straw Waste with Trichoderma sp Activator. International Journal of Economic, Technology and Social Sciencesinjects 2022;3:365–74. https://jurnal.ceredindonesia.or.id/index.php/injects/article/download/856/948/2830

[42] Organo ND, Granada SMJM, Pineda HGS, Sandro JM, Nguyen VH, Gummert M. Assessing the potential of a Trichoderma-based compost activator to hasten the decomposition of incorporated rice straw. Sci Rep 2022;12:448. https://doi.org/10.1038/s41598-021-03828-1.

[43] Muliarta IN, Agung IGAMS, Adnyana IM, Diara IW. Local decomposer increase composting rate and produce quality rice straw compost. International Journal of Life Sciences 2019;3:56–70. https://doi.org/10.29332/ijls.v3n1.273.

[44] Said MI, Hastang, Isra VN. Quality of compost produced from different types of decomposer substrate and composition of straw. IOP Conf Ser Earth Environ Sci 2020;492:012088. https://doi.org/10.1088/1755-1315/492/1/012088.

[45] Zhang Z, Gu Y, Wang S, Zhen Y, Chen Y, Wang Y, et al. Effective microorganism combinations improve the quality of compost-bedded pack products in heifer barns: exploring pack bacteria-fungi interaction mechanisms. BMC Microbiol 2024;24:302. https://doi.org/10.1186/s12866-024-03447-6.

[46] Monica S, Karthik L, Mythili S, Sathiavelu A. Formulation of Effective Microbial Consortia and its Application for Sewage Treatment. J Microb Biochem Technol 2011;03. https://doi.org/10.4172/1948-5948.1000051.