

Greenhouse gases emissions during open pit storage and composting of swine slurry in Brazil

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Abstract

Greenhouse gases (GHG) emissions were monitored from swine slurry (SL) stored in an open pit and treated by composting. Methane (CH₄), carbon dioxide (CO₂) and nitrous oxide (N₂O) emissions were measured through 40 days using dynamic chambers covering the whole emitting surfaces and equipped with fans to control the ventilation rate in order to provide a constant laminar flow above the emission sources. Air samples from chambers' inlet and outlet airflow were continuously analysed by infrared photoacoustic monitor. Results have shown that CH₄ was the main GHG emitted from the slurry deposit being responsible for 97.6% of the global warming potential (GWP) whereas the CO₂ responded for the remaining 2.4%. No N₂O emission was observed which confirms the anaerobic character of the biodegradation in open pits. The aerobic process prevailed during SL composting, and the CO₂ was responsible for 55.7% of GWP and CH₄ and N₂O for 20.3% and 24%, respectively.

Introduction

Swine manure is recognized as an important source of greenhouse gases (GHG) to atmosphere however its proper management can mitigate the contribution of livestock production on global warming [1]. Although the usual practice in Brazil consists in open pit storage followed by crop application, manure composting with sawdust is an alternative treatment that could reduce risks of soil and water pollution by decreasing the mobility of nitrogen and organic matter in the environment and also enabling economically the exportation of the excess of nutrient as compost. Nevertheless such modification on usual manure management could result in an increase on N₂O emission [1, 2] as slurry storages are principally anaerobic and the opportunity to NH₄⁺ nitrification is negligible.

There is lack of information about GHG emissions from storage and treatment systems under tropical conditions. Most part of available data and inventories are supported by mathematical models whose emissions factors were generated from data obtained under temperate climate conditions, which increase the uncertainties about the estimations made for livestock production located in warmer regions.

Recent studies have demonstrated that the production and emission of CH₄ from swine slurry is strongly affected by temperature [3] as well as the usual water management in production facilities adopted by each country, such as frequency of washing and sludge removal [1]. Therefore the aim of this study was to compare the CH₄ and N₂O emissions during the initial forty days of swine slurry composting and pit storage in pilot scale under Brazilian climate conditions. This period (initial 40 days) is characterized by higher GHG emissions in both systems due to manure incorporation and revolving of biomass (composting) and loads that disturb the surface of fresh manure stored (pit). Proper O₂ supply is essential for composting as its limitation can increase N₂O and CH₄ emission [2], therefore CO₂ emission was also analysed to evaluate the aerobic activity in both systems.

Material and Methods

Experiments were conducted in Concórdia-SC, Southern Brazil (27°18'46" S, 51°59'16" W) in a 30 m³ open concrete circular pit and a 3 m³ composting bin of during approximately 40 days from June-July/2012 (winter).

The pit was daily fed with 1 m³ of fresh swine manure (5 days a week) during the whole period of the experiment and composting material was obtained by mixing fresh swine slurry (SL) with 300 kg of wood shavings (WS) in a total of six applications/turning as follows: at day 1 (727 L), day 8 (724 L), day 16 (217 L), day 17 (215 L), day 22 (247 L), and day 30 (252 L) in order to achieve a final ratio of 7.94 L of SL for 1 kg of WS.

Emissions of CO₂, CH₄ and N₂O were measured using dynamic chambers made of transparent PVC film with 10.6 m³ (Figure 1a) and 12 m³ (Figure 1b) of volume to cover the whole emitting surfaces of 19.8 m² and 3.2 m² respectively. The fixed ventilation rate of chambers was controlled using fans equipped with dimmer in order to obtain a constant laminar flow (< 1 m.s⁻¹) above the emission surfaces.

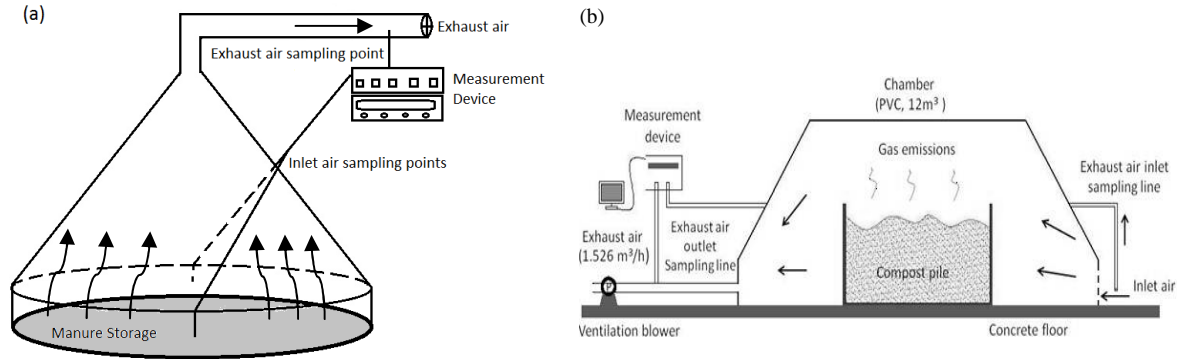


Figure 1: Dynamic PVC chambers used for continuous measurements of emissions from (a) slurry storage and (b) composting heap.

Gas samples were continuously (intervals 2-4 min between each sampling) and automatically sampled by the measurement device – Multipoint Sampler/Infrared Photoacoustic Gas Monitor (INNOVA 1309/INNOVA 1412, Air Tech Instruments, Denmark) – through 4 mm diam. Teflon tubes placed in the sampling points. The greenhouse gas emission flux (g.h⁻¹) was calculated using the equation:

$$E_G = [Q_{air} (C_o - C_i)]/1000 \quad (1)$$

Where: C_o= gas concentration in the outlet air (mg.m⁻³); C_i= gas concentration in the inlet air (mg.m⁻³) and Q_{air}= airflow rate (m³.h⁻¹).

Samples of manure from open pit and compost were collected at each incorporation and load and analysed (DM, VS, N-NH₃, TKN, COD and OC) according to official methods [4]. Emissions of CH₄, N₂O and CO₂ from both systems were expressed in g of C. kg⁻¹ of manure or g of N. kg⁻¹ of manure. The global warming potential (GWP) of both systems were calculated by using the following equation:

$$GWP = CO_2 + 25 CH_4 + 298 N_2O \quad (2)$$

Results

Significant emissions of CH₄ are noticed in both systems however their kinetic behaviours are quite distinct (Figure 2a). In composting the emission is clearly caused by the incorporation of fresh manure into the sawdust and the turning, and also it seems to be proportional to the amount of manure added. In slurry storage, the emission of CH₄ decreases as the pit is being filled and the liquid column increases. Pit storage is a less dynamic process than composting with lower temperature and microbiological activity, therefore it seems that the emissions may be slowed down once the physical barrier increases (depth of slurry in the pit) and the area of the surface of emission remains constant (19.8 m²). Nevertheless the cumulated emission of CH₄-C of the pit was 2.8 times higher than composting, also no N₂O emission was detected (Figure 2b) as slurry remains in predominantly anaerobic state with little opportunity for NH₄⁺ to be nitrified.

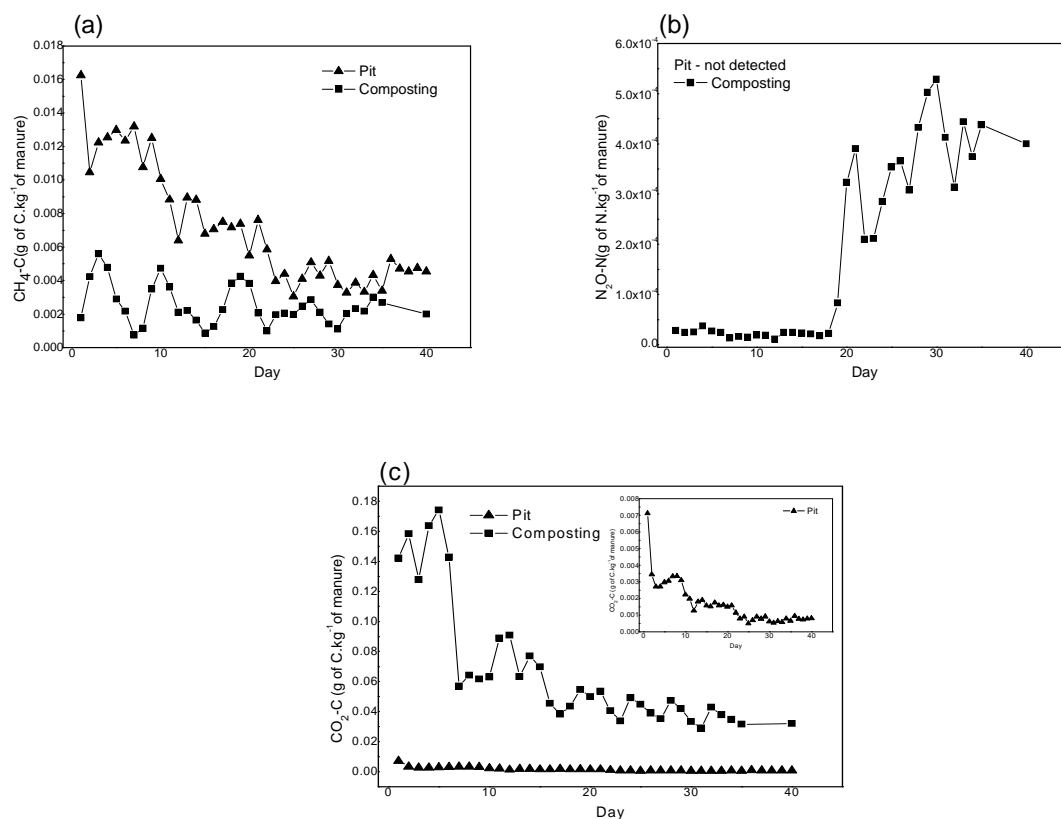


Figure 2: Kinetic of emissions of CH₄-C (a), N₂O-N (b) and CO₂-C (c) during the first 40 days in the management/treatment systems Pit slurry storage (▲) and Composting (■).

Aerobic biodegradation was the main route of organic matter mineralization in composting because 95.8% of detected carbon loss was emitted as CO₂ (Figure 2b and 2c), therefore oxygen supplied by weekly turning seems to be sufficient to keep the compost bin predominantly aerobic. Emission of N₂O began to be detected from the 20th day onwards and there is a tendency of this emission proceeds even after the monitored period. This N₂O production could be resulted from the increase of the activities of nitrifying and denitrifying microorganisms that were inhibited in the initial thermophilic period of composting (first 20 days) as well as by the increase in the density/compacting of composting materials as manure was being added once this could favour microenvironments with low O₂ content and consequently incomplete nitrification [1].

During the 40 days of this study, only 0.036% of the total organic carbon contained in the manure storage was emitted as CO₂ (16.8%) and CH₄ (83.2%) whereas in composting approximately 34.5% of total organic carbon was emitted as CO₂ (95.8%) and CH₄ (4.2%). Composting seems to accelerate the organic carbon mineralization. Additionally about 40.5% of the total nitrogen incorporated to the composting process was lost but N₂O corresponded to 7.7% of that lost.

In terms of Global Warming Potential (GPW) we found that slurry stored during 40 days had GPW= 9.46 g eq CO₂ per kg of manure, of which CO₂, CH₄ and N₂O contributes with 2.4%, 97.6% and 0%, respectively and for composting the GPW= 16.08 g eq CO₂ per kg of manure with contributions of 55.7% from CO₂, 20.3% from CH₄ and 24% from N₂O [6].

Conclusion and perspectives

Composting increased the organic matter degradation kinetics and favoured the aerobic process (CO₂ emission prevail), whereas open pit emitted more CH₄. Emission of N₂O was observed only in composting and seems that it proceed even after the monitored period therefore additional experiments are required to quantify the N₂O emissions until the total stabilization of the compost. To fully understand the contribution of swine slurry composting for GHG mitigation, measurements of GHG emissions from the soil fertilized by both liquid manure and compost should be also performed.

The 40 days of evaluation of these two processes demonstrated that in this period composting was a more dynamic process than manure pit storage due to aeration and heating, thus with more intense GHG emissions. However, it is expected that organic carbon and nitrogen that was kept stored in the pit slurry would be emitted to the atmosphere during and after crop application, while the high humification of the compost could reduce GHG emissions from the soil amended with this organic fertilizer.

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