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Technical Note

Effect of inoculation methods on the composting efficiency of municipal solid wastes

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HIGHLIGHTS

- ▶ Four kinds of inoculation methods were applied during solid waste composting.
- ▶ Inoculation enhanced the degradation of aliphatics, proteins, and polysaccharides.
- ▶ Inoculation increased the molecular weight and humification degree of the composts.
- ▶ The inoculation microbes significantly improved composting progress and efficiency.
- ▶ Multi-stage inoculation best enhanced composting progress and efficiency.

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ABSTRACT

Four types of inoculation methods were studied during the composting of municipal solid wastes and dry grass (MSWG). The methods included a control group as well as initial-stage, two-stage, and multi-stage inoculations. Fulvic acids were extracted from the composting materials and characterized by spectroscopic techniques. The results showed that inoculation of microbes in MSWG enhanced the biodegradation of aliphatics, proteins, and polysaccharides. The inoculation also increased the molecular weight, humic- and fulvic-like compound content, as well as humification degree of the composting products. The inoculation of microbes in MSWG significantly improved composting process and efficiency. The improvement efficiency was in the order of initial-stage < two-stage < multi-stage inoculations. Inoculation of microbes based on composting organic matter composition and temperature enhanced composting efficiency.

1. Introduction

Composting is an effective method for treating municipal solid wastes (MSWs). The resulting products can be used as soil conditioner (He et al., 2011). The composting process can naturally occur with the involvement of microorganisms in MSWs. However, insufficient quantity or poor biodegradability of the indigenous microbial community used may easily lead to low composting efficiency and undesirable compost quality (Xi et al., 2007).

Barrena et al. (2006) reported that inoculum in composting materials could produce a significant acceleration of the composting process. The study by Ghaffari et al. (2011) also suggested that the inoculation increased cellulase activity, promoted biodegradation of organic matter and accelerated composting process. The composting environment, such as temperature and organic matter composition, regularly change during the composting process (He et al., 2011). The microbes needed to decompose the composting materials change accordingly. Therefore, the inoculation measures may play an important role on composting efficiency. The report by Barrena et al. (2006) showed that there were no significant differences among the different inoculation levels (10^5, 10^6 and 10^7 CFU g^{-1}) during the composting process. However, Wei et al. (2007) suggested that the inoculation could accelerate the compost maturation process, and mixed inoculation with complex microorganisms and lingo-cellulolytic microorganisms had a clear advantage over inoculation with complex microorganisms or lingo-cellulolytic microorganisms alone. Huang et al. (2009) found

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that the inoculation with *Phanerochaete chrysosporium* increased the humification degree of humic acid (HA) when inoculated during the curing stage, but not during the active stage. Zeng et al. (2010) also suggested that the inoculation with *P. chrysosporium* during the second fermentation phase was more effective than that during the first fermentation phase. To enhance composting efficiency, inoculating methods should be appropriately applied based on the composting environment.

Composting is a humification process of organic materials. The products of humification, namely, fulvic acid (FA) and HA, are often used to evaluate the stability and maturity of composts (Huang et al., 2006; Wei et al., 2007). FA is significantly chemically reactive in terms of mineral chelating ability and plant growth promotion due to the small size and high carboxyl group content (Amir et al., 2005). Therefore, knowledge on the amount and chemical structure of FA is widely used to characterize the stability and maturity of composts (Amir et al., 2005, 2008; Huang et al., 2006).

Fourier transform infrared (FTIR), UV–Vis, and fluorescence spectroscopic methods can provide information on the composition and chemical structure of organic matter (Shao et al., 2009; He et al., 2011). However, using only one spectroscopic method may be insufficient, and the integration of various techniques is better.

The current study aimed to investigate the composition and transformation of FA during composting when different inoculation methods were applied. Another aim was to evaluate the composting efficiencies of different inoculation methods. The results may provide important information for optimizing inoculation technology and improving the fermentation process during composting.

2. Methods and materials

2.1. Collection and pretreatment of composting materials

The MSW composted in the current study was obtained from the Asuwei Composting Plant, which serves the Chanping and Chaoyang Districts in Beijing, China. Before composting, the metals, plastics, and glasses in the MSW were manually removed. The remaining MSW was then minced, and fragments smaller than 50 mm in diameter were collected for composting. Some basic characteristics of the MSW were: total carbon, 178 g kg^{-1}; total nitrogen, 12 g kg^{-1}; C/N ratio, 15; organic matter content, 51%; moisture, 58%. Dry grass used to adjust the C/N ratio was acquired from the Chinese Research Academy of Environmental Science (Beijing, China). Before composting, the dry grass was minced, and fragments ranging 20–30 mm in diameter were used. Some basic characteristics of the dry grass were: total carbon, 482 g kg^{-1}; total nitrogen, 12 g kg^{-1}; C/N ratio, 40; organic matter content, 80%; moisture, 4%.

2.2. Composting equipment

The composting equipment was composed of two similar compartments, and each of them can be used independently for composting. The core part of each compartment was a cylinder 500 mm in diameter and 400 mm in height, and the volume of the compartment was approximately 78.5 L. A 6 mm trachea was connected to the top of the compartment. A perforated metal plate found at the bottom was used to hold the composting mixtures and to distribute air equally. The composting system was connected to a blower that supplied the reactor with air from the bottom.

2.3. Source and composition of microbes

Deodorizing, cellulose and lignin decomposition composite microorganisms were inoculated in this study. The deodorizing composite microorganisms were composed of strains A-03, N-24 and D-05. Strain A-03 was an ammonia-oxidizing bacterium, while strains N-24 and D-05 were *Nitrobacter* and *Thiobacillus*, respectively. The cellulose decomposition composite microorganisms were composed of strains X-B1, X-B7, X-11, and X-32, while the lignin decomposition composite microorganisms consisted of strains M-B1, M-21, and M-31. Strains X-11, X-32, M-21 and M-31 belonged to fungi, while the rest were classified into bacteria. Before inoculated, fungi were cultivated in the Martin substratum, while bacteria were cultivated by the beef cream-peptone culture medium.

2.4. Composting design and inoculation methods

The MSW and dry grass (MSWG) composted were manually mixed with the dry weight ratio of 1.25:1. The basic characteristics of MSWG were: C/N ratio, 26; water content, 60%; pH value, 7.13. The ventilation rate was set at 0.5 L min^{-1} kg^{-1} MSWG during the composting process.

Four types of inoculation methods were studied in this experiment, and each of them was replicated three times. The first was a control group (CK), in which no microbe was inoculated during the entire composting process. The second was an initial-stage inoculation group (*T*1). In this group, the deodorizing composite microorganisms, cellulose decomposition composite microorganisms, and lignin decomposition composite microorganisms were inoculated at the initial stage of composting before the temperature began to increase. The third was a two-stage inoculation group (*T*2). In this group, the deodorizing composite microorganisms were inoculated at the initial stage of composting. Subsequently, cellulose decomposition composite microorganisms and lignin decomposition composite microorganisms were inoculated at the active stage of composting when the temperature decreased to less than 55 °C. The fourth was the multi-stage inoculation group (*T*3). In this group, the deodorizing composite microorganisms were inoculated at the initial stage of composting. The cellulose decomposition bacteria were then inoculated at the active stage of composting when the temperature decreased to less than 55 °C, followed by the lignin decomposition composite microorganisms inoculated at the curing stage of composting when the temperature was below 40 °C. Each kind of strain was added to composting piles of MSWG at the level of 1.25 mL kg^{-1} dry MSWG, and the concentrations of the strain were above 1×10^8 CFU mL^{-1}.

2.5. Sampling

At the initial stage of composting and at the final stage of the curing stage of composting, the MSWG samples were obtained at three different depths (15, 20 and 25 cm) of the composting piles and then mixed together. 500 g of MSWG was collected from the composting piles of different inoculation treatments. All experimental samples were stored below −20 °C before further analysis.

2.6. Extraction and purification of FA

Fresh compost samples, previously freeze dried and crushed, were mixed with 0.1 M NaOH with a solid to water ratio of 1:10 (w/v). The mixtures were shaken for 12 h with rotational speed of 200 rpm at room temperature, and centrifuged at 10 000 rpm for 15 min. The obtained supernatant was filtered through a 0.45 μm membrane filter, and then acidified to pH 2 with 6 M HCl. The mixtures were allowed to stand for 24 h at 4 °C, and again centrifuged at 10 000 rpm for 15 min. The obtained supernatant was passed through an XAD-8 macroporous resin column and an H^+-saturated cation exchange resin for further FA purification (Ma et al., 2001; Huo et al., 2008). The stationary phases used for the FA purification were XAD-8 resin and 732 cation exchange re-