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Quality of Mushroom Substrate Waste Vermicompost with Addition of Mustard Greens, Papaya and Banana Peel, Produced by *Eudrilus eugineae*

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Abstract

The research aimed to analyze the quality of vermicompost produced from mushroom substrate waste (MSW) with the addition of mustard greens, papaya, and banana peels, using *Eudrilus eugeniae* Kinberg. The study used a Randomized Completely Block Design repeated 6 times. The treatments included MSW without additional feed, and MSW with additional feed of mustard greens, papaya and banana peel. The observed variables included substrate weight loss, vermicompost weight, number of worms, worm weight, total nitrogen (N), total phosphate (P_2O_5; P), total potassium (K_2O; K), number of N-fixing bacteria, and number of P-solubilizing bacteria. The results indicated that adding papaya to MSW vermicomposting produced the highest number and weight of worms (172.8 and 236.3 g, respectively), as well as vermicompost with the highest total N content and the highest number of N-fixing bacteria (2.46% and 2.99×10^4 cfu g^{-1}). All treatments resulted in vermicompost with N + P_2O_5 + K_2O levels > 5%, exceeding the minimum limit set by the Indonesian Minister of Agriculture.

Keywords: Vermicompost; *Eudrilus eugeniae*; Waste; Mustard; Papaya; Banana peel

Introduction

World mushroom production increased 13.8-fold to 42.8 million tonnes over the 30 years from 1990 to 2020 (Okuda 2022). This increase in mushroom production has led to environmental pollution due to waste from mushroom growing media. For every production of 1 kg of mushrooms, 5 kg of oyster mushroom growing media waste i.e., mushroom substrate waste (MSW) is produced (Leong *et al.* 2022). The annual production of MSW reaches 60 million tons (Atallah *et al.* 2021). In addition, large amounts of vegetable waste are produced in vegetable market areas, contributing to environmental pollution (Raja *et al.* 2019). This waste is generated by farmers, fruit and vegetable transporters, warehouse workers, wholesale and retail markets, and supermarkets (Atallah *et al.* 2021). According to Kaza *et al.* (2018), each person produces around 0.74 kg of waste per day. It is projected that global waste accumulation will increase from 2 billion tons in 2016 to 3.4 billion tons in 2050.

The MSW and vegetable waste have high biodegradability and low toxicity, making them ideal for reuse (Malińska *et al.* 2018). One possible method of recycling these two wastes is through vermicomposting. Vermicomposting is the process of converting organic waste by certain species of earthworms into a valuable humus-like material that is used as a natural soil conditioner (Domínguez-Gutiérrez *et al.* 2022). Vermicompost is beneficial for increasing soil fertility and water holding capacity, enhancing soil nutrients, thereby boosting agricultural productivity, increasing soil biodiversity, promoting plant resistance to pests and diseases, and also reducing ecological and other environmental risks (Raja *et al.* 2019). According to Purnawanto *et al.* (2021), the quality of vermicompost is determined by the suitability of the substrate, the type of earthworm, and environmental factors. It is important to note that the quality of vermicompost is crucial as it can affect soil fertility and plant growth when used as organic fertilizer (Bajal *et al.* 2019). Different agricultural wastes can be utilized as substrates for vermicomposting. It is essential to utilize organic waste wisely to improve the quality of the compost formed. The quality of vermicompost primarily depends on the type of raw material and the species of earthworms used (A'ali *et al.* 2017). The selection and combination of substrate play a crucial role in vermicomposting, as it influences worm activity and affects the quality of the organic fertilizer

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formed (Bajal *et al.* 2019).

Vermicompost is rich in nutrients like nitrogen (N), phosphate (P_2O_5; P), potassium (K_2O; K), and micronutrients, as well as beneficial microbes, plant hormones, and enzymes (Bajal *et al.* 2019). According to Quintern *et al.* (2016), using vermicompost in agriculture offers several benefits, such as increased nutrient content, enhanced presence of soil microbes, improved water retention in the soil, and increased plant growth and crop yields. Application of vermicompost can make N, phosphorus, and K in the soil more easily available for plant absorption (Chin *et al.* 2018). It can also replace chemical fertilizers due to its high concentration of mineral nutrients available to plants (Ose *et al.* 2021). Vermicompost contains microbial communities such as P-solubilizing microbes, N-fixers, enzyme producers, and plant growth promoting bacteria. These bacteria influence soil properties, other soil organisms, and nutrient cycles in nature (Vukovic *et al.* 2021). Research by Purnawanto *et al.* (2021) indicates that using MSW as a substrate for cultivating earthworms without additional feed results in vermicompost that meets the requirements of Minister of Agriculture Decree number 261 of 2019 in terms of N, phosphorus, and K levels. Applying MSW vermicompost (without additional feed) can enhance growth and increase corn yields in Ultisol (Purnawanto and Ahadiyat 2022). Therefore, it is important to examine the quality of MSW vermicompost when fed with additional vegetable waste, papaya fruit waste, and banana peel waste.

Vermicompost can serve as an organic fertilizer source for shallot cultivation (Alemu-Degwale 2016). The potential of vermicompost is crucial for increasing shallot production in Indonesia. Shallots are among the prioritized vegetable commodities in Indonesia due to growing domestic and international demand. The demand for shallots, and products made from shallots, has increased with the population and processed products industry (Arrofiq *et al.* 2021; Central Bureau of Statistics 2021). The national census shows that each person in Indonesia consumes an average of 27.72 kg of shallots per year, indicating a need for approximately 7.48 million tons of shallots annually with a population of 270.20 million people. However, Indonesia's shallot production has only reached 1,815,445 tonnes (Central Bureau of Statistics 2021).

According to existing research, the quality of vermicompost is influenced by the substrate utilized. However, the specific impact of using MSW substrate along with additional mustard greens, papaya, and banana peel waste on the quality of vermicompost has not been fully explained.

Materials and Methods

Experimental details

The research was carried out in Karangsoka Village, Kembaran District, Banyumas Regency, Central Java, Indonesia. The research was structured using a Randomized Completely Block Design replicated 6 times. The treatments were 1) MSW (without additional feed) and 2) MSW + mustard greens, 3) MSW + papaya, and 4) MSW + banana peel. The worm used was *Eudrilus eugeniae*. During experiment, first the MSW was separated from the plastic wrapping, then crushed to a smaller size, and filtered using a 6–8 mesh sieve. After that, the MSW was mixed with water until the humidity was 60–70% and put into a container (size 38 cm × 32 cm × 10 cm) with a thickness of around 5 cm. Next, 100 g of adult earthworm were put into a container and spread evenly over the media. After that, the container was covered with gauze so that the earthworms were not exposed to direct light. Every three days, 100 g of additional feed was added (according to treatment). During the vermicomposting process, the media was sprayed with water and turned over so that humidity and air circulation were maintained. After 60 days, the vermicompost was separated from the earthworms by hand sorting.

Observation variables

The variables observed were 1) substrate weight loss, calculated by the percentage of vermicompost that was compared to the weight of the substrate and feed, 2) vermicompost weight, weighed by the weight of the vermicompost, 3) number of worms, calculated by the number of worms at the end of the study, 4) worm weight, weighed by the weight of the worms at the end of the study, 5) total N content, analyzed using the Kjeldahl method (Sáez-Plaza *et al.* 2013), 6) total P_2O_5, analyzed using the Bray I method (FAO 2021), 7) total K_2O, analyzed using the spectrophotometer method (International Fertilizer Industry Association 2009), 8) number of N-fixing bacteria, calculated using the Total Plate Count method (Suliasih and Widawati 2005) and 9) the number of P-solubilizing bacteria, calculated using the Total Plate Count method (Suliasih and Widawati 2005).

Data analysis

The effect of treatment on vermicompost was analyzed using analysis of variance ($\alpha \leq 0.05$) with the SPSS 25 program. Multiple comparisons for treatments with a significant effect were using Duncan's Multiple Range Test (DMRT) with $\alpha \leq 0.05$.

Results

The addition of feed had a significant effect on weight loss, the number of worms, worm weight, total N, total phosphorus, and the number of N-increasing and P-solubilizing bacteria in the vermicompost. Weight loss was highest in the MSW substrate that did not receive additional feed, at 51.23%. The weight loss for the addition of mustard

Table 1: The effect of adding several types of feed to the MSW substrate on the yield of vermicompost and earthworms

Treatment	Substrate weight (g)	Feed weight (g)	Weight loss (%)	Vermicompost weight (g)	Number of earthworms	Earthworm weight (g)
MSW	3285	-	51.23b	1682.8a	112.0a	92.9a
MSW + Mustard	3285	2800	31.07a	1913.6a	165.2bc	158.5b
MSW + Papaya	3285	2800	29.41a	1797.8a	172.8c	236.3c
MSW + Banana Peel	3285	2800	28.45a	1733.4a	145.3b	99.1a

Note: Numbers followed by the same letter indicate that they are not significantly different based on the Duncan Multiple Range Test with $\alpha \leq 0.05$

Table 2: Nutrient content in substrate and earthworm feed

Substrate/feed	N total (%)	P_2O_5 total (%)	K_2O total (%)
Mushroom Substrate Waste (MSW)	1.76	0.32	1.68
Mustard	5.56	1.57	-
Papaya	5.36	0.27	-
Banana Peel	4.69	0.40	-

Table 3: The effect of adding several types of feed to MSW vermicomposting on the quality of vermicompost

Treatment	N total (%)	P_2O_5 total (%)	K_2O total (%)	N-fixing bacteria (cfu g^{-1})	P solubilizing bacteria (cfu g^{-1})
MSW	1.62a	0.51a	3.07a	0.05×10^4a	1.88×10^4a
MSW + Mustard	2.68c	0.74b	3.02a	0.08×10^4b	1.67×10^4a
MSW + Papaya	2.46c	0.57a	3.06a	2.99×10^4d	3.26×10^4b
MSW + Banana Peel	1.90b	0.54a	2.93a	0.92×10^4c	5.64×10^4c

Note: Numbers followed by the same letter indicate that they are not significantly different based on the Duncan Multiple Range Test with $\alpha \leq 0.05$

greens, papaya fruit, and banana peels were 31.07, 29.41 and 28.45%, respectively. There was no significant difference in the weight of vermicompost between the treatments (Table 1).

The addition of feed also affected the number of worms, with the highest number (172.8) obtained from the addition of papaya, which was not significantly different from the addition of mustard greens. The MSW substrate without additional feed had the lowest number of worms. This occurred because papaya and mustard greens have a higher N content than banana peels (Table 2).

The highest total N was found in MSW vermicompost that was added with mustard greens at 2.68%, which was not significantly different from MSW vermicompost added with papaya fruit. The addition of mustard greens also resulted in the highest total phosphorus at 0.74%. There was no significant effect of the additional feed treatment on total K_2O. The highest total of N -fixing bacteria was obtained in the MSW treatment that was added with papaya fruit, while the highest P-solubilizing bacteria count was obtained in the treatment with the addition of banana peels (Table 3).

Discussion

The addition of feed in the MSW vermicomposting process had a significant effect on the weight loss of the substrate. Addition of feed reduces the percentage of weight loss by around 20%. A decrease in weight loss in the additional feed treatment was because not all of the added feed was eaten by the worms. So there was some feed that had not yet turned into vermicompost. This is caused by the worms' ability to eat only a limited substrate and feed. Every day, worms are only able to consume organic waste equivalent to their body weight (El-Haddad *et al.* 2014; John *et al.* 2021).

According to Pradnya *et al.* (2023), the *E. euginae* is an epigeic earthworm that can consume organic material equivalent to its body weight per day. Therefore, the weight of the vermicompost produced is also relatively the same. According to Liberty *et al.* (2022), earthworms really like food that contains a lot of N and can increase their growth. Apart from that, the water content in feed also influences the growth of earthworms. In this context Rusad *et al.* (2016) reported that a lack of water causes disturbances in earthworm activity, especially in increasing the weight of earthworms. Papaya fruit has a water content of 80–85%, while mustard greens contain 65–80% water. This is reinforced by data showing that the addition of papaya fruit food resulted in the highest weight of earthworms, namely 236.3 g (Table 1).

The inclusion of mustard greens and papaya resulted in vermicompost with the highest total N content compared to treatments without additional feed or those fed with banana peels. This is because mustard greens and papaya fruit have higher N levels than banana peels. Additionally, the addition of mustard greens also led to the highest total phosphorus content compared to other feeds, as mustard greens have the highest phosphorus content. This finding aligns with research by Tognetti *et al.* (2007) and Sharma and Garg (2017), who stated that the total N content in vermicompost is primarily influenced by the initial N content of the organic waste used as feed for earthworms.

According to the Decree of the Indonesian Minister of Agriculture No. 261 of 2019, the minimum technical requirements for the quality of solid organic fertilizer for macro nutrient parameters (total N + total P_2O_5 + total K_2O) are at least 2%. Vermicompost produced by treating MSW, with or without additional feeding, has an average total N + total P_2O_5 + total K_2O content of 5.78%, meeting the quality requirements set by the Indonesian government. This level also complies with provisions in Tanzania, the Philippines, and Thailand, which respectively set minimum levels of total N + total phosphorus + total K in compost at 5% (Tanzania Bureau of Standard 2011), 5–7% (Philippine National Standard 2012), and 2% (Thai Agricultural Standard 2005).

The addition of feed can increase the number of N-fixing bacteria and P-solubilizing bacteria in vermicompost. The highest number of N-fixing bacteria was found in the MSW substrate treatment with the addition of papaya fruit, while the highest number of P-solubilizing bacteria was found in the MSW substrate treatment with the addition of banana peels (Table 3). According to Gunina and Kuzyakov (2015), the sugar content in papaya and banana peels can increase the activity of microorganisms by stimulating and maintaining microbial activity. In vermicompost derived from MSW, with or without added feed, the quantity of N-fixing bacteria ranged from 0.05×10^4 cfu g^{-1} to 2.99×10^4 cfu g^{-1}. Meanwhile, the number of P-solubilizing bacteria in vermicompost ranged from 1.67×10^4 cfu g^{-1} to 5.64×10^4 cfu g^{-1} (Table 3). It is important to note that these numbers do not meet the minimum requirement for the presence of functional bacteria in organic fertilizers, as specified by the Indonesian Minister of Agriculture Decree No. 261 of 2019, which requires a minimum of 1×10^5 cfu g^{-1}.

Conclusion

Adding papaya to MSW for vermicomposting resulted in the highest number and weight of worms, which were 172.8 and 236.3 g, respectively. This process also produced vermicompost with the highest total-N content and the largest number of N-adding bacteria, which were 2.46% and 2.99×10^4 cfu g^{-1}, respectively. In all cases, the vermicompost produced had N + P_2O_5 + K_2O levels exceeding 5%, which exceeds the minimum limit set by the Indonesian Ministry of Agriculture.

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Author Contributions

AMP and AM planned the experiments, interpreted the results statistically analyzed the data and made manuscript.

Conflicts of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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