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Additives To Improve Composting: A Review

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Abstract

Organic amendments, which can be used as potting media or soil conditioner, can be transformed from organic waste through the sustainable techniques of composting and vermicomposting. This review aims to provide an overview of the main characteristics of composting and vermicomposting processes with and without additives, and to assess the influence of additives on greenhouse gas emissions during waste degradation, as well as the effects of additives on the properties of the final products. The potential environmental benefits and feasibility of co-composting and co-vermicomposting are also reviewed. It found that the composting process can be impacted by additives affecting parameters such as temperature, pH and moisture. The availability of nutrients for plants appears to be increased by the use of worms and additives. Optimisation of co-composting and co-vermicomposting strategies should be locally implemented, involving the generated amendments in a circular economy, in order to improve the sustainability of agricultural systems.

1. Introduction

Organic waste can be recycled and transformed into a nutrient-rich fertiliser or soil conditioner through composting and vermicomposting. These amendments can be used to increase soil carbon stocks and associated ecosystem services, or as potting media. Compost application has the potential to improve soil structure, reduce erosion and increase water retention capacity (Peltre et al. 2012, Lashermes et al. 2009, Francou et al. 2005 [25, 35]). However, the production of compost is linked to the emission of GHGs such as NO2, CH4 or CO2, which can contribute to global warming. Additionally, immature composts can have a negative impact on plant germination and growth, as well as cause environmental issues such as water pollution and odour emissions [43].

Composting is a type of aerobic decomposition which can be done on a large scale in piles or windrows, or on a smaller scale with a home composter [20]. Manures, green waste, and municipal solid waste and their components are processed by composting [16], and vermicomposting, which involves the use of worms, is also employed for similar purposes [13].

Various materials may be included in the composting process, either organic, biological or a combination of both. The different additives used during composting and vermicomposting and their effect on the main composting parameters and on the quality of the end product in terms of their effect on soil functions and plant growth are presented in this article. Recommendations with regard to additive use during composting and vermicomposting are given. Perspectives and feasibility of using additives during both processes are discussed. The composting process can be improved by the addition of additives, which can reduce leaching [39] and gas emissions, improve aeration, accelerate the decomposition of organic matter, and increase the nutrient content and availability of the final product [41]. The effect of additives on vermicomposting has been evaluated by few studies.

The purpose of this article is to provide an overview of the various additives used in composting and vermicomposting, and to assess their impact on the main composting parameters and the quality of the end product. Additionally, this review will provide recommendations for the use of additives during composting and vermicomposting, as well as discuss the potential and practicality of using additives in both processes.

2. Biological degradation processes and additives used for organic waste treatment

2.1 The composting process

Composting is a process of breaking down organic matter into a nutrient-rich soil amendment. It typically involves three distinct phases: initial activation, thermophilic, and maturation. During the initial activation phase, microorganisms are activated to begin breaking down the organic matter. This is followed by the thermophilic phase, where the temperature of the compost pile rises due to the activity of the microorganisms. Finally, during the maturation phase, the compost pile cools and the micro organisms finish breaking down the organic matter into a nutrient-rich soil amendment. The initial activation of composting typically lasts for 1-3 days, during which microbial communities break down simple organic compounds such as sugars, releasing CO_2, NH_3, organic acids and heat [4]. During this period, the temperature of the composting pile rises. After this, the thermophilic phase begins, during which the temperature reaches its peak. Composting requires a specific temperature range of 40-65°C in order to kill pathogens [8] and allow thermophilic microorganisms to break down fats, cellulose and lignin [4]. As the composting process progresses, the temperature gradually decreases due to reduced microbial activity, resulting in a mesophilic phase or maturation. This is due to the decrease of biodegradable compounds. Throughout the composting process, different microbial communities are present depending on the temperature of the compost pile. Fungi cannot survive in temperatures above 60°C, as bacteria become the dominant organisms in these conditions [22].

Composting produces biogenic carbon dioxide (CO_2) from the aerobic decomposition of organic matter and the oxidation of methane (CH_4) by aerobic methanotrophic bacteria. During the initial and thermophilic phases, CH_4 emissions are more prominent, while nitrous oxide (N_2O) and ammonia (NH_3) emissions may occur throughout the process [4]. NH_3 emissions tend to decrease as the easily degradable materials are used up and the rate of degradation slows down during first 2 weeks.

The success of the composting process and the quality and maturity of the compost are determined by several factors that affect microbial activity. These include the initial pH and carbon to nitrogen ratio of the feedstock, their particle size and distribution, as well as the aeration and moisture content of the compost pile. The temperature of a compost pile is affected by the ingredients used to create it, the amount of air that is circulated through it, the moisture content of the compost, and any additional materials that are added to it. All of these factors can influence the temperature profile of the composting process. The Carbon to Nitrogen ratio of the composted material, the maximum temperature achieved during the composting process, and the aeration of the pile all influence the duration, quality, and maturity of the compost, as well as its sanitisation [7]. Additionally, CO_2 and NH_3 emissions are produced during the thermophilic stage of organic matter degradation. The presence of anaerobic zones can lead to N_2O and CH_4 emissions [33].

Controlling the parameters of composting and adding additives can significantly affect the quality of the compost (maturity, nutrient content, and bioavailability) as well as the environmental impacts of composting, such as the production of greenhouse gases and other volatile compounds like ammonia, sulphur-containing compounds, and volatile organic compounds [31].

2.2 The vermicomposting process

Vermicomposting is a process that involves the use of worms to break down organic matter into compost. The temperature range for vermicomposting is typically between 25 and 37 °C, depending on the species of worm used. The most commonly used worms for vermicomposting are two tropical species (Eudrilus eugeniae and Perionyx excavatus) and two temperate species (Eisenia andrei and Eisenia fetida) [24, 36]. These worms are classified as epigeic worms, meaning they mainly feed on fresh organic matter such as litter, manure and compost. They are popular for vermicomposting due to their high rate of consumption, digestion and assimilation of organic matter, their ability to adapt to a wide range of environmental factors, their short life cycles, high reproductive rates and their endurance and resistance during handling [9].

Vermicomposting, like composting, produces greenhouse gases. The activity of worms speeds up and improves the breakdown of organic matter, resulting in higher carbon dioxide emissions than regular composting [34. The emissions of nitrous oxide may be either higher or lower than those from composting, depending on the type of material being decomposed.

For vermicomposting, it is important to control parameters such as temperature, moisture content, and decomposition rate in order to ensure the quality of the end product, minimize GHG emissions, and prevent worm mortality [27, 40]. When it comes to vermicomposting, the parameters can be adjusted by adding mineral, organic or biological substrates. However, it is important to consider the potential negative effects these additives may have on the worms before making a decision [29].

2.3 Types and sources of additives used

Additives can be used to improve composting and vermicomposting processes and the quality of the final product [4]. These additives can be divided into three categories: mineral, organic, and biological. Mineral additives include things like limestone, gypsum, and rock phosphate. Organic additives include things like manure, straw, and sawdust. Biological additives include things like bacteria, fungi, and enzymes.

Biological additives are microorganisms that are added to compost or vermicompost piles. These microorganisms are usually taken from composts during the thermophilic stage, grown in a laboratory and then sold as a commercial product [30]. Examples of such commercial additives include Effective Microbes and Vertical Transmitter Bacteria. Commercial microbiological additives typically contain Alcaligenes, Bacillus, Clostridium, Enterococcus and Lactobacillus microorganisms.

Organic additives include a wide range of materials, such as straw, compost, green waste compost screenings, grass clippings, crushed hardwood, wood pallet fragments, corn stalks, and bark [10]. When selecting organic additives for composting, it is important to consider the Carbon to Nitrogen (C/N) ratio of the initial mixtures. This will ensure that organic matter is broken down properly and that Nitrogen is not lost through leaching. Biochar, a byproduct of pyrolysis, has recently gained attention as a highly stable organic additive for composting and vermicomposting. Its high aromaticity and stability when added to soil make it an effective tool for carbon sequestration, helping to reduce the effects of climate change [26].

The main inorganic or mineral additives used are lime, clays, and industrial by-products such as red mud and fly ash. Red mud is a residue created during the industrial production of alumina [42] and Fly ash is a by-product of burning coal that is used to reduce the amount of pollutants released into the atmosphere. The main benefits of alkaline materials are their abundance and affordability, as they are often sourced from industrial waste [15].

3 Effects of additives

Composting involves the use of microbial communities to break down organic matter. The microbial community can be altered by adding inoculums, organic materials, or minerals which can affect the aeration, temperature, moisture content, pH, and nutrient availability of the compost.

3.1 Effects on temperature profiles

The temperature profile is an important factor to consider when assessing the removal of pathogens through composting [14, 18]. The presence of additives such as minerals, organic materials, and biological agents can stimulate microbial activity, resulting in an earlier start and a longer duration of the thermophilic phase compared to regular composting. The addition of commercial products containing zeolite, kaolinite, chalk, ashes and sulfates or biochar during biowaste and food waste composting extended the thermophilic phase from two to three weeks, thus reducing the overall composting time [19]. Compost stability was achieved in a relatively short period of time (50-60 days) when biochar was added [44]. Temperature increases were observed when biochar, zeolite, jaggery and polyethylene glycol were added to compost made from animal manure, food waste and green waste. The same temperature profiles were seen when biological or organic additives were used [30]. The faster temperature rise with the addition of certain additives may be attributed to an increase in microbial biomass and activity. However, the temperature profile remains unchanged when additives such as bentonite, phosphogypsum and lime are added [12], indicating that they do not have an effect on microbial biomass.

3.2 To stimulate microbial activity Additives used

The addition of additives to compost piles can have a significant impact on the microbial communities present [11]. This is because the additives can affect the temperature, moisture and aeration of the pile, due to their nutrient and carbon content. For instance, the addition of jaggery has been shown to increase the number of microorganisms present, thus improving the rate of enzymatic degradation of cellulose in green waste composting [12]. The porous structure of biochar may provide a beneficial habitat for microbial activity, as well as protection from grazers. Additionally, biochar can help to regulate moisture and aeration levels, which can have an effect on compost temperature and thus promote microbial activity [44]. It is not advised to use a biochar application rate higher than 20%, as this could prevent the breakdown of organic matter. Alkaline substrates such as fly ash and lime have high nutrient contents, but their high pH does not promote microbial activity [28, 47].

3.3 To improve aeration Additives used

To promote microbial activity during composting, it is necessary to increase aeration. This can be done by mechanically turning the composted material [7, 30]and introducing air through pipes. Too little aeration can lead to anaerobic conditions, while too much can cause excessive cooling, preventing thermophilic conditions. Due to worm activity, These actions are not necessary in the case of vermicomposting. The use of bulking agents such as biochar, residual straws, woodchips, sawdust and crushed branches can reduce the costs of pile turning or forced aeration. These agents increase the natural aeration and porosity of the composting pile by creating numerous pores and having a low moisture content [23]. This helps to form inter- and intraparticle voids. The addition of Biochar can also enhance the aeration of compost due to its porous nature [44].

3.4 Additives to regulate moisture content

The optimal water content for organic matter biodegradation is between 50-70%, which is the ratio of the weight of water to the weight of the material in wet basis [37]. This optimal moisture content during composting affects the oxygen uptake rate and microbial activity, thus decreasing the compost maturation time. Organic wastes can have varying levels of moisture content, for ex. sewage sludge having a particularly high moisture content of 80-90% [21]. This high humidity can lead to anaerobic conditions and odour production during composting. To counteract this, fibrous materials are often used as bulking agents to absorb some of the leachate. Furthermore, The addition of sawdust to the soil increased its water absorption capacity, which in turn increased the rate of degradation due to increased air flow through the particles [10, 32]. Adding materials with high water retention properties, such as clays, to the composting process can help reduce water loss during the early stages, which can otherwise delay the composting process and require additional water sprinkling. During the composting of green wastes, the addition of ash also increased the ability of the material to retain water [2]. Adding eggshells to soil had no effect on its ability to retain water [38], and may even have a detrimental effect on its biological activity.

3.5 Additives to buffer pH

The pH of composting materials decreases during the early stages and increases during the later stages, which affects microbial activity. To improve the composting of acidic feedstocks, such as food waste, additives can be used to raise the pH [46]. For example, the addition of an inoculum consortium has been shown to increase the pH of food waste composting from 4.3 to 6.3, likely due to the degradation of acids and organic matter through increased biological activity. The addition of bulking agents such as bagasse, paper, peanut shell, and sawdust to composting may increase the pH, similar to the addition of fly ash, lime, or red mud [12]. However, these alkaline additives may inhibit the metabolic activity of the compost.

The addition of bamboo charcoal or zeolite to the thermophilic phase helped to balance the increase in pH that would have otherwise occurred due to the breakdown of organic nitrogen into ammonia. These additives have the ability to absorb the ammonia, thus preventing the pH from rising [45]. A lower pH may also reduce the amount of nitrogen lost through ammonia volatilisation, which is more likely to occur at higher pH levels.

4. Conclusion

In conclusion, the use of additives during composting and vermicomposting can have a significant impact on the quality of the end product, as well as the environmental impacts of the process. Additives can be used to improve aeration, regulate moisture content, and buffer pH levels. Additionally, they can be used to stimulate microbial activity and reduce the duration of the composting process. However, it is important to consider the potential negative effects of additives before using them. Optimisation of co-composting and co-vermicomposting strategies should be locally implemented, involving the generated amendments in a circular economy, in order to improve the sustainability of agricultural systems.

Further studies are needed to complete the information on the effects of additives:

- The use of additives during composting can result in end products with varying properties, which can have different effects on soil properties. To ensure an ecologically sound application, further research is needed to determine the relationship between the properties of co-composts, soil parameters, and their effects on plant growth, depending on the species. This will help to improve soil health while avoiding any potential environmental risks.
- The cost-effectiveness of the system can be improved by taking into account the quality and quantity of the additives. Research should be conducted to create a cost-effective system based on co-composting or co-vermicomposting. Vermicomposting is more economical than composting and the final products are usually of higher quality. Therefore, it is important to evaluate the environmental impact of vermicomposting systems after adding organic, mineral or biological materials.
- Ultimately, transformation processes should be tailored to each region, taking into account the availability of organic wastes and additives, as well as the local soil and climate conditions.

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