INNSPUB

Journal of Biodiversity and Environmental Sciences | JBES
ISSN: 2220-6663 (Print); 2222-3045 (Online)
Website: https://www.innspub.net
E-mail contact: info@innspub.net
Vol. 28, Issue: 6, p. 97-102, 2026

RESEARCH PAPER OPEN ACCESS

Comparative effects of bio-inoculant on nutrient dynamics of biodegradable waste

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Key words: Biodegradable waste compost, Biological catalysts, Nutrient dynamics, Total nitrogen, Total phosphorus, Total potassium, Microbial activity, Compost quality

Received: 22 May, 2026 **Accepted:** 06 June, 2026 **Published:** 11 June, 2026

DOI: https://dx.doi.org/10.12692/jbes/28.6.97-102

ABSTRACT

This study evaluated the effects of four bio-inoculants—Fish Amino Acid (FAA), Fermented Plant Juice (FPJ), Indigenous Microorganisms (IMO), and *Trichoderma*—on nutrient dynamics in compost produced from biodegradable fruit and vegetable wastes. A Completely Randomized Design consisting of a control and four bio-inoculant treatments was employed, and the resulting composts were analyzed for total nitrogen (TN), total phosphorus (TP), and total potassium (TK) after a three-month composting period. Analysis of variance showed that TN was not significantly affected by bio-inoculant application (p = 0.0812), whereas TP (p = 0.0192) and TK (p = 0.0000) differed significantly among treatments. TN concentrations increased in all inoculated treatments compared with the control, with the highest values observed in indigenous microorganisms (3.36%) and fish amino acid (3.34%) treatments. In contrast, TP and TK concentrations were generally higher in the control treatment and lower in the inoculated composts. The lowest TK concentration was recorded in the *Trichoderma*-treated compost, indicating substantial microbial assimilation associated with enhanced enzymatic activity. The results suggest that bio-inoculants primarily influence nutrient transformation and microbial-mediated nutrient cycling rather than increasing the total nutrient content of compost. Nitrogen remained relatively stable across treatments, while phosphorus and potassium were more responsive to the type of bio-inoculant applied. These findings demonstrate the importance of considering nutrient dynamics and microbial processes, in addition to conventional indicators such as mass reduction, when evaluating compost quality.

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INTRODUCTION

Fruit and vegetable peelings, along with all other types of biodegradable waste, continue to present a significant environmental issue that requires new and innovative methods to address this problem.

According to UNEP (2016), the world produces about 1.3 billion metric tons of organic waste annually, and this is projected to increase to 2.2 billion metric tons by 2025. The disposal of this continually growing stream of organic waste can lead to serious threats to both the environment and to ecosystem health. Composting is one way to manage this organic waste stream that converts the organic material into nutrient-rich soil amendment while at the same time reducing the amount of waste, thus improving the overall health of the soil (Awasthi *et al.,* 2014). In addition to reducing the amount of waste being incinerated or sent to landfills, the agronomic value of a compost product is directly related to its nutrient quality (including N, P, and K nutrient levels).

The N, P, and K contents of a compost are some of the most significant indicators of its quality and have important roles in encouraging plant growth and root development. N promotes vegetative growth and building proteins, P transfers energy within the plant and promotes root development, and K is needed to activate enzymes and regulate water within the plant (Havlin *et al.,* 2014; Brady and Weil, 2016).

However, the nutrient availability of compost to a plant is largely influenced by the microorganisms present in the compost and the decomposition process.

In order to increase the efficiency and nutrient quality of a compost product, the application of organic bio-inoculants, such as Fish Amino Acid (FAA), Fermented Plant Juice (FPJ), Indigenous Microorganisms (IMO), and Trichoderma, has been used increasingly. Organic bio-inoculants do either one of two things: either contribute nutrients directly to the product; or enhance the microbial activity (decomposition) of organic matter and the transformation of nutrients (Xu *et al.*, 2001; Harman, 2006).

While organic bio-inoculants are used extensively in developing compost products, limited investigation into the variability of the organic bio-inoculants on the availability of nutrients, specifically N, P, and K, still exists.

The research will compare NPK levels of biodegradable waste compost made under four separate bio-inoculant treatments in order to understand the differences in the nutrients from each treatment. This study will look for differences with respect to how various biological inputs provide different degrees of available nutrients so that more efficient and sustainable composting practices can be implemented.

MATERIALS AND METHODS

The study utilized various materials necessary for the preparation, handling, and analysis of compost samples. Mini and large digital weighing scales were used to measure powdered catalysts, particularly *Trichoderma*, and the collected fruit and vegetable wastes. A 20-liter container served as the composting bin for storing and mixing the samples. A chopping board and knife were used to reduce the size of the biodegradable materials, facilitating faster decomposition. Garden gloves were worn to ensure safety and prevent contamination during handling. The four bio-inoculant used in the experiment were Fish Amino Acid (FAA), Fermented Plant Juice (FPJ), Indigenous Microorganisms (IMO), and *Trichoderma*. Measuring cups (1-liter and 30 mL capacity) were used for accurate preparation and dilution of the catalysts. Stainless steel tongs were utilized for mixing and turning the compost materials during the decomposition process.

Research locale

The study was conducted in Zamboanga City, where fruit and vegetable wastes were collected from a local public market. Composting activities were carried out in a home backyard under ambient environmental conditions.

Research design

The experiment followed a Completely Randomized Design (CRD) consisting of five (5) treatments: one

control (no catalyst) and four catalyst-amended treatments, namely Fish Amino Acid (FAA), Fermented Plant Juice (FPJ), Indigenous Microorganisms (IMO), and *Trichoderma*. Each treatment was applied across replicates to ensure the reliability of the results.

Preparation of biodegradable waste

A total of 120 kg of biodegradable waste, composed mainly of fruit and vegetable residues, was collected over five (5) consecutive days at a rate of 24 kg per day. The collected materials were manually chopped using a knife and chopping board to reduce particle size and enhance decomposition. After collection, the wastes were thoroughly homogenized to ensure uniformity before being distributed into composting bins according to treatment and replicate.

Preparation and mixing of bio-inoculant

For FAA, FPJ, and IMO, 30 mL of each catalyst was diluted in 1 L of clean water following recommended preparation procedures (Ati2.da-4b, 2022). For the *Trichoderma* treatment, 10 g of fungal inoculant was mixed with 1 L of clean water based on standard guidelines (MEG BRDC, n.d.).

Application of catalysts

Each composting bin contained 6 kg of biodegradable waste. Bio-inoculant were applied at a rate of 100 mL per kilogram of waste, resulting in a total of 600 mL per compost bin. Catalysts were reapplied every three (3) days to maintain microbial activity. Compost piles were monitored weekly for observable changes during the decomposition process. The composting period lasted for a maximum of three (3) months.

Preparation and analysis of compost product

After the three-month composting period, the finished compost samples were collected and submitted to Department of Agriculture Region IX for laboratory analysis of total nitrogen, phosphorus, and potassium content.

Statistical analysis

The collected data were analyzed using Completely Randomized Design (CRD) analysis of variance (ANOVA). A one-way ANOVA at a significance level of $\alpha = 0.05$ was performed to determine whether significant differences existed among treatments.

RESULTS

Nutrient Composition (Total Nitrogen, Total Phosphorus, Total Potassium)

The nutrient analysis (Table 1) indicated that total nitrogen was not statistically significant ($p = 0.0812$), while total phosphorus ($p = 0.0192$) and total potassium ($p = 0.0000$) showed significant and highly significant differences, respectively.

Table 1. Nutrient content of the compost and corresponding ANOVA *p*-values

Nutrient parameter	*p*-value	Significance
Total Nitrogen (TN)	0.0812	Not significant
Total Phosphorus (TP)	0.0192	Significant
Total Potassium (TK)	0.0000	Highly significant

Fig. 1 shows variations in nutrient content among treatments. Nitrogen levels increased in all catalyst-amended treatments compared to the control, while phosphorus and potassium were higher in the control and lower in the treated setups.

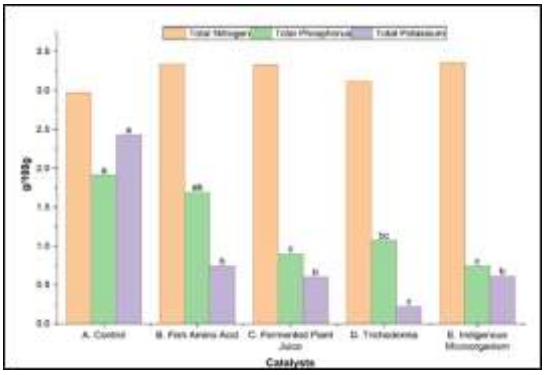

Fig. 1. Nutrient compost quality along with the pairwise comparison analysis among catalysts

DISCUSSION

Nutrient composition

The differences in nutrient composition significance between the treatments measured were consistent with the previous literature; nitrogen demonstrated no significant influence ($p=0.0812$), indicating that either it was not a limiting factor, or that there was sufficient nitrogen in all treatments (Brady and Weil,

2016; Marschner, 2012b). This suggests that internal cycling may have more impact on nitrogen dynamics when compared to treatment variations.

Conversely, the effect of phosphorus (p=0.0192) had a significant effect, which supports phosphorus being an example of a nutrient that is limiting to biological processes (Vitousek *et al.,* 2013). Potassium (p=0.0000) was the most significant in terms of overall significance (Römheld and Kirkby, 2010) shows support for the role of potassium in the activation of enzymes, the transport of nutrients, and the regulation of microorganisms (Nigussie *et al.,* 2021). The findings further support that nutrient availability is relevant to overall efficiency of composting and amount of microbial activity.

Compost quality

Elevated nitrogen concentrations of 3.36% in IMO and 3.34% in FAA indicate higher rates of microbial activity and nitrogen mineralization, confirming past studies that have shown this same phenomenon due to increased nutrient availability from microbial inoculation (Chen *et al.,* 2025b). These findings also reveal improved rates of decomposition; active turnover of the microbial population has increased (Fig. 1).

In contrast, the lower amounts of phosphorus and potassium in the inoculated treatments compared to the control indicate that nutrients are immobilized due to being taken up into microbial biomass during periods of high growth (Wang *et al.,* 2019b); therefore, the reductions in available nutrients being measured represent a critical stage in the nutrient cycling process before they are made available in their mineral form.

The very low concentration of potassium in the Trichoderma treatment supports this explanation, as its high level of enzyme production is thought to have enhanced the uptake of potassium by microorganisms (White, 2006). Overall, our results indicate the impact of biological amendments go beyond just speedily decomposing organic matter; they also affect pathways through which nutrients are transformed.

Collectively, these findings highlight that different microbial and biochemical processes can produce similar amounts of mass loss from organic matter. As such, the long-standing practice of using mass loss from composting as the sole measure of composting efficiency is called into question, and there is a need to include microbial function and nutrient dynamics as part of the evaluation process (Organo *et al.,* 2022). Future research should include an analysis of microbial communities and long-term nutrient cycling and compost maturity indicators to improve our understanding of how biological amendments function.

CONCLUSION

The application of bio-inoculants significantly influenced nutrient dynamics in biodegradable waste compost. Total nitrogen remained relatively stable among treatments (p = 0.0812), whereas total phosphorus (p = 0.0192) and total potassium (p = 0.0000) were significantly affected by the type of bio-inoculant used. Indigenous Microorganisms and Fish Amino Acid enhanced nitrogen retention, while reduced phosphorus and potassium levels in inoculated treatments suggested temporary nutrient immobilization through microbial activity. Overall, bio-inoculants primarily altered nutrient transformation pathways rather than increasing nutrient concentrations. Therefore, compost quality assessment should consider nutrient dynamics and microbial processes alongside conventional indicators such as mass reduction.

RECOMMENDATIONS

Future studies should extend the composting period to better assess nutrient dynamics over time. Investigating combinations of bio-inoculants may help identify synergistic effects that enhance compost quality and nutrient retention. Additionally, optimization approaches such as Response Surface Methodology (RSM) are recommended to determine the most effective waste-to-bio-inoculant ratios and minimize nutrient losses.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the Mindanao State University–Iligan Institute of Technology

(MSU-IIT) and the Department of Science and Technology–Science Education Institute (DOST-SEI) for providing scholarship and research support through the Accelerated Science and Technology Human Resource Development Program (ASTHRDP). The authors also express their gratitude to the Department of Agriculture Region IX for laboratory assistance and to all individuals who contributed to the completion of this study.

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