Studies on Vermicompost from Kitchen and Agricultural Wastes by Using Selected Earthworm Species (Eisenia Fetida)

Pratibha Srivastava[1] & Atul Kumar Mishra[2]
[1,2] Department of Zoology, D.A-V. College, Kanpur, India

Abstract: The swift accumulation of organic waste from residential and agricultural sources presents considerable environmental concerns, including soil and water pollution, greenhouse gas emissions, and public health hazards. Vermicomposting, an environmentally sustainable waste management method, effectively transforms biodegradable trash into nutrient-dense compost through the activity of earthworms, specifically Eisenia fetida. This study investigates the efficacy of Eisenia fetida in the decomposition of kitchen and agricultural waste, emphasizing its biological efficiency, adaptability, and influence on compost quality. Data were obtained from previously published and peer-reviewed literature acquired via academic platforms like PubMed, Research Gate, and Google Scholar. The review emphasizes that Eisenia fetida is exceptionally successful owing to its rapid reproduction, extensive substrate tolerance, and robust environmental resistance. Enhancing composting effectiveness requires the optimization of circumstances, including moisture content, temperature, pH, and the composition of the feeding substrate. Vermicompost generated under optimal conditions has enhanced physicochemical features, including a balanced pH, an advantageous C:N ratio, and increased concentrations of vital nutrients such as nitrogen, phosphorus, and potassium. The research indicates markedly elevated enzymatic activity in vermicompost relative to conventional compost, facilitating accelerated organic matter decomposition and microbial proliferation. These findings validate vermicomposting as an effective approach for sustainable organic waste recycling and the improvement of soil fertility. The incorporation of this method into agricultural and residential systems can enhance environmental conservation and promote climate-smart agriculture.

Keywords: Vermicomposting, Eisenia fetida, kitchen waste, agricultural waste, organic waste management, compost quality

Introduction

Background and significance of Vermicomposting

1. **Environmental Consequences of Organic Waste Accumulation**

The build up of organic waste presents considerable environmental issues. Improper management of organic waste, including food leftovers, yard clippings, and agricultural residues, can result in several adverse consequences:

Water and Soil Contamination: Unregulated organic waste can leach detrimental compounds into aquatic systems, polluting rivers, lakes, and subterranean aquifers. This runoff can modify the nutritional equilibrium in water, resulting in eutrophication, which diminishes oxygen levels and adversely affects aquatic organisms.

Air Pollution and Greenhouse Gas Emissions: The decomposition of organic waste in landfills produces methane, a powerful greenhouse gas that exacerbates climate change. The Environmental Protection Agency (EPA) indicates that organic waste in landfills accounts for around 18% of the nation's methane emissions (Abubakar *et al.*, 2022).

Land Degradation: The accumulation of organic waste in soil can deplete natural nutrients, diminish cropland quality, and impair agricultural production.

Public Health Hazards: Inadequately handled organic waste can attract vermin and disseminate diseases, presenting health threats to communities, particularly underprivileged populations.

The substantial quantity of organic waste is an increasing concern, with food remnants and yard debris collectively constituting over 28% of municipal solid garbage in some areas (Repsol, 2023).

2. Vermicomposting as an Ecologically Sustainable Waste Management Strategy

Vermicomposting provides an efficient, sustainable solution to mitigate the environmental effects of organic waste.

Biological Conversion: Vermicomposting employs earthworms (e.g., Eisenia fetida) and advantageous bacteria to biologically transform biodegradable trash into nutrient-dense compost, referred to as vermicompost.

Mitigates Landfill Waste: By redirecting organic waste from landfills, vermicomposting substantially decreases the quantity of trash that would otherwise generate methane emissions and leachate (Pareek, 2021).

Enhances Soil Health: Vermicompost is abundant in macro- and micronutrients, advantageous soil microbes, and organic matter, hence improving soil fertility, structure, and water retention. This results in enhanced agricultural productivity and less dependence on synthetic fertilizers.

Enhances Biodiversity: The technique fosters the development of advantageous microorganisms and bolsters a more robust ecosystem in agricultural and garden soils (Bajsa *et al.,* 2004).
Economic and Social Advantages: Vermicomposting is economical, adaptable, and can be executed at the household, community, or commercial scales. This method is acknowledged as a socially responsible waste management strategy that empowers communities and promotes sustainable agriculture (Wormgear, 2023).

Role of Eisenia fetida in vermicomposting

1. Biological Attributes of Eisenia fetida

Eisenia fetida, also referred to as the red wiggler, tiger worm, or manure worm, is a little, reddish-brown earthworm noted for its proficiency in digesting organic material. Essential biological characteristics comprise:

Eisenia fetida is approximately 4–5 cm in length, possesses 80–110 body segments, and features a yellowish tail. Each segment possesses unique rings (setae) that facilitate mobility.
Habitat: It is an epigeic species, residing in the higher strata of soil and organic materials, where decaying material is plentiful.
Eisenia fetida exhibits protandrous hermaphroditism, possessing both male and female reproductive organs. It reproduces swiftly, with adults able to generate a cocoon every three days under ideal conditions. Each cocoon can produce up to four hatchlings, and juveniles reach maturity within 4 to 8 weeks.
Adaptability: The species flourishes across a broad temperature spectrum (0–35°C) and favors humid, dim habitats rich in organic matter. Its durability and adaptability have facilitated its global proliferation, with the exception of Antarctica.
Eisenia fetida ingests a diverse array of organic substances, such as kitchen waste, agricultural byproducts, paper, and cardboard, effectively decomposing them into nutrient-dense compost (Vers, 2025).

2. Appropriateness of Eisenia fetida for Composting Kitchen and Agricultural Residues

Eisenia fetida is regarded as the most efficient earthworm species for vermicomposting kitchen and agricultural waste due to various benefits:
Rapid Decomposition: Its insatiable appetite and elevated metabolic rate facilitate the swift processing of organic waste, transforming it into superior compost more rapidly than other earthworm species.
Eisenia fetida exhibits broad dietary tolerance, accommodating a variety of organic materials such as kitchen refuse, yard debris, agricultural wastes, and some industrial

residues like fly ash, hence demonstrating significant versatility across many waste streams.

Elevated Reproductive Rate: The species' swift reproduction guarantees a steady and growing population, crucial for ongoing waste processing in both small-scale and commercial vermicomposting systems (Das *et al.*, 2022).

Environmental Tolerance: Its capacity to flourish across various temperatures and humidity levels renders it appropriate for diverse climates and applications, ranging from domestic containers to extensive agricultural enterprises.

Enhanced Compost Quality: Vermicompost generated by Eisenia fetida is abundant in macronutrients (nitrogen, phosphorus, calcium, magnesium) and exhibits minimal heavy metal content, rendering it safe and advantageous for agricultural applications. This technique diminishes phytotoxicity, guaranteeing the compost's suitability for plant growth.

Sustainable Waste Management: Eisenia fetida effectively transforms organic waste into usable compost, thereby diminishing landfill utilization, reducing greenhouse gas emissions, and enhancing soil health, which supports sustainable agricultural and environmental practices (Yatoo et al., 2020).

Research Objectives

- Isolation and selection of suitable earthworms for production of vermicompost.
- Optimization of the suitable conditions for the vermicomposting of Kitchen and Agricultural wastes.
- Optimization of the favorite feeding substrate to Eisenia fetida, suitable organic growth promoter for pre-composting, than physicochemical parameters of vermicompost produced and growth of Eisenia fetida during vermicomposting of Kitchen and Agricultural wastes.
- Optimization of the extracellular enzymes activities in the normal compost (R-1) and vermicompost (R-2), microbial populations in the gut of E. fetida, in the normal compost (R-1) and vermicompost (R-2)

Methodology

This study on the vermicomposting of kitchen and agricultural waste utilizing Eisenia fetida is fundamentally grounded in a comprehensive review and synthesis of existing academic literature. Data and scientific insights were methodically collected from credible internet sources, including PubMed, Research Gate, Google Scholar, and several peer-reviewed publications and institutional repositories. A systematic literature search was conducted to locate and extract pertinent publications about vermicomposting techniques, the biology and function of Eisenia fetida, composting substrates, environmental parameters, and physicochemical evaluations of compost quality. Keywords including “vermicomposting,” “Eisenia fetida,” “organic waste management," and "soil fertility" were included in diverse combinations to guarantee a thorough scope. Articles were chosen based on their scientific rigor, relevance, recent publication (ideally within the previous 10–15 years), and data reliability. Particular focus was directed towards research addressing the optimization of composting conditions, earthworm reproductive efficacy, enzyme activity, and nutrient composition of vermicompost. Comparative analyses of traditional composting and vermicomposting (R-1 vs. R-2) were included to elucidate the superior effectiveness of the vermicomposting method. The methodology emphasized secondary data collecting owing to the extensive availability of verified research in the domain and the practicality of doing a meta-analysis-style synthesis. All extracted data were rigorously evaluated and cross-verified to ensure precision and uniformity. This research methodology facilitated a thorough, evidence-based comprehension of the biological, chemical, and ecological mechanisms behind vermicomposting and its prospective application in sustainable waste management strategies.

Result

Selection and Isolation of Appropriate Earthworm Species

Collection and Identification of Earthworm Species Collection Methods:

The optimal technique for gathering earthworms is a combination of excavation and manual sifting of soil. This method facilitates the direct extraction of earthworms from soil blocks, which are subsequently scrutinized for various species. This technique is particularly advantageous for near-surface (epigeic) and horizontal burrowing (endogeic) species, although deeper burrowing (anecic) species may necessitate more profound excavation.

Chemical Expellants: Chemical agents such as formalin, mustard, or allyl isothiocyanate (AITC) may be applied to the soil surface. These irritants infiltrate the soil pores and burrows, prompting earthworms to emerge owing to dermal irritation. This approach is most efficacious for larger earthworm species, while it may be less effective for smaller or young specimens (Andleeb *et al.*, 2021).

Electrical Extraction: The application of an electrical current to the soil can stimulate the emergence of earthworms. This technique is less intrusive to the sample region but necessitates specialized apparatus and is hardly employed (Pelosi *et al.,* 2009).

Methods of Identification:

Morphological Identification: Conventional taxonomy depends on morphological traits, including the shape and placement of the prostomium, segment number, clitellum configuration, arrangement of spermathecae, and patterns of setae. This necessitates knowledge because of the nuanced distinctions across species.

Molecular Identification: DNA-based techniques (e.g., 16S rDNA, 18S rDNA, COI sequences) yield precise species identification but necessitate access to molecular biology laboratories and databases (Andleeb *et al.,* 2021).

Image-Based Identification: Recent advancements encompass machine learning models that categorize earthworm species, including Eisenia fetida, from digital photographs. This method shows potential for swift, non-invasive detection (Andleeb *et al.,* 2021).

Isolation Methods for Eisenia fetida

Separation from Soil or Culture:
Eisenia fetida, generally referred to as the tiger worm, can be harvested from vermicomposting systems or directly from soil utilizing the aforementioned techniques.

Following collection, worms are often placed on moist filter paper for several hours in a depuration process to eliminate gut contents and minimize contamination during subsequent processing.

Cell or Tissue Isolation:
Isolation of Coelomic Fluid/Cells:
Position cleaned worms on damp cotton or filter paper for 2 to 3 hours to facilitate defecation.
Decontaminate the surface of worms with 70% ethanol.
Submerge worms in a cold extrusion buffer for 1–2 minutes; external stress triggers the expulsion of coelomic fluid through dorsal pores.
Obtain the fluid, centrifuge to sediment coelomocytes, and rinse as necessary.

Isolation of Intestinal Cells:
Mature worms are subjected to a 24-hour depuration, sedated, and their guts are excised.
The intestinal tissue is enzymatically degraded using collagenase II to liberate primary cells.
The cell suspension undergoes filtration and centrifugation to extract the cells, which can subsequently be cultivated in suitable media (Riedl *et al.,* 2022).

Extraction of Genomic DNA:
High-quality DNA from Eisenia fetida can be obtained by a modified phenol-chloroform approach (Maniatis procedure), incorporating protein precipitation with potassium acetate and a reduced proteinase K digestion duration. Commercial kits are accessible; nevertheless, they may lead to increased contamination of protein or RNA (S. Yadav, 2015).

Criteria for Appropriateness: Morphological and Biological Evaluation

Choosing an appropriate earthworm species for vermicomposting or research necessitates meticulous morphological and biological evaluation. Species like Eisenia fetida are morphologically characterized by their unique pigmentation (reddish-brown with yellow stripes), clitellum placement, and segment number. The existence of a distinct clitellum, arrangement of setae, and body dimensions are significant distinguishing characteristics. Biologically, suitability is ascertained by the earthworm's reproductive rate, growth efficiency, tolerance to environmental variations, and capacity to process organic matter effectively. Eisenia fetida is preferred for its swift reproduction, extensive adaptability to many organic substrates, and robustness under fluctuating environmental circumstances, rendering it especially efficient for large-scale vermicomposting and laboratory research (Mulla & Pathade, 2021) (Paczka *et al*., 2019).

Acclimatization and Sustenance of Eisenia fetida

Acclimatization is an essential process to guarantee the health and production of Eisenia fetida in novel habitats or substrates. Recently acquired or imported worms should be situated in fresh, damp bedding and permitted to acclimatize for several days prior to the introduction of food waste. This interval enables the worms to acclimate to the physical and chemical characteristics of their new environment, thereby diminishing stress and mortality rates. Research indicates that acclimatized earthworms exhibit elevated reproduction rates and enhanced detoxifying skills relative to unacclimated individuals, particularly when subjected to adverse substrates or pollutants. The ideal maintenance parameters for Eisenia fetida consist of a neutral pH of around 7.0, a moisture content ranging from 80% to 90%, and ambient temperatures between 25°C and 30°C. Consistent monitoring and modification of these factors enhance optimal development, reproduction, and vermicomposting efficacy (Kharbouch *et al*., 2017).

Optimization of Conditions for Vermicomposting

Selection and Characterization of Raw Materials

Optimizing vermicomposting commences with meticulous selection and analysis of source materials. The predominant inputs consist of organic waste, including kitchen remnants and agricultural byproducts. These materials must be assessed for their carbon-to-nitrogen (C:N) ratio, moisture content, pH, and any impurities. The optimal C:N ratio for vermicomposting is approximately 25:1, facilitating effective decomposition and promoting earthworm vitality. Raw materials must be devoid of poisonous compounds, excessive salts, or non-biodegradable pollutants to provide a healthy and conducive environment for earthworms.

Collection and Pre-treatment of Kitchen Waste

Kitchen waste constitutes a useful resource for vermicomposting owing to its elevated organic content and nutrient density. The collection must prioritize the segregation of biodegradable materials, like fruit and vegetable peels, coffee grounds, and eggshells, while excluding meats, dairy, greasy foods, and overly processed goods that may attract pests or adversely affect earthworms. Pre-treatment entails cutting or shredding the waste to enhance surface area and facilitate accelerated decomposition. Certain sources advocate for partial pre-composting or thermophilic treatment to diminish pathogens and weed seeds, stabilize the material, and avert excessive heating that may adversely affect earthworms upon their introduction to the vermicomposting system. The moisture content must be calibrated to 60–80%, and the pH should be neutral to slightly acidic (5–8) to ensure optimal worm activity.

Composition and Preparation of Agricultural Waste

Agricultural byproducts, such as crop residues, straw, husks, and animal manure, are extensively utilized in vermicomposting. These materials differ in nutrient makeup and rates of degradation. To optimize vermicomposting, agricultural waste must be shredded to a particle size of 1–1.8 mm to enhance decomposition efficiency and promote earthworm biomass production. Combining various forms of agricultural waste can facilitate the attainment of the optimal C:N ratio and enhance the overall quality of compost. It is advisable to pre-compost or age manures and fibrous materials to diminish ammonia concentrations and pathogens, hence enhancing their safety for earthworms. Moisture levels must be sustained at 60–80%, and the substrate should remain aerated and devoid of excessive salts or poisonous substances to promote robust earthworm populations and effective composting (R. S. Yadav, 2019).

Environmental Parameters Affecting Vermicomposting

Temperature and Moisture Regulation

Thermal and Humidity Control

Temperature and humidity are essential environmental factors in vermicomposting. The ideal temperature for the majority of earthworm species, particularly Eisenia fetida, lies between 15°C to 27°C, with peak activity noted at approximately 25°C. Temperatures beyond this range can inhibit earthworm metabolism, reproduction, and overall composting efficacy. The moisture content should be optimally sustained between 60% and 80% to maximize microbial and earthworm activity. Moisture levels below 50% might impede earthworm development and diminish decomposition rates, whereas excessive moisture (exceeding 80–90%) can obstruct aeration, result in nutrient leaching, and create anaerobic conditions that generate unpleasant aromas (G.Amaravathi & Reddy, 2015). Consistent monitoring and modification—such as irrigating or altering the substrate—are crucial for sustaining these ideal circumstances (Juárez *et al.*, 2011).

pH Monitoring and Adjustment

The pH of the vermicomposting system markedly affects earthworm vitality and microbial function. Earthworms typically flourish within a pH range of 5 to 8, with neutral to slightly alkaline environments being optimal. In vermicomposting, pH may vary due to the generation of organic acids and the release of CO_2, often decreasing from alkaline to more acidic levels as decomposition advances (Juárez *et al.*, 2011). Consistent pH monitoring is essential; if the substrate becomes excessively acidic, it can be rectified by incorporating substances such as crushed eggshells or agricultural lime to buffer the system and ensure earthworm viability.

Aeration and Bedding Conditions

Proper aeration is essential for aerobic decomposition and earthworm respiration. Earthworms generate natural channels in the substrate, facilitating aeration; nevertheless, the substrate must also be routinely moved to avert compaction and guarantee uniform oxygen distribution (Juárez *et al.*, 2011). Bedding materials like shredded paper, coconut coir, or straw must be loose and thoroughly combined with the organic feedstock to enhance ventilation and moisture retention. Appropriate bedding facilitates earthworm mobility and health while stabilizing temperature and moisture, hence enhancing vermicomposting efficiency (Juárez *et al.*, 2011).

Feeding Substrate and Organic Growth Promoter Optimization

The assessment of feeding substrates is crucial for enhancing vermicomposting with Eisenia fetida. Experiments frequently juxtapose monoculture substrates—such as pure bovine manure, sheep manure, or crop residues—with mixed substrates that amalgamate two or more organic components (Singh *et al.*, 2021). Mixed substrate experiments have employed combinations such as soybean straw with cow dung or rice straw with cow dung in varying ratios to evaluate their effects on worm growth, reproduction, and compost quality. Research demonstrates that mixed substrates can augment nutritional content, optimize the carbon-to-nitrogen ratio, and provide superior worm biomass and reproduction relative to monoculture substrates (Garg *et al.*, 2006). The incorporation of straw with cow dung has been demonstrated to enhance the organic carbon and micronutrient levels in the resultant vermicompost, while concurrently fostering vigorous earthworm populations (Zoundji *et al.,* 2024).

Eisenia fetida demonstrates distinct feeding preferences, favoring substrates abundant in decaying organic matter, moderate moisture levels, and a well-balanced nutritional composition. It flourishes on culinary remnants, coffee grounds, paper, cardboard, eggshells, and other agricultural byproducts, adeptly transforming these into superior compost. Buffalo excreta has demonstrated the highest worm biomass and fecundity among animal manures, followed by combinations of sheep and buffalo, as well as goat and buffalo. These preferences manifest in both worm growth and reproductive rates, with optimal outcomes observed in semi-composted substrates that have received pre-treatment to diminish ammonia and pathogens. The selection of substrate—monoculture or mixed—must be determined by local availability, nutrient equilibrium, and the specific objectives of the vermicomposting endeavor, as Eisenia fetida can acclimate to various organic materials but thrives optimally with substrates that are diverse, well-prepared, and devoid of contaminants (Chaudhari, 2023).

Use of Organic Growth Promoters in Pre-composting

The application of organic growth promoters in pre-composting is a crucial method to improve the efficacy and quality of vermicomposting. Organic additives, including cow dung, jaggery, green trash, straw, wasted mushroom compost, and biochar, are frequently chosen for their capacity to enhance microbial activity, equilibrate the carbon-to-nitrogen (C:N) ratio, and facilitate the decomposition process (Rékási *et al.*, 2023). Cow dung is preferred due to its abundance of beneficial bacteria and nutrients, while jaggery acts as an accessible carbon source that promotes microbial proliferation and expedites the decomposition of organic materials (Ball, 2022).

The influence of these organic additions on the rate of decomposition and nutrient enrichment is substantial. Pre-composting with organic growth promoters facilitates the onset of thermophilic decomposition, elevating the substrate temperature and diminishing pathogens, weed seeds, and volatile ammonia that may adversely affect earthworms. This procedure yields a more uniform and stable substrate with regulated pH and less odor potential, enhancing its safety and appeal for earthworms upon introduction for vermicomposting (Bin Dohaish, 2020). The incorporation of additions such as straw, charcoal, or green trash might enhance aeration, hence facilitating organic matter decomposition and mitigating the potential for heavy metal toxicity in the resultant compost. Ultimately, these approaches result in accelerated decomposition rates, increased nutrient availability (particularly nitrogen, phosphorus, and potassium), and a more biologically active, enriched vermicompost product.

Physicochemical Assessment of Vermicompost:

pH, Electrical Conductivity, Organic Carbon, and Carbon-to-Nitrogen Ratio

The physicochemical analysis of vermicompost includes the assessment of characteristics such as pH, electrical conductivity (EC), organic carbon content, and the carbon-to-nitrogen (C:N) ratio. Vermicompost generated by Eisenia fetida often displays a neutral to slightly alkaline pH, typically between 6.8 and 8.0, which is advantageous for plant development and soil vitality. Electrical conductivity, a measure of soluble salts, is typically greater in vermicompost compared to conventional compost, indicating enhanced mineralization and nutrient accessibility; typical EC values range from 0.5 to 0.8 mS/cm. The organic carbon content in vermicompost is marginally lower than that in uncomposted material due to decomposition; nonetheless, it remains significant, often ranging from 21% to 28%, thereby facilitating the enrichment of soil organic matter. The C:N ratio is a vital measure of compost maturity and quality, with ideal values for vermicompost generally ranging from 12:1 to 18:1, indicating well-stabilized organic matter appropriate for soil addition (Abinaya *et al.*, 2024).

Composition of Macronutrients and Micronutrients

Vermicompost is esteemed for its superior nutrient composition. Macronutrients, including nitrogen (N), phosphorus (P), and potassium (K), are found in greater concentrations than in traditional compost. Nitrogen concentration in vermicompost derived from a combination of organic wastes and cow dung can attain 0.74–0.89%, phosphorus 0.81–0.95%, and potassium 0.68–0.84% Furthermore, vermicompost is high in secondary macronutrients such as calcium (Ca) and magnesium (Mg), and is fortified with micronutrients like zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). These micronutrients frequently exist in greater concentrations than in the original feedstock, enhancing the fertility and biological activity of soils enriched with vermicompost. The enhancement of nutrients is a direct consequence of earthworm activity, which improves mineralization and bioavailability (Kumarı *et al.*, 2022) (SUNDARARASU, 2019).

Evaluation of Earthworm Growth and Biomass

Biomass Accumulation and Cocoon Generation

The evaluation of earthworm growth and biomass is a crucial indicator of vermicomposting efficacy. Eisenia fetida demonstrates considerable biomass accumulation when supplied with nutrient-dense, well prepared substrates. Biomass is generally quantified by periodically weighing earthworms, with a consistent increase signifying advantageous conditions and efficient substrate usage (Khalid *et al.*, 2023). Cocoon production, indicative of reproductive output, is another significant indicator. Under ideal conditions, Eisenia fetida can generate several cocoons, each carrying several juveniles, facilitating rapid population expansion and continuous vermicomposting activity (Medina-Sauza *et al.,* 2019).

Reproductive Efficacy of Eisenia fetida

The reproductive efficiency of Eisenia fetida is assessed by quantifying the number of cocoons generated per worm within a defined timeframe and the rate of hatching success. Optimal reproductive efficiency correlates with substrates that provide balanced nutrition, adequate moisture, and consistent environmental conditions (M. B. Devi, 2017). Research repeatedly demonstrates that blended organic substrates and pre-composted materials improve cocoon development and hatching rates, resulting in vigorous earthworm populations and augmented vermicompost yield. This reproductive vitality is crucial for sustaining uninterrupted vermicomposting cycles and optimizing the transformation of organic waste into nutrient-dense compost (Singh *et al*., 2016).

Enzymatic Activities in R-1 (Standard Compost)

Standard compost (R-1) demonstrates a progressive enhancement in extracellular enzyme activities throughout the composting process. Essential enzymes including cellulase, amylase, invertase, protease, and urease are present, exhibiting maximal activity during the latter phases (usually after 28–35 days) before subsequently reducing as compost matures (Pączka *et al.*, 2020). Amylase and invertase activity progressively rise throughout the initial 21–35 days, indicating vigorous organic matter decomposition and microbial metabolism. The function of these enzymes is intricately connected to the dynamics of microbial populations and the gradual degradation of organic substrates. Nonetheless, the total amplitude of enzyme activity in conventional compost is generally inferior to that in vermicompost, as the process depends exclusively on microbial activity, lacking the synergistic influence of earthworms (S. H. Devi *et al.*, 2009).

Enzymatic Activities in R-2 (Vermicompost)

Vermicompost (R-2), which integrates earthworms with microbes, exhibits markedly elevated extracellular enzyme activity compared to conventional compost. Earthworms augment microbial populations and promote the synthesis of essential enzymes, including cellulase, amylase, invertase, protease, and urease (Pączka *et al*., 2020). Peak enzyme activities occur between 21 and 35 days, with vermicompost exhibiting significantly elevated levels of cellulase, amylase, and protease in comparison to standard compost. This heightened enzymatic activity expedites the breakdown of organic materials, resulting in a swifter and more effective transformation of trash into stable compost. The collaborative relationship between earthworms and bacteria accounts for the improved enzymatic composition of vermicompost (Tiquia, 2002).

Conclusion

The research highlights the considerable potential of vermicomposting as an efficient and environmentally sustainable approach for the management of kitchen and agricultural waste. Utilizing Eisenia fetida, a highly effective and adaptable species of earthworm, organic waste can be swiftly transformed into nutrient-rich vermicompost that improves soil health, increases crop output, and diminishes dependence on chemical fertilizers. The literature review indicates that vermicomposting enhances the physicochemical characteristics of compost, including optimal pH, advantageous C:N ratio, and elevated macro- and micronutrient levels, while also expediting organic matter decomposition through increased enzymatic activity and microbial diversity. Eisenia fetida exhibited substantial growth, reproduction, and survival under many environmental conditions, confirming its appropriateness for both large-scale and domestic composting systems. The incorporation of organic growth enhancers and pre-composting techniques enhanced compost quality and earthworm efficacy. Vermicomposting offers a sustainable, economical, and socially advantageous waste management strategy with extensive applications in agricultural and environmental preservation. Ongoing research and community-based implementation can improve its adoption and substantially contribute to circular economy practices and climate-resilient agriculture.

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