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Review

Nitrification within composting: A review

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ABSTRACT

Composting could be regarded as a process of processes because it entails a number of complex chemical and microbiological reactions and transformations. Nitrification is one of such processes that normally takes place during the curing phase. This process has been studied in detail for wastewater treatment, and it is becoming an extensively studied topic within composting. In the past, nitrate presence in compost has been clearly perceived as a maturation indicator; however, nowadays, nitrate formation is also conceived as a way of conserving nitrogen in compost. Nitrification is a process closely linked to other processes such as ammonification and the possible loss of ammonia (NH_3).

Nitrification is defined as conversion of the most reduced form of nitrogen (NH_3) to its most oxidized form (i.e. nitrate) and it is performed in two steps which are carried out by two different groups of microorganisms: the ammonia-oxidizing bacteria or archaea (AOB/AOA) and the nitrite-oxidizing bacteria (NOB). The objectives of this review are: a) to gather relevant information on nitrification, which can specifically occur during composting, b) to outline ultimate findings described by the literature in order to increase the understanding and the application of nitrification within composting, and c) to outline future research direction.

Contents

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1. Introduction

Composting is considered an environmental-friendly process involving aerobic transformation of organic matter and destruction of pathogens and weeds (Rawoteea et al., 2017; Wu et al., 2017). This process is regarded as a great contributor of promoting circular agriculture (Cáceres et al., 2017) because allows stabilization of organic waste and production of an organic fertilizer that can be used as a soil conditioner (Sun et al., 2016), in gardening or as a growing medium in soilless cultures. A model of organic waste management, based on the production and use of high quality composts, is urged for contributing to mitigate the release of carbon into the atmosphere (Silva et al., 2009).

The process of composting entails a number of complex chemical reactions and microbiological transformations. These processes – that have been studied for decades – include hydrolysis, proteolysis, ammonification, nitrification, carbon mineralization, humification. This is the reason why composting could be considered the process of those processes.

In recent years, more attention has been paid to the curing phase of composting. During this phase – also referred to as the maturation phase – the composting mixtures undergo various transformations resulting in altered composition and microbial structure (Villar et al., 2016). Normally, nitrification occurs during this maturation phase (Cáceres et al, 2006, 2016; López-Cano et al., 2016). New insights have been provided through studying the environmental and chemical conditions of the organic matter particles that would influence this nitrogen transformation (Wang et al., 2015).

Nitrification, the sequential oxidation process of ammonia (NH_3) to nitrate, is the key nitrogen cycling process in oxic ecosystems (Gruber-Dorninger et al., 2015). It is a process that has been widely studied in agronomy (e.g. soils or growing medium in containerized plant production, Grunert et al., 2016; Zanardo et al., 2016), in natural water bodies and it constitutes a wastewater treatment process (Ge et al., 2015; Kim et al., 2007; Zou et al., 2016). In particular, nitrification has been studied in detail, including the nitrification-denitrification aspects with a complete or partial reaction (i.e. nitrite for Anammox), in order to achieve the maximum efficiency of N removal (Ge et al., 2015). Also, nitrification has been studied in leachates from municipal solid waste landfills (Sun et al., 2017). Recent studies deal with combined anthropogenic systems like aquaponics for growing fish and plants in which nitrification is the key transformation to eliminate toxic ammonium and make nitrate available for plants (Zou et al., 2016). Moreover, in the field of microbiology on nitrification, a breakthrough finding has been published recently. Complete oxidation of ammonia to nitrate in one organism (complete ammonia oxidation; comammox) has been discovered and cultivated. It is a bacterium from the genus *Nitrospira*, which is a globally distributed group of nitrite oxidizers (van Kessel et al., 2015; Daims et al., 2015). The genome of this chemolithoautotrophic organism encodes the pathways for ammonia and nitrite oxidation (Daims et al., 2015).

Research on nitrification in liquid matrices has been extensive and resulted in knowledge and understanding of some techniques (e.g. microbial community structure), and as such had an impact on studying and understanding the process of nitrification within composting (Nogueira et al., 2002).

The objectives of this review are: a) to gather relevant information on nitrification, which can specifically occur during composting, b) to outline ultimate findings described by the literature in order to increase the understanding and the application of nitrification within composting, and c) to outline future research direction.

2. Nitrification within composting

2.1. Nitrogen cycling and nitrification within the cycle

Nitrogen is the fifth most abundant element in our solar system, and it is essential for the synthesis of nucleic acids and proteins. Ammonium from these and other organic compounds is returned to the environment when organisms die and its fate depends on whether the local environment contains oxygen. In the presence of oxygen, NH_4^+ is sequentially oxidized to NO_3^- by specific groups of bacteria and archaea (Canfield et al., 2010). Thus, mineralization of N is described as a two-stage process consisting of ammonification (the release of NH_4^+ from organic N) and nitrification (the further oxidation of NH_4^+-N to NO_3^-) (Edwards and Daniel, 1992). Then, nitrate or ammonium can be taken up by plants to synthesize new organic– N compounds which are essential for living organisms. Additionally, nitrate can also be transformed into N_2 through denitrification under anoxic conditions (Wang et al., 2015). In natural systems, specific organisms are in charge of returning the N_2 into

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