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Original Research Article

Performance of Bioactivators in Organic Waste Composting: Takakura and Composter Bag

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Abstract

Population growth has significantly increased organic waste generation, requiring sustainable solutions like composting. This exploratory study evaluated the treatment-specific effectiveness of various bioactivators—EM4, biowash, ecoenzyme, and fermented stale rice solution—using Takakura and composting bag methods, with un-activated setups as controls. Composting was conducted for 42 days by monitoring physical and chemical parameters. Results showed that final physical characteristics and pH values (6.0–7.4) across all treatments complied with the Indonesian National Standard (SNI 19-7030-2004). Descriptive comparative analysis revealed that the combinations distinctly influenced final nutrient qualities. In the composting bag system, ecoenzyme performed best, achieving the most optimum and stable C/N ratio of 19.67 along with superior nitrogen retention (1.461%). Conversely, in the Takakura system, the fermented stale rice solution provided better organic matter stabilization compared to EM4 and control setups. Direct container-method comparison was valid only for the shared treatments (EM4 and Control), where the composting bag system exhibited better temperature and moisture stability, minimizing nutrient loss compared to the Takakura method. Ultimately, specific container-bioactivator pairings offer practical and sustainable alternatives for household and community-scale organic waste management.

Keywords: Bioactivator; compost; composting bag; takakura; waste

1. Introduction:

Organic waste management is becoming an increasingly important environmental issue, along with the increasing population and people's consumption patterns that continue to produce waste every day (A.Zukni, et al., 2022). Globally, on average each individual produces about 0.74 kg of waste per day, so the total production of urban waste reaches about 2.01 billion tons per year and only a small part of it can be managed properly (IGNPuger, 2018). In Indonesia, based on data from the National Waste Management Information System (SIPSN) in 2023, around 60% of the waste produced is organic waste from households, markets, city parks, and other public places. The high volume of organic waste is a serious challenge because of its wet, heavy, easily decaying, and producing unpleasant odors. In addition, the accumulation of organic waste in landfills can produce methane gas (CH_4) which has a higher global warming potential than carbon dioxide (CO_2) (W. OdeHervina, et al., 2024). Therefore, environmentally friendly and sustainable waste management efforts are needed to reduce negative impacts on the environment and public health.

One of the alternatives for effective organic waste management is through the composting process. In addition to reducing environmental pollution, composting is also a solution for the use of organic waste into products with useful value. One of the methods that has developed in the community is the Takakura method and the use of composting bags as composting containers. The Takakura method is known to be practical because it uses a closed container so that the decomposition process takes place without causing a strong odor and is suitable for application to narrow areas in densely populated areas (Sulistiyani, et al., 2024). Meanwhile, composting bags made of UV resistant materials are also considered flexible, easy to use, and can be used repeatedly for the composting process. The success of the composting process is influenced by various factors, one of which is the use of bioactivators. Effective Microorganism 4 (EM4) is one of the commonly used bioactivators because it contains photosynthetic bacteria, lactic acid bacteria, yeast, and fermented fungi that are able to accelerate the fermentation of organic matter (Nurjazuli, et al., 2016). In addition to EM4, natural bioactivators such as ecoenzyme, biowash, and fermented stale rice solution are also widely developed because they are cheaper, easier to obtain, and environmentally friendly.

Based on these conditions, this exploratory study was conducted to evaluate the treatment-specific effectiveness of various bioactivators within two distinct household composting systems. Specifically, the study investigated the application of EM4 and a fermented stale rice solution using the Takakura method, alongside ecoenzyme, EM4, and biowash using the composting bag method, with un-activated setups serving as controls for both systems. Due to the distinct sets of bioactivators assigned to each method, direct comparison between the two container types is focused strictly on their shared treatments (EM4 and control). This research focuses on the monitoring of field parameters—including changes in temperature, pH, compost pile height, and physical maturity indicators (color and texture)—as well as laboratory analyses of final macro-nutrients, namely organic carbon (C), total nitrogen (N), phosphorus (P), and potassium (K). The results of this study are expected to provide target-specific insights into suitable bioactivator-container pairings for household organic waste management, thereby supporting localized efforts to reduce waste production and enhance environmental sustainability.

2. Methods

2.1 Research Time and Location

The study was conducted from February to May 2025, with the composting process and field observations taking place over a period of 42 days. This research consists of three main activities, namely the preparation stage, the composting stage, and the testing stage. The preparation and manufacturing stage is carried out at the Green House of the Department of Environmental Engineering, while the testing stage is carried out at the Laboratory of the Department of Environmental Engineering. All of these research locations are at the Faculty of Engineering, Diponegoro University. In addition, the location of organic waste collection is spread from several canteens in the Diponegoro University environment.

2.2 Research Design

This study uses a field experiment method to analyze the effectiveness of the use of various bioactivators in the organic waste composting process using the Takakura method and composter bag. The treatment applied consisted of several variations of bioactivators, namely control without the addition of activators, EM4 and a fermented stale rice solution using the Takakura method. Alongside ecoenzyme, EM4, and biowash using the composting bag method. Each treatment is carried out on a different composting container to determine the effect of the bioactivator on the decomposition process and the quality of the compost produced.

To ensure methodological transparency and address the logistical framework, each unique container-bioactivator treatment was conducted using a single independent experimental composting unit (n = 1). However, to evaluate measurement precision, all subsequent chemical and physical laboratory analyses were performed in triplicate (analytical replicates). The starting material (feedstock) consisted of a uniform mixture of 5 kg of chopped organic waste (comprising canteen food residues, fruit pieces, and vegetable waste) combined with 1.5 kg of dried leaves as brown waste and 1 kg of rice husks to optimize initial porosity. The initial parameters of the raw composite feedstock were characterized by a moisture content of approximately 60% - 65% and an estimated baseline C/N ratio of 30 – 35.

The tools used in the study included a Takakura basket or composter bag, cardboard sheets, shovels, scissors, knives, thermometer, soil meter, sprayer, ruler, and gloves. The research materials consist of organic waste in the form of fruit residues, vegetable waste, and canteen food waste, dried leaves as brown waste, rice husks, compost soil, compost fertilizer, and bioactivators in the form of EM4, biowash, fermented stale rice solution, and eco-enzymes. The organic waste that has been collected is first sorted to separate the materials that can be degraded optimally, then chopped into smaller sizes to speed up the composting process.

The composting stage is carried out by arranging materials in layers in a composting container. A base layer of husks or husk pads ±5–15 cm thick is used as an aeration medium. Next, brown waste in the form of dried leaves is included, followed by green waste such as vegetable waste or organic food waste. Each layer is then covered using compost soil or compost, then sprayed or bioactivators are added as per the treatment. The preparation of the layer is carried out repeatedly until the container is full. In the control treatment, no additional bioactivators were given, while other treatments used 1 liter of EM4, 1 liter of biowash, 1 liter of fermented stale rice solution, and 1 liter of eco-enzyme. The fermentation and decomposition process lasts for 42 days with periodic stirring to maintain air circulation and compost moisture.

The bioactivators used in this study were prepared and dosed using specific standard protocols to ensure consistency. For the EM4 treatment, a 10% working solution was prepared by diluting 100 mL of commercial EM4 stock with 900 mL of distilled water and adding 50 grams of brown sugar as a microbial substrate stimulant. The ecoenzyme and biowash activators were sourced from controlled domestic organic fermentations and applied at a 10% dilution ratio (100 mL stock diluted in 900 mL water). The fermented stale rice solution was prepared by fermenting 500 grams of dried leftover cooked rice in 1 liter of water for 7 days in a sealed anaerobic container prior to application. Each activator solution (exactly 1 liter per designated treatment) was applied as a single initial dose sprayed uniformly onto the waste layers during the initial setup of the containers to kickstart the microbial succession. No supplementary liquid dosing was administered during the weekly stirring phases to prevent artificial anaerobic conditions.

Monitoring is carried out periodically during the composting process by observing physical parameters including temperature, pH, material height, color, and texture of the compost. After the composting process is completed, the quality of the compost is tested in the laboratory to determine the content of the main nutrients, namely carbon (C), nitrogen (N), phosphorus (P), and potassium (K). The data from observations and laboratory tests were then analyzed to compare the effectiveness of each bioactivator treatment on the quality of the compost produced.

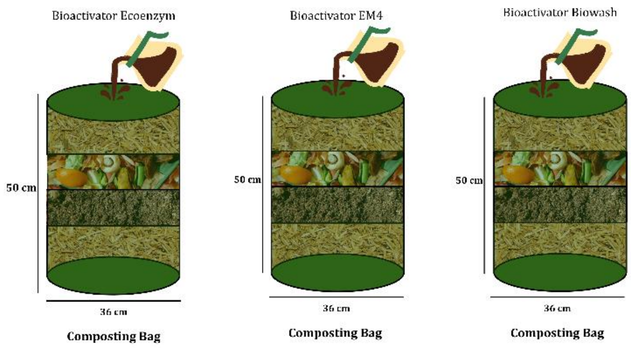

Figure 1. Experimental design using composting bag

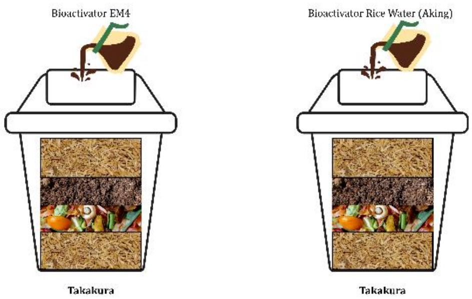

Figure 2. Experimental design using takakura

2.3 Laboratory Testing

The testing stage was carried out at the Environmental Engineering laboratory of Diponegoro University. Some of the parameters analyzed include water content, c-organic content, nitrogen content, phosphate content, and potassium content. The principle of moisture content analysis is to determine the moisture content content in the sample. Moisture content testing was carried out using the Gravimetric method. The moisture content test was carried out using an oven at 105°C for 2 hours which was then cooled into a desiccant for 10 minutes and a watch cup containing the compost was weighed (previously the empty watch cup was first dried in the oven at 105°C for 0.5 hours, but if the weight of the watch cup has not been constant, put it back in the oven for 1 hour).

Nutrient testing includes C-organic, nitrogen (N), phosphate (PO4), and potassium (K) content. Laboratory testing followed strictly standardized protocols. The initial and final Organic Carbon (C-organic) contents were determined using the Walkley-Black chromic acid wet oxidation method, which is preferred over high-temperature loss-on-ignition to prevent the overestimation of carbon from un-decomposed woody fractions. Following the wet oxidation, the green chromic color intensity was measured quantitatively using a UV-Vis Spectrophotometer at a wavelength of 561 nm. Total Nitrogen (N) was analyzed via the Indophenol-Spectrophotometry method following Kjeldahl digestion. For mineral nutrients, total Phosphorus is reported as Total Phosphate (P_2O_5) using the ammonium molybdate colorimetric method via UV-Vis Spectrophotometry, while total Potassium (K) was quantified using an Atomic Absorption Spectrophotometer (AAS). Additionally, the weekly in-situ monitoring of pH was conducted using a digital soil pH meter, which was rigorously calibrated prior to each sampling routine using standard buffer solutions of pH 4.0 and 7.0 to guarantee empirical accuracy. The determination of C-organic, nitrogen (N), phosphate (PO4), and potassium (K) levels was carried out after fermentation of compost for 42 days. The assessment of the level of compost maturity is carried out based on the provisions in SNI 19-7030-2004 regarding compost quality standards. Observation of field parameters and the compost stirring process is carried out periodically every 7 days.

3. Result and Discussion

3.1 Field Test Result

Based on the research conducted, field observation data and test results were obtained. Field observation data was collected during the composting process. During the composting process, the composting bag is opened and stirred weekly to maintain ideal composting conditions, namely good humidity and air circulation within the composter (Harlis et al., 2019). Regular stirring helps ensure that air (oxygen) can enter the compost pile so that aerobic microorganisms can work optimally in breaking down organic material (Jannah et al., 2023). During this stirring, field data will be collected in the form of temperature, humidity, and pH acidity levels as shown in table 2.

The treatments in this study were categorized into two main composting methods—composting bag (CB) and Takakura (TK)—with various bioactivator applications. The composting bag method comprised four distinct treatments: composting with the addition of Ecoenzyme (CB Ecoenzym), with Biowash (CB Biowash), with EM4 (CB EM4), and a control group without any bioactivator (CB Control). Meanwhile, the Takakura method consisted of three treatments, which included the utilization of EM4 (TK EM4), the application of a fermented stale rice solution (TK Rice Solution), and a control group without a bioactivator (TK Control). Each treatment group was monitored under identical environmental conditions to ensure the consistency and validity of the observed data. This comparative setup aims to evaluate the efficiency of each bioactivator type in accelerating the decomposition process within the two different composting systems.

Table 1. Field observation results

Date	Treatment	Observation result		
		Humidity (%)	Temperature (°C)	pH
7th Day	CB Ecoenzyme	100	35	3,5
	CB Biowash	60	31	4,1
	CB EM 4	60	32	4,5
	CB Control	60	32	4,2
	TK EM4	58	34	4,9
	TK Rice Solution	56	31	4
	TK Control	57	33	4,2
14th Day	CB Ecoenzyme	78	45	4.1
	CB Biowash	50	30	5,8
	CB EM 4	60	30	5,7
	CB Control	60	30	5
	TK EM4	60	32	4,2
	TK Rice Solution	59	32	3,9
	TK Control	59	30	5
21st Day	CB Ecoenzyme	75	45	4.2
	CB Biowash	60	30	6,3
	CB EM 4	55	30	6,2
	CB Control	51	31	5,8
	TK EM4	55	30	5,9
	TK Rice Solution	57	30	6
	TK Control	56	30	6
The 28th Day	CB Ecoenzyme	40	43	6.2
	CB Biowash	55	28	6,5
	CB EM 4	60	28	6,8

Date	Treatment	Observation result		
		Humidity (%)	Temperature (°C)	pH
	CB Control	60	27	6,3
	TK EM4	54	26	6,4
	TK Rice Solution	55	27	6,8
	TK Control	54	26	6,5
Day 35	CB Ecoenzyme	55	35	5.3
	CB Biowash	60	28	7,1
	CB EM 4	55	29	7
	CB Control	60	28	6,9
	TK EM4	53	28	6,9
	TK Rice Solution	53	29	7
	TK Control	54	28	6,7
Day 42	CB Ecoenzyme	55	27	6
	CB Biowash	45	28	7,2
	CB EM 4	55	28	7,4
	CB Control	60	27	7
	TK EM4	53	27	6,6
	TK Rice Solution	52	28	7
	TK Control	53	27	6,9

The composting process will go through several phases. The first phase is decomposition, in this phase microbes begin to degrade the most easily degraded materials and will experience an increase in population so that the temperature becomes hot (mesophilic 25 – 45 °C) to (thermophilic > 45 °C). A thermophilic temperature at > 55 °C would be better because it can kill more pathogens, weed seedlings and fly larvae, but if the temperature > 65 °C is not good because it can kill microbes and limit the rate of decomposition in solid waste. This decomposition phase was seen from the first seven days of observation (March 10, 2025) to the 21st day of observation (March 31, 2025).

The second phase is cooling, in this phase gradually the supply of high-energy compounds is exhausted and the temperature will decrease slowly until mesophilic microorganisms are formed. In this cooling phase, it can be seen in the observation of days 28 to 35 (March 31-April 7, 2025). In this cooling phase, the temperature will return to the mesophilic. The last phase is the maturation phase, in this phase the temperature and microbial activity will be low but the tone of the natural process will still occur. In the maturation process, this occurs between the 35th to the 42nd day.

Based on the results of observations that have been made, it is known that the characteristics of the maturity of organic waste compost have a blackish-brown color, smell like soil, smooth and soft like soil texture. Based on the results of observations that have been made, it can be found that the addition of ecoenzyme, biowash, EM4 and fermented stale rice solution bioactivators has an effect on the decomposition process of organic waste, this can be proven by a fairly high temperature increase in the treatment of CB Ecoenzyme, CB Biowash, CB EM4, TK EM4 and TK Rice Solution compared to the control treatment (without the addition of bioactivators). In addition, in the observation of pH and humidity, results were obtained that were not much different between treatments.

The processing of organic waste using the *composting bag* and takakura method produces compost fertilizer with the same characteristics between treatments in color, smell, texture, and temperature, namely blackish-brown, smelly and resembles the texture of the soil, and a temperature of <30°C. This is in accordance with the requirements of SNI: 19-7030-2004 for the physical quality requirements of compost, but there are still parameters that do not meet the requirements, namely pH. The pH level in the last phase (ripening) ranges from 4.8–6. The results of previous studies showed that the physical quality of organic waste compost at all variations of composting doses carried out was obtained that mature compost would blacken brownish, smell soil, have a cold temperature similar to soil, and be easily destroyed (Hutagalung et al., 2023). This shows that the addition *of ecoenzyme bioactivators* has been proven to produce compost in accordance with SNI: 19-7030-2004 quality. Based on the observation of the physical quality of compost, the best compost treatment was obtained, namely in the application of ecoenzyme bioactivator treatment for the composting bag method (CB Ecoensym) and EM4 bioactivator treatment for the takakura method (TK EM4), this is because both treatments have a very similar texture resembling soil and there is the largest volume shrinkage compared to other treatments.

Organic waste processing Becoming composted with the *composting bag* and takakura method has several advantages. This method has several advantages, one of which is the ease of the composting process. Organic matter is simply mixed in containers, and can be added at any time as needed (Destiasari et al., 2024). The containers used are made of UV *resistant* material, are flexible, easy to move, not easily damaged, and have a durability of up to five years of use. The container is also equipped with air vents that allow optimal air exchange during the decomposition process, thus minimizing unpleasant odors. In addition, the top of the container is equipped with a side zipper to facilitate the stirring process and protect against external disturbances. This container also has a special gap designed to make the compost harvesting process more practical (Wahyuni et al., 2023).

The application of processing organic waste into compost can be an alternative to reduce the generation of organic waste. Based on field observations that have been carried out, it can be seen that in all treatments there is a reduction in the minimum waste volume of 60%, with the largest reduction in waste volume, namely in the treatment of CB Ecoenzyme and TK EM4 which reached 63%. The depreciation of the volume or weight of the compost material occurs due to the decomposition process during composting. As the maturity rate of the compost increases, the volume of material will continue to decrease. During this process, certain chemical compounds will naturally evaporate. One of the indicators of compost maturity is the occurrence of material shrinkage of at least 60%. If the shrinkage that occurs is too small, it indicates that the composting process has not been completed (Kriswantoro et al., 2022). The shrinkage rate of dry organic matter is greatly influenced by the type of material and the composting method applied. In addition, several other factors that also affect include the ratio of carbon to nitrogen (C/N), material particle size, temperature, humidity level, aeration, pH, oxygen levels, and the presence of microorganisms or activators (Wijayanti et al., 2023). In order to determine the effectiveness of adding *ecoenzyme bioactivators* in composting, an analysis of C-Organic, Nitrogen, Phospaste and Potassium levels can be carried out. This test was carried out on the 42nd day with the results as shown in table 3.

3.2 Laboratory Test Results (C, N, P, K analysis)

Table 2. CNPK level test results (in%)

Treatment	C-Organic	Nitrogen	C/N Ratio	Phosphate	Potassium	Water content
CB Ecoenzyme	28,741	1,461	19.67	0.134	0,479	52.74
CB Biowash	11,924	0,383	31.13	0,267	2,962	53.21
CB EM 4	10,909	0,479	22.77	0,376	2,450	49.78
CB Control	13,695	0,611	22.41	0,794	3,153	41.58
TK EM4	20,410	0,274	74.48	0,036	1,037	56,62
TK Rice Solution	21,336	0,266	80.21	0,033	0,745	51,18
TK Control	20,092	0,259	77.58	0,035	0,961	53,32

The results of testing the levels of C-organic, nitrogen, phosphate, potassium, and moisture content in various composting treatments showed that the type of composting method and the use of bioactivators had a significant influence on the final quality of the compost. Based on Table 3, the Composting Bag with Bioactivator Ecoenzyme (CB Ecoenzym) treatment produced the highest C-organic content at 28.741%, followed by Takakura fermented stale rice solution (21.336%) and TK EM4 (20.410%) treatments. The high C-organic content of CB Ecoenzyme indicates that the decomposition process of organic matter takes place slower than other treatments, so there are still many complex carbon compounds left in the compost. Ecoenzymes are known to contain various fermentative microorganisms as well as enzymes such as proteases, amylase, and lipases that are able to help the gradual degradation of organic matter (Tang et al., 2020). A high C-organic value indicates the potential of compost in improving soil structure and increasing the soil cation exchange capacity, although if it is too high, it can indicate that the mineralization process is not yet complete. In contrast, CB EM4 and CB Biowash treatments had lower C-organic levels, indicating that the carbon decomposition process was more intensive due to more active microbial activity.

The highest nitrogen content was obtained in the CB Ecoenzyme treatment of 1.461%, much higher than other treatments in the range of 0.259–0.611%. The high nitrogen content in this treatment indicates that the use of ecoenzymes is able to retain the nitrogen element during the composting process. Scientifically, nitrogen is a very easy element to lose through the volatilization of ammonia during the composting process, especially when high temperatures and aeration are less than optimal (Bernal et al., 2009). The high nitrogen content indicates that the activity of microorganisms is stable and nitrogen loss can be suppressed. In addition, the high nitrogen also indicates good compost quality because nitrogen is the main macroelement that plants need for vegetative growth. In the Takakura method, all treatments showed a relatively low nitrogen content, allegedly because the composting process took place faster so that more nitrogen was released in the form of ammonia gas due to the high microbial respiration activity.

In the phosphate and potassium parameters, the best treatment was obtained in CB Control with a phosphate content of 0.794% and potassium of 3.153%, the highest compared to all other treatments. The high content of phosphate and potassium in the control treatment shows that even without the addition of bioactivators, the process of mineralization of nutrients can still take place properly through the activity of natural microorganisms from the compost raw materials. Phosphorus is formed from the decomposition of organic matter containing organic phosphate compounds into inorganic forms available to plants (Sánchez-Monedero et al., 2018). Meanwhile, high potassium indicates the occurrence of elemental concentrations due to the reduction in the mass of organic matter during the composting process. Potassium is a relatively stable element and does not volatile so it tends to increase as the moisture content and compost mass decreases. The CB Biowash and CB EM4 treatments also showed high potassium content, at 2.962% and 2.450%, respectively, indicating that the composting bag method was more effective in retaining the potassium element than the Takakura method.

The moisture content in all treatments is in the range of 41.58–56.62%, which is still within the optimal range for the composting process, which is around 40–60% (Haug, 1993). The EM4 TK treatment had the highest moisture content of 56.62%, while CB Control had the lowest moisture content of 41.58%. The high moisture content in the Takakura method is suspected to be due to the characteristics of the Takakura basket which has a more open air circulation so that the biodegradation process is active and produces higher water vapor. However, too high a moisture content has the potential to reduce the porosity of the material and cause anaerobic conditions that can inhibit the activity of aerobic microorganisms. In contrast, the lower moisture content of CB Control indicates more stable conditions and supports the optimal compost maturation process.

To determine the true maturity level of the compost, evaluating individual absolute macronutrient concentrations is insufficient. Instead, the carbon-to-nitrogen (C/N) ratio serves as the most critical index for assessing the extent of organic waste decomposition and biological stabilization. According to the Indonesian National Standard for compost quality (SNI 19-7030-2004), a mature and stable compost must achieve a C/N ratio between 10 and 20. Based on the computed chemical configurations, the Composting Bag with Ecoenzyme (CB Ecoenzyme) treatment emerged as the most optimal pairing in this study, successfully achieving a final C/N ratio of 19.67. Although this treatment retained a high residual C-organic content (28.741%), this did not strictly indicate incomplete mineralization in a negative context, but rather represented a balanced degradation process wherein high carbon conservation was dynamically matched by an exceptional total nitrogen retention of 1.461%. Ecoenzymes are rich in organic acids and complex hydrolytic enzymes (such as proteases and amylases) that can temporarily depress the local pH, which consequently prevents ammonia volatilization (NH_3) by shifting the chemical equilibrium toward non-volatile ammonium (NH_4^+). This protective mechanism successfully conserved nitrogen within the solid matrix, driving the C/N ratio down into the ideal maturity bracket mandated by SNI 19-7030-2004.

In stark contrast, all treatments utilizing the Takakura method (TK EM4, TK Rice Solution, and TK Control) exhibited critically high final C/N ratios ranging from 74.48 to 80.21, failing to meet the national standard. For example, the TK EM4 treatment yielded a C/N ratio of 74.48 (20.410% C-organic / 0.274% Nitrogen). While its absolute carbon content was lower than that of CB Ecoenzyme, its nitrogen content was severely depleted. The structural design of the Takakura basket features a highly ventilated, open aeration mesh. Although this structural characteristic accelerates initial aerobic respiration and moisture reduction, it simultaneously triggers excessive nitrogen loss through rapid ammonia stripping under warm, alkaline, and well-aerated conditions. Consequently, because nitrogen was drastically lost faster than carbon could be fully gasified into CO_2, the final products of the Takakura system remained highly immature at Day 42. Applying such immature compost with a C/N ratio >70 to agricultural soils would cause severe nitrogen immobilization, where soil microbes strip surrounding soil nutrients to complete their carbon degradation, thereby inducing phytotoxicity and hindering plant vegetative growth.

For the remaining composting bag variants, CB Biowash and CB EM4 failed to hit the ideal SNI target, marking final C/N ratios of 31.13 and 22.77, respectively. These elevated ratios reflect an incomplete stabilization phase, proving that biowash and EM4 required a longer timeline than 42 days to achieve full humification under the composting bag setup. Furthermore, phosphorus (reported as total P2O5) and potassium concentrations were highest in the CB Control (0.794% and 3.153%), highlighting that baseline structural breakdown without added liquids allowed natural microbial populations to concentrate these non-volatile mineral elements efficiently via mass reduction. Overall, this comprehensive chemical evaluation shifts the maturity ranking substantially, proving that the composting bag method paired with an ecoenzyme activator provides the most reliable matrix stability and nutrient preservation for organic waste recycling (Widarti et al., 2015).

Due to the unbalanced setup where the bioactivator sets differed between the two composting systems, a generalized direct comparison between the composting bag and Takakura methods cannot be cleanly drawn across all variations. To maintain methodological rigor, the comparison regarding the container effect was strictly restricted to the shared treatments common to both methods, namely the EM4 bioactivator and the control group. When evaluating these identical setups, the composting bag method demonstrated better performance than the Takakura method in maintaining moisture stability and reducing nutrient loss, particularly for nitrogen and potassium retention. For the remaining treatments (Ecoenzyme, Biowash, and fermented stale rice solution), the outcomes are interpreted independently as treatment-specific effects within their respective container systems.

4. Conclusions

This study shows that the combination of various bioactivators and composting methods distinctly influences the decomposition process and the final quality of organic waste compost. Both the composting bag and Takakura methods successfully produced mature compost characterized by a blackish-brown color, soil-like odor, smooth texture, and a stable final temperature below 30°C over 42 days of observation. Due to the unbalanced experimental design, the evaluation of the composting performance is interpreted through treatment-specific outcomes rather than a generalized superiority of one container system over another. In the composting bag system, the application of an ecoenzyme bioactivator (CB Ecoenzyme) demonstrated the most optimum performance, successfully achieving an ideal C/N ratio of 19.67 and superior nitrogen retention (1.461%). Conversely, in the Takakura system, the fermented stale rice solution (TK Rice Solution) provided better organic matter stabilization and a more stable moisture condition compared to the EM4 and control setups. A direct method-to-method comparison is strictly valid only for the shared treatments (EM4 and Control). For these specific shared setups, the composting bag system exhibited a more controlled decomposition environment that better maintained temperature and humidity stability, resulting in higher retention of nitrogen, phosphate, and potassium compared to the more open Takakura system. Thus, specific pairings of a composting container and an appropriate bioactivator offer effective and sustainable alternatives for localized organic waste management. Further research is recommended to evaluate long-term microorganism dynamics, heavy metal content, and the direct effectiveness of these specific compost products on plant growth.

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Ethics Statement

The research involved organic waste composting experiments and did not include human participants or clinical interventions. All research activities were conducted with consideration for environmental safety, proper waste handling, and laboratory safety procedures. Data collection and analysis were carried out objectively to ensure scientific integrity and research transparency.

This study did not involve animal experiments; therefore, approval from an animal ethics committee was not required. All experimental procedures related to composting and laboratory analysis were performed in accordance with institutional environmental and safety regulations.

CRediT Author Statement

Sri Sumiyati: Idea Development, Research Design, Program Development, Formal Analysis**. Bimastyaji Surya Ramadan:** Resources, Manuscript Draft Preparation, Project Administration, Financial Support, Acquisition. **Budi Prasetyo Samadikun:** Result Verification, Formal Analysis, Investigation**. Anik Sarminingsih:** Data Curation, Manuscript Draft. **Mochamad Arief Budihardjo:** Manuscript Review and Revision

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