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# Comparative analysis of vermicomposting using plant debris and vegetable waste with earthworms: Efficiency and nutrient dynamics

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**Key words:** Vermicompost, *Eisenia foetida*, Biofertilizer, *Perionyx excavates*, *Eudrilus eugeniae*

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**ABSTRACT**

Organic composting involves the natural breakdown of organic waste into nutrient-enriched soil additives. This method supports sustainable agriculture by offering both environmental and agricultural benefits. Research has consistently demonstrated that vermicompost is rich in nutrients and serves as a high-quality compost. However, comparative studies on vermicomposting outcomes based on different organic waste types and available solid waste materials are relatively scarce. The present investigation evaluates the efficiency of three earthworm species *Eisenia foetida*, *Eudrilus eugeniae* and *Perionyx excavates* in processing organic waste through vermicomposting. The experimental setup included eight treatments. Organic matter used for composting consisted of 60% household waste and 40% cow dung. The vermicomposting process lasted 90 days, during which worm development and the physico-chemical characteristics of the compost were observed. The resulting compost was brownish-black and rich in essential macro- and micronutrients. Among the earthworms studied, *Eisenia foetida* demonstrated superior growth and composting performance. The pH of the compost ranged from 7 to 8, remaining within the optimal range throughout nutrient levels, such as nitrogen, potassium, and calcium, increased significantly, while organic carbon content and the C:N ratio showed a decreasing trend across all treatments. Notably, vermicompost produced with *Eisenia foetida* recorded the highest nitrogen, potassium and calcium concentrations, along with favorable C: N ratios of 12.4 and 12.5.This study concluded that vermicomposting is an efficient method for converting paper and household waste into valuable biofertilizer. *Eisenia foetida* emerged as the most effective species for producing nutrient-rich vermicompost and managing organic waste sustainably.

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**INTRODUCTION**

India is an agro based economy. About 60% of Indian population relies directly or indirectly on agriculture. India has a long tradition of agriculture with a rich heritage of ecofriendly agricultural technologies. In India the tropical climate prevailing is very congenial for farming (Julka *et al*., 1986). Waste management is a global challenge, especially economically in developing countries, because of their population growth, lifestyle changes, increasing people's living standards, and increasing waste generation (Taghipour *et al.,* 2016). Composting is a well-known biotechnology used for the treatment and revalorization of organic wastes (Bernal *et al.,* 2009; Ayilara *et al*., 2020). It is a microbiological process involving the action of a diverse range of microorganisms that transform organic matter under controlled conditions (de Bertoldi *et al.,* 1983; Duan *et al*., 2024; Angeles-De Paz *et al.,* 2025; Salinas *et al.,* 2025). This process leads to an increase in temperature, which serves as a selective factor for microbes, and contributes to waste sanitation by eliminating pathogens (Ryckeboer *et al.,* 2003).

Furthermore, composting is an aerobic process, indicating that microorganisms rely on oxygen to proliferate and convert organic matter (Lopez-Gonz alez *et al*., 2015a, 2015b). The final product of composting, known as compost, is a stable and agriculturally valuabe material due to its content of organic matter, plant nutrient and beneficial microorganisms (Tortosa *et al*., 2012, 2023). Vermicomposting, on the other hand, closely resembles traditional composting, but involves the use of earthworms in addition to microorganisms for waste decomposition and occurs at mesophilic conditions (Benítez *et al*., 2002; Fernandez-G´ omez´ *et al*., 2010). Earthworms consume and transform organic waste into vermicompost, a nutrient-rich material that enhances soil quality (Van Groenigen *et al*., 2019; Blouin *et al*., 2019). Vermicomposting is utilized in agriculture as an eco-sustainable method of soil enrichment and is gaining global popularity due to its environmental and economic benefits (Rodriguez-Campos *et al*., 2014; Rehman *et al*., 2023).

Vermicompost (nutrient-rich compost) is widely recognized as a measure of sustainable agriculture (Rashid *et al.,* 2023; Sengupta *et al.,* 2023). Studies on vermicompost have been growing in popularity in recent decades (Ghorbani and Sabour, 2021; Enebe and Erasmus, 2023; Van Hoof *et al.,* 2024). Among which, vermicomposting is also one of them and it is gaining its momentum as can be initiated by household to enterprise level. The vermicompost coupled with coal-based soil conditioner has the potential to improve soil physicochemical properties and enhance the growth of plants (Feng Ai *et al.,* 2025). Vermicomposting is an environmental friendly technology used in solid waste management which has two ways advantage: it helps in management of organic waste and the worm cast can be used as vermicompost, useable forms of compost without any adverse impacts to soil, plant and environment (Gheisari *et al*., 2009; Mehta and Karnwal, 2013). It involves joint action of earthworms and mesophilic microbes (Benitez *et al*., 1999).

Earthworm acts as a mechanical blender by grinding organic matter and increasing surface area exposing to microorganisms (Yadav and Garg, 2011). During composting processes, the micronutrients present in the feed materials are converted through microbial action into forms that are more soluble and available to plants than those in parent substrate (Kaushik and Garg, 2003). Therefore, vermicompost enriches soil with microorganisms which improves soil texture, structure, nutrient retention, water-holding capacity and aeration (Shrivastava and Singh, 2013). The resulting decomposed matter, which often ends up looking like fertile garden soil, is called compost. Fondly referred to by farmers as "black gold," compost is rich in nutrients and can be used for gardening, horticulture, and agriculture (Shelia hu, 2021). Composting is an ancient agricultural technology going back to biblical times that still has important applications in modern agriculture (Mir

Seyedbagheri, 2010). Microorganisms in the compost pile take up nutrients and hold them in their bodies, which prevents leaching (Demmel, 1980; Alleman, 1982). Composting can be broadly categorized into aerobic and anaerobic composting (Vivek Manyapu, 2022).The current study evaluates the effectiveness of vermicompost quantified while assessing the microbiome composition throughout the vermicomposting processes. The effectiveness of vermicompost in promoting plant growth is also evaluated (Masaru Usui *et al.,* 2025).

Vermicomposting is an environmentally friendly technology used in solid waste management. It offers dual benefits: effective management of organic waste and the production of vermicompost—usable compost forms that do not adversely affect soil, plants, or the environment (Gheisari *et al.*, 2009; Mehta and Karnwal, 2013). It involves the joint action of earthworms and mesophilic microbes (Benitez *et al.*, 1999). Vermicomposting is gaining momentum and can be implemented at both household and enterprise levels.

The objective of this study is to assess the quality of vermicompost derived from two different waste mixtures plant debris and decomposed vegetables blended with cow dung in a 60:40 ratio. Incorporating specific microbial strains is expected to improve compost quality compared to the use of organic manure alone. To develop the horticultural nurseries is to produce quality seedling with target morphological and physiological features that guarantee crop success after transplanting (Burdett *et al.*, 1983).

## MATERIALS AND METHODS

### Collection and preparation of raw materials

The raw materials were collected from various locations in and around Sundarakkottai, Mannargudi, in the Thiruvarur District of Tamil Nadu. The selected agro-biodegradable substrates included domestic plant debris and decomposed vegetables. Plant debris was collected from the campus of S.T.E.T. Women's College (Autonomous) Mannargudi and was maintained at a moisture content of approximately 50–60%. Decomposed vegetables were collected from the local market in Mannargudi and sun-dried for two days prior to use.

### Selected earthworm species for vermicomposting

The selected earthworm species *Eisenia foetida* (E1), *Eudrilus eugeniae* (E2), and *Perionyx excavatus* (E3) were procured from Periyar Maniammai University, Thanjavur. *Eisenia foetida*, commonly known as the red wiggler or redworm, has a cylindrical, segmented body measuring 7–10 cm in length and weighing 0.4–0.6 g. Its coloration ranges from reddish-brown to reddish-pink. *Eudrilus eugeniae*, known as the African nightcrawler, is 10–20 cm long, with a body weight of 0.3–0.5 g, and has a dark reddish-brown or purplish hue (Singh and Sinha, 2022). *Perionyx excavatus*, also called the Indian blue worm, has a slimy, cylindrical body 7–10 cm in length, weighing between 0.3–0.6 g, and is characterized by its deep blue to purplish-blue color.

### Preparation of composting set up

Vermicomposting was performed in concrete cylindrical pits, each measuring 2 feet in both width and length. The pits were designed with adequate aeration, ensuring a minimum volume of 1 cubic foot to facilitate airflow. Collection trays were placed beneath the pits to gather excess leachate or drained water. To prevent the earthworms from escaping and to protect them from potential predators, a green shade net was securely placed over the pits.

### Experimental design and sampling (Muhammad Danish Toor *et al.*, 2024)

The vermicomposting experiment consisted of eight treatment groups: T1- Control (plant debris only), T2- Plant debris with *Eisenia foetida*, T3 – Plant debris with *Eudrilus eugeniae*, T4- Plant debris with *Perionyx excavatus*, T5- Control (decomposed vegetables only), T6- Decomposed vegetables with *Eisenia foetida*, T7- Decomposed vegetables with *Eudrilus eugeniae*, and T8- Decomposed vegetables with *Perionyx excavatus*.

For all experimental setups, the substrate mixtures were consistently prepared using 60% plant-based waste (either plant debris or decomposed vegetables) and 40% cow dung.

**Vermicompost pit maintenance**

The vermicompost pit was shielded from direct sunlight to maintain a favorable environment for the earthworms. Moisture levels were carefully monitored and maintained to support optimal composting conditions. The earthworms could not be harmed by pests, so preventative measures were taken. The pit was securely covered to prevent earthworm escape, while sufficient aeration was ensured by regularly stirring the waste, which also helped eliminate foul odors. A protective shed was constructed around the pit to prevent rainwater from entering and disrupting the composting process.

**Cocoon formation**

The clitellum of the earthworm secretes a mucous ring that gradually develops into a protective cocoon. As the worm moves forward, this ring slides along its body and eventually slips off the anterior (front) end. During this process, fertilized eggs resulting from previously exchanged sperm and additional reproductive fluids are deposited into the cocoon. The formation and deposition take several hours. Once completed, the cocoon is laid in the soil, where it remains well-protected due to its resilient nature, capable of withstanding adverse environmental conditions. Upon hatching, the young worms develop within the substrate, maturing over time and eventually beginning their own reproductive process by forming new cocoons.

**Vermicomposting process, harvesting and storage**

Vermicomposting was carried out over a 90 days period, with the temperature maintained at 30°C and moisture content kept at 80% by regularly sprinkling water at appropriate intervals. After 90 days of incubation, the vermicompost was harvested. To facilitate easy handling, no additional water was added for the last 5 days. The finished compost was collected into a separate container, allowing the earthworms that had settled at the bottom to be retrieved and reused for the next batch of vermicomposting. The vermicompost produced had a brownish-black color and a characteristic earthy aroma. It was then packed into polythene bags for storage.

**Extraction of vermiwash**

As part of the vermicomposting process, the leachate produced, referred to as vermiwash, was collected for subsequent analysis. It was collected in trays, then transferred to sterile glass bottles and stored at 4°C in a refrigerator for preservation, following the method outlined by Aruna *et al.* (2006).

**Physiochemical analysis of vermicompost**

All physicochemical parameters were measured both before and after the vermicomposting treatment. The physical parameters included pH (Booth, 1961), color, odor, electrical conductivity (EC), temperature (Ahmed, 2003), and moisture content of the vermicompost. The chemical parameters analyzed included the concentration of organic carbon (measured using the Walkley and Black method), nitrogen (measured by the Micro Kjeldahl method), phosphorus (measured using the Olsen method) (Zheng *et al.*, 2019; Zhou *et al.*, 2016). The, potassium (measured via flame photometry) (Piper, 1996; Jackson, 1973; Ishwaran and Marwaha, 1980), calcium and magnesium (measured by the Walkley and Black method), and the concentration of heavy metals such as zinc, copper, and iron (determined using Atomic Absorption Spectrophotometry [AAS]).Carbon-to-nitrogen (C: N) ratio was calculated.

**Culture and determination of total microbial population**

The total number of bacteria, fungi and actinomycetes were estimated by serial dilution plate method (Allen, 1953). The serial dilutions of each mixture were made by using sterile deionised water and dilution of the manure sample viz. $10^{-4}$, $10^{-5}$ and $10^{-6}$ were prepared. Appropriate dilution viz., $10^{-4}$ for fungi, $10^{-5}$ for actinomycetes and $10^{-6}$ for bacteria were chosen for respective organisms. Rose Bengal Agar medium for fungi (Emmon *et al.,* 1970), Nutrient Agar medium for bacteria (Anonymous, 1977) and Ken knights Agar medium for actinomycetes (Emmon *et al.,* 1970). The petriplates were incubated at room temperature (28°C). The colonies were developed. The colonies were counted on 3rd, 5th and 11th day for bacteria, fungi, actinomycetes respectively using colony counter and expressed the population per gram of oven dried sample.

### Statistical analysis

All reported values represent the mean of three replicates, expressed as mean ± standard deviation (SD). Statistical significance was determined at a probability level of less than 0.05. Data analysis was performed using the SPSS software package, version 16.0 (Rohart *et al.*, 2017). The experimental microbial populationwere tested for their statistical significance using one way analysis of variance (ANOVA) (Emperor *et al.*, 2015).

## RESULTS AND DISCUSSION

The domestic wastes, specifically plant debris and decomposed vegetables, were collected for the study. The efficiency and productivity of three earthworm species *Eisenia foetida*, *Eudrilus eugeniae*, and *Perionyx excavates* were evaluated using various substrate combinations. Two distinct waste mixtures were prepared by blending the waste materials with cow dung in a 60:40 ratio. In our study, the vermicomposting process using various wastes was completed within 90 days (Table 1).

**Table 1.** Details of earthworm numbers in the composting periods

| Name of the raw materials | Earthworms name | Earthworms numbers | |
|---|---|---|---|
| | | 0 days | 90 days |
| Plant debris | *Eisenia foetida* | 50 | 84 |
| Decomposed vegetables | | | 87 |
| Plant debris | *Eudrilus eugeniae* | 50 | 80 |
| Decomposed vegetables | | | 83 |
| Plant debris | *Perionyx excavates* | 50 | 79 |
| Decomposed vegetables | | | 82 |

**Table 2.** Weight loss of organic substrates during vermicomposting by *Eisenia foetida*

| Raw materials name | Initial weight of substrate (kg) | Final weight of vermicompost (kg) | Weight loss (kg) | Loss of % during vermicompost | Total % during vermicompost |
|---|---|---|---|---|---|
| Plant debris | 5 | 2.6 | 2.4 | 48.0% | 52.0% |
| Decomposed vegetables | 5 | 2.9 | 2.1 | 42.0 % | 48.0 % |

**Table 3.** Impact of composting period on earthworm count, biomass, and cocoon production in *Eisenia foetida* with different raw materials (Over 90 Days).

| Raw materials name | Earthworms numbers | | | | Body weight (gm) | | | | cocoon production (kg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 Days | 30 Days | 60 Days | 90 Days | 0 Days | 30 Days | 60 Days | 90 Days | 0 Days | 30 Days | 60 Days | 90 Days |
| Plant debris | 50 | 42 | 65 | 84 | 37.63 | 40.65 | 49.45 | 63.20 | Nil | 16 | 44 | 70 |
| Decomposed vegetables | 50 | 46 | 71 | 87 | 37.63 | 41.36 | 53.57 | 65.15 | Nil | 18 | 48 | 76 |

Vermicomposting involves the chemical and physical transformation of agricultural residues from plant and animal sources through the action of worms and microorganisms (Garg and Gupta, 2009). Composting leads to significant physical and chemical changes in the nutrients. Recycling waste and residues with the help of composting worms enhances the nutrient content of the substrates (Theunissen *et al.*, 2010). As a result, the nutritional quality of decomposed vegetables vermicompost was found to be richer than that of standard vermicompost. Weight reduction during Vermicomposting of Organic Materials was Plant debris showed a higher weight loss of 48%, indicating a greater degree of decomposition and utilization by earthworms and microbes. Decomposed vegetables resulted in a 42% weight loss, slightly lower, possibly due to higher moisture or already partially decomposed nature (Table 2). Table 3 showed that the Earthworm count and biomass **i**ncreased steadily across both substrates, with decomposed vegetables showing slightly higher growth by day 90. Cocoon production followed a similar trend, with decomposed vegetables leading to higher cocoon numbers (76 cocoons by day 90 compared to 70 cocoons with plant debris). This suggests that decomposed vegetables are a more favorable substrate for *Eisenia foetida* development and reproduction. In contrast, Table 4 is the use of decomposed vegetables resulted in a slightly higher cocoon count of 76 cocoons, with 58 kg of vermicompost generated. This gave an average of 1.31 cocoons per kilogram of compost.Although both materials were effective, decomposed vegetables produced a greater quantity of cocoons and vermicompost overall, while plant debris had a marginally higher cocoon-to-compost ratio.

**Table 4.** Comparisons of cocoon production and vermicompost yield from different organic substrates

| Raw material | Total cocoons (90 Days) | Vermicompost produced (kg) | Cocoons per kg of vermicompost |
|---|---|---|---|
| Plant debris | 70 | 52 | 1.35 |
| Decomposed vegetables | 76 | 58 | 1.31 |

**Table 5.** Physicochemical characteristics of vermicompost produced from plant debris and decomposed vegetables using *Eisenia fetida*

| Parameters | Plant debris vermicompost | | | | Decomposed vegetables vermicompost | | | |
|---|---|---|---|---|---|---|---|---|
| | T1 Control | T2 | T3 | T4 | T5 Control | T6 | T7 | T8 |
| pH | 7.2 | 7.2 | 6.8 | 7 | 7.2 | 7.2 | 6.8 | 7 |
| Moisture (%) | 70-81 | 70-81.5 | 70-80 | 70-81 | 70-81 | 70-82 | 70-81 | 70-81 |
| Temperature (°C) | 30.5 | 30.5 | 31.5 | 32 | 30.5 | 30.5 | 31.5 | 32 |
| Color | Brown | Brownish-black | Brownish-black | Brownish-black | Brown | Brownish-black | Brownish-black | Brownish-black |
| Odor | Neutral | Earthy odor | Earthy odor | Earthy odor | Neutral | Earthy odor | Earthy odor | Earthy odor |
| Electrical conductivity | 0.49±0.01 | 0.79±0.05 | 0.80±0.03 | 0.79±0.02 | 0.44±0.08 | 0.75±0.05 | 0.63±0.08 | 0.72±0.04 |
| Organic Carbon (%) | 12.32±0.23 | 12.53±0.01 | 11.02±0.83 | 11.08±0.15 | 12.33±0.23 | 12.13±0.01 | 12.3±0.01 | 11.85±0.06 |
| Nitrogen (%) | 1.63±0.07 | 1.75±0.07 | 1.68±0.08 | 1.69±0.05 | 1.63±0.07 | 1.72±0.05 | 1.70±0.06 | 1.68±0.03 |
| Total phosphorus (%) | 1.20±0.06 | 1.23±0.06 | 1.24±005 | 1.25±0.03 | 1.27±0.03 | 1.24±0.06 | 1.22±0.02 | 1.23±0.03 |
| Potassium (%) | 0.97±0.09 | 1.08±0.01 | 1.05±0.02 | 1.06±0.03 | 0.93±0.06 | 1.09±0.03 | 1.05±0.04 | 1.03±0.02 |
| Calcium (%) | 0.96±0.03 | 1.05±0.08 | 1.05±0.06 | 1.04±003 | 0.96±0.03 | 1.06±0.08 | 1.02±0.05 | 0.98±0.06 |
| Magnesium (%) | 1.56±0.06 | 1.81±0.01 | 1.68±0.04 | 1.63±0.03 | 1.49±0.03 | 1.85±0.02 | 1.76±0.04 | 1.80±0.06 |
| Zinc (%) | 0.98±0.02 | 1.04±0.05 | 1.03±0.03 | 1.01±0.02 | 0.98±0.03 | 1.05±0.05 | 1.03±0.10 | 1.02±0.08 |
| Copper (%) | 0.96±0.07 | 1.07±0.03 | 1.04±0.06 | 1.03±0.04 | 0.94±0.06 | 1.08±0.04 | 1.05±0.06 | 1.02±0.03 |
| Iron (%) | 1.34±0.04 | 1.43±0.01 | 1.42±0.06 | 1.35±0.02 | 1.34±0.06 | 1.40±0.03 | 1.31±0.05 | 1.23±0.07 |
| C/N | 12:1 | 12:4 | 11:3 | 11:2 | 12:1 | 12:5 | 12:2 | 11:1 |

**Physical analysis of vermicompost**

A technical feasibility study was carried out to assess the potential of vermicomposting for converting organic waste into bio-fertilizer. Both the initial (pre-composting) and final (post-composting) stages of vermicomposting were analyzed in terms of physical properties (pH, temperature, moisture, color, smell, and electrical conductivity), chemical composition (macro and micronutrients), and microbial load. The study monitored various parameters over the course of the process, using three different earthworm species, each belonging to distinct substrate categories. All species demonstrated varying degrees of effectiveness in reducing the organic materials used. The final compost produced across all treatments exhibited a brownish-black color, indicating complete decomposition. The pH ranged between 7 and 8, which is ideal for nutrient availability and microbial activity in soils. Significant improvements in key nutrients were recorded in all vermicomposting treatments compared to controls (T1 and T5).

**Macro and micronutrients analysis of vermicompost**

Among the three earthworm species studied, *Eisenia foetida* showed the highest efficiency in enhancing nutrient content .The highest concentrations of nitrogen (1.72±0.05%)**,** potassium (1.09±0.03%)**,** and calcium (1.06±0.08%) were observed (Table 5) in T2 and T6, both of which utilized *Eisenia foetida*. This species demonstrated superior decomposition capability and nutrient recovery compared to *Eudrilus eugeniae* and *Perionyx excavats*. All treatments showed a decline in organic carbon and C: N ratio**,** reflecting efficient decomposition and nutrient mineralization. The C: N ratio, a key indicator of compost maturity, dropped from above 20 in controls to as low as 12.4 and 12.5 in *Eisenia foetida* treatments, aligning with mature compost standards. Among the species, *Eisenia foetida* exhibited better growth and biomass gain, suggesting it adapted more effectively to both plant debris and decomposed vegetable waste. This superior performance may be due to its robust feeding behavior and tolerance to variable organic matter. Comparsion of both wastes plant debris and decomposed vegetables proved to be suitable substrates. However, nutrient values were marginally higher in treatments involving decomposed vegetables, likely due to their higher initial nutrient content and softer structure, which facilitated quicker decomposition.

**Quantitative analysis of microbes**

The fungal flora isolated from the vermicompost of plant debris and decomposed vegetables and mixtures of cow dung shows a total of ten (10) fungal species *Aspergillus flavus, A. niger, A. nidulans, Cladosporium herbarum, Fusarium oxysporum, F. moniliforme, Chaetomium globosum, Penicillium citrinum, Rhizopus nigricans, Mucor plumbeus*. The isolation of bacteria from found to contain six (6) species such as *Pseudomonas aeruginosa, Enterobacter acrogens, Proteus vulgaris, Escherichia coli, Citrobactor diversus and Enterococcus faecivm*. Actinomycetes (2) two species such as (2) *Streptomyces albus, S. griseus* in vermicompost *Eisenia foetida* were identified. Microorganisms are the primary decomposers of organic matter. The role of microbial activity in the vermicomposting of earthworms, in the casts and in the soil is very essential for the degradation of organic waste and release of nutrients in available form to plants (Syers *et al*., 1979).

**CONCLUSION**

The study demonstrated that vermicomposting is an effective technique for converting organic wastes into nutrient rich biofertilizer. Among the all treatments, *Eisenia foetida* in both plant debris and decomposed vegetable substrates T2 and T6 showed the best performance in terms form growth, compost maturity and nutrient enrichment. The compost from these treatments was characterized by favorable pH, EC, color, odor and higher and macro and micro nutrients. The indicates that vermicomposting with *Eisenia foetida* is highly effective in converting household organic waste into nutrient-rich compost, making it a viable solution for sustainable waste management and organic farming. This method not only reduces organic load but also improves soil fertility, making it an environmentally friendly and agriculturally beneficial practice.

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