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Coal fly ash and lime addition enhances the rate and efficiency of decomposition of food waste during composting

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ABSTRACT

To evaluate the use of coal fly ash (CFA) on the decomposition efficiency of food waste, synthetic food waste was mixed with lime at 1.5% and 3% (equivalent to 0.94% and 1.88% $CaCO_3$, respectively), CFA at 5%, 10% and 15% with lime so as to achieve $CaCO_3$ equivalent of 1.88% and composted for 42 days in a thermophilic 20 l composter with two replicates each. Alkaline materials at 1.88% $CaCO_3$ equivalent successfully buffered the pH during the composting and enhanced the decomposition efficiency. When these buffering was achieved with CFA + lime, the composting period could be shortened to ~28 days compared with ~42 days in 3% lime. Organic decomposition in terms of CO_2 loss, carbon turnover and nitrogen transformation were significantly higher for treatments with 1.88% $CaCO_3$ equivalent. Nutrient transformations and compost maturity parameters indicated that addition of CFA (5–10%) with lime at 1.88% $CaCO_3$ equivalent enhances the decomposition efficiency and shortens the composting period by 35%.

1. Introduction

Food waste is the single-largest component of the waste stream by weight and constitutes about 30–55% in different countries. According to HKEPD, domestic wastes generated in Hong Kong contribute about 44% of the total MSW in 2006. During this period, everyday 3619 tons of food wastes, which constitute about 55% of the domestic wastes, were generated (Leung et al., 2008). Most of the food wastes were landfilled during the past years. However, currently waste reduction and recycling getting a bigger stage and are enforced in different forms. Aerobic composting, one of the treatment methods for solid wastes, provides a means to reduce the food waste being landfilled and simultaneously producing a valuable product, compost. The main problem associated with composting of food waste materials is the fermentation of carbohydrates and fats, which lowers the pH of the composting mass leading to retarded decomposition efficiency (Nakasaki et al., 1998). Numerous methods have been suggested to control the drop of pH by increasing aeration (Beck-Friis et al., 2003), inoculation of bacterial or yeast cultures (Choi and Park, 1998; Sundberg and Jönsson, 2005) or the addition of alkaline materials (Nakasaki et al., 1993). Despite this, limited researches have focused on the use of alkaline waste such as coal fly ash (CFA) in food waste composting. Our earlier studies demonstrated the use of CFA and lime as suitable amendments in the composting and/or alkaline stabilization of sewage sludge and pig manure (Wong, 1995; Wong and Su, 1997; Fang et al., 1999; Fang and Wong, 2000; Wong et al., 2001). However, despite numerous studies using CFA as a co-composting material, its usability on the decomposition of food waste during composting has not been focused upon. Hence the present study was designed to evaluate whether CFA could neutralize the acids generated during the initial stage of food waste composting, with the purpose to enhance the decomposition efficiency as well as producing an acceptable compost material. Since disposal of CFA also an environmental problem, successful use of CFA in food waste composting offers multiple advantages.

2. Methods

2.1. Food waste and treatments

The food waste for the experiment was prepared artificially by mixing 1.3 kg bread, 1 kg boiled rice, 1 kg cabbage and 0.5 kg fully boiled pork. All the components were cut into 0.5 cm^3 to ensure a regular mix. The C/N ratio of the food waste was adjusted to 25 by the addition of sawdust (~400 g). Total organic carbon (TOC), total nitrogen (TN), C/N ratio and moisture contents of the individual components used to prepare the food waste are presented in Table 1. Finally, 500 g woodchips of 1 cm^3 was added to achieve a bulk density of 0.5 kg/l. In our preliminary experiment (data not shown), we found that the bulk density of 0.5 kg/l was suitable for the food wastes. One set of experiments includes mixing of food waste with industrial lime at 0%, 1.5% and 3% (the $CaCO_3$ equivalent is 0%, 0.94% and 1.88%, respectively). Another set of experiments includes mixing of food waste with different combination

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Table 1
Total organic carbon, total nitrogen, C/N ratio and moisture contents of the components used to prepare the synthetic food waste used in the present study.

Parameter	Bread	Rice	Vegetable	Meat	Sawdust
Total organic carbon (%)	52.2	52.9	41.7	50.5	53
Total nitrogen (%)	2.49	1.16	3.99	3.71	0.09
C/N ratio	21.0	45.6	10.5	13.6	589
Moisture content (%)	26.5	64.0	91.1	60.2	1.91

of CFA and lime: CFA 5% + lime 2.25%, CFA 10% + lime 1.5% and CFA 15% + lime 0.75%, to achieve a final $CaCO_3$ equivalent of 1.88%. The neutralizing capacity of CFA and lime was determined by incubating them with 1 N HCl for 7 days and the excess HCl were back titrated with NaOH.

2.2. Composting process and analyses

Composting of food wastes was carried out in a computer controlled 20 l reactor in which the minimum temperature was controlled at 50 °C using a thermocable coiled around the reactor. The schematic diagram of the compost reactor is presented in Fig. 1. The temperature was monitored and recorded automatically in a computer system. The CO_2 evolved from the compost reactors were measured by non-dispersive infrared with microprocessor control and linearization using WMA-2 gas analysers (PP systems, Herts, UK), and the data were continuously recorded in the computer. Based on our preliminary experimental result (data not shown), aeration was provided at a flow rate 1 l/kg dry weight/min through an aerator pump. The air was first passed through 100 ml of 8 N NaOH to remove the CO_2 and 150 ml water for moisturizing the inlet air. The gas outlet from the reactor was connected to a spiral condenser to prevent excessive water loss from the system. A 1 l Duran bottle containing 200 ml 8 N NaOH was used to trap the CO_2 in the exhaust. The CO_2 trap was replaced daily and titrated against HCl solution.

Sampling of food waste was carried out on day 0, 3, 7, 10, 14, 21, 28 and 42 of the composting period. The composting mass inside the reactor was taken out and mixed thoroughly in a large vessel with the addition of water to restore the moisture, after that, 150 g of sample was collected for the analysis of pH, extractable ammonium, volatile solids (VS), soluble nitrates, soluble organic nitrogen, TOC, total Kjeldahl nitrogen (TKN) and cress seed germination test as per the standard methods for testing compost materials (TMECC, 2003). Soluble and extractable contents indicated above were analyzed in 1:5 water extracts of the compost sample. For the total heavy metal contents in CFA and composts, samples were subjected to mixed acid digestion (conc. HNO_3 and conc. $HClO_4$) and analyzed using atomic absorption spectrophotometer (Varian Techtron Model AA-10) and graphite furnace atomic absorption spectrophotometer (GFAAS) with deuterium background correction. Mercury and arsenic were analyzed using the Perkin Elmer AAS 3110 connected with Perkin Elmer AS 90 Flow injection module.

2.3. Determination of bacterial population

One gram of fresh sample was shaken with 9 ml of sterile 0.9% NaCl solution for one hour and the extracts after serial dilution was spread on nutrient agar. To enumerate the volatile fatty acid (VFA)-degrading bacteria, Difco Bushnell–Hass agar amended with 1 g/l each of acetic acid, propionic acid, butyric acid, iso-butyric acid, valeric acid and iso-valeric acid was used (Wong et al., 2008). The agar plates were incubated at 37 °C for 48 h; colonies were counted and expressed as colony forming units (CFU)/g dry compost mass.

2.4. Statistical analyses

Analyses were performed in triplicate samples and the mean values with standard deviation are presented. For bacterial and VFA-degrading bacterial population, a composite sample was prepared and the analyses were carried out in triplicates. The data were subjected to one way analysis of variance (ANOVA) and Duncan's multiple range tests using SPSS ver.11.5 software.

3. Results and discussion

3.1. pH

Chemical properties of the composts after 42 days of composting are presented in Table 2. Further, the changes in chemical

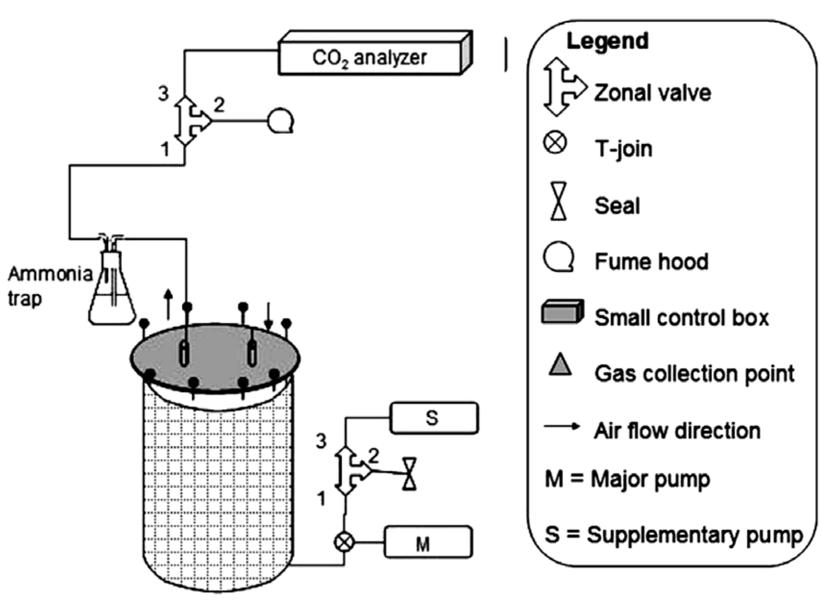

Fig. 1. Schematic diagram of the composter used in the experiment.