Waste Management 72 (2018) 161–167

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Impacts of delayed addition of N-rich and acidic substrates on nitrogen loss and compost quality during pig manure composting

Jishao Jiang[a,*], Kang Kang[b], Dan Chen[a], Ningning Liu[a]

[a] School of Environment, Henan Normal University, Key Laboratory for Yellow River and Huai River Water Environmental and Pollution Control, Ministry of Education, Henan Key Laboratory for Environmental Pollution Control, Xinxiang, Henan 453007, China
[b] College of Mechanical and Electronic Engineering, Northwest A&F University, Yangling, Shaanxi 712100, China

ARTICLE INFO

Article history:
Received 15 June 2017
Revised 8 October 2017
Accepted 11 November 2017
Available online 16 November 2017

Keywords:
Delayed addition
Animal manure
Acidic substrates
Nitrogen loss
Compost quality

ABSTRACT

Delayed addition of Nitrogen (N)-rich and acidic substrates was investigated to evaluate its effects on N loss and compost quality during the composting process. Three different delayed adding methods of N-rich (pig manure) and acidic substrates (phosphate fertilizer and rotten apples) were tested during the pig manure and wheat straw is composting. The results showed that delayed addition of pig manure and acidic materials led two temperature peaks, and the durations of two separate thermophilic phase were closely related to the amount of pig manure. Delayed addition reduced total N loss by up to 14% when using superphosphate as acidic substrates, and by up to 12% when using rotten apples as acidic substrates, which is mainly due to the decreased NH_3 emissions. At the end of composting, delayed the addition of pig manure caused a significant increase in the HS (humus substance) content, and the highest HS content was observed when 70% of the pig manure was applied at day 0 and the remaining 30% was applied on day 27. In the final compost, the GI in all treatments almost reached the maturity requirement by exceeding 80%. The results suggest that delayed addition of animal manure and acidic substrates could prevent the N loss during composting and improve the compost quality.

1. Introduction

Composting is a widely used and efficient technology for the disposal of organic waste (Jaafari et al., 2015; Zhang et al., 2017). It can convert the biodegradable components into nuisance-free, sanitary and humus-like materials, which could be used as soil conditioners, fertilizers, and soil remediation agents (Zhang et al., 2017). Nitrogen (N) loss, however, can become severe when materials with a high N content (i.e. animal manure) are decomposed (Gabhane et al., 2012). The N loss could lead to up the loss of 80% of the initial N during the whole composting process (Nakhshiniev et al., 2014). Therein, the N loss via NH_3 emission accounted for 16–74% of initial N during animal manure composting (Medina et al., 2002; Ren et al., 2010), which in turn decreases the quality of the compost as fertilizer, and causes air pollution (Wang et al., 2016). Therefore, preventing the nitrogen loss and NH_3 emissions in manure composting has attracted lots of attention in environmental research.

In recently years, the delayed addition of N-rich substrate (i.e. animal manure) has been suggested as an effective way to reduce N losses during composting (Dresboll and Thorup-Kritensen, 2005; Nigussie et al., 2017). During the split addition of N-rich substrate, the first addition at the beginning of composting could satisfy the turnover of carbon and raise the temperature of compost. The second addition after the thermophilic phase could increase the N and humus concentrations of compost (Nigussie et al., 2017). Split application of an N-rich substrate reduces N losses mainly via ammonia volatilisation.

In the composting process, NH_3 emission was mainly caused by the ammonization of organic nitrogen during the thermophilic stage (Jiang et al., 2015a; Pagans et al., 2006). Moreover, high pH during high-temperature stage shifts the equilibrium of NH_4-N and NH_3 and results in NH_3 emissions, which increase N loss (Bernal et al., 2009). Therefore, the addition of the acidic materials, such as phosphoric acid, superphosphate, sulfuric acid, bamboo charcoal, nitric acid, and olive pomace is a straightforward and efficient method to control the NH_3 emissions and prevent N loss (Haddadin et al., 2009; Ren et al., 2010; Yang et al., 2015). The optimum pH range for microorganisms is 6.7–9.0 (Bernal et al., 2009). Therefore, if the pH was too low after adding the acidic materials, the microbial activity might be inhibited, slowed down the temperature rise, and prolong the process of composting (Jiang et al., 2014). Also, some acidic materials, such as phosphoric acid and

* Corresponding author.
E-mail address: jiangjishao@163.com (J. Jiang).

https://doi.org/10.1016/j.wasman.2017.11.025
0956-053X/

superphosphate, could react with ammonium to form ammonium phosphate (Luo et al., 2013), resulting in a higher EC. Higher EC with more mineral salts could inhibit the activities of microorganism and decrease the quality of the compost (Wolkers-Rooijackers et al., 2013). Fortunately, split addition of N-rich substrate, as before mentioned, could provide a new strategy for solving the problems with adding acidic materials. However, there is no existing evaluation on the effects of split addition of acidic substrates, neither the split additions of pig manure and acidic substrates on N loss and compost quality during animal manure composting.

Thus, the objectives of this study were (1) to investigate the effects of the split additions of pig manure and acidic substrates on the N loss and NH_3 emissions, and to assess the effectiveness of the split additions of pig manure and acidic substrates on compost quality during pig manure composting.

2. Materials and methods

2.1. Feedstock

Fresh pig manure and wheat straw were collected from a swine farm and local cropland respectively in the suburban districts of Xinxiang, Henan province. They were used as the raw materials for the aerobic composting experiments. The basic characteristics of them, respectively, are as follows: total organic carbon (TOC) was 389.0 and 421.6 g kg^{-1}; total nitrogen (TN) was 27.9 and 8.0 g kg^{-1}; the water content was 70.9% and 14.5%; and the C/N ratio was 13.9 and 52.7. Wheat straw was cut into small pieces with 3.0–5.0 cm length and was used to adjust the water content and C/N ratio to proper levels for composting.

Two additives including phosphate fertilizer and rotten apples were collected from in the Muye districts of Xinxiang, Henan province. The main component of phosphate fertilizer was calcium superphosphate (≥12%), and the pH was 3.1, purchased from the local market. The rotten apples were collected from the fruit store, with the moisture content of 72% and the pH was 4.0.

2.2. Composting experimental design

The composting experiment was carried out for 54 d in a self-built, aerated static composting boxes (0.65 m length, 0.50 m width, and 0.40 m height) made of PVC, and the detailed description of the box was in the reference (Jiang et al., 2015a). The experiment was conducted in a lab with a temperature variation between 18 °C and 25 °C during the experimental period.

Six treatments were conducted to evaluate the impacts of delayed addition of N-rich and acidic substrates on nitrogen loss and compost quality. Fresh pig manure and wheat straw were mixed at a ratio of 10:1 in fresh weight as-received basis. The mixture of pig manure and wheat straw were mixed thoroughly with one of the two acidic substrates. The content of phosphate fertilizer and rotten apples were set as 6% and 15% of the initial dry matter, respectively. The core material and additive of each treatment filed up layer-by-layer on the sieve plate of the reaction chamber but no compaction after under the homogenous conditions.

The pig manure was added to the composting mixtures in three different ways: (i) all pig manure was applied at the beginning of composting, (ii) 70% of the pig manure was applied at the beginning of composting, and the remaining was added after the thermophilic phase, and (iii) 30% of the pig manure was applied at the beginning of composting and the remaining was added after the thermophilic phase. The added amounts of acidic materials were in accordance with the amount of pig manure. To mitigate the inhibiting effect of the acidic materials, the additions of phosphate fertilizer and rotten apples were divided into four times on 0, 4, 27, 31 d when the split addition of pig manure. Details of all treatments are presented in Table 1. The temperature was monitored every day with a depth of 0.20 m inside the compost pile using a thermometer function of a programmable temperature controller (XMT616, Shanghai Renzhong Instrument and Electric Appliance Co., Ltd). Before each sampling, the pile was thoroughly turned manually. The water content of the stock material was adjusted to approximately 65% by water spray.

2.3. Sampling and analytical methods

Sampling of the compost was carried out seven times during the experiment (0, 9, 18, 27, 36, 45, 54 days) based on different stage during the composting process such as 1, 2, and 3 (1, 2, and 3 denote the thermophile, cooling, and maturity phases, respectively) characterized by temperature. Sampling was performed in triplicates by mixing material from each of five points on diagonals into every sample. A visual description of the sampling method is shown in Fig. 1. This representative sample from each box was divided into two parts. The first part was immediately stored at 4 °C until analysis, the second part was air-dried and passed through a 0.25 mm sieve and stored in a desiccator. The electrical conductivity (EC), germination index (GI) and pH were measured on an aqueous extract obtained from the fresh samples of the compost. The aqueous extract was obtained using the method described by Huang et al. (2004). EC and pH were measured using an EC meter and a pH meter, respectively. Chinese pakchoi (*Brassica campestris L. ssp. chinensis Makino*) seeds were used for the GI measurement. Ten Chinese pakchoi seeds were distributed on filter paper (Hangzhou Whatman-Xinhua Filter Paper Co., Ltd.) in Petri dishes (0.1 m diameter) and moistened with 5 mL of the compost extract. Three replicate dishes for each sample of different stages were incubated at 25 °C for 48 h. The number of germinating seeds and their root lengths were measured. Distilled water was used as a reference (Jiang et al., 2014). GI was used to assess phytotoxicity of the compost and calculated using Eq. (1)

Table 1
Detailed descriptions of all treatments.

No.	Code.	Descriptions of the treatments
1	P-100	All pig manure and phosphate fertilizer were applied on day 0
2	P-70/30	70% of the pig manure was applied at day 0 and the remaining 30% was applied on day 27. 35%, 35%, 15%, and 15% of phosphate fertilizer was added on day 0, 4, 27, 31, respectively
3	P-30/70	30% of the pig manure was applied at day 0 and the remaining 70% was applied day 27. 15%, 15%, 35%, and 35% of phosphate fertilizer was added on day 0, 4, 27, 31, respectively
4	A-100	All pig manure and rotten apples were applied on day 0
5	A-70/30	70% of the pig manure was applied at day 0 and the remaining 30% was applied day 27. 35%, 35%, 15%, and 15% of rotten apples was added on day 0, 4, 27, 31, respectively
6	A-30/70	30% of the pig manure was applied at day 0 and the remaining 70% was applied day 27. 15%, 15%, 35%, and 35% of rotten apples was added on day 0, 4, 27, 31, respectively

P and A denote the phosphate fertilizer and rotten apples, respectively.