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Research Paper

Greenhouse gas emissions during composting of dairy manure: Influence of the timing of pile mixing on total emissions

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ARTICLE INFO

Article history:
Received 20 November 2013
Received in revised form
4 July 2014
Accepted 1 August 2014
Published online 26 August 2014

Keywords:
Compost
Dairy manure
Nitrous oxide
Methane
Emissions
Greenhouse gas

The effect of the timing of pile mixing on greenhouse gas (GHG) emissions during dairy manure composting was determined using large flux chambers designed to completely cover replicate pilot-scale compost piles. Approximately 50–70% of total CO_2 and 75–80% of CH_4 emissions occurred within the first two weeks of composting. Total GHG emissions from compost piles that were mixed at 2, 3, 4, or 5 weeks after initial construction were not significantly different from the emissions from unmixed (static) piles during a six week trial period. Although delaying initial pile mixing (2, 3, 4, or 5 weeks) generally lead to decreases in CO_2 emissions, delaying mixing did not significantly affect CH_4 or total GHG emissions. When normalised for degraded volatile solids (VS), CO_2, CH_4, N_2O, and total emissions values ranged from 600–700, 130–150, 50–100, and 800–950 g CO_2-eq per kg VS degraded, respectively. Carbon dioxide, methane, and nitrous oxide accounted for 75%, 14–19%, and 6–12%, respectively, of total GHG emissions from static and mixed piles.

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1. Introduction

Composting is an environmentally friendly technology for treating and recycling a variety of organic wastes (US Composting Council, 2008). However, gaseous emissions of nitrogen-based, sulphur-based, and volatile organic compounds are negative consequences of composting and present practical problems for large-scale facilities and farms (Büyüksönmez, 2012). Emissions of methane (CH_4) and nitrous oxide (N_2O) have attracted attention because of their contributions to total greenhouse gas (GHG) emissions (Leytem, Dungan, Bjorneberg, Koehn, 2011; reviewed in Paul, Wagner-Riddle, Thompson, Fleming, & MacAlpine, 2001; Lou & Nair, 2009; Brown, Kruger, & Subler, 2008; Chadwick et al., 2011). Studies of different composting operations have shown a wide range of CH_4 and N_2O emissions, accounting for 0.01–8% of total carbon (TC) loss and 0.1–5% of total nitrogen(TN) loss, respectively (Brown et al. 2008; Hellebrand, 1998; Hellebrand & Kalk, 2000; Maeda et al., 2013; Sommer, 2001; Sommer, McGinn, Hao, & Larney, 2004; Tamura & Osada, 2006; Wolter, Prayitno, Schuchardt, 2004). Although there are

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http://dx.doi.org/10.1016/j.biosystemseng.2014.08.003
1537-5110/Published by Elsevier Ltd on behalf of IAgrE.

general recommendations for minimising CH_4 and N_2O emissions (such as use of feedstocks with high carbon/nitrogen and low moisture content values) (Brown et al. 2008), there is a continued need for experimentally determined emission factors from a variety of representative agricultural feedstocks under field conditions. In addition, there is a need to develop and evaluate practical management measures for minimising these emissions at the farm-scale.

The goal of this study was to determine whether relatively simple on-farm manure management practices (such as altering the timing or frequency of compost pile mixing) are effective at reducing GHG emissions on U.S. dairy farms. A recent study using large-flux chambers and pilot-scale dairy manure compost piles showed that emissions from piles that were turned four times during an 80-day period were approximately 20% higher than values from unmixed (static) piles (Ahn, Mulbry, White, & Kondrad, 2011). The specific purpose of this study was to test the prediction that delaying pile mixing would decrease GHG emissions during dairy manure composting.

For these experiments, we used large-scale flux chambers that were designed to entirely cover pilot-scale compost piles. Other groups have established the effectiveness of this approach (Andersen, Boldrin, Samuelsson, Christensen, & Scheutz, 2010; Tamura & Osada, 2006; Wolter, Prayitno, & Schuchardt, 2004) and we used this approach recently (Ahn et al., 2011). Previous studies have shown that the majority of total GHG emissions occur within the first 30 days of composting and that CH_4 emissions occur primarily after pile construction and after the first mixing event (Ahn et al., 2011). For these reasons, we limited the trial period to the first 42 days (6 weeks) after pile construction.

2. Methods

2.1. *Compost pile construction and mixing frequency*

Fourteen replicate pilot-scale compost piles were constructed in November 2011 using a 1:1 (v/v) mixture of dairy manure solids and straw bedding from the USDA's Dairy Research Unit in Beltsville. MD. Dairy manure solids consisted primarily of sawdust that was separated from scraped dairy manure and contained about 75% moisture. Uniform cylindrical piles (900 kg mass, 1.9 m^3 volume, 1.2 m height, 1.4 m diameter)

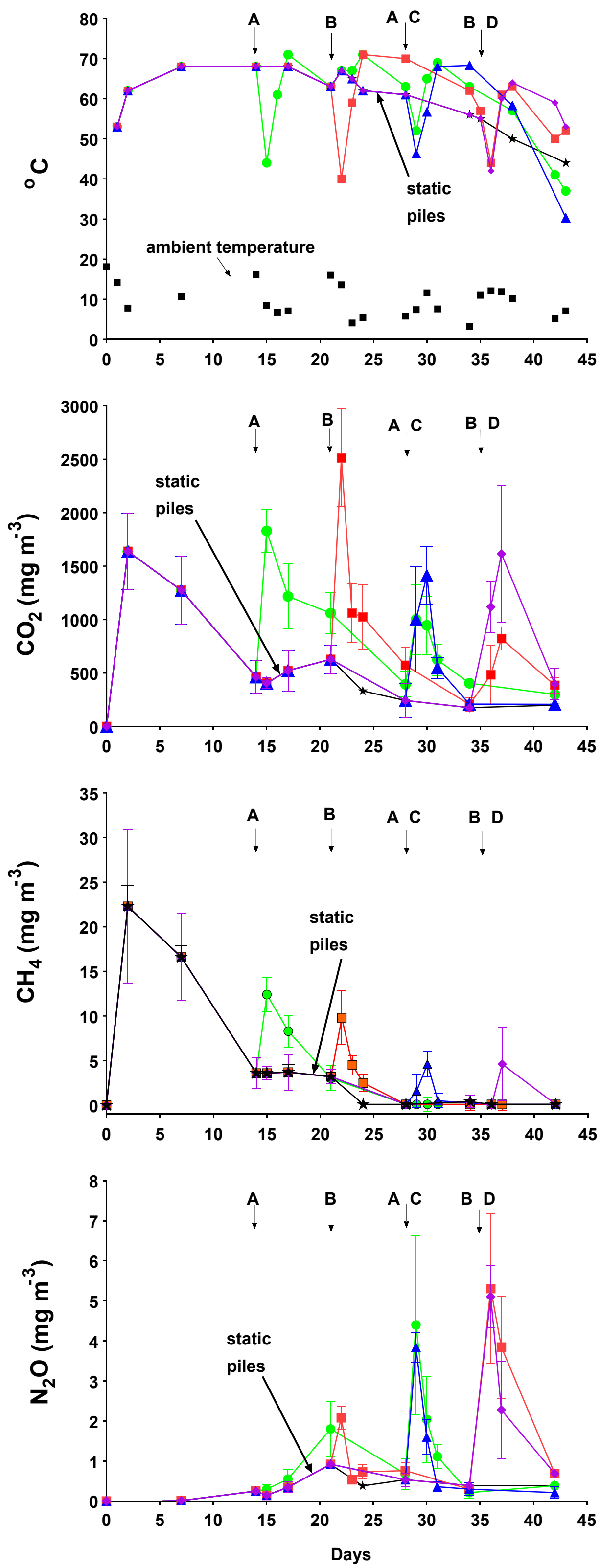

Fig. 1 – Temperatures and CO_2, CH_4, and N_2O concentrations in ambient air and in flux chamber emissions from static and mixed compost piles. Temperature values are from single daily measurements of ambient air (black squares) or are means of measurements from the centres of duplicate or triplicate piles. Standard error values of the temperature means (not shown in order to simplify the figure) typically ranged from 2 to 3 °C. Values for net CO_2, CH_4, and N_2O concentrations are means ± SE in flux chamber emissions from duplicate or triplicate piles. Arrows and letters indicate mixing dates for the mixed pile treatments (A, B, C, D). Treatment A (green circles) piles were mixed at 14 and 28 days; treatment B (red squares) piles were mixed at 21 and 35 days, treatment C (blue triangles) piles were mixed at 28 days, treatment D (purple diamonds) piles were mixed at 35 days. Static piles (black stars) were not mixed during the 42-day trial.