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The Microbiological Aspects of Vermicomposting Organic Waste

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Abstract. Altering natural waste into abundant nutrient-rich vermicompost is an ecologically sound and sustainable method known as vermicomposting. Abiotic factors such as feeding material, bedding material, acidity level, temperature, moisture content, and air circulation affect the process. Various microorganisms and earthworms are the key players in the process. However, earthworms are the primary agents of the process, as they increase the microbial populations by fragmenting and ingesting fresh organic matter. The synergistic relationship between earthworms and bacteria is crucial, although *Eisenia fetida* is the ideal worm for processing various organic wastes such as plant leaf litter, fruit and vegetable waste, animal manure, and municipal solid waste, etc. In short, the literature reviewed showed multiple techniques, including, molecular and culture-dependent analyses, demonstrating that different bacteria are associated with earthworms and organic fertilizers. These bacterial groups include Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes, Planctomycetes, Nitrogen-fixing bacteria, and Ammonifers. Organic fertilizers commonly use Plant Growth Promoting Rhizobacteria (PGPR), which contain plant growth hormones, nitrogen-fixing bacteria, and "Essential nutrients such as nitrogen, phosphorus, and potassium are required for proper growth and development of plants (NPK), and are highly effective in promoting plant growth and development." Therefore, the contribution of PGPR and nitrogen-fixing bacteria like *Azotobacter* in producing organic fertilizers is significant for sustainable agriculture practices. In conclusion, "This fertilizer improves soil fertility, while also suppressing harmful phytopathogens and pathogens, ultimately promoting healthy plant growth."

Keywords: Vermicompost, Earthworm, Bacteria, Organic waste, Organic fertilizer, Nitrogen-fixing bacteria

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Introduction

Solid organic waste management (SOW) is a global challenge, with 38 billion tonnes generated annually from various sources. Its complex composition makes it difficult to manage. SOW management can benefit the environment and the economy by reducing emissions and recovering resources [1]. Even though Vermes is the Latin term for earthworms and vermicomposting (VC), the method's popularity has increased nowadays since a range of organic wastes (OWs) can be handled by it through the employment of different kinds of earthworms. These organic wastes include weeds, animal excrement, food, and agricultural waste [2]. Earthworms can transform organic matter into nutrient-rich castings by consuming it. [3].

Due to poor waste management, there is abundant agricultural waste and animal excrement, which poses a significant health risk to humans and animals. In short, using earthworms is a suitable method for managing OW and producing organic manure [4]. Therefore, studies have shown that it is possible to manage OW by using different species of earthworms to produce worm manure. This potent biofertilizer can be part of sustainable agriculture to reduce artificial fertilizers [5]. Researchers discovered three types of vermi-bacteria from straw and goat waste that can serve as fertilizers and antagonists. These bacteria were identified using molecular technique such as 16S rRNA sequencing. Most bacteria were found to belong to the genera *Bacillus, Pseudomonas,* and *Microbacterium.* Additionally, 49% of them showed antifungal activity against phytopathogenic fungi [6].

Climate change threatens the diverse and complex habitat of soil. Soil microbes play a important role in plant production, nutrient uptake, and ecosystem function while protecting plants from stress [7]. Although, Lyell's idea helped Darwin focus on how worms contribute to creating the earth's surface through their daily activities. Worms help mix the soil and improve nutrient flow in ecosystems [8]. But, inorganic fertilizers (IFs) have been used since the 1950s to provide plants with nutrients quickly. However, their long-term use can be harmful to soil and human health. Livestock manure has long been used, but worm manure is a better alternative because of its high chemical content and the soil-regulating component. It has healthy components like hormones, humic compounds, vitamins, and antioxidants [9]. Finally, this review article discusses the importance of VC in organic waste management for agricultural purposes, focusing on its microbiological aspects.

Vermicomposting

A process where earthworms and microorganisms interact to decompose organic matter, stabilizing it and modifying its properties [10]. Although, the process is an effective way to manage solid organic waste. During the technique, microbes play a crucial role in breaking down complex molecules into simpler compounds with the help of enzymes. In addition, earthworms secrete extracellular polymeric substances that provide nutrients for bacteria to thrive, especially under metal stress [11]. However, the process is a waste management technology that requires a lower price for upkeep and maintenance than alternative approaches. It helps preserve natural balance, safeguards the environment, and creates job possibilities. According to research, this method can clean up soil pollution for recycling organic waste and treating wastewater. It is usually feasible and more eco-friendly than other waste disposal methods [12].

Mechanism of the vermicomposting

By using this method, garbage can be turned into useful items. In order to support microbial communities within the environment, earthworms are essential. They break up and consume fresh organic matter, altering its microbiological structure and physical condition. In the active phase, earthworms look for more recent deposits of undigested waste, which are then broken down by microorganism-produced enzymes. Earthworm castings are rich in minerals and organic debris, but they also provide IFs like ammonium and nitrate that promote plant development [10].

Design of the Vermiculture

Shallow concrete boxes, 0.5 meters high, 0.6 meters wide and 1 meter long, were built inside the house as worm bins, where the worms resided and created compost.

Preparation of the Vermicompost

The goal of the study was to look into the impact of partial fermentation of agricultural residues and animal manure on 11 feed materials. A 20-day fermentation process was used, and the ratio of agricultural residues to animal manure was maintained at 1:2. A variety of substrates, including maize straw, soya beans and grasses, were used to produce the fertilizer, and as a decomposer, *Eisenia fetida* (EF) was employed. The worms were raised in plastic bags that were filled with animal feces and shreds of substrate. Water was sprayed to maintain the ideal humidity levels. Each treatment was provided with a mixture of 3 kg of substrate and 2 kg of dung, and 180 earthworms were added after optimizing moisture levels. The plastic bags were punctured to prevent water accumulation and to keep the worms' food moist [13].

Abiotic Factors Affecting Vermicomposting

This method is dependent on abiotic elements such as temperature, moisture content, acidity, feed material, and bedding material. The feed material is the most important of them to take into account because the physicochemical characteristics of the trash that earthworms eat are vital to the process. These characteristics affect the system's efficiency and must be considered to optimize the process for maximum benefit. Data on abiotic factors and their appropriate range for VC are presented in Table 1. Additionally, a variety of waste materials have been utilized as feedstock for the process, including animal dung, sewage sludge, agricultural waste, and fruit and vegetable waste. However, the right feedstock is necessary for a procedure to be successful [14]. Although, principal component analysis indicated that earthworm distribution positively correlated with pH, moisture, soil texture, and organic carbon content [15].

Table 1

Abiotic factors and their suitable range for vermicomposting [14, 16]

Abiotic Factor	Normal Range
pH	7.5 to 8.0
Moisture	60 to 80%

Temperature	15 to 28 °C.
Stocking density	1.60 kilogram of worms per square meter
C/N ratio	30 or less.
Rate of feeding	1.25 kg feed/kg worm/day

Table 1 displays abiotic factors refer to non-living elements that affect the process of vermicomposting. It is important to ensure that the environmental conditions for vermicomposting fall within their suitable range. This will help to ensure optimal conditions for the worms and microbes involved in the process.

Eco-friendly Earthworms and bacteria associated with vermicomposting

These worms are invertebrates that are members of the phylum Annelida. They are cylindrical, segmented and brownish-black in color, with bilateral symmetry. They have a 3-7 year lifespan and breathe through their moist skin. They can sense light through photoreceptors and are hermaphrodites. During fertilization, two earthworms form a cocoon containing 2-3 young worms [17]. About 3627 species of earthworms live on land around the world. These worms are often called "the farmer's friend" because of the benefits they can bring to agriculture. Earthworms can live in different soil types and comprise 60-80% of the total soil biomass. They can also serve as an indicator of soil health [18]. Based on their habits, earthworm species are divided into three main ecological groups: endogeic, anecic, and epigeic. Epigeic earthworms are most commonly used for VC among these groups. EF, *Eisenia andrei* and *Eudrilus eugeniae* are this group's three most frequently utilized species [19]. Moreover, they facilitate the biological breakdown of organic matter and aid in raising the soil's capacity to retain water. There are many different types of worms, each with its preferred habitat. Table 2 shows a range of ecotypes observed in earthworms, categorized according to their behavioural patterns [20].

Environmentally friendly earthworms are often used to treat waste such as cow dung, rice straw, dry grass clippings, etc. They need certain conditions, such as specific temperatures, humidity and pH levels, to do their job. Still, the chemical analysis confirmed that the nutritional quality of the vermicompost contains all the necessary macro- and micro-nutrients when worm has decomposed these organic wastes [21]. In addition, rice straw and paper waste were studied using earthworms; during the investigation, cow dung was used as a bulking substrate. Also, these wastes were efficiently converted into organic fertilizers. Furthermore, the worm manure has more nutrients and metals but less organic carbon and carbon-nitrogen ratio. Earthworm reproduction and growth are highly dependent on the bulking substrate used [22]. Finally, as bedding, market wastes such as rice straw, cabbage, banana peel, pineapple, and cow dung were used for composting and VC. Though, the process was more effective than regular composting in reducing OW. Composting with cabbage and banana peel produced better nitrogen and potassium levels, while vermicompost made with pineapple and banana peel and *Eudrillus eugeniae* had better absolute phosphorus levels [23]. Table 2 displays that there are various species of earthworms, each exhibiting a preference for a particular habitat type. It is worth noting that the ecological niche occupied by these organisms plays a vital role in determining their distribution and abundance. Understanding the habitat requirements of different earthworm species is crucial in developing effective management strategies for these organisms.

Table 2

Earthworms are alienated into four ecotypes on its behavior [20]

Ecotype	Species
Compost earthworms	*Eisenia fetida, Eisenia andrei and Dendrobaena veneta.*
Epigeic earthworms	*Dendrodrilus rubidus, Lumbricus rubellus, Lumbricus friendi, Eiseniella tetraedra etc.*
Endogeic earthworms	*Apporectodea icterica, Allolobophora chlorotica, Ap. caliginosa, Ap. rosea, etc.*
Anecic earthworms	*Lumbricus terrestris, Ap. longa.*

Association of the bacteria with earthworms and worm manure

Bacteria are microorganisms found in plants and animals with specific associations with particular hosts. Researchers have discovered bacteria in the gut of earthworms, with a consistent and specific association in the nephridia of Lumbricidae earthworms. They found bacteria from four different orders, such as Sphingobacteriales, Burkholderiales, Rhodospirillales, and Rhizobiales, commonly found in the nephridia of basal Crassiclitellata by analyzing 16S RNA sequences [24]. In addition, earthworms depend on microbes to their growth and vice versa. When earthworms eat, they also consume rhizosphere bacteria such as Pseudomonas, Rhizobium, Bacillus, Azospirillum, Azotobacter, etc., which promote plant growth. These bacteria can increase their population in the worm gut and enhance plant growth. *Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes,* and *Planctomycetes* were identified when the bacterial population of organic fertilizer was analyzed using both molecular and culture-dependent techniques. The relationship between earthworms and microbes is complex but essential for both to thrive [25]. Although, analysis of microorganisms in earthworm guts indicated a notable rise in bacteria and actinomycetes compared to the soil [26]. Worm manure has been synthesized from organic materials, including farm-derived components such as cow dung and agricultural residues such as rice and wheat straw. The vermicompost produced by earthworm activity naturally contains cellulose-degrading, phosphate- and zinc-solubilizing bacteria as part of their digestive processes. This integrated approach significantly increases the nutrient content compared to vermicompost produced by earthworm activity alone [27]. However, studying bacterial colonization during cocoon production is important because it significantly affects earthworm fitness. This study looked at the microbiomes of two types of worm cocoons, *Eisenia andrei* and EF. A total of 275 and 176 bacterial species were found in the cocoons, respectively. It was discovered that three symbionts Verminephrobacter, Candidatus Nephrothrix, and Microbacteriaceae – were dominant and transmitted vertically [28]. Table 3 shows the diversity of bacteria linked to various worm species during the VC, including EF, *E. andrei, E. eugeniae, P. excavatus,* and *L. terrestris.*

Table 3

Diversity of bacteria associated with worm manure and earthworms

Earthworm	Name of bacteria	Function	References
E. fetida	*B. subtilis, Staphylococcus hominis, B. thuringiensis*, B. mycoides, etc.	Vermi-bacteria	[29]
E. andrei	*Clostridium, Pseudomonas, Acinetobacter, Anaerobacter,* etc.	Vermi-bacteria	[30]
E. eugeniae	*Clostridium, Aeromonas, Burkholderia, Cellulomonas, Flavobacterium, Aquihabitans, Roseomonas, Rhodobacter.*	Nitrogen cycle. Organic substances.	[31]
P. excavatus	Nitrate-reducing bacteria, nitrifying bacteria, asymbiotic nitrogen-fxing, phosphate solubilizing, and *Azotobacter.*	Phosphate solubilization, Nitrogen-fixing bacteria	[32]
L. terrestris	Verrucomicrobia, actinobacteria, firmicutes, proteobacteria, Acidobacteria, planctomycetes.	Vermi-bacteria.	[33]

Table 3 displays the data about the diversity of bacteria associated with vermicompost and earthworms. This information can be of great significance in environmental science, as it sheds light on the role of earthworms in promoting microbial diversity in soil. The findings presented in this table may be crucial for researchers and practitioners interested in exploring the intricate relationship between soil health and biodiversity.

Fungi associated with vermicomposting

Fungi are crucial for supplying enzymes and being a food source for worms. The earthworm's eating habits can affect fungal populations, but the evidence conflicts regarding the impact on fungal communities. Some worms can survive on fungi only, and the vermicompost they produce has the same or more fungal biomass and diversity than the initial substrates. Earthworms' presence increases fungal biomass, while their absence reduces it [34]. Though, the study also examined the fungal communities in VC treatments and identifies dominant species and potential pathogens. The presence of worms enhances the fungal community, indicating maturity, and worm manure lack pathogenic species, demonstrating their efficacy. Organic fertilizers contain *Streptomyces* spp. with antagonistic properties, but also beneficial fungi such as *Paecilomyces* spp. and *Trichoderma* spp., which caution against their use in agriculture due to reported fungal pathogens in VC products [35]. Although, earthworms are crucial in promoting fungal diversity in vermicompost, which could have significant impacts on agricultural practices and sustainability. Studies indicate that fungi are present in worm manure and earthworms, with some populations identified including *Paecilomyces* spp. and *Trichoderma* spp. Fungal diversity was significantly greater in organic fertilizers than in compost after worm treatment

[33]. However, this study investigated how the fungal community changes during vermiculture and how certain fungal species can transform organic compounds while exhibiting inhibiting qualities against both human and phytopathogens. The researchers used Metabarcoding and the Plating technique to describe the taxonomic structure of the fungal community at different stages of vermiculture. The study found a decrease in fungal species richness in the early stages of vermiculture, followed by a significant increase in species richness in the resulting worm manure [36].

Development in organic waste management to overcome the limitations by using vermicomposting

Vermicomposting of Plant Leaf litter waste

According to a recent study, leaf litter waste can be treated with the white rot fungus, *Oligoporus placenta*, followed by VC with cow dung to reduce its harmful contents significantly. This innovative waste management approach mitigates environmental concerns and generates nutrient-rich biological fertilizers through worm-microbe-induced mineralization. Therefore, it presents promising opportunities for sustainable and eco-friendly practices [37]. In addition, Neem leaves can be converted into valuable organic fertilizer using high-rate VC, which is efficient and productive. This also helps avoid air pollution caused by conventional disposal methods like piling and burning [38]. Although, *Populus nigra* leaf litter was used in both composting and VC. During the study, horse manure was used as a control in composting and VC, but EF was used as the earthworm species. Nitrogen-fixing bacteria were higher in organic fertilizer than in horse manure. Ammonifers, Inorganic nitrogen consumers, and Oligotrophs were present in all treatments. Moreover, *Azotobacter* activity was only observed in worm manure and was absent in compost, however, compared to vermicompost manure, this activity was more substantial in vermicompost leaf litter. This means all these bacteria indicate good organic fertilizer, rich in nitrogen [39].

Vermicomposting of Fruits and Vegetables waste

More than 50% of fruit and vegetables are wasted due to high consumption. A study was conducted to compare two methods of fruit and vegetable waste (FVW) decomposition, with and without worms, to determine their effect on physicochemical properties and microbial profiles. The study showed that decomposing FVW with worms rapidly reduced electrical conductivity and total C and N losses. However, earthworms greatly changed the structure of bacteria and fungi and increased their populations. These results were confirmed by quantitative PCR, gradient gel electrophoresis, and sequence analysis [40]. Though, the study investigated the production of biohydrogen through fermentative processes using a mixture of vermicompost and pre-treated FVW. The study investigated the effect of mild heat pre-treatment, substrate concentration and biological processes on biohydrogen production and biochemical oxygen demand (BOD5) removal. The results showed high levels of BOD5 elimination (50%) and biohydrogen production (63.0 mL/g VS). The experiment provided a suitable environment for the inoculation of microorganisms, particularly *Clostridium* species, and the most prominent

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microbes in the process [41]. The study investigated the effects of worms and the ammonia oxidation during VC of FVW. Two dry systems and one fresh system were compared over 60 days. It was found that earthworms promote the process of ammonia oxidation by increasing both the abundance and diversity of ammonia oxidizing archaea and bacteria [42].

Vermicomposting of Animal manure waste

Overproduction of animal manure needs to be stabilized before it results in health and environmental problems. The study examined how rabbit manure's chemical and microbiological properties changed throughout the course of a continuous operation. The experiment was carried out under precise settings in a controlled setting, including a pH level of 8.3, decreasing to 7.6, and a moisture range of 66% to 76%. Over the course of the 200-day trial, microbial activity measures and phospholipid fatty acid profiles (PLFA) revealed alterations in the microbial population. Bacteria and fungi populations decreased, but there was no change in the electrical conductivity of the profile layers [43]. Though, utilizing the earthworm *E. andrei,* cow manure was utilized in the procedure to track how time affected earthworm biomass as well as the physical, chemical, and biological characteristics of worm manure. There were two stages to the process: a preliminary phase lasting 0-44 days and a final phase lasting 45-120 days. High microbial activity was investigated in the first phase, and the physicochemical alterations in organic fertilizer and a boost in worm density were investigated in the last phase. Finally, high quality organic fertilizer was obtained after 120 days of process. In short, the technique time played a significant part in changing the biological, chemical and physical attributes of the vermicompost [44]. Table 4 presents information on the bacterial diversity of vermicompost made from an assortment of organic waste, including poplar leaf litter, fruits and vegetables, animal manure (cow dung), grass and earthworm *(E. fetida).*

Table 4

Association of different bacteria with vermicompost and *E. fetida*

Organic wastes	Earthworm	Vermicompost associated bacteria	References
Poplar leaf litter	*Eisenia fetida*	*Azotobacter,* Ammonifers, Oligotrophs, Inorganic nitrogen utilizers.	[39]
Fruit and Vegetable	*Eisenia fetida*	*Bacillus reticulotermitis, Sphingobacterium, Pectobacterium carotovorum,* and Actinobacterium.	[40]
Animal manure (Cow dung)	*Eisenia fetida*	Proteobacteria, Bacteroidota, Firmicutes, and Actinobacteria.	[45]
Grass	Eisenia fetida	Actinomycetes, and *Azotobacter*	[46]

Table 4 displays the relationships between organic wastes, the species of VC worm *(E. fetida),* and the bacteria involved in VC. It addresses the advantages of employing EF in the VC process to break down organic materials and the symbiotic relationships that occur, as well as the function of related bacteria in improving the quality of compost.

Benefits of the Vermicomposting

Importance of the vermicompost as a plant growth promoter

Excessive chemical fertilizer usage has harmed soil properties. Organic fertilizer, rich in plant growth-promoting Rhizobacteria (PGPR), was examined alongside worm manure and humic acid effects on basil. Worm manure + PGPR significantly affected height, chlorophyll a, shoot dry weight, shoot wet weight, and essence yield, according to the results, which also showed substantial effects on plant growth. The study applied PGPR via inoculation/non-inoculation, vermicompost through application/non-application, and humic acid via non-application, seed treatment, and foliar application, revealing their combined influence on basil's growth and flavor [47]. On the other hand, when worm manure rich in humic acid was used for plant growth, the density and variety of bacteria and fungi increased. The synergistic role of humic acid-rich vermicompost, *Rhizobium,* and arbuscular mycorrhizal fungi resulted in an increase in total height, fresh weight, and dry weight when compared to chemical fertilizers and control. This enhanced soil enrichment, boosted microbial diversity, and stimulated soil enzyme activity [48]. Furthermore, the usage of chemical fertilizers had detrimental effects on the environment, crop yield, and soil. Organic fertilizer amendment, on the other hand, provides a sustainable method of plant nutrition by enhancing soil fertility and health. The study's main conclusions centered on vermicompost's ability to boost crop yield and guard against biotic stressors like disease and pest assault as well as abiotic stressors like soil salinity and drought [49].

Importance of the vermicompost against phytopathogens and pathogen suppression

Compost and worm manure can provide sustainable sources of nutrients and microbial communities. Through biotic and abiotic variables, these sources can reduce plant illnesses, increase the availability of nutrients in the soil, and encourage plant growth [50]. Moreover, the study tested 16 treatments for mixed organic waste to determine if biochar and microalgal biomass could make vegetable seeds more resistant to phytopathogens. The EF, 6% biochar, and *Navicula* biomass were the most effective treatments, resulting in mature organic fertilizer with a pH of 7, a cation exchange capacity of 70 cmol kg1, and a C: N ratio of 9.5. This product was tested on three vegetable species and found to boost disease resistance in seeds, promote plant growth, reduce the incidence of disease, and increase plant resilience. This treatment also effectively reduced phytopathogens in the worm manure [51]. Decomposing bacteria, vermicompost, and vermiwash work together to combat fungal infections. Worm manure's antifungal properties might stem from bioactive substances found in mucus, skin secretions, and coelomic fluid from earthworms, and metabolites produced by microorganisms that break down organic manure. The coelomic fluid of earthworms, which is naturally protective, inhibits several fungal pathogens. *Bacillus subtilis* in vermicompost produces significant antifungal chemicals, potentially helping plants to resist fungal infections [52]. In short, Arugula vermicompost is an effective way to suppress *Meloidogyne javanica* and reduce its damage to crops. The fertilizer contains a chitinolytic and PGPR detoxification system, making it an environmentally friendly method of controlling root-knot nematodes [53].

Vermicompost's contribution to soil fertility

By increasing important parameters including pH, soil aeration, organic carbon content, and bulk density, organic fertilizers can improve soil quality and promote plant growth. Humic acids, plant growth hormones, and vital minerals like calcium, magnesium, phosphorus, nitrogen, and potassium are all present in it [54]. Earthworms, prevalent in soil, form tubular pathways or caves as they move, enhancing soil porosity by allowing more air and water entry. By lowering bulk density, this enhanced porosity, promotes root development. Rich in Mg and NPK, vermicasts improve soil fertility. Worm castings contain microorganisms whose numbers rise as organic waste breaks down in their gut, promoting nutrient recirculation and microbe growth, facilitating plant growth [55]. Moreover applying these fertilizers as organic amendments improved soil nutritional status, increased cation exchange capacity, microbial activities, microbial biomass carbon and enzymatic activities [56]. Finally, animal waste contains nutrients that can be used to make fertilizers that are rich in nutrients. These fertilizers have an impact on the electrical conductivity, and pH of the soil, as well as plant development when applied to crops. By enhancing the soil's capacity to retain water, drain, and allow air to flow through, organic fertilizer helps to improve the soil. This results in better conditions for plant growth [57].

Conclusions

Vermicomposting, which involves the use of earthworms, bacteria, archaea, and fungi, is an exceptional solution for managing organic waste. This process not only promotes environmental benefits but also provides an effective way to recycle nutrients. When it comes to vermicomposting, two earthworm species, *Eisenia fetida* and *Eisenia andrei,* are widely preferred due to their ability to produce essential bio-nutrients. In fact, over 50% of trials rely on these species for their remarkable nutrient production capabilities. Recent studies have delved into the bacterial community found in worm castings and earthworms, using both molecular and culture-dependent methods. These studies have revealed the presence of various beneficial bacteria, including rhizobacteria that promote plant growth, phosphate solubilizers, vermi bacteria, and nitrogen-fixing bacteria such as Azotobacter. These bacteria play a crucial role in enhancing the quality of vermicompost. One of the key advantages of vermicompost is that it makes essential elements like nitrogen, phosphorus, and potassium more readily available to plants. This availability of vital nutrients ensures that plants receive the nourishment they need for strong and healthy growth. Consequently, vermicompost offers growers and farmers a highly efficient means of producing the highest quality fertilizer, leading to robust crop yields.

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Conflict of interests

The authors declare that they have no conflict of interest.

Authors contribution

Khan I.: contributed as the author and editor of the review article.
Kurovsky A.: contributed as the general supervisor of the article.
Babenko A.: worked as a consultant in the field of Eisenia fetida and earthworm.
Kornievskaya E.: worked as the data curator for the review article.

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Органикалық қалдықтарды вермикомпосттаудың микробиологиялық аспектілері

Аңдатпа. Табиғи қалдықтарды қоректік заттарға бай вермикомпостқа айналдыру вермикомпосттау деп аталатын экологиялық таза және тұрақты әдіспен жүзеге асырылады. Бұл процеске, мысалы, тамақ субстратының түрі, төсеме материалы, pH, температура, ылғалдылық және қоршаған ортаның аэрация дәрежесі сияқты абиотикалық факторлар әсер етеді. Вермикомпостингте шешуші рөлді жауын құрттары атқарады, олар басқалармен қатар әртүрлі микроорганизмдердің өмір сүруіне жағдай жасайды. Жауын құрттары мен бактериялар арасындағы синергетикалық қатынастар ерекше маңызды. Бұл *Eisenia fetida* түрлеріне де қатысты, ол әлемдегі әртүрлі органикалық қалдықтарды мысалы, өсімдік жапырағының қоқысы, жемістер мен көкөністердің қалдықтары, жануарлардың көңі, тұрмыстық қатты қалдықтар және т.б. өңдеу үшін ең көп қолданылады. Тұтастай алғанда, бұл шолу әртүрлі сәйкестендіру әдістерінің, соның ішінде молекулалық-генетикалық және селективті орта әдісінің әртүрлі бактериялардың жауын құрттарымен және органикалық субстраттармен байланысын көрсететінін көрсетті. Жалпы, бұл шолу әртүрлі сәйкестендіру әдістерінің, соның ішінде молекулалық-генетикалық және селективті орта әдісінің әртүрлі бактериялардың жауын құрттарымен және органикалық субстраттармен байланысын көрсететінін көрсетті. Бактериялардың бұл топтарына протеобактериялар, актинобактериялар, фирмикуттар, бактероидтар, планктомицеттер, азотты бекітетін бактериялар және аммонификаторлар жатады. Органикалық тыңайтқыштарда әдетте өсімдіктердің өсуіне ықпал ететін (PGPR) ризобактериялар, субстраттарда өсімдіктердің өсу гормондары, азотты бекітетін бактериялар және өсімдіктердің дұрыс өсуі мен дамуы үшін қажет азот, фосфор және калий сияқты қоректік заттар болады. Бұл үйлесім өсімдіктердің өсуі мен дамуын ынталандыруда өте тиімді. Осылайша, PGPR және *Azotobacter* сияқты азотты бекітетін бактериялардың органикалық тыңайтқыштар өндірісіне қосқан үлесі тұрақты ауылшаруашылық тәжірибелері үшін өте маңызды. Вермикомпост тыңайтқыш ретінде топырақтың құнарлылығын жақсартады, сонымен қатар фитопатогендерді тежейді, нәтижесінде өсімдіктердің сау өсуіне ықпал етеді.

Түйін сөздер: Вермикомпост, жауын құрттары, бактериялар, органикалық қалдықтар, органикалық тыңайтқыш, азотты бекітетін бактериялар

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Микробиологические аспекты вермикомпостирования органических отходов

Аннотация. Преобразование природных отходов в богатый питательными веществами вермикомпост осуществляется экологически безопасным и устойчивым методом, известным как вермикомпостирование. На данный процесс влияют абиотические факторы, такие, как вид пищевого субстрата, вид базового субстрата, pH, температура, влажность и степень аэрации среды. Ключевую роль в вермикомпостировании играют дождевые черви, которые также создают условия для жизнедеятельности различных микроорганизмов. Особенно важное значение принадлежит синергическим отношениям между дождевыми червями и бактериям. Это справедливо и в отношении вида *Eisenia fetida,* который является самым широко используемым в мире для переработки различных органических отходов, таких, как опад из листьев растений, отходы фруктов и овощей, навоз животных, твердые бытовые отходы и т.д. В целом данный обзор показал, что множество методов идентификации, в том числе молекулярно-генетический и метод селективных сред, демонстрируют связь различных бактерий с дождевыми червями и органическими субстратами. К этим группам бактерий относятся Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes, Planctomycetes, азотфиксирующие бактерии и аммонификаторы. В органических удобрениях обычно присутствуют ризобактерии, способствующие росту растений (PGPR), субстраты также содержат гормоны роста растений, азотфиксирующие бактерии и питательные вещества, такие, как азот, фосфор и калий, необходимые для правильного роста и развития растений. Это сочетание является очень эффективным в стимулировании роста и развития растений. Таким образом, вклад PGPR и азотфиксирующих бактерий, таких, как *Azotobacter,* в производство органических удобрений имеет важное значение для устойчивых методов ведения сельского хозяйства. Вермикомпост как биоудобрение улучшает плодородие почвы, а также подавляет фитопатогены, в конечном итоге способствуя здоровому росту растений.

Ключевые слова: вермикомпост, дождевые черви, бактерии, органические отходы. органическое удобрение, азотфиксирующие бактерии

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