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Laboratory scale evaluation of volatile organic compound emissions as indication of swine carcass degradation inside biosecure composting units

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ABSTRACT

Biosecure livestock mortality composting systems have been used to dispose of diseased livestock mortalities. In those types of system, visual inspection of carcass degradation is not possible and monitoring VOCs (volatile organic compounds) released by carcasses is a new approach to assess progress of the composting process. In this study, field-scale livestock mortality composting systems were simulated and a laboratory scale composting system with aerobic and anaerobic test units was designed to collect VOC samples from the headspace of decaying plant materials (70 g dry weight) and swine tissues (70 g dry weight) at controlled operating temperatures. Headspace samples were collected with SPME (solid phase microextraction) and analyzed by a GC–MS (gas chromatography–mass spectrometry) system. Among the 43 VOCs identified, dimethyl disulfide, dimethyl trisulfide, and pyrimidine were found to be marker compounds of the mortality composting process. These compounds were only found to be produced by decaying swine tissues but not produced by decaying plant materials. The highest marker VOC emissions were measured during the first three weeks, and VOCs were not detected after the 6th week of the process, which indicates degradation processes were completed and compost materials microbially stabilized (no additional VOC production). Results of respiration tests also showed that compost materials were stabilized. Results of this study can be useful for field-scale composting operations but more studies are needed to show the effects of size and aeration rate of the composting units.

1. Introduction

The safe disposal of carcasses during emergency animal disease (EAD) outbreaks is a significant issue since diseases can be easily spread to humans and other livestock (Wilkinson, 2007). Improper disposal of carcasses, such as illegal dumping, has become a problem due to cost of mortality disposal and limited number of licensed landfills, incineration and rendering services (Bonhotal et al., 2002). Biosecurity agencies in USA, Canada, Australia, and New Zealand have recognized the potential benefits of composting for emergency management of livestock mortalities (Wilkinson, 2007). Composting of diseased mortalities was first developed for the poultry industry (Spencer et al., 2004; Bendfeldt et al., 2005) with more recent studies being conducted to adapt mortality composting for swine and cattle emergency disposal (Glanville et al., 2006a,b, 2007; Ahn et al., 2007).

In case emergency disposal is necessary, a passively-aerated plastic wrapped mortality composting system has been designed to reduce the potential of spreading live viruses to the environment (Spencer et al., 2004; Ahn et al., 2007; Glanville et al., 2007). In this type of biosecure composting application, carcasses are fully covered with envelope (typically silage, straw, or hay) materials and the entire matrix is wrapped with plastic sheets. It is not safe to turn, mix, or expose the diseased carcasses to the environment until carcass degradation is completed, temperatures have been reached and maintained to inactivate pathogens, and compost is considered stable (Wilkinson, 2007). Since visual inspection of the carcasses is not possible, a new method is needed to assess progress and completion of the degradation process without compromising biosecurity. Temperature is the most commonly used parameter for assessing performance of a composting process. However, monitoring temperature profiles does not necessarily help to evaluate progress and completion of the process. Reasons for low core compost temperatures may be over-aeration of the composting units and low heat retention properties of the envelope materials (Ahn et al., 2007; Glanville et al., 2007). Under

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these conditions, temperature may not increase but the degradation process can still continue. A new approach is to monitor VOCs (volatile organic compounds) released by decaying mortalities inside biosecure compost units (Akdeniz et al., 2009).

Volatile organic compounds emitted from composting of various wastes include a wide group of organic compounds, including sulfur-containing compounds, nitrogen-containing compounds, alcohols, phenols, ketones, esters, volatile fatty acids, and terpenes (Pagans et al., 2006). Typically, VOCs are found in low concentrations (pg/L to μg/L) in the headspace of composting units. Sample preparation for VOCs in headspace requires pre-concentration (Dewulf and Van Langenhove, 2002; Clemitshaw, 2004). Ultraviolet differential absorption spectroscopy (UV-DOAS), Fourier transform infrared spectroscopy (FT-IR), and colorimetric sensors are the techniques that allow measurement of VOCs in headspace without sample preparation but the number of analytes that can be detected is limited (Lin et al., 2004). Gas phase SPME (solid phase microextraction) coupled with GC–MS (gas chromatography–mass spectrometry) based analyses is a more convenient (does not require sample preparation) method for measurement of VOCs in air and headspace (Koziel et al., 1999; Koziel and Novak, 2002). Solid phase microextraction has been used to sample VOCs from biofilter-treated effluent air of swine barns (Chen et al., 2008), landfills (Davoli et al., 2003; Kim et al., 2005a), commercial composts (Kim et al., 2005b) and decaying plant and animal materials (Akdeniz et al., 2007a,b).

There are many variables affecting analytical method development and quantification with SPME. One of the factors affecting air sampling with a SPME fiber is air temperature. Although there are more compounds in the vapor phase when the temperature increases, amounts of volatiles adsorbed can decrease (Jia et al., 1998; Demyttenaere et al., 2003). This can be explained by the fact that adsorption is an exothermic and competitive process (Pawliszyn, 1997). In addition, adsorption induces heat release, which can increase the temperature of the adsorbent and decrease the amounts of analyte adsorbed (Nongonierma et al., 2006).

In this study, a laboratory scale composting system, which simulated a field-scale biosecure composting system was designed, built and tested to specifically monitor VOC emissions. Several operating variables were controlled (i.e., composting time, temperature, and aeration flow rate resulting in aerobic or anaerobic conditions). The objectives of the study were (a) to identify and compare VOCs evolved from decaying swine tissues and plant materials in order to find marker compounds of decaying swine tissues, (b) to develop air sampling and analyses methods for different air temperatures to accurately quantify marker VOC emissions, and (c) to evaluate a potential usage of VOC emissions to test completion of carcass degradation.

2. Methods

Compost test units were designed, prepared, and run in triplicate to identify and compare VOCs evolved from decaying plant and animal materials. These tests included separate plant and animal material compost units and layered (plant-animal material) compost units ($n = 3$ for each treatment). The separate units consisted of corn silage, oat straw, and alfalfa hay, and swine tissues (70 dry grams) composted separately at aerobic and anaerobic conditions (total of 24 units). The layered compost tissues consisted of combinations of corn silage and swine tissues (70 dry grams total), composted under aerobic and anaerobic conditions (total of 6 units). Corn silage was chosen for this combination because it emitted a higher number of VOCs among all plant materials tested (Akdeniz et al., 2007a).

2.1. Aerobic and anaerobic test units

Two oilless pumps (Combined Fluid Products, Lake Zurich, IL) were used to aerate aerobic test units. Air was pumped through hydrocarbon traps (Supelco, Bellefonte, PA) to prevent any VOC contamination from the ambient air. Curved PTFE tubing with

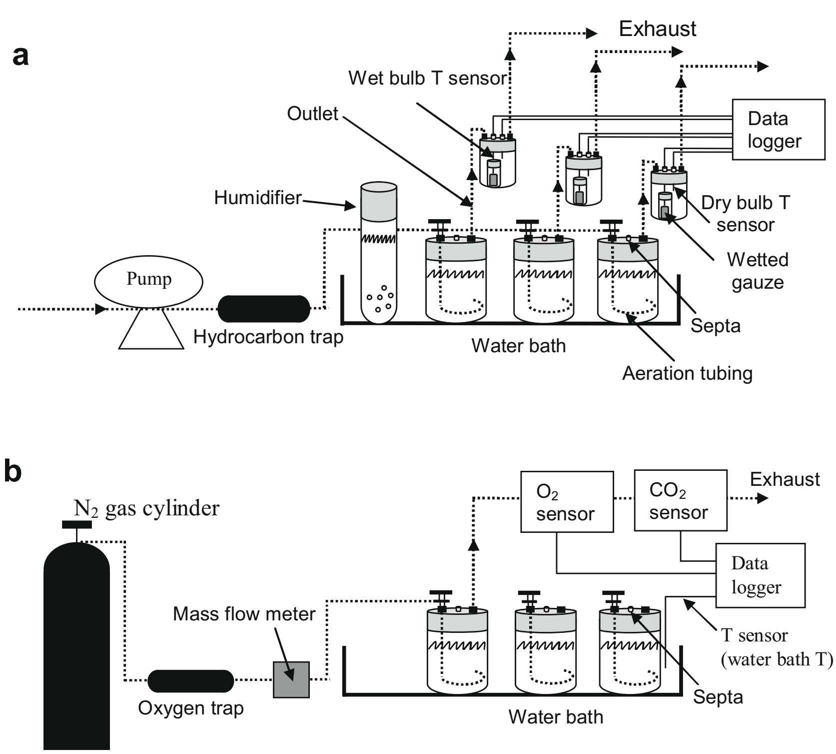

Fig. 1. Schematic of the test units and dry/wet bulb temperature measurements (only 3 of the 12 test units are shown): (a) aerobic, (b) anaerobic.