Role of Microorganisms in Composting and Factors affecting the Process

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ABSTRACT

Composting, the microbial decomposition of biodegradable materials, plays a crucial role in recycling organic waste and producing nutrient-rich soil amendments. In this article, we discussed about microbial communities during composting, exploring their diversity, dynamics, factors affecting composting and impact of compost on crop yield. By understanding the interactions between microorganisms and organic matter, we can optimize composting processes for sustainable agriculture.

INTRODUCTION

One of the main problems of agriculture is the loss of soil fertility, this generates a reduction in crop yield, mainly due to the loss of ecosystem functions of soil microorganisms. Soil comprises a highly dynamic reservoir of biodiversity, in which microorganisms, animals, and plants interact, sustaining the biodiversity of ecosystems. Biodiversity stabilizes ecosystems functioning under fluctuating environmental conditions, therefore, increases ecosystem resilience and productivity under extreme environmental conditions. The soil microorganisms in agriculture regulate the processes, such as the control of organic matter decomposition, availability, nutrient cycling, soil electrical conductivity, pathogen control, pollutant degradation, and greenhouse gases (GHG) reduction.

Aerobic composting is an effective way to recycle solid waste. During composting, microorganisms play a key role in transforming degradable organic matter into mature manure and precursors of humic substances. This process provides nutrient-rich fertilizer for crop growth. Lignocellulosic agricultural byproducts, including crop residues, municipal solid waste and animal dung, represent a vast resource for bioconversion to compost. Composting involves complex microbial interactions among different bacteria, actinomycetes and fungi.

Microbial Succession in Composting

During composting, microbial communities succeed as per the requirements of environmental conditions *eg.* pH, temperature, substrates etc. Existing microbial species make the conditions favourable for upcoming species. The different phases during composting are as follows:

Mesophilic Phase:

During the initial mesophilic phase, rise in microbial activity takes place. Bacteria thrive, breaking down readily available organic compounds. The bacterial population ranges from 10^5 to 10^9 colony-forming units (CFU) per gram of compost during this phase. Prominent bacterial order includes Burkholderiales, Enterobacteriales, Actinobacteria, and Bacillales. Genera *like Staphylococcus, Serratia, Klebsiella, Enterobacter, Terribacillus, Lysinibacillus, Kocuria, Microbacterium, Acidovorax,* and *Comamonas* participate actively in decomposition during this phase (Chandna *et al.*, 2013).

Thermophilic Phase:

As composting heats up, the bacterial population declines. Thermophilic bacteria take central stage this time. At the thermophilic stage, Gram-positive bacteria such as *Bacillus* spp. and Actinobacteria, become dominant These heat-loving organisms continue breaking down complex organic molecules, releasing nutrients. The compost pile reaches temperatures of 50°C to 70°C (122°F to 158°F).

Cooling and Maturation Phase:

During the cooling phase, the bacterial population further decreases. Fungi, particularly lignin-decomposing species, become dominant. The compost matures, developing stable humic substances.

Conditions affecting the microbial succession in the Composting Process

The different microorganisms involved in compost production are grouped in communities that follow one another in a non-random fashion during the process, i.e., when the ability of a species to carry on its physiological functions is hampered by environmental variations (physical or chemical), other organisms become the main component of the process (Aguilar-Paredes *et al.*, 2023). In general, microbial communities are affected by environmental variations related to temperature, aerobiosis, feedstock, and humidity. Controlling these conditions will directly impact the permanence of each microbial community and, in turn, the duration of the process and the final quality of the compost.

Temperature

One of the key elements influencing the composting process is temperature. Usually, the latter can be divided into three phases: (a) Mesophilic (temperature >25 °C), wherein the metabolism of mesophilic bacteria and fungi breaks down simple molecules like sugars and amino acids, etc.; (b) Thermophilic (also known as the sanitization phase, with temperature >50 °C), wherein organic matter (fats, cellulose, hemicellulose, and lignin) is broken down by thermophilic microorganisms; (c) Maturation/stabilization (temperature <50

°C up to environment level) or cooling phase, which is marked by a drop in microbial activity and a drop in temperature. High temperatures have been found to help remove unwanted organisms and promote compost maturity during the composting process.

Aerobiosis

Microbial activity and degradation rate are significantly impacted by aeration rate. Aeration is one of the most important components in composting and is strongly correlated with O_2 content. Proper partial pressure of oxygen (pO_2) not only facilitates organic waste degradation but also lowers greenhouse gas (GHG) emissions, specifically CH_4. Comparing intermittent aeration to continuous aeration, it was discovered that the O_2 supply was more efficient. Aeration can cause cooling and a decrease in thermophilic conditions when it is severe. Additionally, it results in increased NH_3 and N_2O losses, impairs moisture regulation, and loses water; yet, it also creates a higher mitigation of CH_4 emissions, which affects the establishment of some bacteria.

C/N

Microbes break down organic components during composting in order to gain nutrients to support their growth and energy for metabolism. The two most important elements, though, are C and N. C serves as an energy source, and N creates cell structure. For the purpose of creating an effective compost mix, a nutritional balance in the form of an ideal C/N ratio is necessary.

pH

A reduction in pH is noted in the early stages of the composting process, and it is hypothesized that this could be caused by increased CO_2 and acid production from microbial nitrification and NH_3 volatilization. When composting is done in an industrial setting, a very low pH may be problematic because it can hinder the transition from the mesophilic to the thermophilic phase. However, as ammonia is produced and builds up in the compost piles, there is an increase in pH in the later stages of the composting process that may be related to the breakdown of nitrogen-containing compounds. During the process of composting, an ideal pH range is 7.5–8.5, which facilitates the breakdown of organic materials by microbes.

Humidity

When organic matter degrades, the amount of humidity present has a significant impact on the chemical and physical characteristics of waste products. The number of microorganisms, primarily bacteria, grows during the composting process as the moisture content rises because water acts as a channel for dissolved nutrients that are essential for microbial metabolism and physiological activity. Conversely, high humidity causes anaerobic conditions because it fills the pore spaces of solid matrices with water rather than air.

Role of Microorganisms in Compost and Crop Yield Enhancement

1. **Beneficial Microorganisms:** Bacteria and fungi play pivotal roles in nutrient cycling and soil health. Cellulose-decomposing bacteria break down plant cell walls, releasing essential nutrients. Nitrogen-fixing bacteria convert atmospheric nitrogen into plant-available forms. Mycorrhizal fungi form symbiotic relationships with plant roots, enhancing nutrient uptake. Compost inoculants containing beneficial microorganisms accelerate composting and enrich soil fertility.

2. **Harmful Microorganisms:** Some harmful microorganisms may enter compost through original substrates. Pathogenic

bacteria and fungi pose risks to plant health. Proper composting practices minimize the survival of harmful species.

CONCLUSION

Microbial diversity during composting is a dynamic process that influences nutrient cycling, soil health, and ultimately crop productivity. Understanding microbial diversity during composting empowers us to create high-quality compost that enhances soil structure, nutrient availability, and crop yield. By harnessing the potential of beneficial microorganisms, we may contribute to sustainable agriculture and a healthier planet.

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