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Effectiveness of Several Bioactivators on the C/N Ratio and Potassium (K) and Manganese (Mn) Nutrition Content of Coffee Skin Compost (*Coffea sp*)

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ABSTRACT

Coffee skin waste is an abundant agricultural byproduct that can be converted into compost to support sustainable waste management. This study aimed to determine the effectiveness of several bioactivators, namely EM-4, BioTRIBA, and M-Dec, on the C/N ratio and potassium (K) and manganese (Mn) content of coffee skin compost. The research used a completely randomized design with eight treatments and three replications: EM-4 at 10 mL/L, BioTRIBA at 8, 10, and 12 mL/L, and M-Dec at 8, 10, 12, and 14 g/L. Composting was carried out for four weeks, and the observed parameters included pH, temperature, C/N ratio, C-organic, N-total, K-total, Mn-total, and moisture content. The results showed that all treatments reduced the C/N ratio from an initial value of 13.69% to a range of 10.65%–12.16%. The lowest C/N ratio was obtained in the M-Dec 10 g treatment (10.89%), indicating the most effective decomposition process. Potassium content decreased from 5.01% to 3.84%–4.30%, while manganese content increased significantly from 0.01 mg/kg to 108.16–132.25 mg/kg across treatments. The highest Mn accumulation was observed in the M-Dec 8 g treatment (132.25 mg/kg). Among all treatments, M-Dec 10 g was identified as the most effective treatment based on the lowest C/N ratio and balanced nutrient profile, meeting compost quality standards (SNI 19-7030-2004). Overall, the use of bioactivators accelerated decomposition and improved the quality of coffee skin compost, and M-Dec 10 g was the most effective treatment for meeting compost quality standards.

Keyword: Coffee Skin Waste, Bioactivator, Compost Quality, C/N Ratio, Manganese

ABSTRAK

Limbah kulit kopi merupakan limbah pertanian yang melimpah dan dapat dimanfaatkan menjadi kompos untuk mendukung pengelolaan limbah berkelanjutan. Penelitian ini bertujuan untuk mengetahui efektivitas beberapa bioaktivator, yaitu EM-4, BioTRIBA, dan M-Dec, terhadap rasio C/N serta kandungan kalium (K) dan mangan (Mn) pada kompos kulit kopi. Penelitian menggunakan rancangan acak lengkap dengan delapan perlakuan dan tiga ulangan, yaitu EM-4 10 mL/L, BioTRIBA 8, 10, dan 12 mL/L, serta M-Dec 8, 10, 12, dan 14 g/L. Pengomposan dilakukan selama empat minggu dengan parameter pengamatan meliputi pH, suhu, rasio C/N, C-organik, N-total, K-total, Mn-total, dan kadar air. Hasil penelitian menunjukkan bahwa semua perlakuan menurunkan rasio C/N dari nilai awal 13,69% menjadi kisaran 10,65%–12,16%. Rasio C/N terendah diperoleh pada perlakuan M-Dec 10 g (10,89%), yang menunjukkan proses dekomposisi paling efektif. Kandungan kalium menurun dari 5,01% menjadi 3,84%–4,30%, sedangkan kandungan mangan meningkat secara signifikan dari 0,01 mg/kg menjadi 108,16–132,25 mg/kg di seluruh perlakuan. Akumulasi Mn tertinggi diamati pada perlakuan M-Dec 8 g (132,25 mg/kg). Di antara semua perlakuan, M-Dec 10 g diidentifikasi sebagai perlakuan paling efektif berdasarkan rasio C/N terendah dan profil nutrisi yang seimbang, memenuhi

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standar kualitas kompos (SNI 19-7030-2004).. Secara keseluruhan, penggunaan bioaktivator mempercepat dekomposisi dan meningkatkan kualitas kompos kulit kopi, dan perlakuan M-Dec 10 g merupakan perlakuan paling efektif dalam memenuhi standar mutu kompos.

Kata Kunci: Limbah Kulit Kopi, Bioaktivator, Mutu Kompos, Rasio C/N, Mangan

1. Introduction

Coffee (*Coffea sp*) is a type of plantation crop that has long been cultivated and has a fairly high economic value. Coffee farming is spread across several regions of Indonesia, including North Sumatra, with potential in the Simalungun Regency. In 2016, smallholder plantation production was 2,170 tons, with 2,570 Ha used (North Sumatra Plantation Statistics Data 2021)[1]. Based on this data, coffee farming in North Sumatra has increased year over year. Of course, this also affects the coffee waste produced. In the processing of coffee beans, a very large amount of coffe ye shells/skins are produced, namely every 1000 kg of fresh coffee berries produce 43% skin (pulp), 11.8% mucus (mucilage), 38% coffee beans, and 6.1% horny skin (hulls) [2]

One way to address agricultural waste is through recycling, particularly composting. Another advantage of composting waste is that it is safe for both agricultural products and the land. The compost can be made by the general public using readily available, simple materials and a relatively simple process. Until now, coffee husk waste has only been used as animal feed, burned, or taken to the plantation without composting. This has significant potential for use as a composting raw material, and the resulting material can be reused to fertilize coffee plants, increasing coffee production or reducing fertilizer costs. As an organic material containing nutrients, coffee waste, with a little technological advancement, offers numerous economic and environmental benefits for soil and plants [3-5]

The Coffee Research stated that the organic carbon content of coffee fruit skins is 45.3%, with nitrogen content at 2.98%, phosphorus at 0.18%, and Potassium at 2.26%. Furthermore, coffee fruit skins also contain the elements Ca, Mg, Mn, Fe, Cu, and Zn. Based on the analysis, the resulting coffee skin waste has significant potential to be developed into organic fertilizer to support the organic farming system, which is currently experiencing growing demand [6-7].

Rois et al 2025 argue that coffee husk waste is not only useful in agriculture, namely for improving soil fertility and stimulating root, stem, and leaf growth, but also useful in the livestock and fisheries sectors, namely as additional protein and fiber in animal feed [8]. This coffee husk waste has a high organic matter and nutrient content, which can improve soil structure. One way to handle the volume of coffee husk waste is to process it into compost as a source of plant energy. Composting coffee husk waste not only prevents environmental pollution but can also produce compost that is very useful in agricultural cultivation when managed properly, and can create new job opportunities for the community. Compost is an organic material that has undergone decomposition so that it changes its form and is no longer recognizable from its original form, blackish in color, and odorless. Compost can be used as a substitute for artificial fertilizer at a very low cost and can improve the soil's physical, chemical, and biological properties [9-10].

According to [11], soil structure and fertility can be improved by using compost. The compost commonly used by farmers today is made from rice husks or straw, and organic waste. However, its production takes a long time without the assistance of biodecomposer microorganisms. Decomposer agents can be used to accelerate and improve composting results and are commercially produced, generally as consortia of microorganisms called composting bioactivators or biodecomposers.

One widely available activator is EM-4 (effective microorganisms), a mixed culture of various beneficial microorganisms (including fermentation bacteria, fermentation fungi, photosynthetic bacteria, phosphate-fixing bacteria, and yeast) that can be used as an inoculum to increase soil microbial diversity. In addition to the activators already widely available on the market [12], various types of microbes have different functions. To increase the effectiveness of their functions, microbes used in agricultural technology are sourced from selected pure strains that serve as inoculants. The application method and quality of the inoculant are major determinants, so efforts to address the diversity of effectiveness require that the microbial inoculant's quality be standardized. Compost making using activators is already widely available on the market, including EM4, M-Dec, Biotan, BioTriba, OrgaDec, and StarDec. Basically, this activator is a microorganism present in the liquid growth medium. If the liquid containing the microorganism is dissolved in water and mixed into the material to be composted, the microorganism will grow quickly [13].

EM-4 is a decomposer containing photosynthetic bacteria, lactic acid bacteria, actinomycetes, yeast, and fermenting fungi. EM-4 is a pleasant-smelling liquid with a sweet-and-sour taste and a pH < 3.5. The use of EM-4 for each ton/m3 of material is 1 liter [14]. M-Dec is a microbe that can accelerate composting, allelopathy, and suppress the development of diseases, insect larvae, and weed seeds, so that it becomes organic soil material that functions to store and release nutrients around plants. The active ingredients of M-Dec are the microbes Trichoderma harzianum, T. pseudokoningii, Aspergillus sp and Trametes sp. The use of M-Dec for each ton/m3 of material is 1 kg [15]

BioTRIBA is a biofertilizer containing five species of Plant Growth-Promoting Microorganisms (PGPM) and indigenous microorganisms. The microbes contained in the BioTRIBA formula can synergistically provide nutrients, especially N, P, and growth-promoting hormones. Furthermore, cellulolytic microbes can decompose organic matter, ensuring the availability of essential micronutrients for plant metabolism and the production of antibiotic compounds [16].

2. Material and Method

2.1 Equipment

The equipment used in this study included a pH meter, thermometer, plastic buckets, tarpaulin, a shovel, a knife, a machete, plastic rope, and stationery.

2.2 Materials

The materials used in this study were coffee skin waste, EM-4 bioactivator, Bio-TRIBA, and M-Dec.

2.3 Experimental Design

This study used a completely randomized design (CRD) with eight bioactivator treatments applied to 10 kg of coffee skin waste. The treatments were P1 = 10 mL EM-4/L water, P2 = 8 mL BioTRIBA/L water, P3 = 10 mL BioTRIBA/L water, P4 = 12 mL BioTRIBA/L water, P5 = 8 g M-Dec/L water, P6 = 10 g M-Dec/L water, P7 = 12 g M-Dec/L water, and P8 = 14 g M-Dec/L water. Each treatment was repeated three times, resulting in 24 experimental units.

2.4 Data Analysis

The experimental design used in this study was a Completely Randomized Design (CRD) with eight treatments and three replications. The replications were applied to reduce experimental error and to observe consistency of the composting process under each treatment. However, the data were analyzed using descriptive statistical methods. Inferential statistical analysis such as ANOVA was not performed because the primary objective of this study was to evaluate trends in compost quality improvement across different bioactivator treatments rather than to test hypothesis significance. Normality and homogeneity tests were not conducted, as the study emphasized comparative descriptive evaluation of treatment performance based on observed mean values of each parameter (C/N ratio, K, and Mn content). Therefore, the interpretation of results focuses on relative performance among treatments rather than statistically significant differences. Future studies are recommended to apply full inferential statistical analysis (ANOVA followed by post-hoc tests) to strengthen the statistical validity of treatment comparisons.

2.5 Composting Procedure

A composting house was prepared to protect the materials from rain and direct sunlight and to serve as a controlled environment for the experiment. The compost house measured 6.57 m in length, 3.36 m in width, and 3.5 m in height at the roof ridge, with black parapet walls designed to help maintain stable internal temperature conditions during composting. Coffee husk waste was dried under direct sunlight to reduce moisture content and prevent fungal growth. Drying was carried out by spreading the material evenly on a plastic tarpaulin in an open area for approximately 2 days under full sunlight or up to 4 days under lower sunlight intensity. Before composting, the coffee husk waste was analyzed in the laboratory to determine its initial nutrient content as baseline data for evaluating compost quality. The analysis was conducted at the Socfin Indonesia Laboratory. The dried coffee husk waste was cleaned from impurities such as gravel, branches, leaves, grass, and soil. The material was then chopped into approximately 1 cm size to accelerate the decomposition process. Each experimental unit contained 10 kg of coffee husk waste. Bioactivators were prepared by dissolving the required concentration in 1 L of water according to each treatment. The solution was then evenly mixed into the compost material using gloved hands until homogeneous. The composting experiment was arranged according to a Completely Randomized Design (CRD) and placed inside the compost house. Adequate aeration space was maintained in each container throughout the process. Moisture content was controlled during composting by adding water when necessary. The active composting process was conducted for 4 weeks (28 days) as the main experimental period. During this period, temperature, pH, odor, and physical changes were observed regularly. Temperature was measured daily using a thermometer, while pH was measured using a pH meter. In addition to the active composting period, temperature and pH monitoring were extended up to 7 weeks to evaluate compost stabilization behavior after the decomposition phase. After 4 weeks, the compost was considered in the maturation stage based on stabilization of physical and chemical characteristics. The final compost samples were then sent to PT. Socfin Indonesia Laboratory, Medan, for analysis of potassium (K) and manganese (Mn) content.

2.6 Observed Parameters

The observed parameters were moisture content, C/N ratio, pH, temperature, potassium (K) content, manganese (Mn) content, organic carbon (C-organic), and total nitrogen.

3. Result and Discussion

3.1. General Compost Criteria

a. Visual Characteristics of Compost

The visual characteristics of mature compost are odorless, black, easily crushed by hand, and free of insects, worms, caterpillars, or fungi. However, in the laboratory, a C/N ratio below 20 indicates that the composting process has ended. The composting results do not yet show the characteristics of mature compost. The resulting compost shows moderate criteria, meaning some waste still resembles its original form or has not decomposed evenly like soil. The resulting compost still smells, and the material's color has not changed significantly. This is due to the high percentage of lignin content in coffee husk waste. Lignin is difficult to degrade because of its complex, heterogeneous structure, which binds to cellulose and hemicellulose in plant tissue [17]. Lignin also forms strong bonds with polysaccharides that protect polysaccharides from microbial degradation and form a lignocellulose structure.

b. C/N Ratio of Compost

Based on observations of the treatment of several bioactivators on coffee husk compost, it was concluded that the C/N ratio decreased. The results of the observations on the C/N ratio of coffee husk compost are shown in the following table.

Table 1. Observation results of the C/N ratio content of coffee husk compost

Nutrient	Sample	Initial Content (%)	Final Content (%)
C/N	EM-4 10 ml	13.69	10.65
	BioTRIBA 8 ml	13.69	12.16
	BioTRIBA 10 ml	13.69	11.10
	BioTRIBA 12 ml	13.69	11.49
	M-Dec 8 g	13.69	11.01
	M-Dec 10 g	13.69	10.89
	M-Dec 12 g	13.69	10.68
	M-Dec 14 g	13.69	11.54

Based on laboratory analysis, the C/N ratio of coffee husk waste compost tends to decrease during composting, as C-Organic content decreases and N-Total content increases. The C/N ratio in the initial material is 13.69%, indicating that the material has undergone decomposition before it composts. According to Hardiwinoto (2005), the C/N ratio indicates the intensity of the decomposition process of organic material. A large C/N ratio indicates that the material is difficult to decompose, while a C/N ratio that is too low indicates that the material is easily decomposed. In composting, a high C/N ratio is not good for use as plant fertilizer; conversely, a low C/N ratio allows nutrient absorption by plants because microbes have decomposed the organic material into elements that plants can absorb[18]. This is in accordance Sagiarti et al 2020 with opinion that compost with a high C/N ratio is not beneficial to plants, and that when applied directly to plants, it can lead to competition between plants and microbes for available soil nutrients. On the other hand, if the C/N ratio of the compost is low, it means that the nutrients bound to the compost have been released through mineralization, allowing them to be used by plants [19].

c. Compost Temperature

Based on the observation results for the treatments of Bioactivator EM-4 10 ml, BioTRIBA 8 ml, BioTRIBA 10 ml, BioTRIBA 12 ml, M-Dec 8 g, M-Dec 10 g, M-Dec 12 g, and M-Dec 14 g, the compost temperature increased and decreased. The results of the temperature observations are shown in Figures 1 and 2 below.

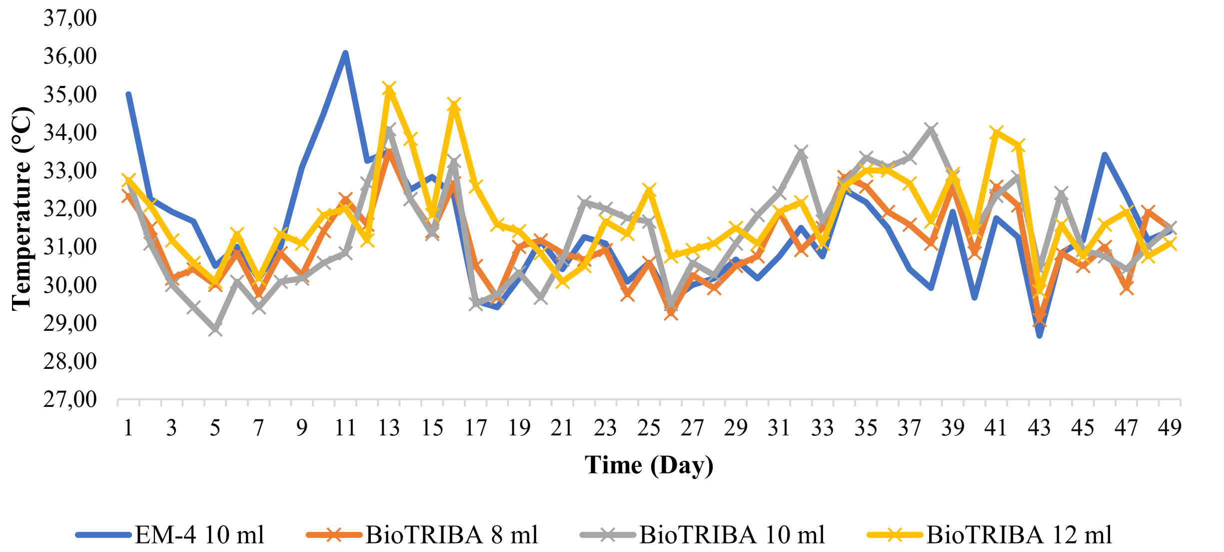

Figure 1. Results: Daily temperature observation of coffee husk waste compost for 7 weeks with the help of EM-4 Bioactivator and BioTRIBA

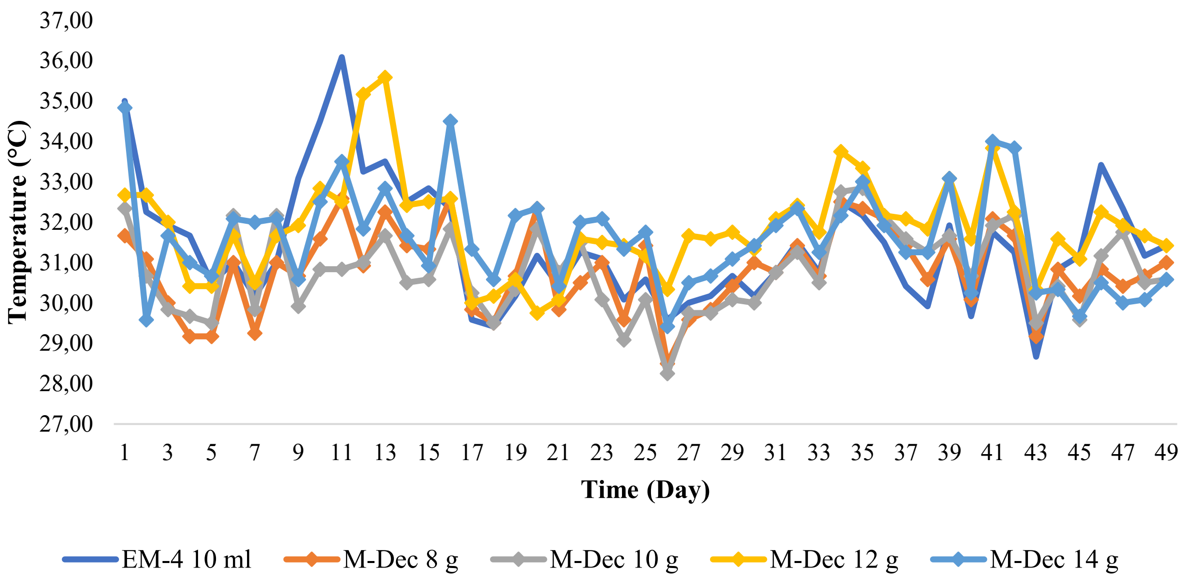

Figure 2. Results: daily temperature observation of coffee skin waste compost for 7 weeks with the help of Bioactivator EM-4 and M-Dec.

From the compost temperature observations, it can be seen that all treatments showed fluctuating temperature patterns during the composting process. The highest temperature was recorded in the EM-4 10 mL treatment, reaching 36.08°C on day 11, while the lowest temperature was recorded in the M-Dec 10 g treatment, reaching 28.25°C on day 26. These temperature values indicate that the composting process occurred under mesophilic conditions (20–40°C). No treatment reached temperatures above 40°C; therefore, the thermophilic phase was not observed in this study. The observed temperature fluctuations were influenced by microbial metabolic activity, aeration conditions, and heat loss to the surrounding environment. In small-scale composting systems using buckets, heat accumulation is limited due to restricted mass volume and high heat dissipation, which prevents the system from reaching higher temperature phases. The decrease in temperature after peak values reflects a reduction in microbial activity as the composting process progressed toward the maturation stage. Overall, compost decomposition in this study was dominated by mesophilic microorganisms throughout the observation period.

d. Compost pH Value

The results of the coffee skin waste observations were measured using a pH meter and recorded in a container filled with coffee skin waste compost. The results of the compost pH analysis are shown in Table 2 below.

Table 2. Results: observation of the average pH value of coffee husk waste compost for 7 weeks.

Average Weekly pH Parameters of Coffee Husk Compost							
Sample	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
P1	8.39	8.48	9.07	9.43	8.65	8.39	9.02
P2	8.49	8.41	8.93	9.46	8.61	8.16	9.02
P3	8.16	8.22	8.71	9.51	8.42	8.16	9.14
P4	8.28	8.19	8.87	9.44	8.36	8.28	9.24
P5	8.08	8.23	8.80	9.38	8.37	8.08	9.05
P6	8.34	8.16	8.86	9.45	8.42	8.34	9.05
P7	8.29	8.41	8.91	9.46	8.52	8.29	9
P8	8.21	8.64	8.89	9.47	8.61	8.21	8.99

Information: P1 = EM-4 10 ml; P2 =BioTRIBA 8 ml; P3 =BioTRIBA 10 ml; P4 =BioTRIBA 12 ml; P5 = M-Dec 8 g; P6 =M-Dec 10 g; P7 =M-Dec 12 g; P8 =M-Dec 14 g

Table 2 above shows that the compost's average pH differed across the bioactivator treatments, as observed in the weekly observations. Changes in the compost's average pH are caused by microorganisms decomposing organic matter during composting. When microorganisms are active, the compost's pH increases. Conversely, if the compost pH is low or acidic, the activity of these microorganisms will be disrupted. The results showed that the pH of all eight treatments increased at the end of the study. The decomposition of organic matter by microorganisms produces OH ions.¯This helps increase alkalinity, which in turn increases the compost's pH. However, with timely and proper temperature monitoring and compost turning, the pH can be maintained at a neutral level [20].

Besides temperature, the degree of acidity (pH) also affects composting because it is a critical factor for the growth of the microorganisms involved. Too high an acidity level increases oxygen consumption and harms the environment. Furthermore, it can cause the nitrogen in the compost to convert to ammonia (NH_3). Conversely, in acidic conditions (low acidity levels), some microorganisms will die. However, compost contaminated with rainwater can cause high pH problems. The decomposition of organic material by microorganisms produces OH ions. thus supporting the increase in alkalinity, which subsequently increases the pH value of the compost [21]. Aguilar-Paredes et al 2023 also stated that, in general, decomposing microbes play a role in the decomposition of organic materials, and these microbes can grow and be active at neutral to alkaline pH (6.5-8.5), while mineralization and nitrification processes are optimal at around pH 7.0. The increase in the compost's pH is also thought to be due to the pH of the water used in the previous Bioactivator dissolution [22].

3.2. The Effect of 10 ml of EM-4 Bioactivator on the C/N, Potassium, and Manganese Ratios of Coffee Husk Compost

Laboratory analysis of coffee husk waste revealed several nutrient elements indicating changes in nutrient content. The analysis of coffee husk waste before and after composting can be seen in Table 3 below: From Table 3 above it can be seen that the initial nutrient content of the material with the final nutrient content of coffee skin compost in the C-Organic nutrient element decreased from 40.55% to 38.91%, the N-Total nutrient element increased from 2.96% to 3.65%, the C/N ratio decreased from 13.69 to 10.65, the K-Total nutrient element decreased from 5.01% to 4.30%, the Mn-Total nutrient element increased from 0.01 mg/kg to 110.57 mg/kg and the Water Content decreased from 71.33% to 53.96%.

Nutrient analysis was performed on coffee husk waste after composting was complete. The analysis showed that some nutrients increased, while others decreased. Some of the nutrients that increased were Total N and Total Mn. The initial nutrient content of coffee husk waste was 2.96% Total N and 0.01 mg/kg Total Mn. After composting, nutrient content increased, with total N reaching 3.65% and total Mn reaching 110.57 mg/kg.

The increase in total N content is due to the activity of photosynthetic bacteria and actinomycetes in the compost, which fix nitrogen. In Mn nutrient content, the increase is due to the number of microorganisms; the greater the number, the higher the nutrient content [23]. In contrast, the decreased nutrient content of coffee husk waste compost is reflected in C-Organic, C/N Ratio, and K-Total. Where the initial nutrient content of coffee husk waste is C-Organic 40.55%, C/N Ratio 13.69%, and K-Total 5.01%. After the coffee husk waste is composted, the nutrient values decrease, namely C-Organic 38.91%, C/N Ratio 10.65%, and K-Total 4.30%. The decrease in C-organic nutrient content in compost occurs because, during decomposition, carbon is used as an energy source to synthesize the cellular material of microorganisms, releasing CO_2. In the C/N ratio, the decrease in nutrient content results from a decrease in C content and an increase in N content during the composting process, leading to a lower C/N ratio. The decrease in the K nutrient content in compost is because, during decomposition, Potassium is used by microorganisms, namely Lactobacillus sp., as a main ingredient for cell formation and self-reproduction [23]. Several nutrient contents in coffee husk waste compost have met the Compost Quality Standard Specifications (SNI 19-7030-2004) [24]. The nutrients that have met the requirements are Total N, Total K, Mn, and the C/N ratio. Meanwhile, the nutrients that have not met the Compost Quality Standard Specifications (SNI 19-7030-2004) are organic C and water content.

Table 3. Results: Analysis of nutrient elements of coffee skin waste before and after composting with the help of EM-4 Bioactivator 10 ml.

Nutrient	Initial Content	Nutrient Content After Composting with Bioactivator EM-4 10 ml
C-Organic	40.55%	38.91%
N-Total	2.96%	3.65%
C/N	13.69%	10.65%
K-Total	5.01%	4.30%
Mn-Total	0.01 mg/kg	110.57 mg/kg
Water content	71.33%	53.96%

Source: Laboratory Test Results

3.3 Effect of 8 ml, 10 ml, and 12 ml of BioTRIBA Bioactivator on the C/N, Potassium, and Manganese Ratios of Coffee Husk Compost

The results of laboratory analysis of coffee husk waste revealed several nutrient elements, indicating changes in nutrient content. The results of the coffee husk waste analysis before and after composting are shown in Table 4 below:

Table 4. Results Analysis of nutrient elements of coffee skin waste before and after composting with the help of BioTRIBA Bioactivator 8 ml, 10 ml, and 12 ml

Nutrient	Initial Content	Final Content		
		BioTRIBA 8 ml	BioTRIBA 10 ml	BioTRIBA 12 ml
C-Organic	40.55%	36.72%	37.60%	40.67%
N-Total	2.96%	3.02%	3.39%	3.54%
C/N	13.69%	12.16%	11.10%	11.49%
K-Total	5.01%	3.96%	4.01%	3.84%
Mn-Total	0.01 mg/kg	108.16 mg/kg	114.56 mg/kg	122.76 mg/kg
Water content	71.33%	53.96%	55.76%	55.38%

Source: Laboratory Test Results

From Table 4 above, it can be seen that the initial nutrient content of the material, with the final nutrient content of coffee skin compost in the C-Organic nutrient element, experienced the greatest decrease from 40.55% to 36.72% in BioTRIBA 8 ml and an increase of 0.12% in BioTRIBA 12 ml. The N-Total nutrient element experienced the highest increase from 2.96% to 3.54% in BioTRIBA 12 ml, the C/N ratio experienced the highest decrease from 13.69% to 11.10%, the K-Total nutrient element decreased the lowest from 5.01% to 4.01% in BioTRIBA 10 ml, the Mn-Total nutrient element increased the highest from 0.01 mg/kg to 122.76 mg/kg and the Water Content decreased the highest from 71.33% to 53.96% in BioTRIBA 8 ml.

From the results of the nutrient analysis test of coffee husk waste after composting is complete. There are differences in nutrient content; some nutrients have increased, and some have decreased. In the treatment with Biotriba at 8 ml, 10 ml, and 12 ml, nutrients increased, namely N-Total and Mn-Total. The initial nutrient content of coffee husk waste is N-Total 2.96% and Mn-Total 0.01 mg/kg. After the coffee husk waste underwent composting, the nutrient content increased, with N-total at 3.02%, 3.39%, 3.54%, and Mn-total at 108.16 mg/kg, 114.56 mg/kg, 122.76 mg/kg.

The increase in the total N nutrient content in compost occurs because Tricoderma lactae functions as a nitrogen fixer, so that the total N nutrient content in the compost increases. The number of microorganisms increases with Mn nutrient content; the higher the nutrient content, the greater the number. The large number of microorganisms, namely the bacteria Bacillus pumilus J2 and the fungus Trichoderma lactis strain TB1, results from cell division in microorganisms [23].

The nutrient elements of coffee husk waste compost that decreased sequentially were C-Organic, C/N Ratio, and K-Total. The initial nutrient content of coffee husk waste was C-Organic 40.55%, C/N Ratio 13.69%, and K-Total 5.01%. After the coffee husk waste was composted sequentially, the nutrient values decreased, namely C-Organic 36.72%, 37.60%; C/N Ratio 12.15%, 11.10%, 11.49%; and K-Total 3.96%, 4.01%, 3.84%. The decrease in the C/N ratio in each bioactivator was due to a reduction in the amount of carbon microbes used as an energy source to decompose organic material in the compost. During the composting process, C reacts with CO2 and CH4, which are present as gases and evaporate, decreasing the carbon (C) content. Meanwhile, the total N in organic matter increases as compost material decomposes, with microorganisms producing ammonia and nitrogen, thereby increasing the compost's total N content. Organic material has been composted or used as fertilizer and can be used for plants if the C/N ratio is < 20 [25].

The decrease in the K nutrient content in compost using the Biotriba bioactivator is because, during the decomposition process, K is used by microorganisms, namely Bacillus panteketkus, as the main ingredient for cell formation and self-reproduction, so that in the composting process, the compost constituents have not been completely decomposed [26].

Several nutrient contents in coffee husk waste compost have met the Compost Quality Standard Specifications (SNI 19-7030-2004). The nutrients that have met the requirements are Total N, Total K, Mn, and the C/N ratio. Meanwhile, the nutrients that have not met the Compost Quality Standard Specifications (SNI 19-7030-2004) are organic C and water content [27-28]

3.4. The Effect of 8 g, 10 g, 12 g, and 14 g of M-Dec Bioactivator on the C/N, Potassium, and Manganese Ratios of Coffee Husk Compost

The results of laboratory analysis of coffee husk waste revealed several nutrient elements, indicating changes in nutrient content. The results of the coffee husk waste analysis before and after composting are shown in Table 5 below:

Table 5. Results Analysis of nutrient elements of coffee skin waste before and after composting with the help of Bioactivator M-Dec 8 g, 10 g, 10 g, and 12 g

Nutrient	Initial Content	Final Content			
		M-Dec 8 g	M-Dec 10 g	M-Dec 12 g	M-Dec 14 g
C-Total	40.55%	38.42%	37.55%	37.11%	40.88%
N-Total	2.96%	3.49%	3.45%	3.48%	3.54%
C/N	13.69%	11.01%	10.89%	10.68%	11.54%
K-Total	5.01%	4.19%	4.30%	4.30%	4.26%
M N	0.01 mg/kg	132.25 mg	131.03 mg	115.23 mg	121.09 mg
Water content	71.33%	52.15%	53.49%	57.12%	52.87%

Source: Laboratory Test Results

From the Table 5 above can be seen that the initial nutrient content of the material with the final nutrient content of coffee skin compost in the C-Organic nutrient element experienced the highest decrease from 40.55% to 37.11% at M-Dec 12 g and increased to 40.88% at M-Dec 14 g, the N-Total nutrient element experienced the highest increase from 2.96% to 3.54% at M-Dec 14 g, the C/N ratio experienced the highest decrease from 13.69% to 10.68% at M-Dec10 g, the K-Total nutrient element experienced the lowest decrease from 5.01% to 4.30% at M-Dec 10 g and 12 g, the Mn-Total nutrient element experienced the highest increase from 0.01 mg/kg to 132.25 mg/kg at M-Dec8 g and Water Content decreased from 71.33% to 52.15% at M-Dec 8 g.

From the results of the nutrient analysis test of coffee husk waste after composting is complete. There are differences in nutrient content; some nutrients have increased, and some have decreased. In the M-Dec treatments of 8 g, 10 g, 12 g, and 14 g, sequentially, nutrients that increased include N-Total and Mn-Total. The initial nutrient content of coffee husk waste is N-Total 2.96% and Mn-Total 0.01 mg/kg. After the coffee husk waste underwent composting, the nutrient content increased, with N-total at 3.49%, 3.45%, 3.48%, 3.54% and Mn-Total at 132.25 mg/kg, 131.03 mg/kg, 115.23 mg/kg, 121.09 mg/kg. High nitrogen levels are caused by the activity of Trichoderma sp. fungi, which simultaneously decompose lignin and cellulose. The breakdown of lignin and cellulose results in a decrease in carbon content and an increase in nitrogen content. Also reported that an increase in organic carbon content occurs during organic matter decomposition. Microorganism activity produces carbon, increasing organic carbon levels. Decomposers then die, and organic carbon levels gradually decrease[29-30].

Furthermore, the increased content of other nutrients, such as Mn, in compost is due to the number of microorganisms, specifically Aspergillus sp., that decompose the organic material. This high number of microorganisms results from Aspergillus sp. fungi's rapid reproduction through cell division. Therefore, a high number of microorganisms will increase the compost's nutrient content [31].

In addition to an increase in nutrient content, the treatment with the M-Dec bioactivator also showed decreases in several nutrients, including C-Organic, C/N Ratio, and K-Total. Where the initial nutrient content of coffee skin waste is: C-Organic 40.55%, C/N Ratio 13.69%, and K-Total 5.01%. After the coffee skin waste was composted, the nutrient values sequentially showed a decrease: C-Organic 38.42%, 337.55%, 37.11%; C/N Ratio 11.01%, 10.89%, 10.68%, 11.54%; and K-Total 4.19%, 4.30%, 4.30%, 4.25%. Nuraini (2009) stated that the decrease in nutrient content is due to the simultaneous degradation of lignin and cellulose by Aspergillus sp. during the composting process. This destruction of lignin and cellulose decreases carbon content and increases nitrogen content, lowering the C/N ratio. The decrease in total potassium content in compost occurs because microorganisms reach an equilibrium state in which the number produced equals the number killed. At this point, microbial activity decreases.

The increase in the total K nutrient content in compost is due to microorganisms entering the log phase. The log phase is when microorganisms begin to grow and divide rapidly [32]. This is also supported by Meilander (2024), who argues that different contents are decomposed at different rates by different microbial communities. Several nutrient contents in coffee husk waste compost have met the Compost Quality Standard Specifications (SNI 19-7030-2004). Nutrients that meet the requirements are Total N, Total K, Mn, and C/N Ratio. Meanwhile, nutrients that do not meet the requirements of the Compost Quality Standard Specifications (SNI 19-7030-2004) include organic C and water content [33].

A limitation of this study is the absence of a control treatment (coffee husk compost without bioactivator addition). All experimental units received bioactivator treatments (EM-4, BioTRIBA, and M-Dec), which makes it difficult to distinguish the extent to which observed changes in C/N ratio, potassium (K), and manganese (Mn) content are solely attributable to the bioactivators or to the natural composting process. Therefore, the results primarily reflect comparative effectiveness among bioactivator treatments rather than absolute effects against a non-treated control.

4. Conclusion

The results of this study show that the application of bioactivators (EM-4, BioTRIBA, and M-Dec) influenced the compost quality of coffee husk waste, particularly in reducing the C/N ratio and altering potassium (K) and manganese (Mn) content. Based on descriptive analysis, all treatments were effective in improving compost quality, with variations in their effects. The M-Dec 10 g treatment showed the lowest C/N ratio value (10.89) compared to other treatments; however, the difference between treatments was relatively small (e.g., M-Dec 12 g = 10.68). Therefore, the determination of the “best treatment” in this study is based on descriptive comparison of mean values rather than statistical significance testing. All treatments can be considered similarly effective in accelerating compost maturation, with slight variations in performance. Future studies are recommended to apply inferential statistical analysis (e.g., ANOVA and post hoc tests) to confirm whether differences among treatments are statistically significant.

5. Conflic of Interest

Authors declare no conflicts of interest.

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