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The effects of apple pomace, bentonite and calcium superphosphate on swine manure aerobic composting

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ABSTRACT

The effects of additives such as apple pomace, bentonite and calcium superphosphate on swine manure composting were investigated in a self-built aerated static box (90 L) by assessing their influences on the transformation of nitrogen, carbon, phosphorous and compost maturity. The results showed that additives all prolonged the thermophilic stage in composting compared to control. Nitrogen losses amounted to 34–58% of the initial nitrogen, in which ammonia volatilization accounted for 0.3–4.6%. Calcium superphosphate was helpful in facilitating composting process as it significantly reduced the ammonia volatilization during thermophilic stage and increased the contents of total nitrogen and phosphorous in compost, but bentonite increased the ammonia volatilization and reduced the total nitrogen concentration. It suggested that calcium superphosphate is an effective additive for keeping nitrogen during swine manure composting.

1. Introduction

Composting is one of the best-known processes for the disposal of organic wastes such as swine manure, which presented as an environmentally friendly and sustainable alternative to manage and recycle organic solid wastes, with the aim of obtaining a quality organic product (compost) that can be used as organic amendment in agriculture (Garcia-Gomez et al., 2005). Nitrogen (N) loss, however, can be severe when materials with a high N content are decomposed. The loss of nitrogen through volatilization of NH_3 during the thermophilic phase of the process is one of the major disadvantages (Gabhane et al., 2012). This loss causes a decline in the value of the compost as fertilizer, as well as complaints regarding disagreeable odors. It is reported that the loss of NH_3 emission accounted for 44–62% of the initial N during a poultry manure composting (Kithome et al., 1999). To reduce N loss and NH_3 emission, enhance microbial activity, facilitate the composting process and improve compost quality, the use of amendments is thought to be the most effective method (Chen et al., 2010).

The first type of amendments acts by lowering the initial pH of the compost, such as sulfuric acid, bamboo charcoal, nitric acid, olive pomace, (Chen et al., 2010; Haddadin et al., 2009; Khan et al., 2009). Secondly, adding materials have physical adsorption properties such as bentonite, peat, fly ash, and lime (Kurola et al., 2010; Lau et al., 2001; Li et al., 2012). In the third method of reducing NH_3 emission, metal salts, the functions of which are to react with or change the properties of raw materials, including $Al_2(SO_4)_3$, $MgSO_4$, and $CaCl_2$ (Kithome et al., 1999), P and Mg salt (Jeong and Hwang, 2005). Bentonite is a widely distributed low-cost mineral, which main constitution is montmorillonite which is a 2:1 mineral with one octahedral sheet and two silica sheets, forming a layer. Bentonite could facilitate organic matter (OM) degradation, increase total nitrogen (TN) content, decrease C/N and reduce the extractable Cu and Zn content during swine manure composting process (Li et al., 2012). Calcium superphosphate is a typical chemical fertilizer containing calcium phosphate, calcium sulfate and free acid, which could bond ammonia by chemical reaction (Jeong and Hwang, 2005). It was reported that struvite crystals could be formed in the aerobic composting reaction provided that Mg and P salts were added. Apple pomace is a by-product of the cider-processing industry representing about 35% of the original fruit, which is the case in shannxi, where approximately 70,000 tons of apple pomace were generated every year. The apple pomace actually contains much of the phytochemicals and fiber found in whole apples (Lavelli and Kerr, 2012). However, this by-product is a poor animal food because of its low protein content and its season-restricted availability, so the exploration of potential alternative uses for this waste is needed. Plaza et al. (2008)

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concluded that the addition of two-phase olive pomace could promote the humification of organic matter and enhance the quality of these materials as soil organic amendments. Canet et al. (2008) studied the composting with pomace and had the same results. Although several studies have been performed examining other pomace, such as olive pomace, no information is available on the effect of apple pomace on the process during the swine manure composting. Furthermore, many researchers had evaluated the effect of one of these additives on composting, but no study has been performed to compare the effects of the use of bentonite, calcium superphosphate and apple pomace, which were three different types of additives, on the composting process.

Thus, the objectives of this study were to evaluate the effects of apple pomace, bentonite and calcium superphosphate on ammonia emissions and maturity during swine manure composting and to explore a new strategy for the disposal of apple pomace.

2. Materials and methods

2.1. Composting materials

Swine manure (SM) and wheat straw (WS) collected from a swine farm and local residents respectively in Yangling town, Shaanxi, PR China, were used as the raw materials for the present aerobic composting. Some characteristics of the raw materials are presented in Table 1. Wheat straw was used to adjust the water content and suitable C/N for composting. Three additives were chosen in present study: apple pomace (AP), bentonite (BN) and calcium superphosphate (CS). The fragmental apple pomace was purchased from a juice factory located in Xianyang city, which pH was 3.9 and the water content was 8%. The pH of bentonite (Sihewei Chemical Co., Ltd.) and calcium superphosphate (Sinpharm Chemical Reagent Co., Ltd.), both chemical pure, ranged from 8–11 and 1.3–3 at 25 °C respectively.

2.2. Composting experiments method and design

Fresh swine manure and wheat straw were mixed at a ratio of 10.5: 1 in fresh weight and then composted in a self-built, aerated static composting box. The dimensions of each bin were 0.65 m × 0.50 m × 0.40 m with a volume of approximately 0.09 m^3. The box was consisted of sealed reaction chamber, sieve tray, holder, air pump, buffer bottle and temperature detector, etc. The outer wall of the box was insulated with 0.08 m plastic foam, which has the effect of retaining the heat generated during composting.

There were four treatments in the experiment, which were named as follows: control, AP, BN, and CS, respectively. The boxes used in each treatment were identical bins. The stock material of each treatment was prepared as below (all in fresh weight):

Control: 21 kg SM + 2 kg WS
AP: 21 kg SM + 2 kg WS + 1.32 kg AP
BN: 21 kg SM + 2 kg WS + 1.21 kg BN
CS: 21 kg SM + 2 kg WS + 1.21 kg CS

The basic 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. Aeration was arranged by pushing fresh air (60 L min^{-1}) using an air pump through a perforated tube at the bottom of each box during the composting, and the frequency of ventilation was twice per day, once at about 9 a.m. and the other at about 3 p.m., and each time 30 mins. In order to study the effect of these additives on composting, the time and rate of aeration were consistent for all treatments. Water content of the stock material was initially adjusted to about 65%. No further adjustment in moisture was made throughout the composting period. The initial chemical properties of composting mixtures were shown in Table 2. A 45-d experiment was conducted between August 10th 2011 and September 25th 2011.

2.3. Composting sampling and analytical methods

Temperature was monitored every day at a depth of 0.20 m using an intelligent thermometer (XMT616) before aeration, and monitored ambient temperature simultaneously. Compost samples were collected seven times over the duration of the experiment (0, 8, 13, 20, 25, 36, 45 d) according to the change of temperature after the start of the experiment. Before sampling, the pile was thoroughly turned manually. Sampling was performed in triplicate, mixing five points into every sample in diagonal method, so the results would be representative of the conditions of every treatment. Representative sample from each bin was divided into two parts. One part was immediately stored at 4 °C till analysis, and the other part was air-dried, passed through a 0.25 mm sieve and stored in desiccator.

Moisture of the fresh samples was determined as weight loss upon drying at 105 °C in an oven for 24 h. Electrical conductivity (EC), Germination index (GI) and pH were measured by aqueous extract of compost obtained from fresh samples. The aqueous extract was obtained with the method described by Huang et al. (2004). EC was measured using an EC meter and pH using a pH meter. Chinese pakchoi seeds were used for Seed Germination Index (GI) measurement. Ten Chinese pakchoi seeds were distributed on filter paper in Petri dishes (0.1 m in diameter) and moistened with 5 mL of the compost extract. Three replicate dishes for each sample were incubated at 25 °C for 48 h. The number of germinating seeds and root lengths were measured. Distilled water was used as a reference. GI was calculated using Eq. (1) (Zucconi et al., 1981) and used to assess phytotoxicity of the compost.

$$GI(\%) = \frac{Seed\ ger\min ation\ (\%) \times Root\ length\ of\ treatment}{Seed\ ger\min ation\ (\%) \times Root\ length\ of\ control} \times 100 \quad (1)$$

Ammonia emitted from the compost was collected by trapping with sulfuric acid (H_2SO_4). During the aeration, an absorption tube with 10 mL H_2SO_4 was connected to compost bin. Gas was sampled twice each day from 2 d to 20 d (the duration of the thermophilic stage), each time 30 mins, and just coincided with aeration, then analyzed by colorimetry at 420 nm. The average of them was calculated as the concentration of NH_3 emission at the day. Note that

Table 1
Properties of raw materials used in the composting.

Raw materials	TOC (g kg^{-1})	TN (g kg^{-1})	Moisture (%)	C/N
Fresh SM	359.0 ± 0.7	27.9 ± 0.7	70.9	12.8
WS	419.6 ± 0.5	5.0 ± 0.6	14.5	83.3

SM: swine manure; WS: wheat straw.

Table 2
Initial chemical properties of composting mixtures.

	pH	EC (mS cm^{-1})	TN (g kg^{-1})	TOC (g kg^{-1})
Control	6.5 ± 0.14 A	3.5 ± 0.02 A	24.6 ± 1.35 A	318.3 ± 7.90 A
AP	6.1 ± 0.15 B	4.1 ± 0.37 B	31.3 ± 2.15 BC	349.1 ± 11.18 B
BN	7.2 ± 0.29 C	3.5 ± 0.28 A	27.5 ± 0.35 A	301.3 ± 6.13 C
CS	6.2 ± 0.05 B	4.8 ± 0.14 C	30.5 ± 0.38 C	300.0 ± 4.31 C

Values are means ± standard deviations. Values followed by uppercase letters are significantly.