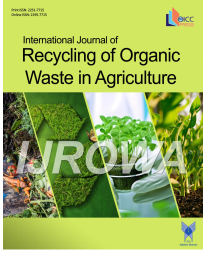

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Vermicompost quality of oyster mushroom Baglogs waste and pineapple residue mix

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Original Research

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Abstract:

Purpose: The study aimed to examine the quality of vermicompost produced through the combination of oyster mushroom Baglogs and pineapple waste using the *Eudrillus eugeniae* species as a decomposer.
Method: Vermicompost and compost were derived from a mixture of oyster mushroom Baglogs and pineapple waste. *Eudrillus eugeniae* earthworms were employed as the decomposers for the vermicomposting process. Vermicompost, compost, and the initial substrate were analyzed using Fourier Transform Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM), Particle Size Analyzer (PSA), chemical composition analysis, and microbiological analysis.
Results: The FT-IR spectra of the vermicompost confirmed an increase in nitrogen-rich compounds and the presence of humic substances. SEM analysis revealed more significant morphological structure changes in vermicompost. Furthermore, the vermicompost showed the smallest particle size (95.85 μm) compared to compost (149.73 μm) and the initial substrate (653.31 μm). The vermicompost demonstrated a 3-fold reduction in C/N ratio compared to the initial substrate. The nutrient content of the vermicompost increased by $1.2-3.2$-fold from the initial substrate. The vermicompost exhibited a higher bacterial population (30.93×10^7 CFU/g) compared to compost (10.05×10^7 CFU/g) and initial raw material (2.47×10^7 CFU/g).
Conclusion: The results demonstrated improvement in the qualities of vermicomposting as a sustainable method for waste recycling. The enhanced nutrient content, particle size reduction, and increased bacterial population in the vermicompost indicated its potential as a valuable resource for improving soil health and plant productivity.

Keywords: Vermicompost composition; Particle Size Analyzer (PSA); Scanning Electron Microscopy (SEM); Fourier Transform Infrared (FT-IR)

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1. Introduction

The use of organic waste as raw material for organic fertilizer production has recently gained increased attention due to its potential to address issues related to waste management and soil degradation (Rashid and Shahzad, 2021; Voběrková et al., 2020). Organic fertilizer presents an excellent solution for waste management and recycling. Its application provides essential plant nutrients and enhances the physical and chemical properties of the soil, thus significantly boosting crop yield. Using organic fertilizer not only manage waste effectively but also tap into its potential to enrich soil fertility and support sustainable agricultural practices (Chen et al., 2020; Syarifinnur et al., 2020).

Vermicompost, an organic fertilizer commonly used in agriculture, has been the focus of extensive research. Studies show that it improves soil health while also promoting crop growth and increasing resistance to diseases (Alshehrei et al., 2025; Oliveira et al., 2024; Wonglom et al., 2024). Moreover, vermicompost contains plant growth-promoting substances, enzymes, and hormones that positively influence plant growth and development (Díaz et al., 2024; Arancon et al., 2019; Hussain et al., 2021). Its demonstrated ability to suppress certain plant diseases further contributes to its popularity as an effective and eco-friendly organic fertilizer (Aynehband et al., 2017; Sharma and Garg, 2019).

Utilizing vermicompost offers numerous advantages over conventional chemical fertilizers, such as reducing nutrient leaching and minimizing environmental pollution (Liu et al., 2020; Castillo Diaz et al., 2017). Its slow-release nature ensures a steady supply of nutrients to plants over an extended period, thereby reducing the risk of nutrient runoff and wastage (Suhani et al., 2025). Moreover, the use of vermicompost supports a closed-loop nutrient cycle, where organic waste materials are recycled back into the soil, completing the sustainable circle of nutrient management (Pączka et al., 2021).

Various sources of organic waste, including oyster mushroom Baglogs and pineapple waste, can be utilized to improve the quality of vermicompost. These waste materials are rich in nutrients and provide an ideal feedstock for earthworms to convert into nutrient-dense vermicompost through their digestion process (Zziwa et al., 2021; Castillo-González et al., 2019). The application of nutrients in the form of oyster mushroom baglog waste can provide micro and macro nutrients for plants, which can influence plant growth (Prabowo et al., 2020; Prasetyo et al., 2023). Oyster mushroom baglog waste is a byproduct of oyster mushroom production, and with the increasing demand for oyster mushrooms, waste generation has also been on the rise. If left unattended, the accumulation of mushroom baglog waste can negatively influence the environment and the surrounding oyster mushroom farming. The unrecycled waste piles become favourable sites for spore growth and dissemination, leading to potential contamination of the mushroom farming area by wind or clothing and ultimately causing crop failure (Wan Mahari et al., 2020).

The pineapple production in Indonesia reached 3.2 million tons in 2022, an increase from the previous year (2021) by 2.89 million tons (BPS-Statistics, 2023). This increase in production indirectly leads to a rise in the amount of residual waste, including leaves, pulp, stems, and peels generated from the pineapple processing industries (Nyamwaro et al., 2018). The use of pineapple waste as organic fertilizer in several studies has shown satisfactory results, and the efficient decomposition of pineapple wastes by earthworms has highlighted the viability of vermicomposting as a recycling technology to enhance soil productivity (Castillo-González et al., 2019; Zziwa et al., 2021; Cristina et al., 2022).

Despite the increasing interest in organic waste utilization for vermicomposting, limited research has focused on the comparative analysis of composting and vermicomposting of oyster mushroom Baglogs and pineapple waste as separate and combined feedstocks. Furthermore, previous studies have primarily examined individual waste materials, overlooked potential synergies when used in combination. This study aims to bridge this knowledge gap by evaluating the quality and characteristics of vermicompost produced from oyster mushroom Baglogs and pineapple waste in combination.

To convert a mixture of oyster mushroom Baglogs and pineapple waste into vermicompost. *Eudrillus eugeniae* earthworms were employed as the decomposers. Eudrilus eugeniae is renowned for its exceptional efficiency in decomposing pineapple waste, transforming it into a high-quality, nutrient-rich organic fertilizer (Gnanamani and Vijayalakhsmi, 2023; Syarifinnur et al., 2023). The utilization of *Eudrilus eugeniae* as decomposers in the vermicomposting process further underscores the potential benefits of this simple yet effective technology in recycling organic waste and producing a valuable input for enhancing soil health and plant growth (Arumugam et al., 2018; Ayilara et al., 2020; Syarifinnur et al., 2022).

This study also provides a novel comparison of microbial decomposition (composting) and earthworm-mediated decomposition (vermicomposting) as distinct processes, assessing their efficiency in nutrient transformation and organic matter stabilization. The findings will contribute to the development of sustainable organic waste management strategies and offer new insights into optimizing vermicomposting techniques for enhanced soil fertility and agricultural productivity.

The objective of this study was to determine the quality and characteristics of a combination of oyster mushroom Baglogs and pineapple residue for vermicompost production by *Eudrilus eugeniae*. The study evaluated composting, which relies on microbial decomposition, and vermicomposting, which involves earthworm activity, as separate processes. The nutrient composition and overall quality were analyzed at each stage to compare both methods.

2. Materials and methods

Study area and collection of samples

The research was conducted at the IMSA Organic organization in Mataram City (−8.56481, 116.11849, 65.7 m). The oyster mushroom Baglogs and pineapple waste used in this study were sourced from local suppliers within the Mataram city area, West Nusa Tenggara, Indonesia. The Baglogs consisted of spent mushroom substrate left after the oyster mushrooms (*Pleurotus* sp.) had been harvested, while the pineapple waste, primarily including peels and other byproducts from pineapple processing, was collected from fruit vendors selling pineapples (Fig. 1). The utilized part of the pineapple waste was the peels, while the crown and core were not used. The earthworm species utilized was the mature *Eudrilus eugeniae*, identified by the presence of a clitellum. Stock cultures of *Eudrillus eugeniae* were carefully preserved in laboratory settings to be used for research purposes. The cattle manure from a farm near the research site was used in the study. Cattle manure was used in this study because it serves as a nitrogen-rich organic amendment that enhances microbial activity, accelerates decomposition, and improves the overall nutrient balance in both composting and vermicomposting processes. Its high moisture content and microbial diversity also create favourable conditions for earthworm activity, promoting efficient organic matter breakdown and nutrient enrichment in the final vermicompost. The initial physicochemical characteristics of oyster mushroom Baglogs, pineapple waste, and cattle manure are presented in Table 1.

Oyster mushroom Baglogs

Pineapple waste

Figure 1. The materials used in the compost and vermicompost production process.

Experimental design

The experiment aimed to evaluate the composting and vermicomposting processes using a combination of pineapple waste peels, oyster mushroom Baglogs, and cattle manure. The pineapple peels were cut into uniform sizes of approximately $4-10$ cm using a stainless-steel cutter to ensure consistency in decomposition. The oyster mushroom Baglogs were air-dried for 48 hours. The cattle manure was collected fresh from a nearby farm and pre-dried for 24 hours before use to reduce excess moisture and improve handling.

The establishment of study materials involved pre-treatment of pineapple peels, oyster mushroom Baglogs, and cattle manure, followed by the experimental design comprising three treatments to compare composting and vermicomposting processes. The raw materials were mixed in a 1:1:1 ratio based on dry weight and transferred into cubic composting containers measuring 48 × 35 × 20 cm. One liter of water was added to each container to maintain an initial moisture content of approximately $60-70\%$. The mixture was manually turned every three days to ensure even decomposition and aeration. The temperature and moisture levels were monitored daily using a digital thermometer and a soil moisture sensor.

After one week of composting, 100 adults *Eudrilus eugeniae* earthworms (identified by their developed clitellum) were introduced into designated vermicomposting containers. The earthworms were acclimatized for 24 hours in a separate container before introduction to prevent stress. The study consisted of three treatment groups: (i) initial raw material mix (control), (ii) composting without earthworms, and (iii) vermicomposting with *Eudrillus eugeniae*. Each treatment had three replications. The decomposition process lasted for 40 days, based on previous studies indicating that this duration is sufficient for stabilization of

Table 1. Characteristics of raw materials in compost and vermicompost (Mean ± SE, n = 3).

Parameters	**Oyster mushroom Baglogs**	**pineapple waste**	**Cattle manure**
Moisture Content (%)	25.45 ± 1.34	84.74 ± 0.97	76.89 ± 0.96
pH	9.22 ± 0.25	2.68 ± 0.18	9.10 ± 0.08
C-Organic (%)	50.43 ± 1.49	55.40 ± 1.16	44.82 ± 0.45
Nitrogen (N) (%)	0.63 ± 0.02	0.96 ± 0.07	0.71 ± 0.04
Phosphorus (P) (%)	0.41 ± 0.02	0.32 ± 0.03	0.34 ± 0.02
Potassium (K) (%)	0.77 ± 0.03	1.18 ± 0.17	1.37 ± 0.04
Manganese (Mn) (ppm)	76.70 ± 0.96	60.71 ± 1.32	90.05 ± 0.95
Iron (Fe) (ppm)	87.60 ± 0.75	98.45 ± 1.22	95.65 ± 0.87
Zinc (Zn) (ppm)	15.50 ± 0.86	10.87 ± 0.83	12.45 ± 1.25
Copper (Cu) (ppm)	46.40 ± 0.69	14.89 ± 0.67	32.67 ± 0.68
C:N ratio	80.04 ± 4.84	57.43 ± 4.89	39.67 ± 3.61

organic matter in both composting and vermicomposting processes (Syarifinnur et al., 2023). No additional feed was provided during the incubation period, and moisture levels were maintained at $60-70\%$ by periodic water spraying.

Further analyses were conducted using FT-IR (Fourier Transform Infrared) analysis, PSA (Particle Size Analyzer) analysis, SEM (Scanning Electron Microscopy) analysis, bacterial quantification analysis, chemical, macronutrient, and micronutrient analysis.

The data were analyzed using one-way ANOVA to identify statistically significant differences ($P < 0.05$). Least Significant Difference (LSD) test was used to determine the homogeneous treatment groups.

Fourier transform infrared spectroscopy (FT-IR) analysis

The instrument used for the analysis of initial raw material mix, compost, and vermicompost was the Perkin Elmer FT-IR Spectrometer Spectrum Two with a scanning capacity ranging from 4000 cm^{-1} to 400 cm^{-1}, covering a wide range of infrared wavelengths for the analysis of samples. The instrument performed 16 scans during each measurement, which allowed for increased data averaging and improved signal-to-noise ratio. The resolution of the spectrometer was set at 4 cm^{-1}, ensuring precise and detailed spectral data. The analysis was conducted at a constant temperature of 25 °C to maintain a stable environment and minimize potential temperature-related effects on the measurements.

Scanning electron microscopy (SEM) analysis

The SEM images were acquired using a JEOL JSM-IT 200 scanning electron microscope with a magnification of 1000 X. This high-resolution imaging allowed for a detailed observation of the specimens' surface morphology and microstructure.

Particle size analyzer (PSA) analysis

The Particle Size Analyzer utilizes a quantitative testing method, with the Horiba Partica LA-960 serving as the designated instrument. The testing parameter measures particle sizes within the micrometer scale, encompassing a measurement range from 0.01 μm to 5000 μm.

Analysis of chemicals, macronutrients, and micronutrients

Organic carbon (Organic C) was determined using the Walkey-Back method. The pH was measured through extraction with distilled water at a ratio of 1:5 (v/v). Kjeldahl's method quantified total nitrogen (total N). Total phosphorus (Total P) and total potassium (Total K) were determined using HNO_3-$HClO_4$ digestion. The content of total manganese (Mn), total zinc (Zn), total copper (Cu), and total iron (Fe) was analyzed using an absorption spectrophotometer (Shimadzu AA 7000) following the methodology outlined in Balittanah (2009).

Population of bacteria

The dilution plate cultivation technique was employed to quantify the bacterial colony-forming units (CFU). Three sets of initial raw material, compost, and vermicompost samples (each weighing 10 grams) were suspended in 90 mL of 0.85% physiological solution and homogenized using an ultrasonic bath. The samples were then serially diluted (ranging from $10-4$ to $10-7$) and plated (0.1 mL) on nutrient agar (NA). The plates were subsequently incubated in the dark at 28 °C for two days.

3. Results and discussion

Analysis of chemical composition by FI-TR spectroscopy

FT-IR analysis is used to determine the chemical composition of a material by identifying the presence of functional groups (Thamizharasan et al., 2024). Peaks corresponding to specific functional groups in the FT-IR spectrum indicate the existence or absence of these groups in the metabolites (George et al., 2023; Elakiya and Arulmozhiselvan, 2021). These bands are crucial for comparing and assessing the processes of degradation and stabilization of the material during the bioconversion process (Saravanan et al., 2023; Soobhany et al., 2017). Based on the FTIR spectra analysis (Fig. 2: a, b, c), the initial raw material, compost, and vermicompost revealed several peaks corresponding to different functional groups of primary and secondary metabolites. The FT-IR spectra of the initial raw material, compost, and vermicompost exhibited characteristic peaks at approximately 3337 cm^{-1}, 1623 cm^{-1}, 1319 cm^{-1}, 1034 cm^{-1}, and 444 cm^{-1}. These peaks were associated with specific functional groups in the compounds.

The spectral range between 3300 and 3500 cm^{-1} typically corresponds to the stretching vibrations of hydrogen-bonded O-H and N-H functional groups. This region is crucial for identifying hydroxyl groups in compounds like alcohols, phenols, carboxylic acids, amines, and amides (Subhash et al., 2015). The presence of a wavenumber around 3300 cm^{-1} might indicate the N-H stretching in a primary or secondary amine. During the decomposition process, microorganisms and enzymes in vermicompost can break down complex organic compounds, resulting in the formation of simpler compounds such as amines (R-NH_2) or amides (R-$CONH_2$) (Amritha and Jayasree, 2020). Wavenumber around 1634 cm^{-1} indicates aromatic ether from lignin decomposition structure. The increase in aromatic carbon levels indicates advanced organic matter humification, signifying the maturity and stability of the vermicompost. It represents converting organic materials into a highly humified substrate (Elakiya and Arulmozhiselvan, 2021). Wavenumbers 1400 cm^{-1} - 1450 cm^{-1} confirm the carbonyl acids (COO- stretches) and amide III (C-N stretches), indicating escalated amounts of nitrogen substances. These peaks are attenuated during composting, indicating a reduction in aliphatic content due to the decomposition process facilitated by earthworms (Ahmed and Deka, 2022; Lv et al., 2013). This wavenumber range is not visible in the initial material. The 1047 cm^{-1} -1091 cm^{-1} peak indicates the presence of ether, ester, and polysaccharide groups (C-O stretch). All these functional groups determine the humic substance level in compost and vermicompost (Rajiv et al., 2013; Ravindran et al., 2013). Wavenumbers in the $435-1443$ cm^{-1} range are often associated with Aryl disulfides (S-S stretch) (Velmurugan and Annamalai, 2023;

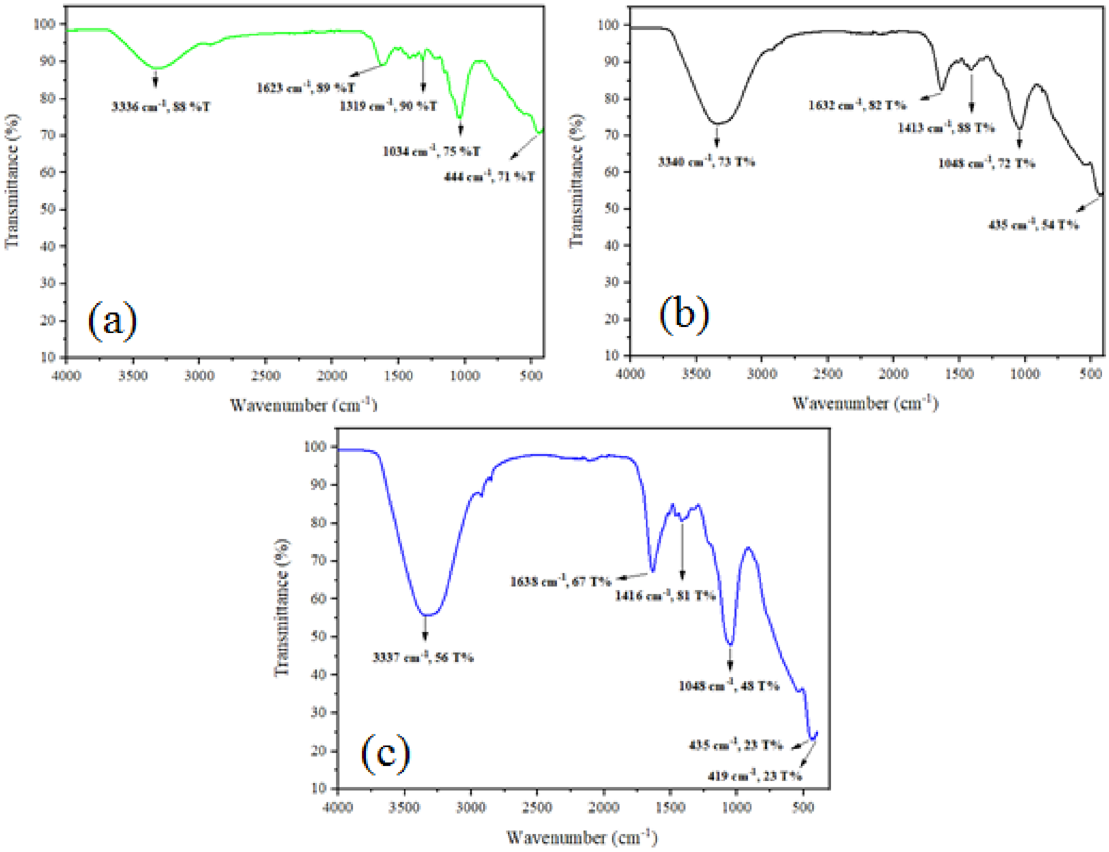

Figure 2. FTIR spectrum of initial raw material (a), compost (b), and vermicompost (c).

Nandiyanto et al., 2019). In vermicompost, two peaks were found, whereas in compost and the initial raw material mix, only one rise was present. This difference is attributed to the earthworms' ability to break down complex compounds into new compounds with different structures. These findings provide valuable insights into the potential benefits of using vermicomposting to produce high-quality organic fertilizers (Srivastava et al., 2024; Wu et al., 2014).

Scanning electron microscope (SEM) analysis

The SEM images illustrate the changes in organic surface morphology before and after the decomposition process (Luo et al., 2025; Bhat et al., 2017). The morphology of initial raw material, compost, and vermicompost samples was illustrated in Fig. 3 (a, b, c). The electron microscope clearly depicts the enhancement of degradation structures of the organic substrate (1.000 X). The micrographs of the initial samples revealed clear and distinct lines. However, after composting and vermicomposting, the structures began to fade, and irregularities surfaced. In the process of vermicomposting, the structures underwent significant changes in shape and appearance. The changes observed on the surface structure of the vermicompost indicate a more degradation process with earthworms (Rout and Arulmozhiselvan, 2019; Hema and Meena, 2020).

Population of bacteria

The total number of bacteria among the treatments showed significantly different (Anova, LSD, $P < 0.05$). The higher number of bacteria observed in vermicompost compared to compost and the initial raw substrate can be attributed to the unique characteristics of vermicomposting. During the decomposition process, bacteria actively participate in the decomposition of organic waste materials (Kumar et al., 2024; Arumugam et al., 2018). The average bacteria in vermicompost was 30.93×10^7 CFU/g, while compost and initial substrate were 10.5×10^7 CFU/g and 2.47×10^7 CFU/g (Table 2). Bacteria within earthworms decompose waste into smaller particles, increasing the surface area available for microbial colonization (Erkul and Ucaroglu, 2025; Ravindran et al., 2013). This enhanced physical breakdown facilitates easier access for microorganisms, leading to accelerated decomposition and an increase in bacterial populations (Pathma and Sakthivel, 2012; Soobhany, 2018). Moreover, earthworms have a symbiotic relationship with beneficial microorganisms present in their gut. These microorganisms aid in the digestion of organic matter and contribute to the release of nutrient-rich compounds during the vermicomposting process. These beneficial microorganisms in the vermicompost create an environment conducive to the proliferation of bacterial populations. (Das and Deka, 2021; Mupambwa et al., 2016). When vermicompost is added to soil, the bacterial populations continue to thrive and contribute to the improvement of soil health. The presence of beneficial bacteria can suppress the growth of harmful pathogens, enhance soil structure, and promote plant growth (Zhao et al., 2019; Joshi et al., 2015; Sreevidya et al., 2016).

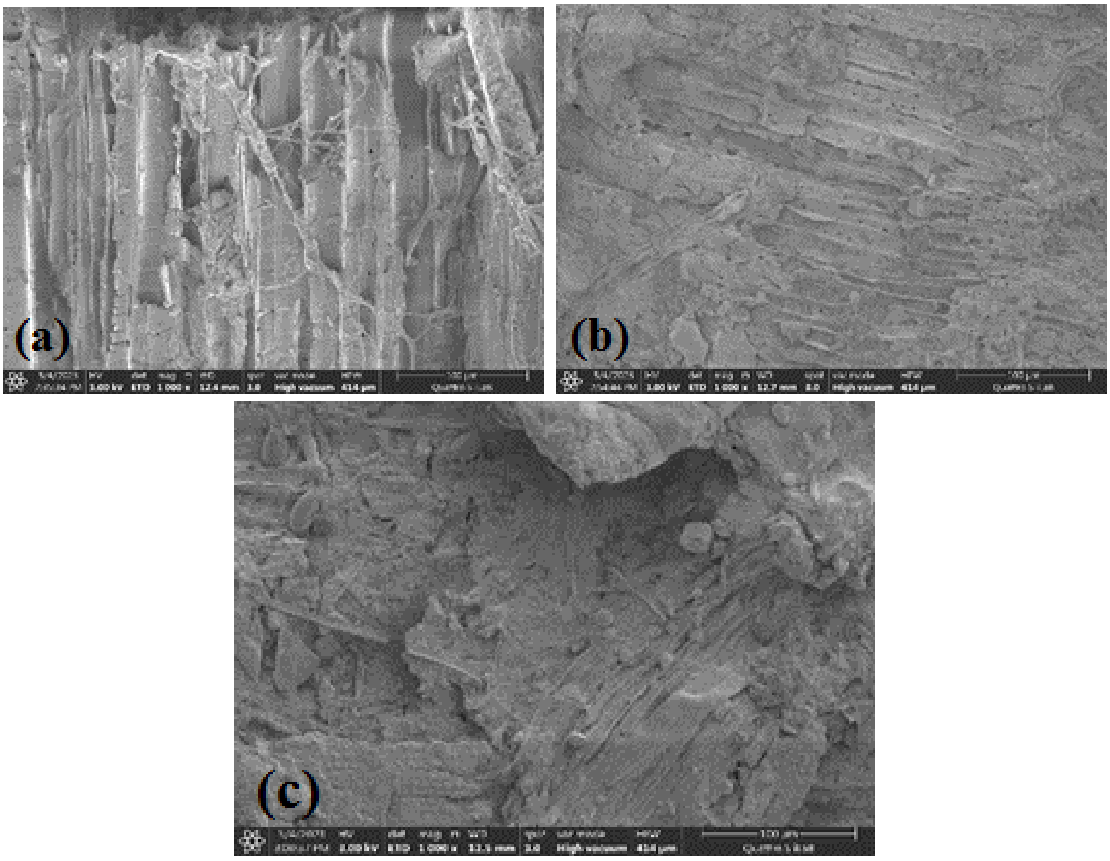

Figure 3. Scanning Electron Microscopy (SEM) of initial raw material (a), compost (b) and vermicompost (c).

Particle size analyzer (PSA)

The Particle Size Analyzer (PSA) is a device that employs dynamic light scattering principles to assess the size distribution of particles in motion due to Brownian motion. Utilizing PSA for particle size determination offers a quicker and more precise method (Riyanto et al., 2022). Increasing the decomposition in vermicompost increases the particle size decrease in the surfactant amount. The particle size analyzer results show that vermicompost has smaller particle sizes compared to compost and the initial substrate. According to Table 2, the particle size of compost was 149.73 μm, the particle size of vermicompost was 95.85 μm, and the particle size of the initial raw material was 653,31 μm. During vermicomposting, earthworms and beneficial microorganisms break down organic waste materials. Reducing particle size led to a decline in organic carbon content and a rise in macronutrients, micronutrients, and ash content. These organisms feed on and process organic matter, leading to a more complete decomposition into finer particles (Singh et al., 2025; Haynes et al., 2015). Earthworms play a crucial role in the vermicomposting process by physically grinding and fragmenting the organic waste, which reduces particle size.

Additionally, earthworms' digestive enzymes and gut microorganisms further break the organic matter into finer particles during digestion. The variation in particle size offers significant advantages in agronomic applications. Reduced particle size increases surface area, enhancing contact with plants and soil, promoting easier nutrient absorption by roots, improving fertilizer efficiency, and boosting crop productivity. (Hanc and Hrebeckova, 2023; Hanc and Dreslova, 2016). The particle size distribution is shown in Fig. 4 (a, b, and c). The peak of the curve represents the distribution area of the particle size.

Table 2. Total number of bacteria, particle size, pH, and C/N ratio of the initial raw material, compost, and vermicompost (Mean ± SE, n = 3).

Treatment	**Total number of bacteria** (CFU/g)	**Particle Size** (μm)	**C/N Ratio**	**pH**
Initial raw material	$2.47 \times 10^7 \pm 0.17 \times 10^7$ a	653.31 ± 1.39 c	71.40 ± 2.11 c	8.60 ± 0.28 b
Compost	$10.05 \times 10^7 \pm 0.06 \times 10^7$ b	149.77 ± 0.21 b	37.81 ± 0.34 b	6.74 ± 0.03 a
Vermicompost	$30.93 \times 10^7 \pm 0.14 \times 10^7$ c	95.85 ± 0.18 a	19.02 ± 0.73 a	6.58 ± 0.18 a

Values with the same letter in a column are not significantly different at a 5% significance level by *Least Significant Difference* (LSD) test.

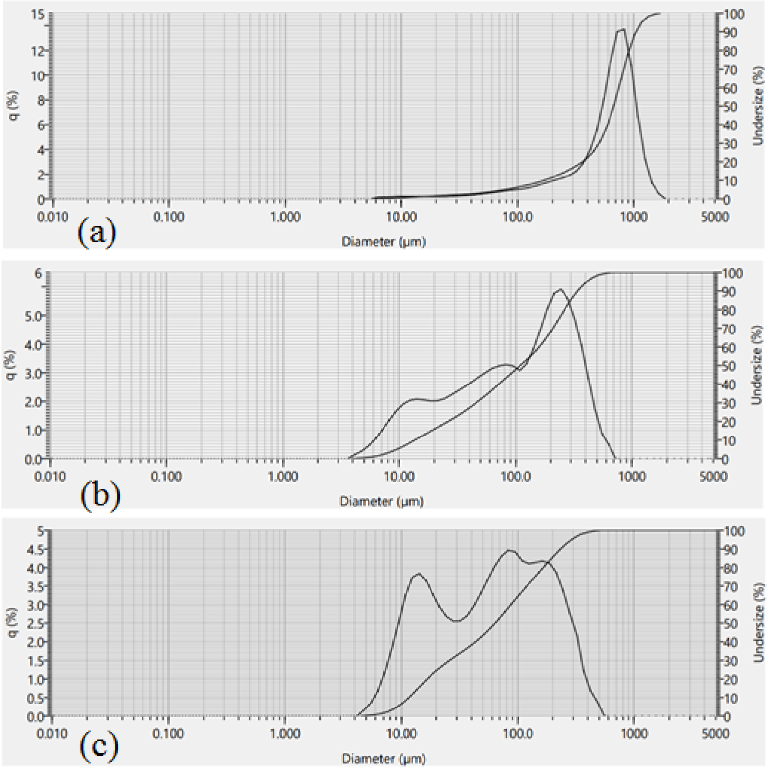

Figure 4. Particle size distribution initial raw material (a), compost (b), and vermicompost (c).

C/N ratio and pH

Based on the results (Table 2), there was a significant decrease in the C/N ratio in both compost and vermicompost. The C/N ratio value exhibits approximately a 2-fold decrease in compost and a 3-fold decrease in vermicompost compared to the initial raw substrate. This decrease in vermicompost indicates a high degree of organic matter stabilization and underscores its substantial agricultural potential due to earthworm activity (Das and Tangjang, 2024; Deka et al., 2011). The results are in line with previous studies that reported a reduction ranging from 57.69% to 84.41% in the C/N ratio in six vermiculture treatments (Gupta and Garg, 2008). Similar findings also indicate a decrease in the C/N ratio by 19 to 102% in nine vermibin (Sharma and Garg, 2018). The higher decline in the C/N ratio during the vermicomposting process is attributed to increased decomposition and mineralization. The decrease is primarily due to the presence of earthworms and is supported by microorganisms within the earthworms' bodies, assisting in the breakdown of organic matter (Iswahyudi et al., 2024; Karmegam et al., 2019; Yadav and Garg, 2019). The pH values indicate no significant difference between the compost and vermicompost treatments. There was a difference in pH values when compared to the initial substrate. The difference in pH values is likely due to the decomposition processes and increased nitrification in compost and vermicompost, resulting in the production of organic acids, which can lower the pH values (Nurhayati et al., 2024; Raza et al., 2024; Zhang et al., 2015; Boruah et al., 2019).

Macronutrients and micronutrients of initial raw material, compost, and vermicompost

The macronutrient levels among the treatments showed significantly different results (Anova, LSD, $P < 0.05$). The macronutrient (N, P, K) composition of the initial raw material, compost, and vermicompost were presented in Table 3. The results demonstrate a significant enrichment of macronutrients in the vermicompost sample compared to the compost and initial raw substrate. The end products of vermicompost exhibited a 2.74-fold increase in nitrogen content. Several factors, such as earthworms, consume nitrogen-rich organic matter, breaking it down with their

Table 3. Macronutrients of the initial raw material, compost, and vermicompost (Mean ± SE, n = 3).

Treatment	Total N (%)	Total P (%)	Total K (%)
Initial raw material	0.72 ± 0.02 a	0.35 ± 0.03 a	1.08 ± 0.04 a
Compost	1.09 ± 0.01 b	0.97 ± 0.05 b	1.70 ± 0.03 b
Vermicompost	1.92 ± 0.04 c	1.28 ± 0.03 c	1.63 ± 0.02 b

Values with the same letter in a column are not significantly different at a 5% significance level by *Least Significant Difference* (LSD) test.

enzymes and microbes into plant-friendly forms. Microbial decomposition of organic material releases nitrogen compounds and significantly elevated nitrogen levels. This nitrogen-rich vermicompost acts as a powerful organic fertilizer, improving soil nitrogen levels and promoting robust plant growth (Cruz et al., 2024; Ravindran and Mnkeni, 2016; Zziwa et al., 2021; Fornes et al., 2012). Vermicompost increased by 3.56-fold in total phosphorus compared to the initial raw material, while compost reached 2.77-fold. This higher potassium concentration in earthworm-processed materials was attributed to a faster mineralization rate resulting from enhanced microbial and enzyme activities (Kamdi et al., 2024; Yadav and Garg, 2011; Das et al., 2016) and the process of decomposing pectin compounds through the enzymatic hydrolysis process of pectinase enhances the phosphorus levels in vermicompost (Singh et al., 2020; Busato et al., 2012). The total potassium (K) in compost and vermicompost did not show a significant difference, but it differed significantly from the initial raw material. The total K result may be attributed to the specific composition of the substrate mixture used in this research. These results are supported by a study conducted by Rékási et al. (2019), which indicates no significant difference between compost and vermicompost treatments in terms of total K parameters. However, in other substrate mix combinations, there is a significant difference between compost and vermicompost.

The micronutrient levels among the treatment showed significantly different (Anova, LSD, $P < 0.05$). The concentrations of total micronutrients (Fe, Zn, Mn, and Cu) exhibited a significant increase in vermicompost, as illustrated in Table 4. These concentrations ranged from 1.2 to 4 times higher than those in the initial raw material and compost. The increased micronutrient concentration in vermicompost results from the mineralization of partially digested worm feces by bacteria and fungi (Singh et al., 2025; Vieira et al., 2025; Karwal and Kaushik, 2020). This finding aligns with the research conducted by Deka et al. (2011) and Mago et al. (2022), which demonstrated that the micronutrient content during the vermicomposting process can increase by $3.2-5.6$ times. The study provides further support for the conclusion that the activities of bacteria and fungi in the mineralization of worm feces play a crucial role in enriching the micronutrient content in organic materials (Wang et al., 2019; Patra et al., 2022). The results of similar studies also indicate an increase in micronutrient content ranging from 1.14 times to 6.67 times for total Cu and total Zn compared to the control (Bakar et al., 2014). The increase in micronutrient content in vermicompost is also demonstrated in a study by Mago et al. (2021), showing an enhancement in micronutrient values ranging from 1.28 to 3.65 times.

4. Conclusion

The study's findings indicate that the vermicompost derived from a combination of oyster mushroom Baglogs and pineapple waste, with Eudrillus eugeniae earthworms as decomposers, shows promise as a nutrient-rich fertilizer for sustainable agriculture. The vermicompost demonstrated enhanced nutrient content, increased beneficial microbial activity, and improved physical characteristics. These positive attributes make it a potential candidate for supporting soil fertility and promoting sustainable agricultural practices. Further investigations and field trials are recommended to validate these results and explore the practical application of this nutrient-rich vermicompost in real-world agricultural settings.

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Authors contributions

The authors confirm the study conception and design: Syarifinnur, Suriadi, Hadiawati, Khaerana, Susilowati. Data collection: Syarifinnur, Hadiawati, Nugraha, Arifin. Methodology and formal analysis: Syarifinnur, Suriadi, Hadiawati, Khaerana, Arifin, Susilowati. Software and data curation: Syarifinnur. Investigation and project administration: Hadiawati, Nugraha, Arifin. Resources: All authors. Validation: Syarifinnur, Suriadi, Hadiawati. Visualization: Nugraha, Susilowati. Funding acquisition: Nugraha. The draft manuscript preparation was carried out by Syarifinnur, Suriadi, and Hadiawati. All authors contributed to reviewing and editing the manuscript. The final version of the manuscript was read and approved by all authors.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 4. Micronutrients of the initial raw material mix, compost, and vermicompost (Mean ± SE, n = 3).

Treatments	**Total Fe** (ppm)	**Total Mn** (ppm)	**Total Cu** (ppm)	**Total Zn** (ppm)
Initial raw material	93.13 ± 3.18 a	85.57 ± 11.40 a	32.1 ± 0.87 a	13.39 ± 0.58 a
Compost	263.37 ± 4.26 b	351.90 ± 13.40 b	39.50 ± 2.08 b	14.16 ± 0.72 a
Vermicompost	444.63 ± 5.36 c	568.73 ± 11.03 c	50.07 ± 1.87 c	17.27 ± 0.58 b

Values with the same letter in a column are not significantly different at a 5% significance level by *Least Significant Difference* (LSD) test.

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