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Effect of aeration rate on composting of penicillin mycelial dreg

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ABSTRACT

Pilot scale experiments with forced aeration were conducted to estimate effects of aeration rates on the performance of composting penicillin mycelial dreg using sewage sludge as inoculation. Three aeration rates of 0.15, 0.50 and 0.90 L/(min·kg) organic matter (OM) were examined. The principal physicochemical parameters were monitored during the 32 day composting period. Results showed that the higher aeration rate of 0.90 L/(min·kg) did not corresponded to a longer thermophilic duration and higher rates of OM degradation; but the lower aeration rate of 0.15 L/(min·kg) did induce an accumulation of $\text{NH}_4\text{-N}$ contents due to the inhibition of nitrification. On the other hand, aeration rate has little effect on degradation of penicillin. The results show that the longest phase of thermophilic temperatures $\geq 55^\circ\text{C}$, the maximum $\text{NO}_3\text{-N}$ content and seed germination, and the minimum C/N ratio were obtained with 0.50 L/(min·kg) OM. Therefore, aeration rates of 0.50 L/(min·kg) OM can be recommended for composting penicillin mycelial dreg.

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Introduction

China has been regarded as one of the largest producers and exporters of antibiotics, and the annual yield of antibiotics from manufacturers reached approximately 147 thousand tons in 2009 (Li et al., 2012b). Among these antibiotics, penicillin production accounted for about 100 thousand tons (Fang, 2014). Penicillin mycelial dreg (PMD) is a type of bio-waste from the penicillin production process, mainly containing the organic medium designed for *penicillium* growth and reproduction, and the remaining penicillin. Therefore, PMD is characterized by a high proportion of nutritional materials such as starch, maize slurry, glucose, peptone and nutrient salts as well as the high levels of penicillin residue. In order to utilize its nutritional value and medical effect, PMD had been applied as a feed additive for livestock and poultry to promote growth and reduce pathogenic bacterial infection (Zhang, 2000, 2002). However, the

poor absorption by animals results in 70%–90% of the antibiotic residue being excreted in manure (Kumar et al., 2005; Phillips et al., 2004). It is likely that if these manures were used for land application without pretreatment, the antibiotics contained in them would be transported into surface water and ground water, posing a potential risk to the environment, namely promoting the generation and spread of antibiotic resistant bacteria (Jiang et al., 2013).

Composting is one of the most effective ways of reducing the danger of solid wastes (Ding et al., 2014; Hu et al., 2011) and transforming them into a resource that can be applied to soil systems (Seymour et al., 2001; Veeken et al., 2002). Composting is also a controlled-microbiological aerobic process to degrade organic matters through the actions of enzymes, microorganisms and oxygen during the entire process. The main products of biological metabolism are carbon dioxide, water and heat under aerobic conditions (Bari and Koenig, 2001). Thus, a suitable level of aeration is

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essential for maintaining a relatively high activity of microbes, being directly responsible for the substrate degradation rate and temperature variation during the composting process; and aeration rate is believed to be one of the most important parameters influencing the composting process and compost quality (Gao et al., 2010; Kuter et al., 1985). Too little aeration can induce an anaerobic environment, while too much aeration can induce premature cooling, impairing the thermophilic conditions giving the optimum decomposition rates (Ahn et al., 2007). Therefore, it is important to obtain an appropriate aeration rate to make the composting process more efficient.

Various aeration rates were used in some previous studies. Gao et al. (2010) investigated composting of chicken manure and sawdust at aeration rates from 0.3 to 0.7 L/(min·kg) organic matter (OM) and found that an aeration rate of 0.5 L/(min·kg) OM is more efficient than others. Guo et al. (2012) reported that the aeration rate of 0.48 L/(min·kg) dry matter was suitable for co-composting of pig feces and corn stalks. Kulcu and Yaldiz (2004) found that the highest OM degradation and temperature value were obtained at the aeration rate of 0.4 L/(min·kg) OM in composting of agriculture wastes. Li et al. (2008) suggested an aeration rate of 0.25 L/(min·kg) OM in the composting of dairy manure with rice straw. Rasapoor et al. (2009) recommended a rate of 0.4–0.6 L/(min·kg) OM for composting of active municipal solid waste. These variations in the recommended aeration rate show that there might be a close association between the optimal aeration rate and the resource material composition in composting. Although a vast amount of research has been conducted on the aeration rate for effective composting, there is lack of information on the effect of aeration rate on the composting of PMD, rice straw and sawdust (as bulking agent) with sewage sludge (as inoculation). The main objectives of this work were to investigate the evolution of various physical and physicochemical properties in composting at different aeration rates to obtain an optimal aeration rate, with a view to saving operational cost for practical application.

1. Methods

1.1. Source materials

The PMD was provided by a local biological pharmaceutical industry (Harbin, China). Dewatered sewage sludge, consisting of primary and secondary biosolids, was collected from a local municipal wastewater treatment plant (Harbin, China). Both

PMD and sewage sludge were stored in a freezer at -20°C prior to use. Sawdust (SD) and rice straw (RS) were collected from a local wood processing facility in Harbin. SD is characterized by powdery particles of sawn wood, the average diameter of which was about 0.55 mm. RS was manually cut into a length of 1.0–2.0 cm. They were used as bulking agents in the experiments. The physical and chemical properties of the source materials are presented in Table 1.

1.2. Composting experiment

The composting reactor has a volume of 390 L (100 cm height, 65 cm length and 60 cm width) and was covered with 2 cm thickness styrene cystosepiment (foam board) for thermal insulation. To ensure a uniform gas distribution, the composting material was supported by a stainless steel grid installed in the reactor about 7 cm above the bottom. Three sampling ports (5 cm inter diameter) on the side of the reactor were set at equal intervals (30 cm). The central positions of three sampling ports were located at the heights of 17 cm, 47 cm and 77 cm from the bottom of the reactor, respectively (Fig. 1). The ports were sealed by rubber stoppers during the reaction.

The rectangular reactor had a removable lid. A Pt100 temperature sensor (WRPX-12, Changjiang Temperature Meter Factory, Shanghai city, China) located at 50 cm height from the bottom was connected to a digital thermometer (XMT, Changjiang Temperature Meter Factory, Yuyao city, Zhejiang, China) to automatically record the data. A hole on the side near the reactor bottom was used for aeration.

In our previous study, a series of experiments on the effect of bulking agents on the composting performance were conducted (data not shown here). Results revealed that the mixture of PMD, sewage sludge, SD and RS added with the wet weight ratio of 2.0:1.6: 1.0:1.0 was optimal. Thus, three composting treatments (T-1, T-2 and T-3) using the aforementioned ratio were conducted to investigate the effect of three aeration rates, namely 0.15, 0.50, and 0.90 L/(min·kg) OM. Each treatment weighed about 98 kg and was carried out in triplicate. The homogeneity of each composting treatment was ensured before composting. The characteristics of the raw materials are presented in Table 2.

Each composting process lasted 32 days. The initial water content and C/N was adjusted to about 65% and 23, respectively. The C/N ratio adjustment focuses on C due to the relatively excess N in the matrix. According to Li et al. (2013), the C source supplement depended partly on glucose. The treatments were turned on the 9th day, and water was added

Table 1 – Physicochemical parameters of penicillin mycelial dreg (PMD), sewage sludge, sawdust (SD) and rice straw (RS).

Parameters	PMD	Sewage sludge	RS	SD
pH	7.3 ± 0.4	6.8 ± 0.7	7.0 ± 0.4	6.4 ± 0.3
Moisture content (%)	76.5 ± 1.5	78.3 ± 1.7	11.1 ± 0.5	13.5 ± 0.7
OM ^a (g/kg)	765.7 ± 16.8	414.5 ± 11.1	801.4 ± 10.4	862.4 ± 12.2
TOC ^a (g/kg)	446.4 ± 8.3	205.6 ± 6.2	483.3 ± 8.8	471.7 ± 8.3
TKN ^a (g/kg)	75.6 ± 1.9	26.6 ± 0.7	5.1 ± 0.4	2.7 ± 0.6
C/N	5.6	7.7	87.2	182.3

^a Dry weight base; data are presented as mean ± standard deviation of 3 replicates; OM: organic matter; TOC: total organic carbon; TKN: total Kjeldahl nitrogen; C/N: carbon/nitrogen ratio.

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