P-ISSN: 0119-3058
E-ISSN: 2945-4093

The Vector: International Journal of Emerging Science, Technology and Management
Volume 34, Issue 1, January - December 2025

Bioconversion Of Food Waste Using Black Soldier (*Hermetia illucens*) Fly Larvae and African Nightcrawlers (*Eudrilus eugeniae*)

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ABSTRACT

The global reliance on synthetic fertilizers and growing concern over food waste highlight the need for sustainable alternatives. Despite these concerns, synthetic fertilizers remain a cornerstone of agricultural practices. This study evaluates the bioconversion of food waste using Black soldier fly (Hermetia illucens) larvae (BSFL) and African nightcrawlers (Eudrilus eugeniae), focusing on temperature, pH, humidity, macronutrients, and biomass conversion efficiency of the bioconverters using the following: T0 (control, no decomposers), T1 (100% BSFL), T2 (100% African nightcrawlers), and T3 (50% BSFL, 50% African nightcrawlers). Additionally, to determine whether a significant difference exists between and among the physicochemical properties in terms of temperature and pH levels of organic fertilizer. It utilized a 21-day experimental design to evaluate the compost's physicochemical properties by monitoring temperature, pH, humidity, nutrient content, and biomass conversion. Food waste was collected and segregated, bioconverters were reared and applied to the treatment, and physical and chemical analyses were performed throughout the process. T1 showed the highest temperature range (29.2–35.2°C). T0, T1, and T2 produced pH values ranging from acidic to alkaline (5.21–7.75) and humidity levels of 42–77%. All treatments yielded very high nitrogen (>4.5%) and phosphorus (>20 ppm) and sufficient potassium (11–150 ppm). T3 had the highest biomass conversion efficiency (84.4%). Temperature, pH, and biomass conversion differed significantly among treatments at the 0.01 level. These results demonstrate that the bioconverters can provide a cost-effective, eco-friendly method for converting waste into fertilizer, thereby supporting broader adoption. Future research should evaluate fertilizer performance across various crops, assess cost-yield benefits, and conduct long-term environmental assessment of productivity.

Keywords: *waste reduction, biomass conversion, macronutrients, physicochemical properties, organic fertilizer*

INTRODUCTION

On a global scale, food waste affects multiple aspects of society and the environment. Approximately one-third of all food produced for human consumption is lost or wasted annually (Gustavsson et al, 2011). This problem is exacerbated by rapid urbanization, changing consumption patterns, inefficient waste management systems, and a lack of awareness about sustainable practices.

P-ISSN: 0119-3058
E-ISSN: 2945-4093

The accumulation of food waste contributes to environmental degradation, greenhouse gas emissions, and strains on landfill capacity. Therefore, developing efficient and sustainable methods for food waste reduction is crucial. The United Nations Sustainable Development Goals (SDGs) highlight the importance of responsible consumption and production, underscoring the urgent need to reduce food waste. In the United States alone, an estimated 30–40% of the food supply is wasted each year, occurring across all stages of the supply chain—from production and distribution to consumption and disposal (Saadat et al., 2020). In India, fruit and vegetables are occasionally mechanically damaged during storage, transportation, and food processing, resulting in significant food waste. Other contributing factors in the generation of waste are mass consumption and mass waste disposal (Bisht & Singh, 2024).

Meanwhile, the Department of Science and Technology-Food and Nutrition Research Institute (2018) claims that 1,717 metric tons of food are wasted every day in the Philippines. This significant food waste exacerbates food insecurity by abandoning large amounts of edible food, leaving Filipinos hungry and malnourished, particularly the vulnerable communities (Baarion et al., 2023). German et al. (2023) further noted that vegetable waste is often discarded in municipal landfills or dumping areas, contributing to various environmental concerns. Improper disposal endangers the environment by polluting bodies of water through runoff. Additionally, decomposition in open spaces poses environmental and health dangers. Furthermore, organic waste emits methane, a powerful greenhouse gas that exacerbates climate change (Lenka, 2025). Additionally, it could lead to some economic losses for both producers and consumers. Despite ongoing initiatives, the complexity of the food system and persistent consumer behavior patterns continue to limit progress, underscoring the need for innovative and sustainable solutions (Martin, 2023).

Nutrient cycling through decomposition and/or composting is a critical component of sustainable agriculture, supported by policies at both the international and local levels. Composting transforms organic waste into nutrient-rich compost, reducing gas emissions and reducing reliance on synthetic fertilizers. Furthermore, through recycling, waste is converted to valuable resources that support the 5Rs Principles (Phonthanukitithaworn et al., 2024). These practical strategies are supported by Republic Act 9003, otherwise known as the Ecological Solid Waste Management Act of 2000, to reduce their environmental impact (Andaya et al., 2025).

By using food waste to produce organic fertilizer, the study encourages sustainable waste management practices and minimizes garbage sent to landfills or incineration. This is consistent with SDG 12, which aims to ensure sustainable consumption and production practices. Furthermore, it helps fulfill SDG 13: Climate

P-ISSN: 0119-3058
E-ISSN: 2945-4093

Action by reducing the demand for synthetic fertilizers, which have a higher carbon footprint due to production and shipping. In this context, the conversion of agricultural waste, such as lignocellulosic biomass (Raboy, 2021), into valuable resources has emerged as a promising strategy to enhance food security, strengthen economic resilience, and improve environmental sustainability (Ilac et al., 2025).

Solutions harnessing the bioconversion capabilities of specific organisms can reduce the burden on waste management systems and promote sustainable practices. The bioconversion process allows recycling of nutrients present in food waste, such as nitrogen and phosphorus, into the organic fertilizer. Bioconversion agents stand out as a compelling strategy for transforming organic waste into valuable resources. Black soldier fly larvae and nightcrawlers are particularly effective bioconverters due to their efficient decomposition of organic matter. Black soldier fly larvae are known for their rapid consumption of organic matter, facilitated by enzymatic properties that enhance the breakdown of waste. African nightcrawlers, used in vermicomposting, improve soil aeration and contribute significantly to the decomposition of organic substrates and nutrient cycling. The composting process for most food waste typically takes a considerable amount of time, ranging from 4 to 5 weeks (Listya & Khasanah, 2022) to as long as 7 months (Keng et al., 2010). However, a study by Priyambada and Wardana (2018) found that incorporating two different additive microorganism compositions can significantly accelerate composting, reducing the time to 7-14 days. Bioconverters, such as the black soldier fly (*Hermetia illucens*) and African nightcrawlers (*Eudrilus eugeniae*), are instrumental in converting organic materials into valuable products or energy through biological processes. These bioconverters, adept at processing various organic substrates and efficiently transforming waste into high-quality fertilizers, offer a cost-effective approach to managing waste (Siddiqui et al., 2024).

The emergence of bioconversion presents a solution by repurposing food waste into sustainable organic fertilizers. Implementing such methods on a larger scale could reduce the environmental footprint of food waste disposal, alleviate landfill pressures, and create valuable byproducts like nutrient-rich compost or animal feed. A method that offers practical benefits for industries, waste management authorities, and policymakers seeking innovative solutions to address food waste.

Black soldier fly (BSF) larvae contribute to organic waste reduction by diverting waste from landfills, efficiently decomposing complex organic compounds, and cycling nutrients. This integrated approach to waste management promotes sustainable agricultural systems, reduces greenhouse gas emissions, and supports a circular economy by minimizing waste sent to landfills and maximizing the value of organic waste (Surendara et al., 2016). Additionally, Black soldier fly (BSF) larvae have emerged as a promising nutrient alternative due to their high protein and fat

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E-ISSN: 2945-4093

contents, making them a suitable substitute for traditional animal feed sources such as fishmeal and fish oil. As per the research conducted by Win et al. (2018), black soldier fly larvae have been studied as a potential feedstock for anaerobic digestion biogas production. The biomethane potential of black soldier fly larvae is largely determined by their diet, and oil extraction reduces their BMP. The biogas produced can be used as a renewable energy source, such as biomethane, which can be utilized as a biofuel. These uses across the life stages of Black soldier fly larvae highlight their potential as a sustainable and eco-friendly solution for organic waste management and animal feed production (Bessa et al., 2020).

African nightcrawlers *(Eudrilus eugeniae)* are highly valued in agriculture for their ability to break down organic matter and produce nutrient-rich vermicompost, which can be used to enrich soil and improve crop yields while reducing the need for synthetic fertilizers (Blakemore,2015). Researchers have developed automated systems for vermicomposting with African nightcrawlers to improve efficiency and scalability, including features such as worm migration and monitoring to maintain optimal environmental conditions. Vermicomposting with African nightcrawlers is particularly beneficial in tropical regions such as the Philippines, where the worms can thrive under favorable weather conditions, providing a sustainable source of fertilizer, reducing waste disposal costs, and supporting more resilient agricultural practices (Sarimong et al., 2019).

In the local context, vegetable vendors generate substantial seasonal food waste, primarily consisting of bananas, cabbage, okra, and eggplant, much of which remains unutilized. Despite its abundance and nutrient-rich composition, this waste has not been explored as a resource through bioconversion using *Hermetia illucens* larvae (Black soldier fly) *and Eudrilus eugeniae* (African nightcrawlers). This gap misses an opportunity to recover and recycle essential nutrients, hindering nutrient cycling critical for sustainable farming.

Hence, this study aims to address this gap by evaluating the bioconversion of vegetable food waste into organic fertilizer using Black soldier fly larvae and African nightcrawlers. By transforming waste into valuable biofertilizers, this approach offers a sustainable alternative to chemical fertilizers, promoting soil health, enhancing crop productivity, and reducing environmental pollution. The research will advance the understanding of innovative bioconversion techniques for food waste management and nutrient recycling. Furthermore, it supports inclusive, sustainable development by encouraging effective waste management practices among both men and women, reducing dependence on synthetic fertilizers, and fostering a transition to organic farming solutions.

P-ISSN: 0119-3058
E-ISSN: 2945-4093

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Objectives of the Study

This study aimed to evaluate the bioconversion of food waste into organic fertilizer using Black soldier fly larvae and African nightcrawlers as bioconverters. Specifically, to (1) assess the physicochemical properties of the food waste compost as organic fertilizer in terms of temperature, pH level, and humidity using four treatments: T0 Control without decomposer, T1 100% BSF Larvae, T2 100% African nightcrawlers, and T3 50% BSF Larvae and 50% African nightcrawlers, (2) quantify the macronutrients present in food waste compost as organic fertilizer (3) determine the biomass conversion of the Black soldier fly larvae (BSFL) and African nightcrawlers (4) determine significant difference between and among the physicochemical properties of food waste compost as organic fertilizer in terms of temperature, and pH level using the different treatments. (5) significant difference between and among the biomass conversion of the Black soldier fly larvae (BSFL) and African nightcrawlers.

METHODOLOGY

This section outlines the components of the research methodology, including the research design, materials used, data-gathering or experimental procedures, ethical considerations, and statistical analysis methods for data interpretation. The methodology follows the framework established by Sebeyang et al. (2022).

Research Design. This study utilized a completely randomized design (Renon et al., 2024) with four treatments. The bioconversion of different treatments was conducted in the community garden of Barangay Cabalangan, Bantay, Ilocos Sur, Philippines. Physicochemical characteristics, including temperature, pH, and humidity, of the food waste compost were monitored over 21 days. Additionally, the weight of the bioconverters was assessed, and the macronutrient content was analyzed at the Provincial Agriculture Office of Ilocos Norte.

Data Gathering Procedure. The procedures employed in this study were based on the methodologies outlined by Sebeyang et al. (2022).

Collection and Segregation of Food Waste. Food waste was collected from vegetable vendors in Barangay Cabalanggan, Bantay, Ilocos Sur, Philippines. The waste, particularly banana, cabbage, okra, and eggplant, was manually segregated, and other residues were removed. After which, the food waste was chopped into smaller pieces.

Procurement, Rearing of Bioconverters, and Preparation of Treatments. The BSF eggs were obtained from an accredited source. It was allowed to hatch for 10 days and fed with wet chicken feed. Rearing was done at temperatures ranging from 24

P-ISSN: 0119-3058
E-ISSN: 2945-4093

to 40 degrees Celsius until the larvae stage was ready for bioconversion. Similarly, the African nightcrawlers were procured from an authorized vermiculture source and acclimatized for three days before experimentation. Acclimatization was carried out on a substrate made up of cow manure and chopped banana trunks. The experiment consisted of four treatments: T0, which served as the control group and lacked bioconverters, T1, 100% African nightcrawlers at 250 grams, T2, 100% BSF Larvae with 250 grams, and T3, 50% African nightcrawlers and 50% BSF Larvae with 125 grams each. Each treatment was replicated three times and maintained under the same environmental conditions.

Feeding and Maintenance of Bioconverters. Treatments were fed on the 1st, 7th, and 15th days with a homogenized mixture of chopped cabbage, okra, and eggplant. Each treatment received an equal amount of food waste, consisting of 62.50 grams of each type. This is to ensure equitable distribution and quantity. The bins were covered with fine mesh nets to prevent bioconverters from escaping. To ensure optimal conditions, ventilation and moisture levels were checked daily and adjusted by misting with water as needed.

Physicochemical Analysis of Food Waste Compost. Physicochemical parameters were examined daily throughout the 21-day experimental period. Temperature was measured with a thermometer, pH with a pH meter, and humidity with a humidity meter. All instruments were calibrated before use in accordance with the standard calibration protocols.

For the nutrient analysis, a representative compost sample from four treatments was collected, air-dried, pulverized, and sieved. Before submission to Ilocos Norte, the Provincial Agriculture Office weighed and stored the produce in airtight plastic containers. The amounts of nitrogen, phosphorus, and potassium were assessed using the colorimetric method.

The researchers used the following norm to interpret the NPK level of the food waste compost:

Nitrogen	%OM Values	Phosphorus	Pppm
Low	0 to 2	Low	0 to 6
Medium	2.3 to 3.5	Moderately Low	7 to 10
High	3.6 to 4.5	Moderately High	11 to 15
Very High	> 4.5	Very High	> 20

Potassium	Kppm
Low	0 to 75
Sufficient+	76 to 113
Sufficient++	114 to 150
Sufficient+++	>150

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E-ISSN: 2945-4093

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Biomass Conversion of the Bioconverters. The bioconverters were weighed before and after the 21-day experimental period to track changes in mass. Each treatment is replicated thrice. Biomass conversion efficiency was calculated using the following:

$$\text{Biomass Conversion Efficiency} = \frac{\text{Final Weight}}{\text{Initial Weight}} \times 100\%$$

Disposal of Organisms. The organisms were buried at a sufficient depth to prevent scavenging and avoid contamination. The burial site was marked and documented to prevent any unintentional disturbance.

Statistical Treatment of Data. Statistical methods were used to analyze relationships within and between datasets and to identify potential errors in the study.

1. Means were calculated to determine the average pH, temperature, and biomass conversion of the bioconverters using food waste as an organic fertilizer.

2. ANOVA was employed to determine the significant difference between and among the physicochemical properties of food waste as organic fertilizer using the Black soldier fly and African nightcrawlers in the different treatments, and the significant difference between and among the weight loss of Black soldier fly and African nightcrawlers in the different treatments.

3. Scheffé's test was used to determine which treatment pairs differed significantly.

RESULTS AND DISCUSSIONS

This section presents, analyzes, and interprets data gathered in the study. The data were presented in figure, tabular, and narrative forms.

1. **Physicochemical Properties of the Food Waste Compost as Organic Fertilizer using the Black Soldier Fly Larvae (BSFL) and Nightcrawlers as Bioconverters in terms of temperature, pH Level, and humidity using the Different Treatments.**

P-ISSN: 0119-3058
E-ISSN: 2945-4093

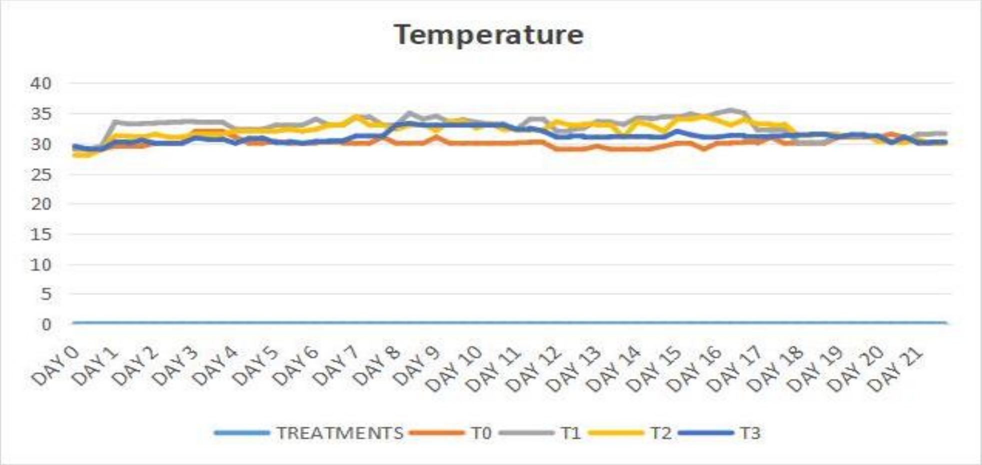

Figure 1
Overall Temperature Level of Food Waste Compost for 21 Days

Temperature (°C)

The study observed temperature variations in compost treatments using different bioconverters over 21 days: T1 (BSF Larvae): Showed the widest temperature range (29.2°C to 35.2°C) and the highest maximum temperature (34.5°C on Day 15), indicating rapid aerobic decomposition. A significant temperature spike occurred on Day 1, suggesting that BSF larvae quickly initiate decomposition and heat generation. T2 (African nightcrawlers): Had a temperature range of 28.3°C to 34.1°C, with the highest temperature recorded on Day 15. The temperatures rose by Day 4, indicating active breakdown processes, but then stabilized at intermediate levels. T3 (African nightcrawlers and BSF Larvae): Exhibited temperatures from 29.2°C to 33.1°C, with a peak on Day 8. This combination showed a slight synergistic effect on decomposition. T0 (Control): Maintained the narrowest temperature range (29.0°C to 32.0°C) and the lowest overall temperatures, with minor fluctuations and the highest temperature recorded on Day 3.

The introduction of bioconverters led to noticeable temperature increases across all treatments, indicating heightened metabolic activity and efficient decomposition processes. This observation aligns with the findings of Chen (2023), Kamdem et al. (2020), and Bello et al. (2020), who reported that elevated temperatures in compost containing BSF larvae and African nightcrawlers signify effective organic matter breakdown and pathogen elimination, driven by the heat generated during active decomposition.

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pH Level

The composting process is influenced by various factors, including pH levels and the activity of bioconverters like Black soldier fly larvae (BSF) and Nightcrawlers.

Understanding pH fluctuations is crucial for nutrient cycling and producing high-quality organic fertilizer. This analysis examines 21 days of pH level data from different composting treatments involving BSF Larvae, Nightcrawlers, and their combination.

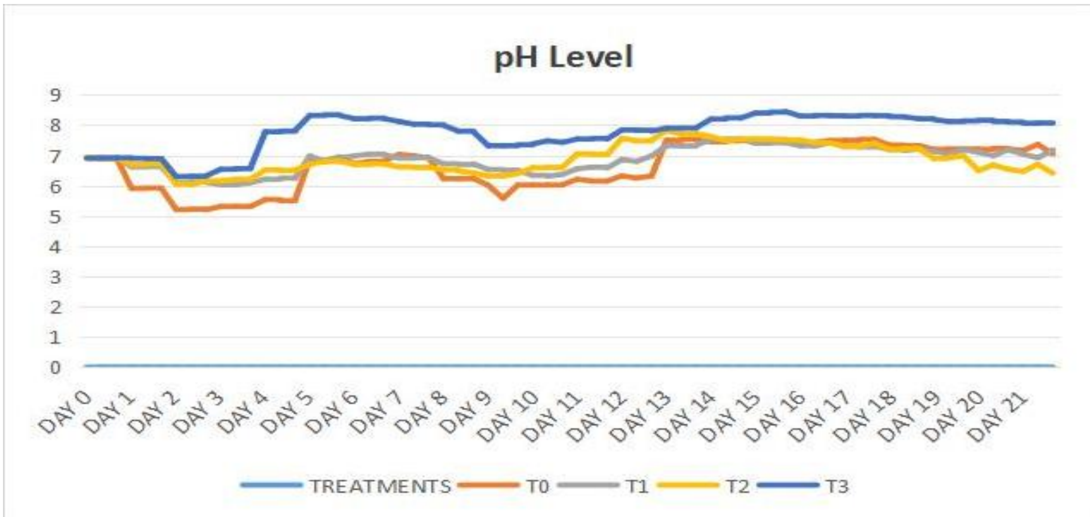

Figure 2
Overall pH Level of Food Waste Compost for 21 Days

At the start of the experiment, pH levels for all treatments ranged from 6.90 to 6.92. By the final day, pH levels increase to between 7.05 and 8.06, indicating uniform starting conditions. The pH levels fluctuate dynamically across all treatments, reflecting ongoing biochemical processes. The combination of Nightcrawlers and BSF Larvae (T3) shows the greatest increase in pH. These trends highlight changes in compost acidity or alkalinity due to microbial activity, decomposition rates, and converter metabolism. Overall, pH levels tend to decrease over time, indicating gradual acidification, though T2 (African nightcrawlers) and T3 (BSF Larvae and African nightcrawlers) have a more pronounced effect on increasing pH compared to T1 (BSF Larvae).

T0 control without decomposers, T1 BSF larvae and T2 African nightcrawlers exhibited acidic to alkaline (pH 5.21 to 7.75). According to Sebayang (2022), using Black Soldier Fly (BSF) larvae and African nightcrawlers in vermicomposting accelerates the decomposition of cow manure and banana stem waste. This method

P-ISSN: 0119-3058
E-ISSN: 2945-4093

also produces vermicompost with a slightly acidic pH, enhancing the overall composting efficiency and nutrient content. According to the Agricultural Machinery Testing and Evaluation Center (2019), the recommended pH range for the compost mixture is 5.5–8.0.

In addition, the T3 BSF larvae and African nightcrawlers exhibited the highest pH level of 8.43, indicating a basic pH. This aligns with findings by Priyambada and Wardana (2018) that the composting process can occur within a pH range of 5.5 to 9. Therefore, the conditions observed with T3 BSF larvae and African nightcrawlers are well within the optimal range for effective composting, suggesting their suitability in facilitating this process.

Humidity

The air humidity within the experimental room varied from 40% to 77% over 21 days, impacting the composting process. Humidity measurements revealed the lowest humidity on Day 1 (42%) and the highest on Day 9 (77%), indicating unstable and dynamic daily humidity levels. This range suggests that the humidity levels were generally suitable for the biodegradation of food waste for BSF larvae and African nightcrawlers.

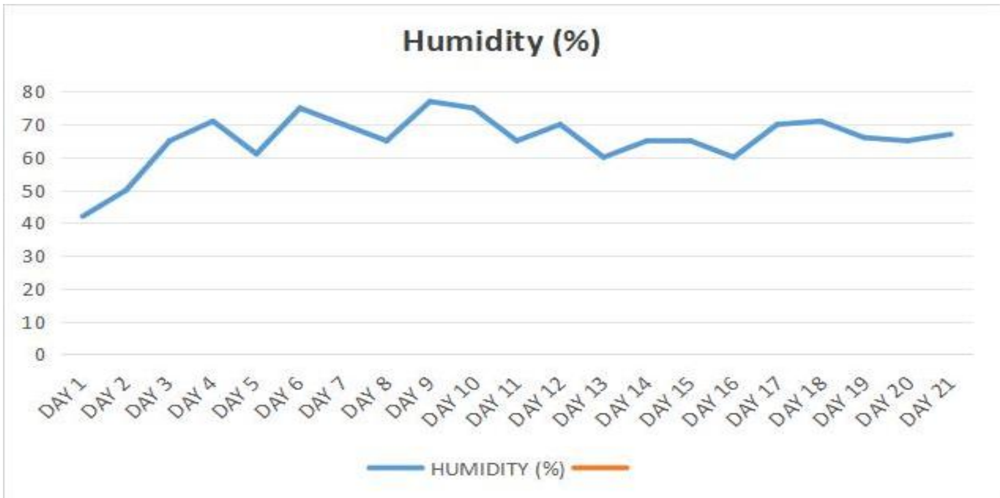

Figure 3
Humidity of Food Waste Compost for 21 Days

According to Morsy et al. (2022), the ideal humidity for biodegradation is 60- 65% for BSF larvae, with optimal moisture content at 65-90%. For African Nightcrawlers, suitable humidity is around 80%, with optimal moisture content at 77-80% (Smith, 2017). For microorganisms, the optimal moisture content is 50-60%,

P-ISSN: 0119-3058
E-ISSN: 2945-4093

The Vector: International Journal of Emerging Science, Technology and Management
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which is crucial for composting because it affects the physical structure and the biodegradation of organic material.

Optimal moisture levels, as identified by previous research, play a vital role in maximizing biodegradation. Maintaining stable, appropriate humidity enhances composting effectiveness while preventing the development of anaerobic conditions that can inhibit microbial activity and slow organic matter breakdown. Observations of moisture content in compost with BSF larvae, African nightcrawlers, and microorganisms indicate that these levels are crucial for optimizing the composting process, thereby promoting more efficient and effective biodegradation of organic waste. This underscores the importance of monitoring and understanding moisture levels to support sustainable and efficient composting practices.

2. Macronutrients Present in Food Waste Compost as Organic Fertilizers Using the Different Treatments

Analyzing compost macronutrient content, as outlined in Table 1, is crucial for understanding its nutritional composition. Key nutrients such as nitrogen, phosphorus, and potassium offer valuable insights into the compost's nutritional value.

Table 1
Results of the Compost Analysis in terms of Macronutrients after 21 days

Treatments	Replication	% Organic Matter	% OM Values	Phosphorous	P (ppm)	Potassium	(ppm)
T0 Control	R1	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150
	R2	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150
	R3	Very High	> 4.5	Very High	>20	Sufficient+	14 to 150
T1 BSF Larvae (100%)	R1	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150
	R2	Very High	> 4.5	Very High	>20	Sufficient+	14 to 150
	R3	Very High	> 4.5	Very High	>20	Sufficient+	14 to 150
T2 African Night Crawlers (100%)	R1	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150
	R2	Very High	> 4.5	Very High	>20	Sufficient+	14 to 150
	R3	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150
T3 African	R1	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150
	R2	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150

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Treatments	Replication	% Organic Matter	% OM Values	Phosphorous	P (ppm)	Potassium	(ppm)
Night Crawlers and BSF Larvae	R3	Very High	> 4.5	Very High	>20	Sufficient+	114 to 150

Legend:

Nitrogen	%OM Values	Phosphorous	Pppm	Potassium	Kppm
Low	0 to 2	Low	0 to 6	Low	0 to 75
Medium	2.3 to 3.5	Moderately Low	7 to 10	Sufficient+	76 to 113
High	3.6 to 4.5	Moderately High	11 to 15	Sufficient++	114 to 150
Very High	> 4.5	Very High	> 20	Sufficient+++	>150

Source: Bureau of Soils and Water Management

In all treatments, nitrogen levels were notably "Very High," supported by organic matter values greater than 4.5%. Phosphorus levels were also "Very High," with concentrations over 20 parts per million (ppm), while potassium levels were "Sufficient+," ranging from 114 to 150 parts per million (ppm). This could mean that the Black Soldier Fly (*Hermetia illucens)* Larvae and African nightcrawlers (*Eudrilus euginiae)* convert the organic matter in food waste into macronutrients. Also, the presence of essential elements may influence soil fertility and provide essential nutrients for plant growth.

Black Soldier Fly (BSF) larvae and African nightcrawlers represent advanced methods for organic waste degradation, as highlighted by Sebayang and Sabrina (2022). Utilizing BSF larvae for composting significantly increases the nitrogen, phosphorus, and potassium (NPK) content in organic fertilizers, according to Sarpong et al. (2019). The frass produced by BSF larvae, which is rich in NPK, serves as an effective organic fertilizer that promotes plant growth and yield (Basri et al., 2022; Khalil & Agah, 2016; Agustiyani et al., 2020; Anyega et al., 2021). Similarly, African nightcrawler worms enhance NPK levels in compost and expedite the composting process, thereby improving soil fertility and boosting plant productivity (Kamdem et al., 2020). Without the aid of decomposers, composting can take significantly longer, often 1-3 months or even 6-12 months (Priyambada & Wardana, 2018).

Nitrogen (N) is particularly important for leafy growth and is often associated with the production of amino acids, which are essential for protein synthesis. It plays a key role in the development of plant tissues, particularly in the early stages of growth (Sun et. al, 2020). Phosphorus (P) is vital for root development and supports physiological processes such as photosynthesis, respiration, and nucleic acid synthesis. It is also essential for the formation of

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E-ISSN: 2945-4093

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flowers and fruits, as it helps regulate the development of reproductive structures (Malhotra et. al, 2018). Potassium (K) enhances (Sardans & Peñuelas, 2021).

3. Biomass Conversion of the Black Soldier Fly Larvae (BSFL) and Nightcrawlers using the Different Treatments

The study measured the biomass conversion of black soldier fly larvae and African nightcrawlers and presented the results in Table 2.

Table 2 shows the biomass conversion of Black Soldier Fly (BSF) larvae and African nightcrawlers. Among the treatments, T3 50% BSF larvae and 50% African nightcrawlers had the highest biomass conversion efficiency of 84.40, followed by T2 100% African nightcrawlers at 80.13. This indicates that the combined bioconverters had a minor synergistic effect in converting organic materials from food waste into macronutrients. The outcomes of physicochemical and nutrient analyses can support the effectiveness of treatment. These analyses indicate that during decomposition, the pH remains within the optimal range of 5.5 to 9.0 for effective composting and that there are very high levels of nitrogen and phosphorus, along with sufficient potassium. Bioconverters can transform waste into valuable products, reducing the amount of food waste produced and thereby reducing the incidence of open dumping, thereby preventing environmental threats such as emissions, soil, and water contamination.

Table 2

Biomass Conversion Efficiency of the Bioconverters in Different Treatments

Treatments	Biomass Conversion Efficiency		
	Replications	Biomass Conversion Efficiency	Overall Biomass Conversion Efficiency
T0 (Control)	R1	0	
	R2	0	0
	R3	0	
T1 BSF Larvae (100%)	R1	73.60	
	R2	63.60	77.33
	R3	94.90	
T2 African Nightcrawlers (100%)	R1	83.80	
	R2	82.40	80.13
	R3	75.20	
T3 50%African Nightcrawlers and 50% BSF Larvae	R1	82.00	
	R2	84.00	84.40
	R3	87.20	

P-ISSN: 0119-3058
E-ISSN: 2945-4093

According to Schreven et al. (2021) and Moo & Hasan (2022), variation in biomass conversion efficiency may be due to substrate composition, nutrient availability, environmental factors, and feeding rate. Biowastes comprising a smaller amount of readily available carbon and a high proportion of carbon in lignin-rich material are less likely to be reduced readily by BSFL treatment. Black soldier fly larvae can successfully reduce biowaste by 77.0–96.1% by weight and 72.8–89.0% by volume (Lalander et al., 2019). Additionally, Ocoy and Armercin (2023) found that applying African nightcrawlers to different substrates affected the speed of decomposition. It was discovered that treatments containing bioconverters had the highest degradation rate compared to treatments without African nightcrawlers.

4. **Significant Difference Between and Among the Physicochemical Properties of Food Waste Compost Using the Black Soldier Fly Larvae (BSFL) and African Nightcrawlers as Bioconverters in terms of Physicochemical Characteristics Using the Aforementioned Treatments.**

Table 3
Summary of the Analysis of Variance (ANOVA) on Temperature of the Food Waste Compost for 21 days

		Sum of Squares	df	Mean Square	F	p-value
As A Whole	Between Groups	12.853	3	4.284	2749.38	0.00*
	Within Groups	0.012	8	0.002		
	Total	12.866	11			

Legend: *significant at .01 level

Table 3 shows an overall computed F-value of 2749.38, with a p-value of 0.00 (<0.01), indicating rejection of the null hypothesis. This indicates that the different treatments are not comparable in terms of the temperature generated in the food waste compost, resulting in variable temperatures.

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E-ISSN: 2945-4093

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Table 4

Scheffe Multiple Comparison Test on the Significant Difference Between and Among the Physicochemical Properties of Food Waste Compost as Organic Fertilizer Using the Black Soldier Fly Larvae and African Nightcrawlers as Bioconverters in terms of Temperature Using the Aforementioned Treatments

Treatments				Mean Difference	Std. Error	p-value
As a Whole	T0	VS	T1	-2.75*	0.03	.000
			T2	-2.02*		
			T3	-1.04*		
	T1	VS	T2	0.73	0.03	.000
			T3	1.71		
	T2	VS	T3	0.98*	0.03	.000

* significant at 0.01 level

Table 4 shows that all pairs of treatments are significantly different, with a p- value of .000 which is less than .01. These are T0 Control without decomposer and T1 100% BSF Larvae, T0 Control without decomposers and T2 100% African nightcrawlers, T0 Control without decomposers and T3 50% BSF Larvae and 50% African nightcrawlers, T1 100% BSF Larvae and T2 100% African nightcrawlers, T1 100% BSF Larvae and T3 50% BSF Larvae and 50% African nightcrawlers, T2 100% African nightcrawlers and T3 50% BSF Larvae and 50% African nightcrawlers.

This result is similar to that of Chen (2023), who found that an increase in temperature in compost using Black soldier fly larvae highlights the larvae's effectiveness in waste treatment. Temperature rise is crucial for organic matter breakdown and pathogen destruction, essential aspects of composting. Moreover, the temperature increase signifies organic matter degradation, as emphasized by Bello et al. (2020).

Additionally, the study by Rehman et al. (2023) found that the larvae's ability to break down organic matter at higher temperatures enhances the overall efficiency of the composting process. Furthermore, the research by Liu et al. (2021) demonstrated that larvae's enzymes play a significant role in degrading complex organic compounds, thereby contributing to improved compost quality. These previous studies have examined the impact of elevated temperatures on composting processes, particularly those involving black soldier fly larvae (BSFL). A higher temperature can accelerate the degradation of organic matter, improve compost quality, and significantly affect microbial community dynamics. The findings underscore the importance of using black soldier fly larvae in composting, as they enhance the process's efficiency and effectiveness.

Table 5
Summary of the Analysis of Variance (ANOVA) on pH Level of the Food Waste Compost for 21 days

Treatments		Sum of Squares	df	Mean Square	F	p-value
As A Whole	Between Groups	2.18	3	4.284	3786.38	0.00*
	Within Groups	0.00	8	0.002		
	Total	2.18	11			

*Legend: *significant at .01 level*

Table 5 shows a computed F-value of 3786.38 and a p-value of 0.00, which is less than the 0.01 probability level. This indicates that the null hypothesis should be rejected. This means that, for food waste used as an organic fertilizer, the pH levels under different treatments significantly affect ammonia production during decomposition.

Table 6
Scheffe Multiple Comparison Test on the Significant Difference Between and Among the Physicochemical Properties of Food Waste Compost as Organic Fertilizer Using the Black Soldier Fly Larvae (BSFL) and African Nightcrawlers as Bioconverters in terms of pH Level Using the Aforementioned Treatments

Treatments				Mean Difference	Std. Error	p-value
As a Whole	T0	VS	T1	-0.21*	0.01	.000
			T2	-0.22*		
			T3	-1.10*		
	T1	VS	T2	-0.00	0.01	.000
			T3	-0.89		
	T2	VS	T3	-0.89	0.01	.000

*Legend: *significant at 0.01 level*

Table 6 shows that five pairs are statistically significantly different with a p-value of 0.00, which is less than 0.01. These are T0 Control without decomposer and T1 100% BSF Larvae, T0 Control without decomposers and T2 100% African nightcrawlers, T0 Control without decomposers and T3 50% BSF Larvae and 50% African nightcrawlers, T1 100% BSF Larvae and T3 50% BSF Larvae and 50% African nightcrawlers, T2 100% African nightcrawlers and T3 50% BSF Larvae and 50% African nightcrawlers.

pH alterations influence nutrient availability, affecting concentrations of soil nitrate, ammonium, phosphorus, and potassium (Howell et al, 2024). During food waste composting, pH is critical for achieving optimal nutrient cycling and the production of high-quality organic fertilizer. The increase in pH during composting is attributed to the release of ammonia during protein degradation (Kalamdhad & Kazmi, 2009). Furthermore, composting additives have been found to accelerate the disintegration of organic material, which can affect the compost's pH (Noor, 2024).

5. Significant Difference Between and Among the Biomass Conversion of the Black Soldier Fly Larvae (BSFL) and African Nightcrawlers Using Different Treatments

Table 7
Summary of the Analysis of Variance (ANOVA) on Biomass Conversion of the Bioconverters in Different Concentrations

		Sum of Squares	df	Mean Square	F	p-value
As A Whole	Between Groups	14700.85	3	4900.28	70.26	0.00*
	Within Groups	557.97	8	69.75		
	Total	15258.83	11			

Table 7 Analysis of Variance indicates a significant difference in biomass conversion efficiency among the different treatments, with a p-value of 0.00, leading to rejection of the null hypothesis. This implies that the pairs differ significantly in the rate at which organic matter is converted into macronutrients.

Table 8
Scheffe Multiple Comparison Test on the Significant Difference Between and Among the Biomass Conversion of Bioconverters Using the Aforementioned Treatments

Treatments				Mean Difference	Std. Error	p-value
As a Whole	T0	VS	T1	-77.33*	6.82	0.00
			T2	-80.13*		
			T3	-84.40*		
	T1	VS	T2	-2.80		0.98
			T3	-7.07		0.79
	T2	VS	T3	-4.27		0.94

Legend: *significant at 0.01 level

P-ISSN: 0119-3058
E-ISSN: 2945-4093

Table 8 demonstrates that three pairs are statistically significantly different with a p-value of 0.00, which is less than 0.01. These pairs include T0 Control without decomposer and T1 100% BSF Larvae, T0 Control without decomposers and T2 100% African nightcrawlers, T0 Control without decomposers and T3 50% BSF Larvae and 50% African nightcrawlers. This indicates that African nightcrawlers and Black soldier fly larvae are efficient bioconverters, accelerating the degradation of food waste and nutrient cycling. The resulting frass and vermicompost serve as nutrient-rich, eco-friendly soil amendments.

Shao et al. (2024) highlight that employing the optimal developmental stages of Black soldier fly larvae and African nightcrawlers significantly improves bioconversion efficiency through synergistic interactions. This approach is essential for sustainable soil and waste management by not only improving nutrient recycling but also potentially reducing the emission of volatile organic compounds during decomposition.

In contrast, substrates without bioconverters rely solely on abiotic degradation processes, leading to slower nutrient turnover. This reduced nutrient cycling rate may adversely affect soil nutrient availability, thereby limiting agricultural productivity and diminishing soil fertility over time.

CONCLUSIONS

The physicochemical characteristics of the food waste compost demonstrated active and successful bioconversion with temperatures ranging from 29.20 to 35.20 degrees Celsius, pH values ranging from acidic to alkaline, and humidity levels between 40% to70%. All compost treatments contained very high nitrogen and phosphorus concentrations and sufficient potassium levels. Treatment incorporating 50% African nightcrawlers and 50% Black Soldier Fly larvae demonstrated synergistic interactions, resulting in a significant improvement in biomass conversion efficiency. Moreover, significant differences exist among the temperature, pH, and biomass conversion efficiency of black soldier fly larvae (BSFL) and African nightcrawlers as bioconverters.

RECOMMENDATIONS

Conduct regular screening of physical and chemical parameters, such as temperature, pH, and humidity, to ensure bioconverter survival and monitor the decomposition process. Farmers may adapt bioconversion of waste to produce cost-effective and environment-friendly fertilizers using Black soldier fly larvae and African nightcrawlers. The Local Government Units and other concerned agencies may implement programs and activities to educate the community about the potential of bioconverters in managing food waste. Future research should evaluate fertilizer performance across various crops, assess cost-yield benefits, and conduct long-term environmental assessment of productivity.

ETHICAL STATEMENT

Ethical clearance was secured from the College of Arts and Sciences Research Ethics Review Committee and the Research and Development unit, with approval number CAS-RDU Ethics Review No. 2024-018. The study adhered to guidelines for animal research. The study prioritized the ethical treatment of all organisms, ensuring optimal living conditions and minimizing any potential stress. The Black soldier fly larvae and African nightcrawlers were kept in environments tailored to their specific requirements, with enclosures offering ample space, suitable temperatures, and essential resources to maintain their health and well-being.

ACKNOWLEDGEMENT

The researchers express their heartfelt gratitude to the Ilocos Norte Provincial Agriculture Office, officials from Barangay Cabalanggan, Bantay, Ilocos Sur, and the University of Northern Philippines- Research and Development Office for their invaluable leadership, cooperation, and assistance throughout the conduct of this research.

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