OPEN ACCESS

Middle East Research Journal of Agriculture and Food Science
ISSN: 2789-7729 (Print) & ISSN: 2958-2105 (Online)
Frequency: Bi-Monthly
DOI: 10.36348/merjafs.2024.v04i02.006

KUWAIT SCHOLARS PUBLISHER
Website: http://www.kspublisher.com/
Email: office@kspublisher.com

Advancing Agricultural Sustainability: Vermicomposting as a Biochemical Pathway for Improved Soil Health and Climate Resilience

Guta Amante[1*]
[1]Ethiopian Institute of Agricultural Research, Teppi Agricultural Research Center, P.O. box 34, Teppi, Ethiopia

Abstract: This comprehensive review explores the multifaceted role of vermicomposting in sustainable agriculture, emphasizing its biochemical processes and impact on soil systems. Beginning with the concept, the document delves into the intricacies of the vermicomposting process, including the selection of suitable earthworm species for vermiculture. It further examines the biochemical transformations that occur during vermicomposting, such as the optimization of the carbon to nitrogen ratio, alterations in organic carbon content, and the modulation of soil pH and electrical conductivity. The accumulation of heavy metals and the transformation of nitrogen and phosphorus are also discussed, alongside the process of humification. Subsequently, the profound effects of vermicompost on soil properties, highlighting its influence on physical characteristics, organic matter content, mineralization, and nutrient dynamics, as well as the enhancement of humus content was deeply reviewed. The document also investigates the implications of vermicomposting on plant growth and yield, providing insights into its potential to increase agricultural productivity. Additionally, the review addresses the impact of vermicomposting on greenhouse gas emissions, underscoring its significance in the context of climate-smart farming practices. Arising from detailed synthesis of the findings, vermicomposting is a pivotal component of climate-resilient agriculture, offering a pathway to healthier soil ecosystems and a sustainable future.

Keywords: Earthworms, Eisenia Fetida, Humification, Nitrogen, Vermicomposting.

Review Paper

***Corresponding Author:**
Guta Amante
Ethiopian Institute of Agricultural Research, Teppi Agricultural Research Center, P.O. box 34, Teppi, Ethiopia

How to cite this paper:
Guta Amante (2024). Advancing Agricultural Sustainability: Vermicomposting as a Biochemical Pathway for Improved Soil Health and Climate Resilience. *Middle East Res J. Agri Food Sci.*, *4*(2): 86-94.

Article History:
| Submit: 16.03.2024 |
| Accepted: 17.04.2024 |
| Published: 18.04.2024 |

1. INTRODUCTION

Earthworms are used in the biochemical process of vermicomposting, which produces a substance called vermicompost that looks like humus from organic waste. Earthworms sustain aerobic conditions during the vermicomposting process when temperature and moisture levels are ideal. They consume organic waste materials and excrete a humus-like substance that is more homogenous than the organic wastes or raw materials used (Sharma and Garg, 2018). The earthworms are involved in this process through both physical and biological pathways. While enzymatic digestion, nitrogen enrichment, and the movement of both organic and inorganic elements are examples of biochemical activities, fragmentation, turnover, and aeration are examples of physical actions. Vermicomposting is a basic biotechnological composting method that uses specific earthworm species to improve waste conversion and yield a higher-quality final product (Gandhi *et al.*, 1997). Earthworms are frequently described as nature's ploughmen and farmers' companions. Because they eat organic waste, break it up, and mix it thoroughly with mineral particles to produce aggregates, earthworms play a crucial role in the creation of soil. Earthworms speed up the decomposition of organic materials and the stability of soil aggregates by significantly increasing microbial activity during feeding. It has been thoroughly demonstrated that some earthworm species are capable of consuming a broad variety of organic leftovers, including sewage sludge, animal feces, crop residues, and industrial wastes. When earthworms feed, they break up the waste substrate, which increases microbial activity and speeds up the material's breakdown. This process is known as composting or humification, and it oxidizes and stabilizes unstable organic materials.

Thus, the aim of this review was to consolidate efforts made by many scholars over various countries on vermicomposting process and role regarding nutrient cycling. It was also intended to explore major scientific findings on the effect of vermicompost on preventing nutrient loss and reducing greenhouses gases emission during the process of composting and after application to agricultural soils. Web of science and google scholar were used to search peer-reviewed journal from highly indexed by using keywords, vermicomposting and/or nutrient dynamics/ transformation.

2. Vermicomposting

2.1. Composting Process

Vermicomposting (VC) is a biological process wherein organic wastes are transformed into a humus-like substance called vermicompost by earthworms. Earthworms maintain aerobic conditions in the vermicomposting process, consume organic waste materials, and expel a humus-like substance that is more homogeneous than the organic wastes or raw materials employed, if the temperature and moisture levels are favorable (Lazcano *et al*., 2009). In this process, the earthworms' actions are both biological and physical. While the biochemical processes include enzymatic digestion, nitrogen enrichment, and the movement of both organic and inorganic components, the physical actions include fragmentation, turnover, and aeration. During this process, important plant nutrients such as nitrogen, potassium, and phosphorus present in the waste materials are converted through microbial action into chemical forms that are more soluble and available to plants than those in the original substrate. This could be because the digestive tracts of earthworms include a variety of enzymes, such as proteases, lipases, amylases, cellulases, chitinases, and others, which break down the proteinaceous and cellulose components of organic waste (Pramanik *et al*., 2007). Earthworms and the microbes they eat for the purpose of breaking down the organic stuff in their meal are mutually beneficial.

Various steps of waste degradation by earthworms are as follows.

- Ingestion of organic waste material
- Softening of organic waste material by the saliva in the mouth of the earthworms
- Softening of organic waste and neutralization by calcium (excreted by the inner walls of the esophagus) and passed on to the gizzard for further action in the esophagus of the worm body
- Grinding of waste into small particles in the muscular gizzard
- Digestion of organic waste by a proteolytic enzyme in stomach
- Decomposition of pulped waste material components by various enzymes including proteases, lipases, amylases, cellulases, and chitinases secreted in intestine and then absorbing the digested material in the epithelium of intestine
- Excretion of undigested food material from worm castings

2.2. Species of Earthworms Suitable for Vermiculture

It has been determined that six different species of earthworms may be the most beneficial in decomposing organic waste. These are from temperate regions: Eudrilus eugeniae, Perionyx excavatus, and Perionyx hawayana; from the tropics: Dendrobaena veneta, Lumbricus rubellus, and E. fetida (and the closely related Eisenia andrei) (Edwards 2004). Though these are the most prevalent, other species can also be utilized. These species' growth, survival, mortality, and reproduction have all been thoroughly investigated in the lab using a variety of organic wastes, such as activated sewage sludge, potatoes, cattle, ducks, turkeys, chickens, and pigs. Although all of the tested species were able to grow and survive in a variety of different organic wastes, some were significantly more prolific, others grew more quickly, and still others quickly reached a large biomass. These characteristics all contributed in different ways to the practical usefulness of the earthworms in making vermicomposts or serving as a source of protein for animal feed. Nonetheless, these earthworms' biology and ecology varied greatly amongst their species.

3. Biochemical Changes during Vermicomposting Process

3.1. Carbon to Nitrogen Ratio of Substrates

Ratio of carbon to nitrogen is one of major determinants of quality assurance while selecting material in vermicomposting process. Carbon-to-nitrogen (C/N) ratio plays a major role during the vermicomposting process where the correct ratio provides nutrition for the earthworms and it is essential for microbial activity and multiplication (Jiang *et al*., 2011). Normally C/N ratio tends to decrease due to the decomposition of organic materials and reduction of organic carbon. The reduction of organic carbon during vermicomposting is mainly attributed to the respiratory activity of microorganisms and earthworms with a synchronized increase in nitrogen added through the mucus and nitrogenous excretion by the worms (Boruah *et al*., 2019). The C/N ratio is one of the most widely used indices for maturity of organic wastes and it decreases in the substrate with time. The loss of carbon as carbon dioxide in the process of respiration and production of mucus and nitrogenous excrements enhance the level of nitrogen, which lower the C/N ratios. Vermicompost process will progress properly by starting the process with a C: N ratio around 25-30 and it will decrease during the process. Carbon reduces because heterotrophic bacteria use organic material as source of electron and carbon is oxidized to CO_2 and releases to atmosphere.

We can conclude that vermicomposting can lead to mineralization process which reduced C by N ratio of vermicompost. Majlessi *et al*., (2012) stated that vermicomposting process due to the depletion of easily degradable carbon compounds and C losses as CO_2 as a result of involved activity of earthworms which modify wastes physically and feces excreted by worms can increase the activity of the microorganisms so that the rate of mineralization to be faster(kumar *et al*., 2017).

3.2. Organic Carbon

The digestion of carbohydrates and other polysaccharides from the substrates by earthworms may cause carbon reduction during vermicomposting of organic wastes (Suthar, 2010). Some part of organic carbon may be converted to worm biomass through the assimilation process, which consequently reduces the carbon budget of waste substrate used. Furthermore, losses in organic carbon decrease in pH (Yadav and Garg, 2011), mineralization of the organic matter containing proteins and conversation of ammonium nitrogen into nitrate may be responsible for increasing nitrogen fraction in vermicompost (Atiyeh *et al.,* 2000). The combined action of earthworms and microorganisms was the main reason for more total organic carbon loss from raw manure as relative to the raw material (Lv *et al*., 2016).

3.3. pH and EC

Vermicomposting significantly modified the physical and chemical properties of raw substrates. The pH was obviously lower in final vermicompost as compared to the initial manure. This might be ascribed to the generation of organic acids from microbial metabolism during decomposition of raw substrates (Lv, *et al*., 2016). Moreover, the nitrification could decrease the pH as well. On the contrary, to pH, EC of vermicompost increase as it becomes matured. The release of soluble salts, such as phosphate, ammonium and nitrate could contribute to the increase of EC (Lazcano *et al*., 2008). It should be noted that vermicompost had higher EC than worm unnoculated waste, which indicating that more available mineral salts are accumulated in vermicompost by organic matter degradation.

3.4. Heavy Metals Accumulation

Earthworm species involved in vermicomposting species such as E. fetida and are capable of accumulating a number of essential and nonessential heavy metals in waste(Mohee and Soobhany, 2014). Earthworm ingests large amount of substrates and are therefore exposed to heavy metals through their skin and intestine. They concentrate heavy metals in their body from the substrates (Mupondi *et al*., 2018, Morgan and Morgan, 1999) due to this reason; vermicomposting can be used in the toxic metals removal and breakdown of complex chemicals to non-toxic forms. Heavy metals absorption in the vermicompost decreased with increasing composting time (Shahmansouri *et al*., 2005). Vermicompost can be used effectively as a natural absorbent for heavy metal accumulation. Mohee and Soobhany (2014), have reported decrease in total heavy metals content in the vermicompost earthworms(*E.fetida)* accumulate higher concentration of heavy metals during vermicomposting of sewage sludge. Singh *et al*., (2011) reported that there is a risk of heavy metals in compost whereas in vermicompost, heavy metals are removed and accumulated within worm bodies. Even though carbon losses, through mineralization increased the total amount of heavy metals in a vermicomposting system, the amounts of bio available heavy metals is decreased significantly. Earthworms have been considered as important bio-accumulators of environmental contamination of persistent pollutants like heavy metals (Goswami *et al*., 2016). A protein called metallothionein, which plays a critical role in regulation of heavy metal ion chemistry within cells, has been reported to be produced within the gut of earthworms upon exposure to heavy metals (Goswami *et al*., 2016; Usmani *et al*., 2017).

3.5. Nitrogen Transformation

Earthworms had a great impact on nitrogen transformations in the manure, by enhancing nitrogen mineralization, so that mineral nitrogen was retained in the nitrate form. The net total nitrogen, in all treatments and times, decreased; losses being more marked during the final stages when earthworm activity was higher (Lv, *et al*, 2016).. The different nitrogen fractions followed trends similar to the total nitrogen. During the final stages of the process, when the earthworm population was bigger and more active, important reductions in organic nitrogen content and a high nitrification rate were noted. This suggests that worm involved in produced conditions in the manure that favored nitrification, resulting in the rapid conversion of ammonium-nitrogen into nitrates(Atiyeh *et al.*, 2000). Similar results were reported by Hand *et al*., (1988) who found that *Eisenia fetida* in cow slurry increased the nitrate-nitrogen content of the substrate. Different bioavailable forms of nitrogen, such as NH_4^+, NO_3^-, and readily mineralizable forms, appeared to be more commonly found in the earthworm-treated series. This behavior was mainly ascribed to elevated concentrations of nitrogen-fixing bacteria as well as increased microbiological activity in the vermicomposted samples (Bhattacharya and Chattopadhyay, 2004).

3.6. Phosphorus Transformation

Vermicomposting increases phosphorus bioavailability, microorganisms, and earthworms; including organic acid production, which solubilizes inorganic P (Pramanik *et al*., 2007, Scervino, *et al*., 2010). Saha *et al*., (2008) showed that phosphatases was helpful on faster transformation of organic P by using of earthworm casts in soil. Earthworms have a marked impact on P mineralization and are able to increase the availability of P for plants because of their efficient digestive system, while they excrete nutrients through intestinal and cutaneous mucus (Busato *et al*., 2012). Consequently, earthworms enhance the rate of organic matter transformation and promote high microbiological diversity and activity (Fracchia *et al*., 2006). Organic matter modifies supplement soil phosphatase activity. Phosphorus available forms are important for plant production. Earthworm and microorganisms were helpful, changed mineralization P of organic forms that transform P from non-available, organically bound forms, into bioavailable phosphate ions (Mupondi *et al*., 2018, Nuntawut *et al*., 2013). Accordingly, the degradation of organic wastes by earthworm and microorganism were helpful on the amount and quality of the humic acid (Pramanik *et al*., 2007). After earthworm and microorganism activity. Vermicomposting can be proficient technology for transformation of unavailable forms of phosphorus to easily available forms for plants. The organic wastes passing through the gut of worm was produced phosphatase and it was released of P may be microorganisms in casts (Nuntawut *et al*., 2013).

3.7. Humification during Vermicomposting

Organic wastes, to be compatible with their agricultural uses and to avoid adverse effects on plant growth, must be transformed into a humus-like material and become stabilized. In this case, decreases in the carbon from fulvic acids and increases in the percentages of the carbon from humic acids were observed throughout the vermicomposting process, and this was also much more marked at the end of the process, so clearly earthworm activity accelerates humification of organic matter. Moreover, during Vermicomposting, the humic materials increased from 40 to 60 percent, which was more than the values obtained in a composting process using the same materials (Dominguez and Edwards, 2004). Humification processes are enhanced not only by the fragmentation and size reduction of the organic matter, but also by the greatly increased microbial activity within the intestines of the earthworms and by aeration of the soil through earthworm movement and feeding (Sharma and Garg, 2018. As evidenced by the high ammonium concentration in mucus, the earthworms' mucus caused the substrate with low organic content to humify (Bityutskii *et al*., 2012). Substrates containing mucus had greater rates of mineralization and humification than the controls. This suggests that vermicomposting systems with high organic content benefit from the mucus (Sharma and Garg, 2018.

4. Effect of Vermicompost on Soil Properties

4.1. Influence on Physical Properties of Soil

Soil chemical properties such as pH, electrical conductivity, organic matter and nutrient status improved significantly and led to better plant growth and yield owing to vermicompost application (Lim *et al*., 2015). It imparts positive impact on physiochemical properties of soil. It helps to improve soil aggregation, stability, pH, EC, bulk density, water holding capacity (WHC), organic matter (OM), micro and macronutrients. VC increases soil structural stability thus reducing the vulnerability of soil to calamities like erosion. VC amendment reduces large aggregate formation in soil thus increasing aggregate stability in all aggregate size fractions. This can be explained by that organic matter application may have caused changes in the exchange complex that resulted in breakdown of larger fractions (Aksakal *et al*., 2016). Correspondingly, (Doan *et al*., 2015) reported reduction on leaching and runoff at highest quantity by vermicompost compared to control (Piya *et al*., 2018). Soil WHC also increases with amendment of VC. This is because VC has high WHC and increases porosity when mixed with soil making pore spaces available for storing water. Also this is related to a higher proportion of hydrophilic/hydrophobic groups of the humic substances (Manh and Wang, 2014).

4.2. Organic Matter Content

Earthworm ingested soils often have much higher content of soil organic carbon and nutrients availability as compared to surrounding soils. Maheswarappa, (1999) reported that vermicompost addition in soil enhanced organic carbon status, decreased bulk density, improved soil porosities and water holding capacities, increased microbial populations and dehydrogenase activity in the soils. Organic matter content in worm casts was about four times more than in surface soil with average values of 48.2 and 11.9 g kg-1 soil, respectively (Lee, 1985). Earthworms' casting contains a high percentage of humus. Humus helps in aggregation of soil particles resulting into better porosity, which in turn improve aeration and water holding capacity of the soils. Moreover, humic acid present in humus provides binding sites for the several plant nutrients viz. calcium, iron, potassium, sulphur and phosphorus. These nutrients are stored in the humic acid in the form readily available nutrients and are released when the plants require them (Adhikary 2012). It is justified that amendment of VC and its extract on soil increases organic carbon percentage compared to chemical fertilizer which rather reduces it. This is because chemical fertilizers do not contain carbon whereas organic content of VC is slowly released into soil making it plant available (Piya *et al.*, 2018).

4.3. Vermicomposting and Soil Mineralization

Mineralization is the process by which chemicals present in organic matter are decomposed or oxidized into easily available forms to plants. Transformation of organic molecules in soil is mainly driven by its microbiota such as fungi and bacteria along with earthworms (Doran, 2002) Earthworm activity decrease the organic matter and carbon by fragmenting the organic matter. Mesophilic temperature during vermicomposting favors the heterotrophic and heterogeneous microbial population, which enhances mineralization through metabolization of carbon compounds like soluble sugars, organic acids, and so on. Mixing organic matter, mineral particles, and microorganisms creates new contact surfaces for the bacteria and enhances the mineralization process (Lim and Wu, 2016). The burrowing activities of earthworms not only enhance the decomposition process but also form humus and facilitate the cycling of nutrients. However, it is food quality and other soil properties that decide its nutrient fate and mineralization after the addition of vermicompost in soil.

During the mineralization, nitrogen is converted to inorganic forms (NH_4, NO_2, and NO_3) by three reactions: aminization, ammonification, and nitrification. These reactions are regulated by dissolved organic nitrogen and ammonium, the activity of the microorganisms, and their requirements for carbon and nitrogen. Earthworms also have a great impact on nitrogen transformations during vermicomposting through modifications of the environmental conditions and interacting with microbes. Earthworms enhance nitrogen mineralization, thereby producing conditions in the organic wastes that favor nitrification, resulting in the rapid conversion of ammonium-nitrogen into nitrates (Edwards *et al.,* 2004). Hence, presence of ammonium and nitrate ions in vermicompost and compost sample has been considered as an index of maturity.

Vermicompost as a soil amendment builds up soil organic carbon that helps in slow release of nutrients in the soil and enables plants to absorb available nutrients. Decreased C/N ratios in soil with an increasing application dose of vermicomposts indicate a higher mineralization rate ensuing the availability of a considerable extent of micronutrients (Ansari and Sukhraj, 2010).Vermicompost amendment increased the formation of enzymes immobilized in soils' humic matrix, which prolongs any increase in soil enzymatic activities and plant cover.

4.4. Vermicomposting and Soil Nutrient Dynamics

Nutrient availability increased in the soils that were fertilized with vermicompost as compared to those fertilized with animal manure and chemical fertilizers. Manivannan *et al*., (2009) reported that the macro- and microelements were significantly increased in soil treated with vermicompost. Similarly, Doan *et al*., (2013) showed that application of vermicompost increased the mineralizable nitrogen and available phosphorus content in the soil. In fact, vermicomposts can be extremely rich in available nutrients depending on the parent material, allowing not only an instantaneous supply of plant nutrients but also increasing reserves for future crops.

Arancon *et al*., (2005) reported higher amounts of nitrate and orthophosphates, and higher microbial biomass nitrogen in soils treated with cattle manure vermicompost than soils treated with inorganic fertilizers only. Soil nutrients like NPK increased with an increasing dose of vermicompost as fertilizer. The large surface area of vermicompost offers many sites for microbial activities, which ultimately lead to strong retention of nutrients and provide strong absorption capacity.

Table 1: Nutrient concentration in the vermicompost

Nutrient	Content
Organic carbon	9.15 - 17.98 %
Total nitrogen	1.5 - 2.10 %
Total phosphorus	1.0 - 1.50 %
Total potassium	0.60 %
Ca and Mg	22.67 - 47.60 meq/100g
Available S	128 - 548 ppm
Copper	2 - 9.5 ppm
Iron	2 – 9.30 ppm
Zinc	5.70 – 11.5 ppm

Source: Online: http://agritech.tnau.ac.in/org_farm/orgfarm_vermicompost;http://www.hillagric.ac.in/edu/coa/agronomy/lect/agron-3610/Lecture-10-BINM

4.5. Humus Content

Vermicompost contains considerable amounts of humic acid and plant-growth hormones such as auxins, gibberellins, and cytokinins. Vermicompost may contain 17-36% of humic acid and 13%-30% fulvic acid of the total concentration of organic matter (Krishnamoorty and Vajrabhiah, 1986). Humification is the natural process of changing organic matter into humic substances (humus, humate, humic acid, fulvic acid, and humin) by geo-microbiological mechanisms. With the infinite variety of plant materials that exist in nature and with the infinite access to chemical radicals, humification produces humic substances that are infinitely variable.

Soil humic substances are quantitatively and qualitatively the most important components of soil organic matter affecting the health and productivity of soil. To analyze the maturity and stability of the composting process, humic fraction is a reliable parameter (Zbytniewski and Buszewski, 2005). These substances play a vital role in the carbon cycle and soil mineralization, and act as source of nutrition for plants, providing a more available form of nutrients. Vermicomposting accelerates the humification of organic matter and increased it by 40-60% as compared to the natural composting process. This is mainly due to acceleration of microbial activity in earthworm gut and by aeration of the soil through earthworm movement and feeding. Humic acid content in vermicompost was found to be 28% higher than normal compost, because earthworms fragment the soil more rapidly; hence-finer particles react and retain humic acid in a high amount (Sharma and Garg, 2018.

5. Effects on Plants Growth and Yield

Earthworms mineralize the nitrogen (N) and phosphorus (P) and all essential organic & inorganic elements in the compost to make it bio-available to plants as nutrients. They recycle nitrogen in soil in very short time ranging from 20 to 200 kg N $ha^{-1}year^{-1}$ and increase nitrogen contents by over 85%. The report from (Sinha *et al*., 2010) emphasized that the soil with living worms contained higher level of nitrate nitrogen (N), compared with the controlled soil which had only very low nitrate. Vermicompost contain enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil (to release the nutrients and make it available to the plant roots) even after they have been excreted. They also increases the levels of some important soil enzymes like dehydrogenase, acid and alkaline phosphatases and urease. Urease play a key role in N-cycle as it hydrolyses urea and phosphatase bio convert soil phosphorus into bio-available form for plants (Chaoui *et al*., 2003).

Vermicompost affects the plant growth through improving soil structure and converting the nutrients (nitrate, available phosphorus, potassium, calcium, and magnesium) in a form that can be readily taken up by the plants. Hence, vermicompost application positively improves the plant production (growth, yield, and quality of different plants) relative to conventional chemical fertilization (Sharma and Garg, 2018).

Basically, vermicompost influences plant growth by two mechanisms, direct and indirect.

Table 2: Direct and indirect effects of vermicompost on plants

Direct-mechanism	Indirect-mechanism
- Providing micro and macro nutrients - Altering soil properties - Increase humic substances - Acting as source of hormone - Enhancing microbes' population - Stimulation of microbial activity	- Plant disease suppression - Increase biological resistance - Increase availability of nutrients - Enhancing microbes' population decrease insect pest, mites, nematodes etc

Direct influence of vermicompost includes a source of plant macro- and micronutrients causing changes in the physical properties of soil such as bulk density, water holding capacity, total porosity, conditioning root growth, providing plant growth regulating hormones, and initiating microbe population (Aksakal, *et al*., 2016). One of the most outstanding properties of vermicompost that makes it an excellent plant growth promoter is that it acts as a slow releaser of nutrients.

Vermicompost also has a positive influence on vegetative growth, stimulating shoot growth and root development (Edwards *et al.*, 2004). The other positive influence of vermicompost application include alterations in morphology of crop plants such as increased leaf area and root branching and stimulated flowering, increase in the number and biomass of flowers (Lazcano *et al.*, 2009). Vermicompost application consistently improved seed germination, enhanced seedling growth and increased plant productivity significantly. Application of vermicompost gave higher germination (93%), growth and yield of mungbean (*Vigna radiate* L.) in comparison with no addition of vermicompost (84%) (Nagavallemma *et al*., 2004).

6. Effect on Greenhouse Gases (GHGs) Emission

Thermophilic composting has a few disadvantages, including increased greenhouse gas emissions. High microbial activity during the composting process's active phase raises temperature and oxygen consumption, which in turn raises the creation of CH_4 (Nigussie *et al*., 2016).

The same author demonstrated that, regardless of substrate quality (i.e., C:N ratio, moisture content, and existence of a labile C pool), vermicomposting lowers overall N loss, CH4, and N_2O emissions when compared with thermophilic composting methods. Increased earthworm abundance speeds up the decomposition process and lowers CH_4 emissions. The findings from Nigussie *et al*., (2016) demonstrated that vermicomposting significantly reduced nitrogen loss by 10–20% compared to thermophilic composting, decreased nitrous oxide emissions by 25–36%, and decreased methane emissions by 22-26%, despite the fact that it highly depends on earthworm density, quality of substrate used, and moisture level. Compared to non-earthworm treatments, vermicomposting increased total cumulative CO_2 emissions by about 30%. A faster rate of biodegradation and stabilization is indicated by higher total cumulative CO_2 emissions (Chan *et al*., 2011).

Earthworms maintain aerobic conditions during vermicomposting by continuously moving organic debris, which improves air circulation. Second, through their interactions with related bacteria, earthworms have an impact on nitrification, denitrification, mineralization, and N cycling (Lazcano *et al*., 2008). Third, because ammonia emissions rise with temperature, vermicomposting is a mesophilic process (< 30 °C), suggesting that ammonia volatilization is less likely to occur (Nigussie *et al*., 2016). Vermicomposting reduces the quantity of CO_2 released into the environment by absorbing and storing atmospheric CO_2 in the soil (Panda *et al*., 2022).

The results presented by Robin *et al*., (2011) demonstrated that an increase in manure intake led to an increase in CO_2 emissions. However, treatments which involves earthworms showed reductions in nitrous oxide and ammonia emissions as well as a methane sink, indicating that earthworm abundance might be used to deter the production of greenhouse gases. Because of the earthworms' burrowing activity, the vermicomposting system's decreased nitrous oxide emissions were likely balanced by a decrease in anaerobic denitrification (Chan *et al*., 2011).

7. CONCLUSION

Vermicomposting is a biotechnological process in which earthworms convert the organic wastes into humus-like material known as vermicompost. Processes and changes take place various biochemical during these non-thermophilic composting. Vermicomposting is also an ecofriendly ways of converting different household, industrial and urban wastes into valuable organic fertilizer. During these bioconversion earthworms have ability to accumulate high heavy metal in wastes and degrade them in their gut by help of enzyme they produce, reduces C: N ratio of substrates. Vermicompost has high essential elements in plant available forms. Vermocompost imparts positive impact on physiochemical properties of soil. It helps to improve soil aggregation, stability, pH, EC, bulk density, water holding capacity, organic matter, micro and macronutrients and thus positively affect plant growth and yield. Various evidence were reviewed from environmental researchers that vermicomposting process reduce rate of greenhouse gases emission, which is drawbacks of conventional composting and making vermicomposting the best options for climate smart farming. Most of papers investigate process and effect of vermicomposting in controlled and specific areas. Further future works should better focus on how earthworms affect nutrient dynamics within their natural soil.

REFERENCES

- Adhikary, S. (2012). Vermicompost, the story of organic gold: A review. *Agricultural Sciences*, *3*(7), 905-917.
- Aksakal, E. L., Sari, S., & Angin, I. (2016). Effects of vermicompost application on soil aggregation and certain physical properties. *Land degradation & development*, *27*(4), 983-995.
- Ansari, A. A., & Kumar, S. (2010). Effect of vermiwash and vermicompost on soil parameters and productivity of okra (Abelmoschus esculentus) in Guyana. Current Advances in Agricultural Sciences. *An International Journal*, *2*(1), 1-4.
- Arancon, N. Q., Edwards, C. A., Bierman, P., Metzger, J. D., & Lucht, C. (2005). Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia*, *49*(4), 297-306.
- Atiyeh, R. M., Domínguez, J., Subler, S., & Edwards, C. A. (2000). Changes in biochemical properties of cow manure during processing by earthworms (Eisenia andrei, Bouché) and the effects on seedling growth. *Pedobiologia*, *44*(6), 709-724.
- Bhattacharya, S. S., & Chattopadhyay, G. N. (2004). Transformation of nitrogen during vermicomposting of fly ash. *Waste Management and Research*, *22*(6), 488-491.
- Bityutskii, N. P., Maiorov, E. I., & Orlova, N. E. (2012). The priming effects induced by earthworm mucus on mineralization and humification of plant residues. *European Journal of Soil Biology*, 50, 1-6.
- Boruah, T., Barman, A., Kalita, P., Lahkar, J., & Deka, H. (2019). Vermicomposting of citronella bagasse and paper mill sludge mixture employing Eisenia fetida. *Bioresource technology*, *294*, 122147.
- Busato, J. G., Lima, L. S., Aguiar, N. O., Canellas, L. P., & Olivares, F. L. (2012). Changes in labile phosphorus forms during maturation of vermicompost enriched with phosphorus solubilizing and diazotrophic bacteria. *Bioresource technology*, *110*, 390-395.
- Chan, Y. C., Sinha, R. K., & Wang, W. (2011). Emission of greenhouse gases from home aerobic composting, anaerobic digestion and vermicomposting of household wastes in Brisbane (Australia). *Waste Management & Research*, *29*(5), 540-548.
- Chaoui, H. I., Zibilske, L. M., & Ohno, T. (2003). Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. *Soil Biology and Biochemistry*, *35*(2), 295-302.
- Doan, T. T., Ngo, P. T., Rumpel, C., Van Nguyen, B., & Jouquet, P. (2013). Interactions between compost, vermicompost and earthworms influence plant growth and yield: A one-year greenhouse experiment. *Scientia Horticulturae*, *160*, 148-154.
- Dominguez, J., & Edwards, C. A. (2004). *Vermicomposting organic wastes: A review. Soil zoology for sustainable development in the 21st century*, Cairo, 369-395.
- Dominguez, J., Edwards, C. A., & Subler, S. (1997). A comparison of vermicomposting and composting. *Biocycle*, *38*, 57-59.
- Doran, J. W. (2002). Soil health and global sustainability: translating science into practice. *Agriculture, ecosystems & environment*, *88*(2), 119-127.
- Edwards, C. A. Ed. (2004). Earthworm Ecology (2nd Edition). CRC Press, Boca Raton, FL, London, New York, Washington. 448 pp.
- Edwards, C. A., & Arancon, N. Q. (2005, November). *The science of vermiculture: the use of earthworms in organic waste management*. In Vermi technologies for developing countries.

Proceedings of the international symposium–workshop on vermi technologies for developing countries, Philippine Fisheries Association Inc, Los Baños, Laguna, Philippines (pp. 16-18).

- Edwards, C. A., Dominguez, J., & Aranconl, N. Q. (2004). 18. The Influence Ofvermicomposts on Plant Growth and Pest Incidence. *Soil Zoology for Sustainable Development in the 21st Century*; Hanna, HSH, Mikhail, WZA, Eds.
- Fracchia, L., Dohrmann, A. B., Martinotti, M. G., & Tebbe, C. C. (2006). Bacterial diversity in a finished compost and vermicompost: differences revealed by cultivation-independent analyses of PCR-amplified 16S rRNA genes. *Applied microbiology and biotechnology, 71*, 942-952.
- Gandhi, M. (1997). Composting of household wastes with and without earthworms. *Environment and ecology, 15*, 432-434.
- Goswami, L., Pratihar, S., Dasgupta, S., Bhattacharyya, P., Mudoi, P., Bora, J., & Kim, K. H. (2016). Exploring metal detoxification and accumulation potential during vermicomposting of Tea factory coal ash: sequential extraction and fluorescence probe analysis. *Scientific reports, 6*(1), 30402.
- Hand, P., Hayes, W. A., Frankland, J. C., & Satchell, J. E. (1988) Vermicomposting of cow slurry. *Pedobiologia 31*, 199–209.
- Jiang, T., Schuchardt, F., Li, G., Guo, R., & Zhao, Y. (2011). Effect of C/N ratio, aeration rate and moisture content on ammonia and greenhouse gas emission during the composting. *Journal of Environmental Sciences, 23*(10), 1754-1760.
- Krishnamoorthy, R. V., & Vajranabhaiah, S. N. (1986). Biological activity of earthworm casts: an assessment of plant growth promotor levels in the casts. Proceedings: *Animal Sciences, 95*, 341-351.
- Kumar, A. N. A. N. D., Gupta, R. K., & Kumar, S. U. R. E. S. H. (2017). Variation in organic carbon content and carbon nitrogen ratio in vermicompost as affected by substrate Straw. *Forage Res, 43*(1), 46-49.
- Lazcano, C., Arnold, J., Zaller, J. G., Martín, J. D., & Salgado, A. T. (2009). Compost and vermicompost as nursery pot components: effects on tomato plant growth and morphology. *Spanish journal of agricultural research, 4*, 944-951.
- Lazcano, C., Gómez-Brandón, M., & Domínguez, J. (2008). Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure. *Chemosphere, 72*, 1013–1019.
- Lee, K. E. (1985). *Earthworms, their Ecology and Relationships with Land Use*. Academic Press, Sydney, pp. 411.
- Lim, S. L., & Wu, T. Y. (2016). Characterization of matured vermicompost derived from valorization of palm oil mill byproduct. *Journal of agricultural and food chemistry, 64*(8), 1761-1769.
- Lim, S. L., Wu, T. Y., Lim, P. N., & Shak, K. P. Y. (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. *Journal of the Science of Food and Agriculture, 95*(6), 1143-1156.
- Lv, B., Xing, M., & Yang, J. (2016). Speciation and transformation of heavy metals during vermicomposting of animal manure. *Bioresource Technology, 209*, 397-401.
- Maheswarappa, H. P., Nanjappa, H. V., & Hegde, M. R. (1999). *Influence of organic manures on yield of arrowroot*, soil physico-chemical and biological properties when grown as intercrop in coconut garden.
- Majlessi, M., Eslami, A., Najafi Saleh, H., Mirshafieean, S., & Babaii, S. (2012). Vermicomposting of food waste: assessing the stability and maturity. *Iranian journal of environmental health science & engineering, 9*, 1-6.
- Manh, V. H., & Wang, C. H. (2014). Vermicompost as an important component in substrate: effects on seedling quality and growth of muskmelon (Cucumis melo L.). *APCBEE procedia, 8*, 32-40.
- Manivannan, S., Balamurugan, M., Parthasarathi, K., Gunasekaran, G., & Ranganathan, L. S. (2009). Effect of vermicompost on soil fertility and crop productivity-beans (Phaseolus vulgaris). *Journal of environmental biology, 30*(2), 275-281.
- Mohee, R., & Soobhany, N. (2014). Comparison of heavy metals content in compost against vermicompost of organic solid waste: Past and present. Resources, *Conservation and Recycling, 92*, 206-213.
- Morgan, J. E., & Morgan, A. J. (1999). The accumulation of metals (Cd, Cu, Pb, Zn and Ca) by two ecologically contrasting earthworm species (Lumbricus rubellus and Aporrectodea caliginosa): implications for ecotoxicological testing. *Applied Soil Ecology, 13*(1), 9-20.
- Mupondi, L. T., Mnkeni, P. N. S., Muchaonyerwa, P., & Mupambwa, H. A. (2018). Vermicomposting manure-paper mixture with igneous rock phosphate enhances biodegradation, phosphorus bioavailability and reduces heavy metal concentrations. *Heliyon, 4*(8).
- Nagavallemma, K. P., Wani, S. P., Lacroix, S., Padmaja, V. V., Vineela, C., Rao, M. B., & Sahrawat, K. L. (2004). Vermicomposting: Recycling wastes into valuable organic fertilizer. *Global Theme on Agroecosystems Report no*. 8.
- Nigussie, A., Kuyper, T. W., Bruun, S., & de Neergaard, A. (2016). Vermicomposting as a technology for reducing nitrogen losses and greenhouse gas emissions from small-scale composting. *Journal of cleaner production, 139*, 429-439.

- Nuntawut, C. N., Chuleemas, B. I., Mongkon, & Taoun., S. S. (2013). The Change of Phosphorus Form in Vermicompost Using Cassava Pulp. *International Journal of Environmental and Rural Development, 4*(1), 81-87.
- Panda, A. K., Mishra, R., Dutta, J., Wani, Z. A., Pant, S., Siddiqui, S., & Bisht, S. S. (2022). Impact of Vermicomposting on greenhouse gas emission: a short review. *Sustainability*, *14*(18), 11306.
- Piya, S., Shrestha, I., Gauchan, D. P., & Lamichhane, J. (2018). Vermicomposting in organic Agriculture: Influence on the soil nutrients and plant growth. *International Journal of Research, 5*(20), 1055-1063.
- Pramanik, P., Ghosh, G. K., Ghosal, P. K., & Banik, P. (2007). Changes in organic–C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants. *Bioresource technology, 98*(13), 2485-2494.
- Robin, P., Germain, P., Lecomte, M., Landrain, B., Li, Y., & Cluzeau, D. (2011). Earthworm effects on gaseous emissions during vermifiltration of pig fresh slurry. *Bioresource technology, 102*(4), 3679-3686.
- Saha, S., Mina, B. L., Gopinath, K. A., Kundu, S., & Gupta, H. S. (2008). Relative changes in phosphatase activities as influenced by source and application rate of organic composts in field crops. *Bioresource technology, 99*(6), 1750-1757.
- Scervino, J. M., Mesa, M. P., Della Mónica, I., Recchi, M., Sarmiento Moreno, N., & Godeas, A. (2010). Soil fungal isolates produce different organic acid patterns involved in phosphate salts solubilization. *Biology and fertility of soils, 46*, 755-763.
- Shahmansouri, M. R., Pourmoghadas, H., Parvaresh, A. R., & Alidadi, H. (2005). Heavy metals bioaccumulation by Iranian and Australian earthworms (Eisenia fetida) in the sewage sludge vermicomposting. *Journal of Environmental Health Science & Engineering, 2*(1), 28-32.
- Sharma, K., & Garg, V. K. (2018). Solid-state fermentation for vermicomposting: A step toward sustainable and healthy soil. *In Current developments in biotechnology and bioengineering* (pp. 373-413). Elsevier.
- Singh, R. P., Singh, P., Araujo, A. S., Ibrahim, M. H., & Sulaiman, O. (2011). Management of urban solid waste: Vermicomposting a sustainable option. Resources, *conservation and recycling, 55*(7), 719-729.
- Sinha, R. K., Agarwal, S., Chauhan, K., & Valani, D. (2010). The wonders of earthworms & its vermicompost in farm production: Charles Darwin's 'friends of farmers', with potential to replace destructive chemical fertilizers. *Agricultural sciences, 1*(02), 76.
- Suthar, S. (2010). Pilot-scale vermireactors for sewage sludge stabilization and metal remediation process: comparison with small-scale vermireactors. *Ecological engineering, 36*(5), 703-712.
- Usmani, Z., Kumar, V., & Mritunjay, S. K. (2017). Vermicomposting of coal fly ash using epigeic and epi-endogeic earthworm species: nutrient dynamics and metal remediation. *RSC advances, 7*(9), 4876-4890.
- Yadav, A., & Garg, V. K. (2011). Recycling of organic wastes by employing Eisenia fetida. *Bioresource technology, 102*(3), 2874-2880.
- Zbytniewski, R., & Buszewski, B. (2005). Characterization of natural organic matter (NOM) derived from sewage sludge compost. Part 1: chemical and spectroscopic properties. *Bioresource technology, 96*(4), 471-478.