

## GREENHOUSE GAS EMISSIONS ON THE TREATMENT OF SWINE SLURRY BY COMPOSTING

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**ABSTRACT:** The treatment of swine manure through composting is seen as an alternative to minimize environmental impact and improve nutrient recycling. However, the degradation of organic matter during the composting process promotes greenhouse gas emissions (GHG: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O), NH<sub>3</sub> and water vapor. The objective of this study was to measure the flux of these gases to perform the mass balance (DM, TN, C and P) of composting piles. Three compost piles (3 m<sup>3</sup>, initial mass 2.935 kg of sawdust and slurry) were mounted inside PVC tunnels with controlled ventilation (flow 1.526 m<sup>3</sup>/h). We evaluated temperatures and humidity (Datalogger TESTO 174H) inside and outside the tunnels and inside the biomass (TESTO Mod. 926, Type T), performed physical-chemical analysis of compost and measured GHG, NH<sub>3</sub> and water vapor emissions every 4 min through infrared photoacoustic spectroscopy (INNOVA 1412). The average temperature observed in the biomass during composting was 45.53 ± 5.48°C. The average H<sub>2</sub>O balance error (between input and output) recorded was 5.52%. Gaseous losses of N-NH<sub>3</sub> and N-N<sub>2</sub>O totaled 1.21 kg, representing 10.4% of the original 11.63 kg of N applied in the compost piles. NH<sub>3</sub> represented 78% of measured total N gaseous losses (NH<sub>3</sub>+N<sub>2</sub>O). The total C emitted as CH<sub>4</sub> and CO<sub>2</sub> gases totaled 80.96 kg, representing 40.2% of the original 201.28 kg of TOC in compost piles (sawdust+slurry). CO<sub>2</sub> emission accounted for 97% of total C losses. Considering the global warming potential (GWP) of each GHG, 615.3 kg of CO<sub>2</sub>eq were emitted during composting. CO<sub>2</sub> emissions accounted for 46.8% of total CO<sub>2</sub>eq emission, while CH<sub>4</sub> and N<sub>2</sub>O represented 11.1 and 42.2%, respectively. Mitigation of CH<sub>4</sub>, and especially N<sub>2</sub>O emissions, during composting is critical due to the higher GPW of these gases. The presence of pathogenic microorganisms (*Escherichia coli* and coliform bacteria) was observed in the input slurry, but those microorganisms were not detected in the final compost. It was possible to accurately measure and verify gas emissions with the association of direct measurements and mass balance.

**Keywords:** swine manure, manure treatment, global warming potential, carbon dioxide, methane, nitrous oxide, ammonia

**INTRODUCTION:** Residues from animal production systems are responsible for greenhouse gas (GHG) emissions and water and soil contamination in Southern Brazil (Sardá et al., 2010). These residues have an important role in ammonium (NH<sub>3</sub>) and methane (CH<sub>4</sub>) emissions to the atmosphere (IPCC, 1995). Composting has been appointed as an alternative to minimize the environmental impact of the animal production residue management allowing nutrient recycling (Oliveira and Higarashi, 2006). However, during organic matter degradation, other gases could be emitted beyond CH<sub>4</sub> and NH<sub>3</sub>, such as nitrous oxide (N<sub>2</sub>O) (Paillat et al. 2005). The reason for these emissions is not completely understood, mainly in Brazil, where the composting process developed by Oliveira and Higarashi (2006) is currently widely adopted for the treatment of swine slurry. The objective of this study was to determine GHG

(N-N<sub>2</sub>O, C-CH<sub>4</sub> and C-CO<sub>2</sub>) and N-NH<sub>3</sub> fluxes and to perform mass balance in the swine slurry composting process in Southern Brazil.

**1. METHODS:** Three tunnels (12 m<sup>3</sup>) with controlled aeration were built and covered with PVC film. Inside each tunnel 2.52 m<sup>3</sup> static composting piles were mounted in wooden boxes. Composting was divided into two phases. The first was the absorption phase where swine slurry was applied to the piles and was considered a period with high carbon/nitrogen ratio (C/N) in the compost piles. During this first phase swine slurry was applied to the piles once a week. The pile was rotated 3 days after every slurry application or when the composting pile moisture was over 80%. The second phase was the maturation of the biomass, when slurry was no longer applied to the composting piles. During this phase, the composting piles were rotated once a week. Gas emissions were monitored only in the absorption phase when GHG and NH<sub>3</sub> emissions are expected to be higher (Paillat et al., 2005). The absorption phase lasted 35 days and 2,600 L of swine slurry was incorporated into compost piles in 7 applications. Each application was performed observing the maximum incorporation rate (3 L/kg of sawdust) (Oliveira and Higarashi, 2006) to avoid slurry percolation and runoff from composting piles. Gas emissions were calculated based on the air flux inside each tunnel determined by a hot wire anemometer (TESTO 435), and gas concentrations in the tunnels' inlets and outlets every 4 minutes by trace gas analyzer INNOVA 1412 (infrared photoacoustic spectroscopy),

following the equation proposed by Robin et al. (2006):

$$\phi = Q_{ar} \times \rho_i \times (C_i^m - C_e^m) \quad \text{Equation (1)}$$

Where,  $\phi$  is the gas emission rate (g/h in dry air);  $Q_{ar}$  is the air flow (m<sup>3</sup>/h);  $\rho_i$  is the conversion factor from air flow volume to air mass flow, allowing the implementation of mass and energy conservation laws (m<sup>3</sup>/h to kg/h). The ideal gas law was used considering the air temperature as 20°C for the conversion of the gas using equation 2:

$$C_i^m = C_i^v \times \frac{M_m}{V_m} \times \frac{M_m}{M_{mol}} \quad \text{Equation (2)}$$

Where,  $C_i^m$  is the equivalent concentration of C and N in gases (mg/m<sup>3</sup>), measured at time  $i$  (C-CH<sub>4</sub>; C-CO<sub>2</sub>; N-NH<sub>3</sub>; N-N<sub>2</sub>O);  $C_i^v$  is the concentration of the measured gas (ppmv);  $M_m$  is the equivalent molecular mass of C and N in the considered gas (ie. CH<sub>4</sub>=12, NH<sub>3</sub>=14, N<sub>2</sub>O=28 g de N.mol<sup>-1</sup>);  $M_{mol}$  is the molar mass in each gas molecule (CO<sub>2</sub>=44, CH<sub>4</sub>=16, NH<sub>3</sub>=17).  $V_m$  is molar volume (L/mol) corresponding to the molecular mass of a perfect gas at pressure (P) and temperature of 20°C (T). Beyond gas emissions, other parameters were evaluated, such as air temperature and moisture inside and outside the tunnels. Compost was submitted to physical-chemical analysis. Mass balance was performed based on C and N inputs in the system through swine slurry and sawdust, along with the concentration of these elements of the compost biomass. The differences in C and N mass were considered losses of these elements as gaseous emissions and were compared to measured C-CH<sub>4</sub>, C-CO<sub>2</sub>, N-NH<sub>3</sub>, and N-N<sub>2</sub>O emissions. Phosphorus balance and water concentration in the compost pile were used to estimate errors on mass balance, considering the used methodology. The characteristics of sawdust and swine slurry used in the experiment are shown in Table 1.

Table 1. Physical-chemical characteristics of materials used in the composting ( $\text{g.kg}^{-1}$ ).

Material	Dry matter (%)	Tot. Nitrogen	Organic Carbon	Phosphorus ( $\text{PO}_4$ )
Swine slurry	3,8 – 36,4	2,3 – 6,7	13,3 – 57,1	0,8 – 3,9
Sawdust	89,31	2,17	537	0,20

Sawdust substrate granulometry was characterized by coarse particles with a high superficial area. Phosphorus content in sawdust was minimal. Total organic carbon in sawdust was 161 kg per compost pile. C/N ratio in sawdust was 200/1, while C/N ratio in swine slurry was 7/1. On average, of three compost piles, 11.03 kg of N were applied and incorporated into the sawdust substrate. The initial compost biomass C/N ratio was 46/1. After 35 days, the C/N ratio of the biomass decreased to 26/1, pH maintained alkaline during the whole absorption phase.

**2. RESULTS AND DISCUSSION:** The temperature of the compost biomass ranged between 40 and 50°C during the absorption phase. The moisture was maintained between 70 and 80%. When biomass moisture increased beyond 70%, the temperature of the compost pile decreased. Higher moisture content could allow the formation of anaerobic zones inside compost biomass, which is not desirable in this process. The C- $\text{CO}_2$  and C- $\text{CH}_4$  fluxes measured during the absorption phase are presented in the Figure 1. The letters A and R identify the days when slurry was applied and compost piles were rotated, respectively.

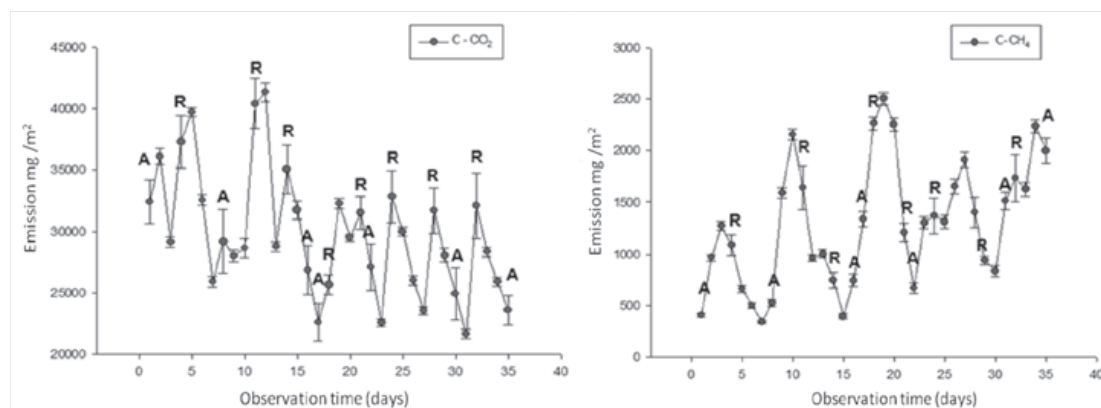


Figure 1. C- $\text{CO}_2$  and C- $\text{CH}_4$  fluxes during composting. Letter A identifies the days when slurry was applied to the substrate and R identifies the days when compost piles were rotated.

C- $\text{CO}_2$  and C- $\text{CH}_4$  emission profiles showed that increase of oxygen saturation when compost piles were rotated decreased emissions of these gases. However, slurry application increased C- $\text{CO}_2$  and C- $\text{CH}_4$  emissions. These results reinforce evidence for the presence of moments of higher reduction of oxygen concentration in compost piles, since the production of  $\text{CH}_4$  occurs under anaerobic conditions, while  $\text{CO}_2$  emissions are mainly aerobic.

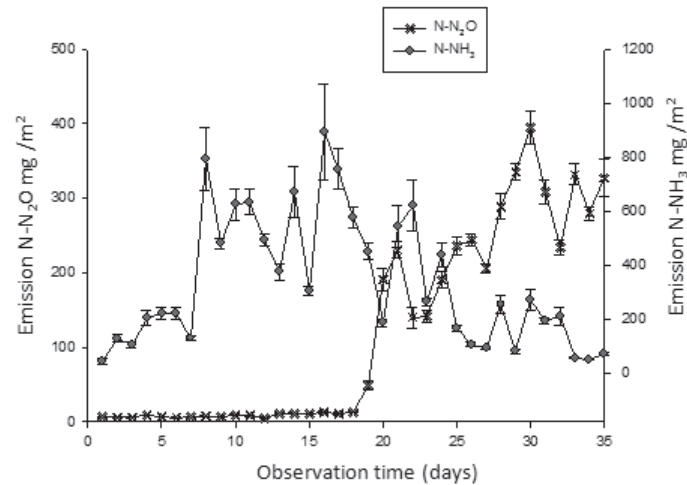


Figure 2.  $N-NH_3$  and  $N-N_2O$  emission profile during swine composting.

The observation of  $N-N_2O$  and  $N-NH_3$  emissions during the 35 days of the absorption period is shown in Figure 2.  $N-N_2O$  emissions became significant only when  $N-NH_3$  emissions started to decrease after 18 days. By comparing the measured emissions for both gases and by results reported by Fukumoto et al. (2003), it is possible to conjecture that microorganisms had oxygen as the main energy source for the oxidation of organic carbon in the compost piles, limiting nitrate formation in the first 18 days. With the exhaustion of labile organic carbon, nitrate started to be produced. When compost piles were rotated, nitrate was displaced from the top to the bottom of the piles under anaerobic conditions, increasing  $N-N_2O$  emissions. Therefore,  $N_2O$  produced in the bottom layers of the compost piles was released when the substrate was rotated. The results of the mass balance for water, natural matter, dry matter, organic matter, carbon and nitrogen in compost piles are presented in Table 2. Mass balance indicates that 38.9% and 40.8% of the total nitrogen and organic carbon added to the system were lost during the composting process.

Table 2. Mass balance of water, natural matter (NM), dry matter (DM), organic matter (OM), organic carbon and total nitrogen in the compost piles.

	Water	NM	DM	OM	C	N
	kg					
Inputs (1)	2,485.16	2,935.97	450.80	406.90	233.77	11.63
Output (2)	1,124.49	1,448.26	323.77	288.32	142.82	6.88
Losses (1-2)	1,360.67	1,487.71	127.03	118.58	90.95	4.75
Measure emissions*	1,221.55	-	-	-	80.96	1.21
Gases/Losses (%)	89.77	-	-	-	89.01	25.47
Mass/Losses (%)	54.75	50.67	28.18	29.14	38.90	40.84

\*Gases emissions: sum of  $C-CO_2 + C-CH_4$ , and  $N-NH_3+N-N_2O$ .

Total C and N losses measured by the mass balance of the compost piles were compared with the results of measured  $N-NH_3$ ,  $N-N_2O$ ,  $C-CO_2$ , and  $C-CH_4$  emissions. The average N losses, as  $N-NH_3$  and  $N-N_2O$ , accounted for 1.21 kg of nitrogen in relation to a total nitrogen loss of 4.75 kg, as determined in the mass balance. In the composting process, the main nitrogen losses occur as  $N_2$  emissions (Paillat et al., 2005; Robin et al., 2006). Thus, considering that  $N-NH_3$  and  $N-N_2O$  represented

25.47% of the total N losses, the remaining 74.53% could be considered as N<sub>2</sub> emissions.

Total C losses, as C-CO<sub>2</sub> + C-CH<sub>4</sub>, totaled 80.96 kg during the 35 days absorption composting phase. C-CO<sub>2</sub> emissions accounted for 97% of the total C losses from composting piles.

**CONCLUSIONS:** In this study we found agreement between gas emissions assessment for C-CH<sub>4</sub>, C-CO<sub>2</sub>, N-NH<sub>3</sub>, and N-N<sub>2</sub>O, and the C and N mass balance in composting piles. When the compost piles were managed to ensure proper aeration, low emissions of N<sub>2</sub>O and CH<sub>4</sub> were verified. Main gaseous losses of C and N occurred as N<sub>2</sub>, NH<sub>3</sub> and CO<sub>2</sub>, which are gases that present low global warming potential.

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