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A negative-pressure aeration system for composting food wastes

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Abstract

A pilot-scale active aeration reactor was studied for composting food wastes in an open-top container aerated with negative pressure by vacuum. A biological filter bed was used to remove NH_3 from the emission. In addition to monitoring system parameters, the compost stability and fertilizer content were also examined to ensure product quality. The compost temperature rose to above 65 °C the first day and maintained at the high temperature fermentation level for 30 days. The pH decreased from the initial 5.2 to 4.3 on the first day and then rose slowly to 7.4 on the 60th day. After 60 days, the C/N ratio dropped from 32 to below 20. The final compost contains 1.6% nitrogen, 0.6% phosphate, and 1.4% potassium with total coliforms below 3 MPN/100 mL. Using the biological filter to remove NH_3, the emission contains less than 1 ppm of NH_3. This system proves to be effective and environmental friendly.

Keywords: Organic waste composting; Thermophilic disinfection; Acidic disinfection; Odor prevention; Ammonia emission

1. Introduction

Methods to maintain an aerobic fermentation condition in composting reactor include pile turning, forced aeration of static pile, and passive aeration of static pile (Solano et al., 2001) to enhance the rapid growth of aerobic, oxic and facultative microorganisms for decomposing organic materials (Diaz et al., 1993; Polprasert, 1996). The traditional method to aerate a pile of compost depends on mechanical equipment to turn over the material twice daily to once every other day. After stirring, the compost has the highest oxygen content but the oxygen gradually depletes so that anaerobic conditions may develop in the compost until the next stirring. While the stirring provides oxygen, it also disperses the odor to cause serious environmental pollution. The odorous emission is difficult to control with mechanical aeration. It causes the general public to complain about the odor and even appeal to regulatory agencies for the problem. Additionally, traditional mechanical composting may take as long as 2–6 months to mature (Solano et al., 2001; Goldstein and Gray, 1999; Li and Jang, 1999; Wei et al., 2000; Trois and Polster, 2001). How to shorten the composting time and alleviate the odor problem is an emerging topic for research on composting technology.

Using the forced-air (positive pressure) aeration that blows air from the bottom of the composting container to diffuse air upward for aeration will maintain a favorable composting environment to reduce the composting time to about 28–35 days. A major disadvantage of this method is the emission of odorous gas to the environment causing serious pollution. The odor problem can be controlled if extra equipment is attached to collect and treat the odor-containing gaseous emission at extra costs (Li et al., 2008). Additionally, improper design and/or operation of the forced-air system will cause the moisture content in the composting material near the bottom of the reactor too low to support adequate microbial growth.

The negative-pressure aeration uses perforated pipes placed near the bottom of the composting reactor and connected to a blower. When the blower is turned on to withdraw air from the reactor, negative pressure is created in

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the reactor. Air is gently forced by atmospheric pressure into the reactor downward through the open top to aerate the compost mixture and maintain an oxic fermentation environment (Chen et al., 2005). The foul volatile gaseous produced during the fermentation process, e.g. volatile organic acids, ammonia, methylamine, mercaptan, etc., can be collected and treated in a biological filter bed or elution tower for controlling the odor problem. Additionally, if watering properly at the reactor top, the air flow will bring the moisture downward evenly to maintain adequate moisture in the entire reactor to support adequate microbial growth.

The aforementioned review clearly indicates that both mechanical compost stirring and forced-air (positive pressure) aeration will make the composting an open process such that the escaped odor will cause environmental pollution problems. Taiwan is densely populated with limited land space; the odor problem must be carefully evaluated and controlled to avoid the resistance from the general public against building a composting plant in their backyard. Using the negative-pressure aeration composting reactor will maintain adequate oxic conditions and moisture content during composting while controlling the odor problem to avoid the general public's resistance. Thus, this technology is suitable for and should be developed in Taiwan. In this research, the negative-pressure aeration composting system was tested for composting food wastes. Physical and chemical parameters that affect the fermentation process and the product quality were valuated. The information can be referenced for design and operation of future composting plants.

2. Methods

2.1. Equipment

Dimensions of the negative-pressure fermentation reactor are 150 cm (L) × 150 cm (W) × 170 cm (H). Perforated polyvinylchloride (PVC) pipes (1.5 in. dia.) with holes drilled at every 4–5 cm are placed at the bottom for every 30 cm. The pipe was connected to a vacuum motor (No. LF-70; 60 Hz) that maintained a static pressure of 320 mm AQ to aerate the reactor continuously with vacuum at 1.8 L air/kg dry solid-min. A biological filter made of 300-L (76 cm dia.) plastic and filled with mature compost (adjusted water content to about 60% and maintained during operation) was used to remove the odor from the exhausted gas. The odorous gas entered the filter from the bottom and dispersed upward evenly allowing the moisture in the compost media to absorb odor, which was then decomposed by nitrifying microorganisms contained in the media.

2.2. Operational procedures of the negative-pressure composting reactor

Food waste weighing 800 kg was shredded to 1-cm particles or smaller. After mixed with 250 kg of sawdust (20%, w/w) and 210 kg of mature compost (16%, w/w), the composition of the prepared mixture is listed in Table 1. Mature compost product was added as seeding materials (Wang, 2005; Chang et al., 2006) and sawdust was added as needed to reduce the initial compost mixture to 60–65% range. After thorough mixing, the seeded mixture was transferred to the composting reactor for carrying out the study. The initial moisture content and C/N ratio of the compost mixture were 63% and 32%, respectively. When the compost moisture content fell below 50%, water was added to maintain 50–60% moisture content such that an adequate environment was maintained to enhance microbial fermentation. In this study, mature compost was used as the bio-filter media to absorb and decompose the odorous exhaust gas from the composting process. The process to convert organic waste into compost is affected by many parameters to influence the composting rate, compost quality, and the generation of odorous gas. Parameters used to monitor the progress of a composting process and the product quality include temperature, moisture content, pH, EC, C/N ratio, NH_3, total coliforms, N, P, K, etc. (Diaz et al., 1993; Polprasert, 1996; Rantala et al., 1999; Sundberg et al., 2004; Ekinci et al., 2006; Liang et al., 2006). During the 60-day composing period, variations of temperature, moisture content, pH, EC, C/N ratio, ammonia, total coliforms, N, P, and K were monitored.

2.3. Analyses

Table 2 lists the items and methods of the analyses for monitoring the composting process. Temperature was measured with a TES 1310 K-type digital thermometer equipped with a 1.2-m probe (±0.1 °C sensitivity). The temperature was measured at 50 cm inside the compost with the average of three readings taken as the measured temperature. For measuring EC, 5 g of the compost was added to 25 mL of de-ionized water. After mixing and filtering through filter paper, the filtrate EC was measured using a conductivity meter. Oxygen content, carbon mon-

Table 1
Characteristic of the component food waste, compost product, and sawdust used for preparing the initial compost mixture

Items	Weight (kg)	Weight % (w/w)	Moisture content (%)	pH	EC (dS/m)	C/N ratio	N (%)	P (%)	K (%)
Food waste	800	64	85	4.57	2.39	36	1.1	0.6	1.2
Compost product	210	16	35	7.46	2.62	23	1.6	0.3	1.1
Sawdust	250	20	12	4.20	0.49	58	0.8	0.1	0.3
Initial compost mixture	1260	100	63	5.20	3.12	32	1.2	0.5	1.1