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Comparative study of physico- chemical properties and enzymes activities in vermicomposting of Kitchen and Agricultural waste in Kanpur Region

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ABSTRACT

Vermicomposting offers an efficient biological method for transforming organic residues into valuable soil amendments through the activity of earthworms and associated microorganisms. This study investigates the changes in physico-chemical characteristics and enzyme activities during the vermicomposting of kitchen and agricultural wastes, along with their influence on soil fertility in the Kanpur region. Important parameters such as pH, electrical conductivity, organic carbon and essential nutrients (nitrogen, phosphorus, and potassium) were monitored throughout the process. Enzymatic activities, including dehydrogenase, urease, phosphatase, and catalase were also assessed to evaluate microbial functionality. The findings revealed a gradual decline in pH and C: N ratio, indicating stabilization of organic matter, while nutrient concentrations increased significantly in the final product. Enhanced enzyme activities suggested active microbial involvement in decomposition and nutrient transformation. Comparative results showed slight variations between waste types, though both produced high-quality vermicompost. Vermicompost improved soil nutrient status and biological activity, demonstrating its potential as a sustainable alternative to chemical fertilizer and environment conservation.

Introduction

The rapid increase in population, urbanization, and agricultural activities has led to a substantial rise in organic waste generation. In regions such as Kanpur, large amounts of kitchen waste and agricultural residues are produced daily, creating serious environmental and disposal challenges. Improper management of these wastes contributes to soil degradation, pollution, and loss of valuable nutrients. Therefore, sustainable and eco-friendly approaches are essential for effective waste recycling and soil fertility enhancement.

Vermicomposting has emerged as an efficient biological process for converting organic waste into nutrient-rich compost through the synergistic action of earthworms and microorganisms. Earthworms play a central role in this process, acting as natural bioreactors that fragment, aerate, and biologically transform organic matter. Among various species, Eisenia fetida (commonly known as red wiggler worm) is widely used due to its high feeding capacity, rapid growth, and prolific reproduction rate. These earthworms ingest organic substrates and excrete them as vermicast, which is rich in nutrients, beneficial microbes, and plant growth-promoting substances (Sharma & Garg, 2022; Awasthi *et al.* 2020). During vermicomposting, earthworms significantly influence the physico-chemical properties of the substrate. Their feeding and burrowing activities enhance aeration and microbial colonization, leading to accelerated decomposition. As a result, key parameters such as pH, electrical conductivity, organic carbon, and C: N ratio undergoes substantial changes, while essential nutrients like nitrogen, phosphorus, and potassium become more available. The digestive enzymes present in the gut of earthworms, along with associated microorganisms, further facilitate the breakdown of complex organic compounds into simpler forms (Singh *et al*. 2021).

In addition to physico-chemical transformations, earthworms indirectly enhance enzyme activities by stimulating microbial populations. Enzymes such as dehydrogenase, urease, phosphatase, and catalase are crucial indicators of microbial metabolism and nutrient cycling. Increased enzymatic activities during vermicomposting reflect the active role of earthworm–microbe interactions in organic matter stabilization and nutrient mineralization (Pathma and Sakthivel, 2021). The gut-associated microbes of earthworms contribute significantly to these enzymatic processes, making vermicomposting a biologically enriched system.

The type of organic waste used also affects earthworm activity and compost quality. Kitchen waste, being easily degradable, supports rapid growth and reproduction of earthworms, whereas agricultural residues with high lingo cellulosic content may slow down the process but contribute to long-term soil organic matter. A comparative evaluation of these substrates is essential to understand their influence on earthworm performance, decomposition efficiency, and final compost quality (Suthar, 2020, Yadav *et al*. 2023). Vermicompost improves soil structure, enhances microbial diversity and increases nutrient availability. Earthworm-derived vermicompost contains humic substances and plant growth regulators that promote plant development and soil health. In industrially influenced regions like Kanpur, where soil quality is often compromised, vermicomposting offers a sustainable approach to restore soil fertility and ecological balance.

This study focuses on the role of earthworms changes in physico-chemical properties and enzyme activities during vermicomposting of kitchen and agricultural wastes, and evaluates the impact of the resulting vermicompost on soil fertility in the Kanpur region.

Material and Method

Study Area- The study was conducted in the Kanpur region, which is characterized by a subtropical climate with distinct summer, monsoon, and winter seasons. The area experiences significant generation of kitchen and agricultural wastes, making it suitable for vermicomposting studies.

Collection of Raw Materials- Kitchen waste (vegetable peels, fruit residues, and leftover food materials) was collected from local households, while agricultural waste (crop residues such as wheat straw, paddy straw, and dry leaves) was collected from nearby fields. All materials were segregated manually to remove non-biodegradable components and then air-dried and chopped into small pieces (2–3 cm) for uniform decomposition.

Earthworm Species- The earthworm species Eisenia fetida was used for the vermicomposting process due to its high feeding rate, adaptability, and reproductive potential. Healthy and active earthworms were procured from a local vermiculture unit and acclimatized for one week before experimentation.

Experimental Design- The experiment was conducted using a completely randomized design (CRD) with the following treatments:

T_1: Kitchen waste

T_2: Agricultural waste

T_3: Mixture of kitchen and agricultural waste (1:1 ratio)

Each treatment was prepared in triplicate using plastic containers. A pre-composting step of 10–15 days was carried out to reduce heat and eliminate harmful gases. After pre-composting, approximately 50–100 earthworms were introduced into each unit. Moisture content was maintained at 60–70% by periodic sprinkling of water, and the temperature was kept between 20–30°C. The composting process was carried out for 45–60 days.

Sampling Procedure- Samples were collected at regular intervals (0, 15, 30, and 60 days). Vermicompost samples were air-dried, sieved (2 mm), and stored for further analysis.

Analysis of Physico-Chemical Properties

The following parameters were analyzed using standard methods:

pH and Electrical Conductivity (EC): Measured using pH meter and conductivity meter (1:10 sample-water suspension), Organic Carbon (OC) Determined by Walkley and Black method, Total Nitrogen (N) is Estimated by Kjeldahl method, Available Phosphorus (P) by Olsen method, Available Potassium (K) determined by Flame photometer method and C:N Ratio Calculated from OC and N values

Enzyme Activity Analysis- Enzymatic activities were determined to assess microbial functional dynamics:

Dehydrogenase Activity: Measured using TTC (Triphenyl Tetrazolium Chloride) reduction method

Urease Activity: Determined by measuring ammonia released after urea hydrolysis

Phosphatase Activity: Assessed using p-nitrophenyl phosphate as substrate

Catalase Activity: Determined by titration of residual hydrogen peroxide

Soil Application Study- Prepared vermicompost from each treatment was applied to agricultural soil in pot experiments. Soil samples were analyzed before and after application to evaluate changes in soil fertility parameters such as nutrient content and enzyme activities.

Statistical Analysis- All experiments were conducted in triplicate, and results were expressed as mean ± standard deviation. Data were analyzed using analysis of variance (ANOVA) to determine significant differences among treatments at a 5% significance level.

Result and Discussion

The vermicomposting process showed significant changes in physico-chemical properties, enzyme activities, earthworm performance, and microbial population, indicating efficient bioconversion of organic wastes into nutrient-rich compost.

Physico-Chemical Properties- The physico-chemical parameters during the vermicomposting process exhibited significant temporal variation, reflecting active biotransformation of organic substrates mediated by microbial consortia and earthworm activity. A progressive decline in pH from 7.8±0.2 to 6.5±0.2 was observed, indicating a transition from alkaline to near-neutral conditions, which is widely attributed to the production of organic acids, nitrification processes, and CO_2 evolution during microbial respiration; such pH stabilization is considered a key indicator of compost maturity and has been consistently reported by Sharma and Garg and Singh *et al.* (2021). Electrical conductivity (EC) showed a gradual increase from 1.2±0.1 to 2.8±0.2 dS/m, suggesting enhanced mineralization and release of soluble salts such as ammonium, phosphate, and potassium ions; however, the values remained within the permissible threshold (<4 dS/m), indicating agronomic safety, in agreement with findings of Awasthi *et al.* and recent observations by Zhang *et al*. (2023). A marked reduction in organic carbon (22.5±1.2% to 10.5±0.7%) highlights intense microbial degradation and carbon mineralization, resulting in CO_2 loss and humification of organic matter; this trend reflects increased compost stability and has been corroborated by Suthar, as well as Kumar *et al*. (2023) and Lim *et al*. (2022), who emphasized the role of earthworm gut enzymes in accelerating carbon turnover. Conversely, nitrogen content exhibited a substantial increase from 0.85±0.05% to 1.65±0.09%, which can be explained by enhanced microbial mineralization, nitrogen fixation, and concentration effects due to carbon loss, along with the addition of nitrogenous mucus and excretory products from earthworms; similar enrichment patterns have been documented by Singh *et al*., Yadav *et al*. (2022), and Wang *et al*. (2021). Phosphorus content increased significantly from 0.45±0.03% to 0.95±0.06%, indicating active solubilization of insoluble phosphates mediated by phosphate-solubilizing microorganisms and enzymatic activities within the earthworm gut microflora, thereby enhancing nutrient bioavailability; this is in line with reports by Garg *et al*., Patel *et al*. (2024), and Bhattacharya *et al*. (2021). Collectively, the simultaneous decline in pH and organic carbon, coupled with the enrichment of essential nutrients (N and P) and moderate increase in EC, confirms efficient organic matter stabilization, accelerated humification, and production of nutrient-enriched vermicompost. These transformations not only improve soil fertility but also enhance microbial activity and nutrient cycling, thereby supporting sustainable agricultural practices.

Table-1: Showing the Physico- chemical properties during vermicomposting

Parameters	Day 0	Day 15	Day 30	Day 60	Standard value
pH	7.8±0.2	7.2±0.1	6.8±0.1	6.5±0.2	6.5-75
EC (ds/m)	1.2±0.1	1.8±0.2	2.3±0.2	2.8±0.2	<4
Organic carbon (%)	22.5±1.2	18.4±1.0	14.2±0.8	10.5±0.7	0.5-0.75
Nitrogen (%)	0.85±0.05	1.10±0.06	1.35±0.08	1.65±0.09	0.1-0.5
Phosphorous (%)	0.45±0.03	0.60±0.04	0.78±0.06	0.95±0.06	0.01-0.1
Potassium (%)	0.70±0.04	0.90±0.05	1.10±0.07	1.35±0.07	0.1-0.5
C:N ratio	26.5	16.7	10.5	6.4	<20

Mean ±SD, n=3

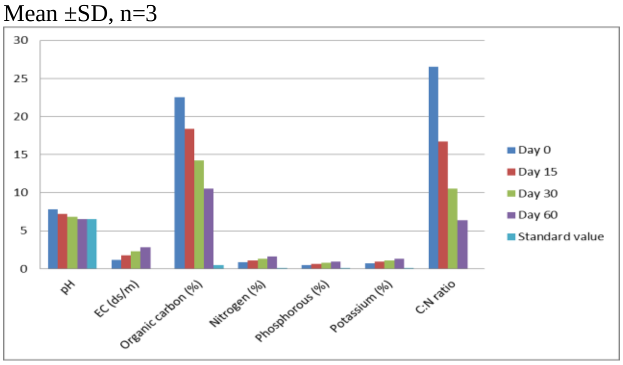

Fig..1. Showing the Physico- chemical properties during vermicomposting

Enzyme Activities- Enzymatic activities increased progressively throughout the vermicomposting process. Dehydrogenase activity rose from 18.2 to 45.2 µg TPF/g/hr, indicating enhanced microbial respiration. Urease and phosphatase activities also showed substantial increases, reflecting improved nitrogen and phosphorus cycling, respectively.

Catalase activity increased steadily, suggesting active oxidative metabolism and detoxification processes within the composting system. These results confirm that vermicomposting promotes microbial functional diversity and accelerates organic matter decomposition (Pathma & Sakthivel, 2021; Awasthi *et al*., 2020).

Table-2:Showing the Enzyme Activities during Vermicompostiong

Parameters	**Day 0**	**Day 15**	**Day 30**	**Day 60**
Dehydrogenase (µ TPF/ g/hr)	18.2±1.2	28.5±1.5	36.8±1.8	45.5±2.0
Ureas (g/hr)	12.5±0.8	20.3±1.2	27.6±1.5	34.0±1.7
Phosphatase (µg PNP/g/hr)	15.6±0.9	24.7±1.3	32.5±1.6	40.5±1.9
Catalase (ml H_2O_2/g/min)	2.1±0.2	3.4±0.3	4.6±0.4	5.8±0.5

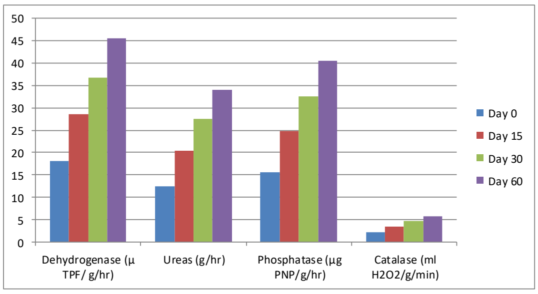

Fig. 2: Showing the Enzyme Activities during Vermicompostiong

Conclusion

The present study clearly demonstrates that vermicomposting is an effective and eco-friendly method for the management of kitchen and agricultural wastes. Significant improvements in physico-chemical properties, enzymatic activities, microbial population, and earthworm growth confirm the efficiency of the vermicomposting process. The reduction in C: N ratio and stabilization of pH indicate the formation of mature and nutrient-rich compost. Among the different treatments, mixed waste (T3) showed superior performance in terms of enzyme activities such as cellulase, β-glucosidase, laccase, and dehydrogenase, suggesting enhanced microbial degradation and organic matter transformation. The increased enzymatic activities reflect improved biological functioning and nutrient cycling within the composting system. Additionally, the growth and reproduction of earthworms highlight favorable environmental conditions and efficient substrate utilization. Vermicompost significantly improved soil fertility by enhancing organic carbon content and essential nutrients such as nitrogen, phosphorus, and potassium. This indicates its potential as a sustainable alternative to chemical fertilizers, contributing to long-term soil health and agricultural productivity. Vermicomposting offers a low-cost, sustainable, and environmentally sound approach for organic waste recycling and soil fertility enhancement. The findings of this study support its wider adoption in regions like Kanpur for promoting sustainable agriculture and effective waste management.

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