The Potential of BioTP to Enhance Macronutrient Content in Household Organic Waste Compost

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ABSTRACT
Household waste is predominantly organic, consisting of food scraps, vegetables, and fruits that naturally decompose. However, the decomposition process may lead to environmental and health problems if not properly managed; therefore, appropriate waste management is essential. One method for managing household waste is composting. This study aimed to determine the potential of the bioinoculant BioTP to enhance macronutrient content in household organic waste compost. This research employed an experimental pretest–posttest with control design. Macronutrient levels (N, P, and K) in household organic waste were measured before and after the decomposition process in both the treatment group (with BioTP) and the control group. The data were analyzed using a t-test. The results showed that after decomposition, all macronutrients (N, P, and K) in the treatment group increased. The macronutrient content in all treatments met the standards for organic fertilizer. Statistical analysis before and after decomposition indicated a significant difference in nitrogen (N) levels in both the treatment and control groups ($p < 0.05$), whereas phosphorus (P) and potassium (K) levels showed no significant differences ($p > 0.05$). Comparison between the treatment and control groups also revealed no significant differences in N, P, and K levels ($p > 0.05$). In conclusion, BioTP has the potential to enhance macronutrient content in household organic compost; however, its effect has not yet reached an optimal level.
Keywords: household organic waste; decomposition; bioinoculant; macronutrients

INTRODUCTION
Waste is defined as the residual material from daily human activities and/or natural processes in solid form. Household waste refers to waste generated from everyday domestic activities, excluding feces and specific waste streams [1]. The composition of household waste consists of 47.25% organic waste and 37.52% recyclable waste, including 10.38% paper and paper products, 9.88% glass, 6.92% metal, 5.39% plastic, 3.57% textiles, and 1.38% rubber and leather, while the remaining 15.23% comprises other types of waste [2]. Organic waste constitutes the largest proportion of household waste and, if not properly managed, may pose risks to human health and the environment. Organic compounds derived from food waste can cause serious environmental problems [3].

Decomposing household organic waste produces leachate and gases that may lead to soil, water, and air pollution. Leachate pollutants may include heavy metals, organic and inorganic substances, and other chemical compounds. These pollutants can alter the geological properties of soil during leachate migration and contribute to water contamination. Gas emissions may occur due to chemical volatilization, material degradation, and conversion reactions; gases generated during decomposition can contribute to air pollution [4,5].

Composting is one method that can be used to address environmental pollution caused by waste. Composting is an effective aerobic biodecomposition process for treating household waste. It offers advantages over other disposal strategies by reducing waste volume by 40–50% and eliminating pathogens through the heat generated during the thermophilic phase [6,7]. Composting is an organic waste management method aimed at converting organic materials into humus or stable substances [8]. Natural composting utilizes indigenous microorganisms present in the environment to degrade organic materials and typically requires 3 to 4 months. However, with the addition of selected microorganisms, the composting process can be accelerated to approximately one month [9]. Microbial composting is an economical and environmentally friendly approach for managing large volumes of waste [10].

Microorganisms play a crucial role in the waste decomposition process [11]. They secrete extracellular enzymes that are essential for degrading organic materials. Bacteria and fungi are key microorganisms involved in litter decomposition [12]. Fungi, in particular, can shorten the composting period, act as primary decomposers of waste, and are capable of degrading lignin, cellulose, and hemicellulose in organic matter [13].

Numerous composting studies have utilized microorganisms. Raimi et al. (2024) investigated the use of varying volumes (20–100 mL) of effective microorganisms (EM) for composting and found that the optimal amount required to decompose 600 grams of food waste exceeded 80 mL [14]. Nieto-Cañarte et al. explored the efficacy of microbial applications, specifically comparing *Trichoderma* with microbial biocatalysts for solid organic waste treatment. Their findings indicated that Treatment 6 (T6) was the most effective and efficient in degrading organic matter, highlighting the potential of microorganisms, particularly *Trichoderma*, in enhancing solid organic waste processing [15].

The Temporary Waste Disposal Site (TPS) in Mangkujayan Village is one of the facilities located in Magetan Subdistrict, Magetan Regency. At this site, organic and non-organic waste separation has been implemented. Household organic waste is already subjected to composting; however, the volume remains substantial, indicating the need for optimization. This study conducted decomposition of household organic waste collected from the TPS in Mangkujayan by adding microorganisms as a bioinoculant. The bioinoculant used was BioTP, a consortium consisting of bacteria, molds, yeasts, and actinomycetes at a 1% dosage. The decomposition process lasted for 30 days. The parameters measured were macronutrient levels (N, P, and K) before and after decomposition.

Based on the background, the aim of this study was to determine the potential of BioTP to enhance macronutrient content in household organic waste compost.

METHODS
The study was conducted from July to October 2024 at the Diploma III Sanitation Study Program, Magetan Campus. This study employed an experimental design using a pretest–posttest with control group approach. Macronutrient levels (N, P, and K) in household organic waste were measured before and after the decomposition process in the treatment group (with BioTP) and the control group (without BioTP). The decomposition period for household organic waste was one month. The object of this study was household organic waste collected from the Temporary Waste Disposal Site (TPS) in Mangkujayan Village, Magetan Subdistrict, Magetan Regency. Waste separation had already been implemented at the TPS. The separated household organic waste was randomly selected as the research sample.

The variables in this study consisted of independent and dependent variables. The independent variable was the bioinoculant used in the decomposition process, namely BioTP. The dependent variables were the compost macronutrient levels, including nitrogen (N), phosphorus (P), and potassium (K). Separated household organic waste was collected from TPS Mangkujayan and transported to the Diploma III Sanitation Study

Program, Magetan Campus. The waste was cut into 1–3 cm pieces and mixed thoroughly. A total of 30 kg of household organic waste was used, divided into 15 kg for the treatment group and 15 kg for the control group. The bioinoculant used in this study was BioTP, coded as A, consisting of a consortium of molds, yeasts, and Actinomycetes at a 1% dose, while code C represented the control without the addition of microorganisms [16].

Each treatment group consisted of 5 kg of household organic waste and was replicated three times, requiring 15 kg for the treatment group. Molasses and diluent water were added to the bioinoculant. The calculation of the microbial consortium in the bioinoculant was based on species composition. The composition of the microbial consortium in BioTP is presented in Table 1.

Table 1. Composition of microbial consortium in the bioinoculant (BioTP)

Bioinoculant code	Microbial consortium (ml)			Total (ml)	Molasses (ml)	Diluent water (ml)
	Molds (K)	Yeasts (Kh)	Actinomycetes (Act)			
C (Control)	0	0	0	0	37.5	0
BioTP (A)	107	32	11	150	37.5	150

The stages of decomposition of household organic waste was: a) Weighing: thirty kilograms of chopped household organic waste were weighed and placed into six plastic bags, each containing 5 kg; b) Bioinoculant mixing: three plastic bags (5 kg each) were prepared for the control group, three bottles of bioinoculant code C (312.5 ml each) were prepared, one 5 kg waste sample was placed in a container and mixed with one bottle of bioinoculant C until homogeneous, then transferred into a polybag labeled C1, the procedure was repeated for C2 and C3, the same procedure was applied for bioinoculant code A (BioTP) and on day 0, samples were collected to analyze macronutrient content (N, P, and K) in both treatment and control groups; c) Decomposition Process: after bioinoculant addition, the decomposition process was carried out for 30 days. Temperature, pH, and moisture were measured every two days (day 0, 2, 4, and so forth). Moisture content was maintained between 40–60% by turning the compost and sprinkling water as needed. At the end of the decomposition period, samples were collected for macronutrient (N, P, and K) analysis.

Samples were collected after mixing in both treatment and control groups. Approximately 200 grams of decomposed waste were taken from each polybag, placed in labeled plastic clip bags, sealed, and sent to the laboratory for analysis. Macronutrient levels (N, P, and K) were analyzed before and after decomposition. Nitrogen (N) was determined using the Kjeldahl method, while phosphorus (P) and potassium (K) were analyzed using HNO_3 and $HClO_4$ extraction methods. Laboratory analysis was conducted at the Laboratory of the Faculty of Agriculture, Universitas Sebelas Maret (UNS), Surakarta. Temperature was measured using a thermometer inserted into the decomposing waste for 3–5 minutes, and the recorded value was noted. pH and moisture were measured using a soil tester inserted into the compost for 3–5 minutes; the indicated values were recorded accordingly. Macronutrient data (N, P, and K) were analyzed using the T-test.

RESULTS

The results of macronutrient (N, P, K) analysis before and after the decomposition process showed a slight increase in all parameters in the treatment group (BioTP). In the control group, nitrogen (N) and phosphorus (P) increased, while potassium (K) decreased. The results of N, P, and K measurements are presented in Table 2.

Table 2. Mean values of N, P, and K before and after the decomposition process

No	Treatment	Macronutrient	Before (percent)	After (percent)	Note
1	A (BioTP)	N (Nitrogen)	1.47	1.73	A = BioTP bioinoculant (consortium of molds, yeasts, and *Actinomycetes*)
		P (P_2O_5)	1.65	1.74	C = Bioinoculant without microorganisms
		K (K_2O)	1.61	1.70	
2	C (Control)	N (Nitrogen)	1.47	1.68	
		P (P_2O_5)	1.73	2.05	
		K (K_2O)	1.45	1.35	

There were differences in macronutrient levels (N, P, and K) before and after decomposition in both the treatment and control groups. The differences in N, P, and K are illustrated in Figure 1.

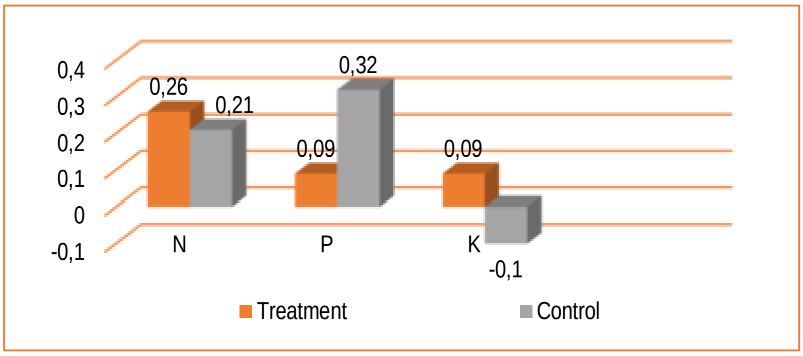

Figure 1. Differences in N, P, and K before and after decomposition

The results of the t-test analysis showed that for nitrogen (N), both the treatment and control groups had p-values less than alpha (α), indicating significant differences. In contrast, phosphorus (P) and potassium (K) had p-values greater than alpha (α), indicating no significant differences. Detailed results are presented in Table 3.

The t-test results for the differences in N, P, and K between the treatment and control groups showed p-values greater than alpha, indicating no significant differences. Detailed results are presented in Table 4.

Table 3. Statistical test results of macronutrients (N, P, K) before and after decomposition

No	Treatment	Macronutrient	Mean (before)	Mean (after)	t	p	Remark
1	A (BioTP)	N	1.4700	1.7267	-5.50	0.032	Significant
		P	1.6533	1.7367	-0.441	0.702	Not Significant
		K	1.6067	1.7033	-0.545	0.640	Not Significant
2	C (Control)	N	1.4700	1.6800	-5.196	0.035	Significant
		P	1.7300	2.0467	-3.06	0.092	Not Significant
		K	1.7033	1.3533	0.394	0.732	Not Significant

Temperature, moisture, and pH influence the waste decomposition process; therefore, these parameters were measured throughout the composting period [17]. The pH values in all treatments during decomposition ranged from 6.1 to 7.8. The ideal pH range for composting is 5.5–8.0 [18]. Temperature measurements ranged from 21°C to 50°C. Composting consists of three phases: the mesophilic phase (20–45°C), the thermophilic phase (50–70°C), and the maturation phase when temperature returns to the mesophilic range [10]. Moisture levels ranged from 38% to

60%, while optimal moisture content for organic waste decomposition is between 40% and 60% [19]. Based on these measurements, all treatments were within the optimal and relatively similar ranges of pH, temperature, and moisture. Therefore, these factors did not significantly influence the decomposition process across treatments.

Table 4. Statistical test results of differences in macronutrients (N, P, K) between treatment and control groups

No	Macronutrient	Mean (treatment)	Mean (control)	t	p	Remark
1	N	0.2567	0.2100	0.756	0.492	Not Significant
2	P	0.0833	0.3167	-1.083	0.340	Not Significant
3	K	0.0967	-0.0967	0.638	0.558	Not Significant

DISCUSSION

Based on Table 2, after the decomposition process the treatment group (A) showed nitrogen (N) content of 1.73%, phosphorus (P_2O_5) of 1.74%, and potassium (K_2O) of 1.70%. In the control group (C), the post-decomposition values were 1.68% for nitrogen, 2.05% for phosphorus, and 1.35% for potassium. The minimum compost quality standards require nitrogen ≥ 0.40%, phosphorus (P_2O_5) ≥ 0.10%, and potassium (K_2O) ≥ 0.20% [20]. Referring to BSN 2004 standards, the N, P, and K contents in both the treatment and control groups met the requirements for organic fertilizer. In the treatment group, all macronutrients increased after decomposition.

As illustrated in Figure 1, differences in N, P, and K levels were observed before and after decomposition in both groups. In the treatment group, N, P, and K increased, indicating that the addition of bioinoculant contributed to improving macronutrient content in compost. The application of lignocellulolytic bacterial isolates has been reported to increase N, P, and K levels [21]. In the control group, nitrogen and phosphorus increased, whereas potassium decreased. Potassium is highly water-soluble; without microorganisms that help retain it, potassium may leach from organic material during decomposition. The decrease in K in the control group highlights the role of bioinoculants in maintaining potassium availability during composting. The use of lignocellulolytic bacterial isolates can enhance N, P, and K content [21].

Based on Table 3, statistical analysis showed that nitrogen (N) levels before and after decomposition in both treatment and control groups had p-values less than alpha (α), indicating significant differences. Nitrogen plays an important role in determining the C/N ratio of compost; higher nitrogen content reduces the C/N ratio, and a low C/N ratio indicates compost maturity [20]. The significant difference in nitrogen levels before and after decomposition in the treatment group suggests that the bioinoculant influenced the decomposition process. The increase in nitrogen during composting occurs because microorganisms convert ammonia into nitrite as part of the decomposition process. Higher nitrogen availability accelerates organic matter degradation, as microorganisms require nitrogen for growth and metabolism [22]. Microorganisms play a critical role in transforming organic waste into stable forms and producing humus [10], and they enhance composting by accelerating decomposition [23]. Microbial bioinoculants are important for accelerating lignocellulose degradation; however, their effect on increasing bioavailable nutrient concentrations is often limited [24].

In the control group, a significant difference in nitrogen before and after decomposition was also observed, likely due to natural microbial activity. In contrast, phosphorus and potassium in both groups had p-values greater than alpha (α), indicating no significant differences before and after decomposition, despite slight increases. This suggests that the bioinoculant had limited influence on enhancing P and K levels. Microbial bioinoculants are known to accelerate lignocellulose degradation but may have only marginal effects on bioavailable nutrient concentrations [24].

Based on Table 4, the differences in N, P, and K between the treatment and control groups showed p-values greater than alpha (α), indicating no significant differences in macronutrient levels between groups. Although Table 2 shows that all macronutrients increased in the treatment group, the absence of significant differences compared to the control suggests that the bioinoculant was not yet optimal in enhancing nutrient content. Microbial bioinoculants are important for accelerating lignocellulose degradation but generally exert only limited (marginal) effects on nutrient availability [24].

The lack of significant differences in N, P, and K between treatment and control groups may be attributed to several factors, including decomposition conditions and nutrient losses during the process. The temperature during decomposition in both groups ranged from 21–50°C, which largely corresponds to the mesophilic phase [8][10], potentially reducing the effectiveness of the bioinoculant in enhancing N, P, and K levels. Nitrogen may be lost as ammonia (NH_3) gas through volatilization under certain composting conditions. Phosphorus and potassium are water-soluble and may be lost through leaching if the compost becomes excessively moist.

This study used BioTP at a concentration of 1%, based on prior findings that BioTP is effective in reducing the C/N ratio [16]. However, the results indicate that the use of BioTP at 1% concentration has not optimally enhanced macronutrient content in household organic waste compost. Therefore, further investigation is needed, particularly by evaluating higher concentrations of BioTP to improve macronutrient enhancement during the decomposition of household organic waste.

CONCLUSION

After decomposition, N, P, and K levels increased in the treatment group, and all treatments met the standards for organic fertilizer. Overall, BioTP shows potential to enhance macronutrient content in household organic compost; however, its effect has not yet been optimal.

Ethical consideration, competing interest and source of funding

-This study did not involve human or animal subjects; therefore, ethical approval was not required. However, all procedures were conducted in accordance with institutional safety regulations, environmental protection standards, and principles of scientific integrity.

-There is no conflict of interest related to this publication.

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