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Research paper

The use of concentrated monosodium glutamate wastewater as a conditioning agent for adjusting acidity and minimizing ammonia volatilization in livestock manure composting

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ABSTRACT

In this study, concentrated monosodium glutamate waste (CMGW) was proposed as a conditioning agent to adjust acidity and decrease ammonia (NH_3) volatilization in thermophilic aerobic composting based on two incubation experiments. The results showed that with the addition of CMGW, NH_3 volatilization of compost mixture under high temperature phase decreased significantly and pH met the current national standard within 5.5–8.5. When CMGW dosage increased to 2% (v/w), the decrease in NH_3 volatilization was as high as 78.9%. This effect was enhanced by repeated application of CMGW. Furthermore, although the electrical conductivity increased with the application of CMGW, both the germination index and the microbial respiration of compost mixture implied that CMGW had no negative effects on the maturity of compost, instead, a comprehensive maturity might be accelerated. It was concluded that CMGW was an optional conditioning agent for thermophilic aerobic composting of livestock manure in regards to adjusting acidity and preventing nitrogen loss from NH_3 volatilization.

1. Introduction

With economic development and improvement in the standard of living, livestock industry production has been scaled up continuously to meet market demands (Rae and Zhang, 2009). This has, in turn, placed severe pressure on agroecological environment in regards to poultry excrement waste. Currently, such waste is usually transferred into organic fertilizer via thermophilic aerobic composting to realize its bio-safety disposal and reutilization (Bernal et al., 2009).

During the thermophilic phase of composting, however, decomposition of organic matter which is enhanced by the microbial proliferation may trigger ammonium nitrogen (N) accumulation and subsequent pH rise in composting, consequently leading to ammonium loss (Darees Boucher et al., 1999; Eiland et al., 2001; Shah et al., 2013) and nutrient value decline in organic fertilizer products, as well as a severe odor problem in full-scale compost facilities(Jeong and Kim, 2001; Switzenbaum et al., 1994). Ammonia (NH_3) volatilization has been found to account for 62% of initial N during composting of poultry layer manure (Kithome et al., 1999), and over 92% of total N loss during composting of beef cattle feedlot manure (Eghball et al., 1997). It has been reported that N loss which often caused by the volatilization of NH_3 in thermophilic phase was usually resulted from the high pH and high temperature of composting materials (Eiland et al., 2001; Shah et al., 2013). Because of the necessity of high temperature for decomposition and bio-safety disposal of waste in composting (by killing pathogenic microorganisms) and the relevance of pH and NH_3 volatilization (Bernal et al., 2009), adjusting acidity might be essential for preventing N loss to optimize the high temperature

Abbreviations: CMGW, concentrated monosodium glutamate waste; DW, distilled water; QNV, quantity of NH_3 volatilization; AQNV, accumulative quantity of NH_3 volatilization; GI, germination index.

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composting process. In addition, it will also be vital for organic fertilizer products to meet the current national standard of pH within 5.5–8.5 (Agriculture Ministry, 2011).

Chemical conditioners, such as sulfur (Mari et al., 2005), sodium acetate (Yu and Huang, 2009), phosphoric acid (Jeong and Kim, 2001; DeLaune et al., 2004), ferric chloride (Darees Boucher et al., 1999), peat and zeolum (Bernal et al., 1993; Witter and Kirchmann, 1989), have been applied during composting to adjust the matrix acidity by neutralization and absorption, as well as to prevent the loss of N and the emission of odors(Mahimairaja et al., 1994). However, many of these amendments are inert conditioners which cannot adjust C/N to achieve the nutritional conditions for microorganisms, while those active conditioners are difficult to screen after degradation (Zhang et al., 2007). The conditioners efficiencies are highly dependent on their dosages. Wang et al. (2004) indicated that an agent with 3% ferrous sulfate, 10% calcium superphosphate and 9% peat was appropriate for the fermentation of chicken manure. Nevertheless, this agent might also add to the cost of organic fertilizers as each conditioner dosage was almost the highest in this report. In addition, the chemical amendments would be relatively expensive to be put into the commercial production. Therefore, it is critical to look for an accessible compost conditioner with favorable price and high efficiency.

Concentrated monosodium glutamate wastewater (CMGW), with very low pH, is rich in proteins, amino acids, sulfate, and total organic carbon (TOC), and free of heavy metals pollution (Bai et al., 2004). It may be a promising conditioner that can deal with the excessively high pH of compost as well as the decrease in nutrient value through NH_3 volatilization during composting. Currently, however, there are few reports on CMGW as a conditioner in composting. Based on two incubation experiments, the present study investigated the effects of CMGW application dosages and frequency on the amount of N loss due to NH_3 volatilization, as well as the physicochemical properties (especially pH), germination index and strength of microbial respiration of compost mixture under high temperature phase to assess the feasibility of CMGW as a conditioning agent for adjusting acidity and preventing N loss from NH_3 volatilization in livestock manure composting.

2. Material and methods

2.1. Material

The compost material used in this study was taken from a large-scale compost during the high temperature phase (>50 °C) conducted at the compost plant of Jinhua Shengneng Biotechnology Co., Ltd (China). It was composted with cattle manure, chicken manure and mushroom residue at a ratio of 3:1:1 in volume with 1% (v/w) fermentation bacterial agent for 7 days. The fermentation bacterial agent was prepared as the Example 1 of patent ZL 200510049704.9 (Fang and Zhu, 2005). The physicochemical properties of the raw materials are shown in Table 1.

The concentrated monosodium glutamate wastewater (CMGW), with a pH of 3.01 and electrical conductivity (EC) of 31.2 ms/cm, was provided by Anhui Huanyu Fertilizer Co., Ltd (China). As shown in Table 2, it was free of heavy metal pollution and contained 25.9% TC, 4.01% TN, 2.07% TK, 0.16% TP, 5.51% Na, 15.1% S, 0.26 g/kg Fe, 0.62 g/kg Ca, 0.93 g/kg Mg, 9.17 mg/kg Mo, 2.16 mg/kg Zn, 2.54 mg/kg Cu, and 2.29 mg/kg Ni.

Table 1
Physicochemical properties of compost raw material (dry matter basis).

Material	pH	EC[a] (ms/cm)	OM[b] (%)	N (mg/kg)	C/N
Cattle manure	8.8	1.4	38.2	28.8	13.3
Chicken manure	8.2	10.3	36.2	31.2	11.6
Mushroom residue	7.9	1.9	38.4	11.0	34.9

[a] Electrical conductivity.
[b] Organic matter.

2.2. Experimental design

2.2.1. Experiment 1: Composting mixture incubation with different CMGW dosages

The composting material was mixed thoroughly with CMGW at dosages (v/w) of 0% (CK), 0.5% (M1), 1% (M2) and 3% (M3). Distilled water (DW) was applied to adjust the moisture content of each mixture to the same level of 60%. Every 150 g mixture sample was placed in a 1000 ml triangle flask, and every CMGW dosage treatment was repeated in triplicate. A test tube with 20 mL 20 g/L boric acid-indicator (methyl red and bromocresol green) solution was inserted into each flask. An additional three flasks without composting mixture served as a blank contrast group. The flasks were finally sealed and incubated in a thermostat incubator (Hangzhou Qianjing Instruments & Equipment Co., Ltd, China) at 50 °C for 3 days. The tubes were replaced by new ones every day to investigate the NH_3 volatilization.

2.2.2. Experiment 2: Composting mixture incubation with repeated application of different CMGW dosages

This incubation experiment included three treatments of different CMGW dosages and each dosage applied triple times as shown in Table 3. A mixture sample of 200 g for each treatment was placed in a 1000 mL triangle flask, and each treatment was performed in triplicate. Two test tubes, one with 10 mL 20 g/L boric acid-indicator (methyl red and bromocresol green) solution and the other with 10 mL 5 mol/L NaOH alkaline solution, were inserted into each flask. The flasks were sealed and cultured in the thermostat incubator at 50 °C.The test tubes were replaced by new ones every day for the first 10 days to monitor NH_3 volatilization and microbial respiration. The flasks were shaken just before the new tubes were inserted so as to renew the air and blend the mixture thoroughly again. Another three flasks without composting mixture served as a blank contrast group. This experiment lasted 25 days. The mixture was sampled on the first and twenty-fifth day of the incubation and each sample was divided into two parts: the fresh part was used to test pH and EC directly, and the other part was dried at 45 °C and sieved over 60 mesh to measure total nitrogen (TN) content.

2.3. Volatilization of NH_3

The alkaline hydrolysis diffusion method of soil hydrolysis nitrogen (Yu, 1999) was modified to monitor the volatilization of NH_3 every day as follows: The boric acid solution in each test tube was removed from the flask after 24 h incubation, diluted with DW to the volume of 50 mL once transferred into a 150 mL triangle flask, and then titrated with 0.01 mol/L 1/2 H_2SO_4. The titration was ceased when the solution turned red from blue, and the consumed volume of standard 1/2 H_2SO_4 was recorded to determine the NH_3 volatilization (mg) per day per kilogram (kg) of composting

Table 2
Content of heavy metals in concentrated monosodium glutamate waste (CMGW).

Element	Cd	Hg	Pb	Cr	As
Content (μg/kg)	0.56	Not found	Not found	2.426	0.536
Control standards (mg/kg) [a]	3	5	100	300	30

[a] Control standards for urban waste (GB8172-87).