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Effect of turning frequency and season on composting materials from swine high-rise facilities

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ABSTRACT

Composting swine slurries has several advantages, liquid slurries are converted to solids at lower moisture, the total volume and weight of material is reduced and the stabilized product is more easily transported off-site. Despite this, swine waste is generally stored, treated and applied in its liquid form. High-rise finishing facilities (HRFF) permit liquid slurries to be converted to solids which are partially decomposed underneath the HRFF and then finished in compost windrows. The purpose of this study was to evaluate the effect of turning frequency and ambient weather conditions on biological, physical and chemical properties of composted slurry-woodchip mixtures from HRFF. Compost trials were conducted in either fall (FT) or spring (ST) and piles were turned once or three times per week or upon compost temperature reaching 65 °C. Physical, chemical and microbiological characteristics were measured over the course of 112 (FT) or 143 (ST) days of composting. Total carbon, total nitrogen (N) and inorganic N decreased in all piles. Ammonium decreased while nitrate increased in all piles (including unturned), but total N losses were greatest in piles turned more frequently during the ST. Microbial populations of nitrifiers were dominated by ammonia-oxidizing archaea (3.0×10^3–4.2×10^6 cells g^{-1} compost) but ammonia oxidizing bacteria (below detection to 6.0×10^5 cells g^{-1} compost) varied in response to turning and compost temperature; denitrifiers were present in high concentrations throughout the process. Swine HRFF materials composted well in windrows regardless of turning frequency and despite significant differences in starting materials and low initial C/N. Volume reduction, low moisture and low readily degradable organic matter suggest that the finished compost would have lower transportation costs and should provide value as a soil conditioner.

1. Introduction

In the United States (U.S.) swine slurry, a mixture of feces, urine and wash water, is normally stored in deep pits beneath the facility or in lagoons located adjacent to confinement areas (Key et al., 2011). The stored slurry is spread on nearby crop and pasture lands by irrigation, surface application or injection. The manure is a valuable resource for crop fertilization and soil conditioning. However, in areas with high livestock density, manure production may outpace land available for application resulting in increases in manure application intensity and the potential for negative environmental impacts (i.e., release of excess nutrients or green house gases, accumulation of salts, growth of deleterious microorganisms). Application of slurry on land in these areas is often restricted and alternative disposal technologies are being evaluated (Aita et al., 2012; Key et al., 2011; Larney et al., 2007; Ten Hoeve et al., 2014).

Composting is an aerobic biological degradation process that decreases manure volume and results in a stable end product that costs less to transport. It is a readily accepted and commonly utilized technique for treating waste materials and has been studied extensively as a manure management tool (recently reviewed by Bernal et al. (2009)). When applied to agricultural land, compost has been shown to improve soil quality (i.e., increased soil organic matter, aggregate stability and drought tolerance) and act as a slow release fertilizer (Bernal et al., 2009; Bustamante et al., 2008;

Abbreviations: HRFF, high-rise finishing facility; FT, fall trial; ST, spring trial.

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Eghball et al., 2004; Lee et al., 2006). Recent research on swine slurry composting and its application to agricultural soils has provided new insights into how swine slurry compost management (turning, moisture, bulking material, temperature, etc.) affects nitrogen dynamics (Angnes et al., 2013; Fukumoto et al., 2009), green house gas emissions (Fukumoto et al., 2003; Selvam et al., 2012; Zhong et al., 2013), pharmaceuticals (Derby et al., 2011) and microbial populations (Kuok et al., 2012; Mc Carthy et al., 2011; Pan et al., 2013).

Despite the proven economic and environmental advantages of composting, the process has not been widely applied for manure management on large scale swine production facilities in the U.S. In fact, the percentage of producers spreading solid swine manure declined 30% over ten years with 96% of swine raised on farms using either pits or lagoon systems (Key et al., 2011). The high volume and liquid nature of swine slurry and the requirement for a ready supply of low cost, high carbon (C) bulking material to absorb liquid have limited its application on large scale swine production facilities in the U.S. (USEPA, 2004). However, as livestock intensification trends continue and nutrient application regulations and transportation costs increase, composting should become a more appealing option for manure management at these facilities.

In the past two decades, swine high-rise finishing facilities (HRFF) have been evaluated as an alternative to liquid slurry management systems (Frederick et al., 2002; Keener et al., 2001; Stowell, 2002). In HRFF, the production area is on the second floor (3.5 m above ground) while the first floor is used for manure management. Woodchips, straw or cornstalks act as a bulking material for aeration and to absorb liquids from wash water, manure, urine and spilt feed that falls through the slatted floor of the living area above. These systems are not common in the U.S. but past studies have found them to be environmentally and economically viable with swine performance on par with traditional facilities (Frederick et al., 2002; Stowell, 2002). The slurry–bulking material mixtures are partially decomposed under the house, but must be finished in windrows outside of the facility. Frederick (2002) showed that composting partially decomposed slurry–bulking materials from HRFF substantially reduced manure volume (62–63%) in comparison to deep-pit finishing systems. However, those studies did not evaluate the effect of composting parameters (i.e., turning schedule, environment, or variability in starting material) on finishing partially decomposed materials from swine HRFF. Therefore the purpose of this study was to investigate the effect of turning frequency and compost conditions on biological and physicochemical properties of decomposed swine slurry-woodchip mixtures from a functional HRFF.

2. Materials and methods

2.1. Compost material, study design and sampling

Decomposed materials (a mixture of swine slurry and woodchips) were obtained on two separate occasions from a swine HRFF located in western Kentucky. The HRFF houses between 4000 and 4800 swine which are placed in the facility at 18–20 kg and are removed after three months (weighing about 105 kg). The high-rise floor raises the living area 3.7 m above the ground. Manure, excess feed, water and wastewater drop through slatted floors into 2.5 cm screened woodchips (average size 1.9 ± 0.9 cm). The slurry-woodchip material was turned up to three times per week while under the HRFF. When the material was visibly moist, reducing its ability to absorb additional waste materials, it was removed from the facility for finishing in windrows. In fall 2011 (FT) and Spring 2012 (ST), HRFF slurry-woodchip mix (approximately 60 m^3 weighing 48.4 Mg) was brought by semi-trailer trucks to the Western Kentucky University Agricultural Complex where materials were divided into three or four windrow piles. In the FT, swine slurry-woodchip mixes having a bulk density of 849.6 $kg\ m^{-3}$ and consisting of around 19.6 m^3 of material were formed into three piles of approximately 10.4 m × 2.1 m × 0.9 m ($L \times W \times H$). In the ST, swine slurry-woodchip mixes having a bulk density of 778.4 $kg\ m^{-3}$ and consisting of around 18.8 m^3 of material were formed into three piles of approximately 5.8 m × 2.7 m × 1.2 m ($L \times W \times H$) and a fourth batch (unturned) was left piled at the side (0×; 3.6 m^3). In each study, piles were turned using a windrow compost turner (Model CT-10, HCl Machine Works, Dos Palos, CA) either once per week (1×), three times per week (3×) or upon the internal compost temperature reaching 65 °C (@65). Compost for the FT @65 treatment heated to 65 °C by day 14 and was turned 11 times over the course of the trial. However, during the ST, the @65 pile did not heat for the first 63 days (mean temperature 27 ± 8 °C) therefore weekly turning was initiated at that time. Following recommendations of Tiquia et al. (2000), who found that that statistically valid data were obtained from triplicate composite compost samples taken from different locations within a single windrow pile, data were replicated in this study by visually dividing the compost piles into three sections and taking five composite cores from each section. Compost samples were taken by digging into the pile 15 cm and using a soil corer to take 15 cm compost cores from each section. The five composite cores collected from each section were combined to make one replicate for a total of three replicates from each pile. The cores were mixed thoroughly before sub-samples were taken for microbiological and chemical analyses. A separate corer was used for each treatment and corers were sterilized with 70% ethanol between replicates. Samples were taken on days 0 and three and then weekly for the first 12 weeks and bi-weekly until composting was stopped at day 112 for the FT and day 142 for the ST. Initial characteristics of HRFF slurry-woodchip mixes used for windrow composting are shown in Tables 1 and 2.

2.2. Physical and chemical analysis

Compost temperature was monitored at one hour intervals at three different locations in each pile by HOBO® Pro V2 temperature sensors (Onset Computer Corp., Bourne, MA, USA). Data on ambient weather conditions (temperature, precipitation) were obtained from the Kentucky Mesonet weather station (Warren County, Kentucky Mesonet, http://www.kymesonet.org, accessed Jan. 2015) located within 15 m of the compost site. Physical and chemical characteristics of compost samples were measured as previously described (Sistani et al., 2010). Briefly, dry weight of compost samples was determined after drying 24 h at 105 °C. Composite compost samples were analyzed for ammonium nitrogen (NH_4–N), and nitrate nitrogen (NO_3–N) after extraction with 2 M KCl ((Kenney et al., 1982); 1:10 soil:KCl extraction ratio) using flow injection analysis (QuickChem FIA+, Lachat Instruments, Milwaukee, WI). Total nitrogen (TN) and total carbon (TC) in the soil were measured using a Vario Max CN analyzer (Elementar Americas, Mt. Laurel, NJ). The remaining elements were measured using inductively coupled plasma-optical emission spectroscopy (ICP–OES; Vista-Pro Axial; Agilent Technologies, Santa Clara, CA) after microwave digestion with HNO_3 and HCl. The pH of compost samples was measured using a 1:1 (w/v) compost to water solution using a combination electrode (Accuphast electrode, Fisher Scientific, Pittsburg, PA). Percent change between the initial and final nutrient (element) concentration was determined by ((Final concentration − initial concentration)/initial) $*$ 100). A positive value indicated an increase in concentration and a negative value indicated a decrease in concentration.