Bioresource Technology 151 (2014) 174–182

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

# Greenhouse gas emissions from home composting in practice

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## HIGHLIGHTS

- Concentration ratios $CH_4$:$CO_2$ and $N_2O$:$CO_2$ show emission rates linked to degradation.
- Methane emissions from home composts were lower than from large-scale systems.
- Methane emissions increased with temperature (range −2 to 62 °C) and mixing.
- Low median emission values indicate that most compost emission rates were low.
- Ammonia losses from home composting were very low due to low temperatures.

## ARTICLE INFO

*Article history:*
Received 6 August 2013
Received in revised form 10 October 2013
Accepted 15 October 2013
Available online 23 October 2013

*Keywords:*
Ammonia
Carbon dioxide
Food waste
Methane
Nitrous oxide

## ABSTRACT

In Sweden, 16% of all biologically treated food waste is home composted. Emissions of the greenhouse gases $CH_4$ and $N_2O$ and emissions of $NH_3$ from home composts were measured and factors affecting these emissions were examined. Gas and substrate in the compost bins were sampled and the composting conditions assessed 13 times during a 1-year period in 18 home composts managed by the home owners. The influence of process parameters and management factors was evaluated by regression analysis. The mean $CH_4$ and $N_2O$ concentration was 28.1 and 5.46 ppm (v/v), respectively, above the ambient level and the $CH_4$:$CO_2$ and $N_2O$:$CO_2$ ratio was 0.38% and 0.15%, respectively (median values 0.04% and 0.07%, respectively). The home composts emitted less $CH_4$ than large-scale composts, but similar amounts of $N_2O$. Overall $NH_3$ concentrations were low. Increasing the temperature, moisture content, mixing frequency and amount of added waste all increased $CH_4$ emissions.

## 1. Introduction

Home composting is a widespread treatment option for household kitchen waste. In Sweden, over 50,000 tonnes or 16% of all food (kitchen) waste treated biologically was home composted in 2011 (Swedish Waste Management, 2012). During composting, organic material is degraded by microorganisms, mainly in aerobic processes, which after sufficient time and under suitable conditions results in a stable, non-toxic, pathogen-free and plant nutrient-rich product. Large-scale composting systems have been well studied (e.g. Amlinger et al., 2008; Eklind et al., 2007), but knowledge of the process efficiency and environmental effects of home composting is limited.

During composting, oxygen ($O_2$) is consumed and carbon dioxide ($CO_2$) is released along with methane ($CH_4$), nitrous oxide ($N_2O$), ammonia ($NH_3$) and other volatile substances produced by microbes. Greenhouse gases (GHG) $CH_4$ and $N_2O$ have high estimated global warming potential (GWP), 25 and 298 $CO_2$-equivalents by weight respectively over 100 years (IPCC, 2007), and thus their emissions need to be minimised. Methane is produced by methanogenic archaea under anaerobic conditions and $N_2O$ by nitrifying and denitrifying bacteria and archaea under various oxygen conditions (Angnes et al., 2013; Hellmann et al., 1997).

In home composting, continuous addition of fresh organic material creates a heterogeneous and variable environment for microorganisms, allowing many different composting processes, such as aerobic degradation, nitrification, denitrification and methanogenesis, to occur simultaneously. Estimation of variables and parameters affecting emission sources is therefore more difficult in home composts than in large-scale or other batch composts.

Several process parameters, including moisture, temperature and aeration can significantly affect compost development, efficiency and environmental emissions. A material moisture level of

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*Abbreviations:* BW, biological waste; FW, food waste; GHG, greenhouse gas; GW, garden waste; GWP, global warming potential; HW, household waste; RSD, relative standard deviation; SA, structural amendment.

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http://dx.doi.org/10.1016/j.biortech.2013.10.049

50–60% is normally recommended for good composting (Ermolaev et al., 2012; Zhang et al., 2011). Increasing moisture results in more efficient degradation by aerobic microorganisms until oxygen supply is restricted, whereupon $CH_4$ emissions are stimulated (Amlinger et al., 2008; Jiang et al., 2011; Szanto et al., 2007). A moisture content in the range 40–60% can increase $N_2O$ emissions by promoting simultaneous nitrification and denitrification (Angnes et al., 2013; Hwang and Hanaki, 2000).

The process temperature influences the activity of methanogens, nitrifiers and denitrifiers (Hellmann et al., 1997). Temperatures within the range 40–60 °C were reported to induce $CH_4$ and $N_2O$ emissions (Amlinger et al., 2008), while temperatures above 60–65 °C could inhibit the overall degradation rate (Beck-Friis et al., 2001; Hellmann et al., 1997).

Oxygen is the most important regulator of $CH_4$ fluxes from the composting process, and $CH_4$ emissions normally correspond to 1–4% of initial carbon (Jiang et al., 2011; Szanto et al., 2007). Jiang et al. (2011) showed that the $CH_4$ emissions decrease sharply with increasing oxygen supply. Mixing can be used to ensure good aeration, but in home composts it can increase the release of GHG (Andersen et al., 2010a).

Fluxes of $N_2O$ are also coupled to factors such as C:N ratio, temperature, pH, compost process stage and microbial development (Andersen et al., 2010b; Angnes et al., 2013; de Guardia et al., 2010b; Jarvis et al., 2009; Jiang et al., 2011). The reported magnitude of $N_2O$ emissions varies greatly, for instance Szanto et al. (2007) found that 0.5–10% of initial N was lost as $N_2O$ over 100 days.

Ammonia emissions are highest at the beginning of composting (during the thermophilic phase) of nitrogen-rich substrates, when temperature is high and pH is above 6 (Jarvis et al., 2009; Sundberg et al., 2004). Overall, $NH_3$ can represent from 3% up to 98% of total gaseous N losses (Angnes et al., 2013; Eklind et al., 2007).

The scale of composting influences the rate of change in moisture, structure and temperature in the substrate (Sundberg and Jonsson, 2005). Large-scale composts rely on structural amendment, forced ventilation and/or frequent turning to promote good aeration, while home composts usually contain little structural amendment, are passively aerated and are seldom turned. Thus, the scale and management of composting are important factors to study when trying to understand the GHG emissions dynamics.

The overall aim of the present study was to determine the influence of real-life management on GHG emissions from home composts under Swedish conditions and to assess the seasonal variations in emissions and in compost management. Specific objectives were to: (1) determine emissions of $CH_4$ and $N_2O$ from home composting of food and garden waste in relation to degraded organic material (expressed as $CO_2$ production) and (2) analyse possible influences on the emissions ratios ($CH_4$:$CO_2$ and $N_2O$:$CO_2$) of different process parameters and management factors.

## 2. Methods

### 2.1. Selection and monitoring of composts

Gas and material samples from 18 small home composts in Uppsala, Sweden (59°48′N, 17°39′E) were collected and analysed 13 times during the period June 2010–June 2011. The composts were managed by private households, which agreed to join the study. In Sweden home compost must be registered before treating kitchen waste. For this study, every third entry in the municipal register of households with home composts in a few areas of Uppsala was initially contacted by telephone and asked to participate. The 18 households that agreed to participate were requested to keep an ongoing record of the management and feeding routines for their compost, using provided forms. They were asked to include information on the type and amount of waste added (kitchen waste, garden waste or other material) and date of additions, mixing and emptying. All households were requested to continue managing their compost as normal.

### 2.2. Gas sampling and analysis

The compost gas in each composting unit and the ambient air were sampled on 13 occasions. It took between 1 and 12 days (6 on average) to sample all 18 composts. At each sampling, compost gas was collected from under the unopened lids of the compost units and injected into four 20-ml sealed glass vials, using a 60 ml syringe connected to a 50 cm plastic tube (3 ml void volume). Two samples of ambient air were taken about 5 m from the compost bins using a similar procedure.

Half the vials were analysed for $CH_4$ and $N_2O$ using a Perkin Elmer Clarus 500 (Perkin Elmer, Waltham, MA, USA) gas chromatograph (GC) equipped with capillary columns (Elite-Plot Q), flame ionisation (FID) and electron capture (ECD) detectors. The remaining vials were analysed for $CO_2$ and $CH_4$ using a Perkin Elmer Clarus 500 GC equipped with two packed steel columns in series (Heysep N69/80 and Molecular sieve 13 × 45/60), followed by thermal conductivity (TCD) and FID detectors. A headspace autosampler (TurboMatrix 110, Perkin Elmer) fed the gas samples into the GC systems.

In the present study, the objective was to analyse the GHG emissions in relation to degradation. The $CO_2$ concentration is a good indicator of organic material degradation, as all aerobically degraded C is converted to $CO_2$, while in anaerobic degradation approximately 50% of the degraded C is converted to $CO_2$. Composting is predominantly aerobic. Thus, in this study the GHG emissions are presented as $CH_4$:$CO_2$ and $N_2O$:$CO_2$ ratios, calculated after subtracting the ambient concentration for each gas.

Ammonia concentrations were measured on 6 of the 13 sampling occasions. The samples were collected as described above for the GHG samples, but instead of the syringe a 100-ml Kitagawa (AP-20, Komyo Rikagaku Kogyo K.K., Japan) gas pump with ammonia detection tube was used. The tubes initially (first sampling occasion) had a detection range of 5–260 ppm (105SC Ammonia) and thereafter 0.2–20 ppm (105SD Ammonia). The detection limit was further lowered, to 1 and 0.1 ppm respectively, by pumping more gas through each detection tube.

### 2.3. Material sampling and analyses

On each sampling occasion, the temperature of ambient air and compost material was measured using a K-type thermocouple (Probe type 80104, Thermo-Electra, Pijnacker, Netherlands) attached to a Fluke 52 K/J thermometer (Fluke Co., Everett, WA, USA). The temperature inside the compost was measured at 13 cm depth in the centre of the bins. After gas sampling and temperature measurement was completed without disturbing the compost, a material sample of approximately 200 ml was gently extracted from the centre of each bin at 10 cm depth with minimal disturbance to the rest of the pile. These samples were sealed in plastic bags and analysed within the same day (in rare cases frozen at −20 °C on arrival at the laboratory and analysed later) for pH, moisture and ash content. For pH measurement, the material was diluted with deionised water in proportions of 1:5 by volume, thoroughly mixed and analysed after 30 min using an inoLab Level 1 meter (WTW GmbH & Co., KG, Weilheim, Germany) equipped with a SenTix 81 electrode (WTW GmbH & Co., KG). The moisture content was determined by drying 100 ml of material split between three ceramic or aluminium cups at 105 °C for 14 h (Eklind et al., 2007). Ash content was determined after combusting the dried and weighed samples in an oven at 550 °C for 4 h (Eklind et al., 2007).