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COMPARATIVE EVALUATION OF ORGANIC RESIDUES FOR HIGH-QUALITY VERMICOMPOST PRODUCTION AND NUTRIENT ENRICHMENT

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ABSTRACT

A vermicomposting study was conducted during the late *rabi* season of 2022–23 at the Vermicomposting Unit, Siksha 'O' Anusandhan, Bhubaneswar, Odisha, to evaluate the efficiency of different organic residues in producing nutrient-rich compost. Five treatments (T_1: Mushroom straw waste, T_2: Kitchen waste, T_3: Green kitchen waste + Mushroom straw waste, T_4: 3 parts kitchen waste + 1 part dry leaves, and T_5: 3 parts dry leaves + 1 part kitchen waste) were arranged in a Completely Randomized Design and replicated thrice. Each pit received a base layer of sand and alluvial soil, followed by the respective organic residues and cow dung slurry, with earthworms introduced after approximately 50% decomposition. Moisture, temperature, pH, electrical conductivity, organic carbon, C:N ratio, and nutrient contents (N, P, K) were analyzed. Moisture, temperature, and pH were statistically non-significant among treatments, while significant differences were observed in organic carbon, nitrogen, phosphorus, potassium, and C:N ratio. T_2 (Kitchen waste) showed the highest nutrient enrichment and lowest C:N ratio, indicating rapid decomposition, whereas T_4 stood next to it. T_1 (Mushroom straw) exhibited slower decomposition and lower nutrient release. The study concludes that kitchen waste, alone or in combination with dry leaves, is the most effective substrate for producing high-quality vermicompost, ensuring nutrient stability and sustainable organic waste recycling for agricultural use.
***Keywords* :** Vermicomposting, pit composting, organic carbon, nitrogen content, C:N ratio

Introduction

Agriculture is the largest sector in India, generating enormous quantities of organic waste, including crop residues, animal manure, and agro-industrial by-products. Poor disposal or burning of these wastes contributes to serious environmental concerns, including soil degradation, water pollution, and greenhouse gas emissions (Pathak *et al.*, 2023). Effective agricultural waste management has thus become essential not only to mitigate pollution but also to recycle nutrients and maintain soil health. The primary objectives of agrarian waste management include reducing indiscriminate disposal or burning of residues, preventing disease transmission, improving water quality as well as soil fertility, and promoting sustainable and economically beneficial waste recycling systems (Sarkar *et al.*, 2020). It aids in minimising the dependency on chemical inputs, encourages hygienic waste disposal, enhances farmers' socioeconomic status, and increases public awareness regarding the environmental impacts of agricultural residues.

India, being an agricultural nation, possesses vast potential for organic waste utilisation. The country generates about 141 million tonnes of crop residues annually, in addition to nearly 92 million tonnes waste that are burned (Gatkal *et al.*, 2024). Major residues include rice and wheat straw, sugarcane bagasse, cotton stalks, and other lignocellulosic materials. Despite their abundance, these materials are not properly managed. Agricultural waste can serve as a valuable raw material for producing organic fertilisers, biofuels, and soil conditioners (Reddy *et al.*, 2025). Thus, developing sustainable waste management strategies has become a priority for achieving environmental protection and resource conservation.

Among the different techniques available, composting and vermicomposting have gained prominence as eco-friendly, cost-effective, and efficient methods of waste recycling (Adetunji *et al.*, 2009). Composting is a biological process where microorganisms convert organic residues into stable humus-like material, whereas vermicomposting involves the synergistic action of earthworms and microbes to accelerate the decomposition process and enhance the nutrient quality of the compost (Zhou *et al.*, 2022). Vermicomposting not only reduces the volume of organic waste but also produces a nutrient-rich, microbially active organic amendment that improves soil physical, chemical, and biological properties (Manzoor *et al*., 2024). Moreover, it helps in maintaining ecological balance and promoting sustainable agriculture by reducing reliance on synthetic fertilisers. Rajendra and Rajendram (2014) reported that *E. eugeniae* produced vermicompost with higher nitrogen, phosphorus, and potassium contents and a lower C:N ratio, suggesting its efficiency in generating high-quality compost.

Therefore, vermicomposting represents a promising approach for managing the vast agricultural waste resources in India. It not only addresses environmental concerns associated with waste accumulation but also enhances soil fertility, crop productivity, and farmers' income. The present study was undertaken to evaluate the efficiency of vermicomposting as a sustainable agricultural waste management technique, focusing on the quality of compost produced from different organic wastes and the performance of earthworm species involved in the process.

Materials and Methods

The vermicomposting experiment was conducted during the late Rabi season of 2022–23 at the Vermicomposting Unit, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha. The experimental site is geographically located at 20.288° N latitude and 85.764° E longitude, experiencing a tropical climate with humidity of 73.38% and mean temperatures ranging from 22° to 30°C during the experimental period. The experiment was laid out in a Completely Randomized Design (CRD) with five treatments replicated thrice. Vermicomposting was carried out in the pit and drum method, the pit measures 8 ft × 3 ft × 4 ft, and for drum, which measures 3 ft × 2.5 ft × 2.5 ft, served as a separate treatment unit. Different organic waste materials were used as substrates to evaluate their efficiency in vermicompost production, and the treatment details are presented in Table 1. All pits were prepared with a base layer of sand and alluvial soil to enhance aeration and moisture retention. The respective organic wastes were layered according to the treatment composition, followed by the addition of cow dung slurry as a microbial inoculant at the top. Each treatment received 200 kg of kitchen waste, spent mushroom substrate (SMS), or dry leaves, mixed with 20 L of cow dung slurry as per the treatment design. The materials were periodically turned, moisture was maintained through regular sprinkling of water, and after 50% decomposition, *Eisenia fetida,* also known tiger earthworms (1 kg per treatment) were introduced and showed in Fig. 1. Compost maturation occurred in 95 days, indicated by a dark brown color, granular texture, and earthy odor. Before decomposition and after compost maturation, moisture content, temperature, pH, organic carbon, C:N ratio, and nutrient contents (N, P, K) were analyzed. Moisture content was determined by the oven-dry method (Piper, 1966), temperature was recorded with a compost thermometer (Richards, 1954), pH using a pH meter with a glass electrode (Jackson, 1973), electrical conductivity by the conductimetry method (Jackson, 1973), and organic carbon by the chromic acid wet digestion method (Walkley and Black, 1934). The C:N ratio was computed from total organic carbon and nitrogen values (Jackson, 1973). Total nitrogen, phosphorus, and potassium were estimated using the Micro-Kjeldahl method (Humphries, 1956) and triple acid digestion, followed by colorimetric and flame photometric estimations (Jackson, 1973). Statistical significance was tested using the F-test at a 5% level of probability, as suggested by Gomez and Gomez (2010).

Results and Discussion

Physico-chemical properties of compost

The initial and final physico-chemical properties of composting materials as influenced by different organic residue combinations are presented in Table 2 and Table 3. Considerable variations were recorded among the treatments with respect to organic carbon, nitrogen, phosphorus, potassium, and C:N ratio, whereas moisture content, temperature, and pH were found to be statistically non-significant. Moisture content varied from 60% in T_5 (3 parts dry leaves + 1 part kitchen waste) to 68% in T_2 (kitchen waste). Although the difference was statistically non-significant, T_2 maintained slightly higher moisture, possibly due to the high water-holding capacity of kitchen waste materials. Regular watering also helped maintain moisture levels across all treatments within the desirable range of 60–68% for efficient vermicomposting. The results are in agreement with the recent findings of Peng *et al*. (2024), who reported that consistent watering during composting maintains uniform moisture conditions essential for microbial and earthworm activity. The temperature of the compost pits ranged between 26.3°C and 27.1°C, which indicates stable mesophilic conditions suitable for earthworm growth and microbial activity. The slight variation might be due to differences in decomposition rates of organic residues. Similar stable temperature ranges were reported by Zhou *et al*. (2021) during the vermicomposting process. The pH values ranged from 7.5 to 8.0, indicating near-neutral to slightly alkaline conditions. T_2 recorded a pH of 8.0, followed closely by T_3 (7.9), while T_5 maintained a slightly lower pH (7.5). The minor fluctuations in pH may be due to the balance between the release of organic acids during initial decomposition and the formation of ammonia during mineralisation. A near-neutral pH is favorable for nutrient availability and the activity of composting organisms, as also noted by Singh *et al*. (2006).

Organic carbon and nutrient content

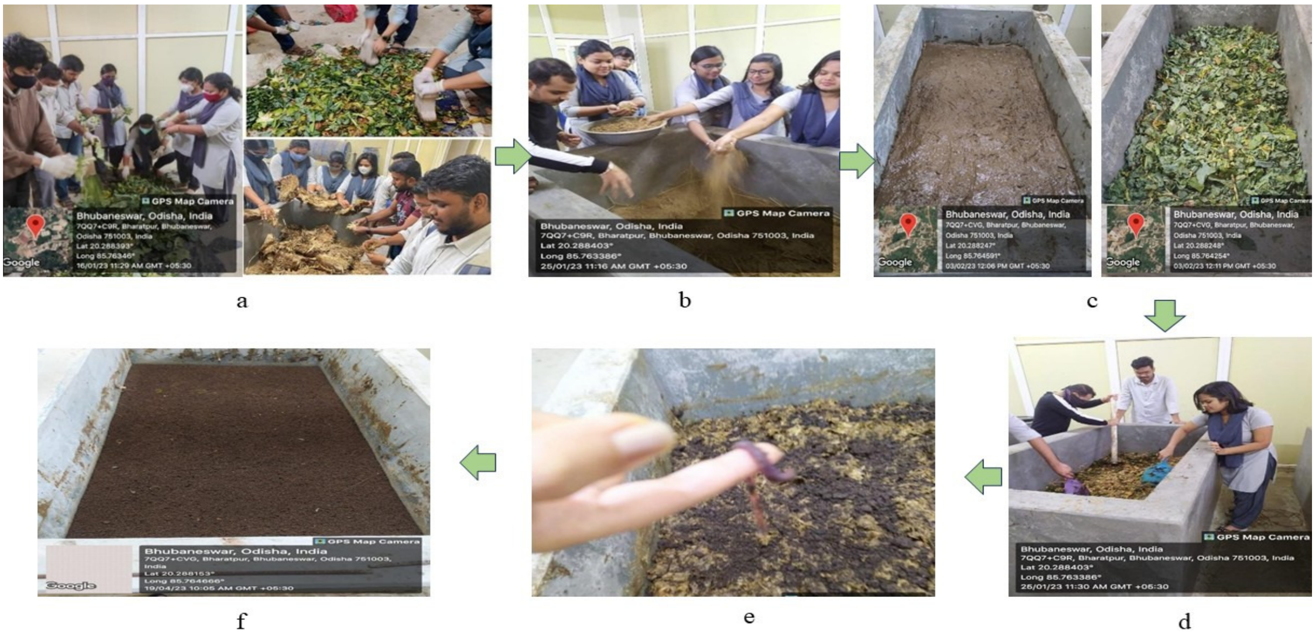
Significant differences were observed in organic carbon (OC) content among treatments, as shown in Table 3. The highest organic carbon value was recorded in T_3 (42.9%), followed by T_5 (41.8%) and T_4 (40.0%), while the lowest (26.3%) was recorded in T_2 (kitchen waste). The higher OC content in T_3, T_4, and T_5 might be due to the slower decomposition of lignocellulosic materials such as mushroom straw and dry leaves, resulting in greater carbon retention. Conversely, the rapid degradation of kitchen waste in T_2 resulted in lower residual carbon. Similar results were reported by Vane *et al*. (2001), who noted that mixed organic substrates tend to retain higher organic carbon due to balanced decomposition rates. Nitrogen content varied significantly among treatments. The higher nitrogen content in T_2 (1.60%) could be attributed to the presence of protein-rich residues and enhanced microbial mineralization. Treatment T_4, which was on par with T_2, also showed appreciable nitrogen content, indicating a synergistic decomposition between kitchen waste and lignocellulosic materials. A similar trend for phosphorus and potassium was found in treatment T_2 showed higher content of phosphorus and potassium, and was on par with treatment T_4. The increased P and K content in T_2 might be due to enhanced mineral solubilization and microbial enzyme activity during the composting process, as suggested by Suthar *et al*. (2012).

C:N ratio and compost stability

The C:N ratio ranged from 16.4 in T_2 to 30.8 in T_1. The lowest ratio in T_2 indicates rapid decomposition and better stabilization of organic matter, which reflects the maturity and nutrient richness of the compost. Treatments containing mixed wastes (T_3 and T_4) also recorded moderate C:N ratios, signifying balanced decomposition rates and enhanced microbial efficiency. A C:N ratio below 20 generally denotes mature compost, which was evident in T_2. The results corroborate the findings of Salangsang *et al*. (2022), who observed that nutrient-rich organic residues such as kitchen waste decompose rapidly, resulting in a sharp decline in C:N ratio.

Conclusion

Kitchen waste alone or mixed with dry leaves produced nutrient-rich, well-stabilized compost with balanced pH and C:N ratio, making it the most efficient and sustainable substrate for vermicomposting. It also enhanced nitrogen, phosphorus, and potassium content, supporting soil fertility. Mushroom straw alone showed slower decomposition and lower nutrient release, indicating the importance of substrate selection for efficient composting.



(a-Collection of organic resides, b- pouring sand as bedding material, c- filling the pits with organic residues, d- improving aeration, e- inoculation of earthworms, f-vermicompost after 3 months)

Fig. 1: Schematic representation of pit preparation and vermicomposting process

Table 1 : Treatment details

Treatment	Treatment Details
T_1	Mushroom straw waste
T_2	Kitchen waste
T_3	Green kitchen waste + Mushroom straw waste
T_4	3 parts kitchen waste + 1 part dry leaves
T_5	3 parts dry leaves + 1 part kitchen waste

Table 2 : Initial physicochemical properties of organic residues before composting

Treatment	Moisture (%)	Temperature (°C)	pH	Organic Carbon (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	C:N Ratio
T1	58.3	26.4	6.5	42.6	0.82	0.33	0.90	52.0
T2	68.9	27.1	6.7	38.5	1.52	0.55	1.45	25.3
T3	62.8	26.8	6.6	42.9	1.30	0.47	1.22	33.0
T4	65.1	26.9	6.8	40.4	1.48	0.52	1.38	27.3
T5	60.4	26.3	6.4	43.1	1.10	0.40	1.06	39.2

Table 3 : Post-analysis of vermicompost from various organic residues

Treatment	Moisture (%)	Temperature (°C)	pH	Organic Carbon (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	C:N Ratio
T1	62	25.2	7.8	33.9	1.10	0.45	1.10	30.8
T2	70	24.1	8.0	26.3	1.60	0.59	1.56	16.4
T3	65	24.3	7.9	40.3	1.35	0.51	1.31	29.9
T4	67.3	23.7	7.7	37.2	1.53	0.56	1.47	24.3
T5	62	25.7	7.5	41.8	1.22	0.48	1.17	34.3
SEd	3.83	1.63	0.46	2.26	0.06	0.03	0.07	1.88
CD (p= 0.05)	NS	NS	NS	4.53	0.13	0.06	0.15	3.76

Conflicts of Interest

The authors declare no conflict of interest.

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