C TRANSFORMATIONS DURING STORAGE OF FARMYARD MANURE

Moral R.[1*], Bustamante M.A.[1], Misselbrook T.H.[2], Chadwick D.R.[2], Camp V.[2], Donovan N.[2]
[1]Department of Agrochemistry and Environment, Miguel Hernandez University,
EPS-Orihuela, ctra. Beniel Km 3.2, 03312-Orihuela (Alicante), Spain.
*Phone: +34 966749651; E-mail: raul.moral@umh.es
[2]North Wyke Research, Okehampton, Devon EX20 2SB, UK

1 INTRODUCTION

The strategy of manure management on farms has an important role not only in agronomic terms, but also in relation to environmental issues, such as carbon emissions. Aerobic and anaerobic decomposition occurs in stored farmyard manure (FYM), with carbon dioxide (CO_2) and methane (CH_4) fluxes. CH_4 may be produced during FYM storage as a consequence of the microbial degradation of soluble lipids, carbohydrates, organic acids and proteins present in manures (Chadwick et al., 2005).

Globally, domestic livestock are estimated to produce 80 Tg a^{-1} of CH_4 with another 25 Tg a^{-1} being emitted from their manures (Chynoweth, 1996). In addition, CH_4 from stored manure as a proportion of total CH_4 from cattle has been estimated to range from 13 to 14% (Külling, et al., 2002). However, it is difficult to ascertain CH_4 emission from livestock manure (Johnson and Ward, 1996) and little is known in relation to the simultaneous CH_4 emission from the animal and their manure under controlled and varying conditions (Külling et al., 2002).

Therefore, the objective of this work was twofold: i) to quantify emissions of CO_2 and CH_4 from the FYM storage; ii) to improve our understanding of C transformations and controlling factors during the storage of FYM, such as temperature, available carbon or moisture content.

2 MATERIALS AND METHODS

Carbon dynamics in cattle FYM during storage was evaluated in terms of mass balance, considering solid, liquid and gaseous components. For this purpose, three storage bunkers were constructed at IGER (North Wyke, Okehampton, Devon, UK) with concrete bases and concrete block walls to hold FYM from beef cattle. The FYM stores were 3.5 m x 5 m x 1.1 m with a storage capacity around 19 m^3.

Around 4 t of cattle manure (fresh weight) were put into each of three replicate storage bunkers with a large dynamic chamber used to sample and quantify the gaseous fluxes from the heaps. Gaseous emission measurements were made from each heap during a storage period of 52 days with 16 sampling periods (at days 0, 1, 2, 3, 4, 7, 8, 9, 10, 11, 15, 17, 22, 25, 32 and 52 after heap establishment). Gas samples were taken from the inlet and outlet of the dynamic chamber at 0, 60 and 120 min for each sampling period and stored in evacuated 20 ml vials prior to their analysis for CH_4 and CO_2 by gas chromatography (GC). Following the methodology of Chadwick (2005), fluxes were calculated for each measurement occasion according to:

$$F = (C_{outlet} - C_{inlet})\ Y/\ Mt,$$

where F is the flux (g gas t^{-1}FYM h^{-1}); C_{outlet}, the concentration in outlet air flow (g/m^3); C_{inlet}, the concentration in inlet air flow (g/m^3); Y, the total air flow through the emission hood (m^3); M, the initial fresh weight of the FYM heap (tonnes) and t, the duration of the measurement (h). The air flow rate through the chamber with the optimal recovery of gases was chosen for the experimental measurements and a correction factor, derived from the calibration, was applied to the measured fluxes from the FYM heaps.

Representative samples of FYM were taken from each heap at the start and at the end of the storage period, in order to determine the mass balance of total and inorganic C. In addition, dry matter content, total C and P were analysed in representative sub-samples taken from each heap according to the methods described in MAFF (1986). Temperature sensors were placed in the middle of each FYM heap and average hourly temperature was recorded. Leachates were collected periodically from the individual collection tanks from each manure heap and the total volume measured. Sub-samples of leachate were taken for determination of total C content.

3 RESULTS AND DISCUSSION

3.1 Evolution of farmyard manure characteristics

During the storage of cattle FYM, the constituents are subject to microbial transformations, chemical reactions, the leaching action of rainfall and "natural" drainage within the heaps (Chadwick, 2005). Table 1 shows the changes in the manure composition throughout the experiment.

TABLE 1 **Composition of farmyard manure, at the beginning and end of the storage period (standard errors in brackets).**

Total heap content	Beginning of the experiment	End of the experiment
Dry matter content of FYM (%)	20.6 [0.30]	19.5 [0.20]
Total fresh weight per heap (t)	4.72 [0.32]	3.63 [0.31]
Total dry weight per heap (t)	0.98 [0.07]	0.75 [0.07]
Total C (%) d.w.	43.4 [0.2]	42.6 [0.6]
Total C per heap (kg)	423 [34]	319 [33)]
Total P (g/kg) d.w.	3.38 [0.2]	4.45 [0.4]
Total P per heap (kg)	3.30 [0.3]	3.31* [0.3]

* Including P from leachates.

As it can be seen, after 52 days of storage, 23% of the heap dry matter and 24% of total C had been lost through decomposition and leaching processes (Table 1). Similar or higher values have been reported by other authors. Parkinson et al. (2004) observed losses of 50% in an experiment to investigate the effect of turning regime and seasonal weather conditions on nitrogen and phosphorus losses in static cattle FYM heaps. Chadwick (2005) reported losses of total dry matter of 35-46% and 40-50% losses of total C during an experiment of 3 months of conventional storage, carried out to evaluate the effect of compaction and covering on the storage of cattle manure.

3.2 Methane and carbon dioxide emissions and C balance

The patterns of emission for CO_2-C and CH_4-C are shown in Figure 1a and 1b, respectively. The greatest emissions occurred at the beginning of the experiment, during the first week of storage, as a consequence of the temperature values reached in the heaps during that period (Fig. 2a).

Non aerobic conditions were dominant for much of the storage period, according to the significant and long duration of the methane emissions in the heaps, with an emission rate ranging from 0.5 to 1.7 g CH_4-C ton^{-1} h^{-1}. The peak in CH_4 emission coincided with the temperature profile of the middle part of the heap, probably correlating oxygen consumption and facultative anaerobic conditions in this area (Figs. 1a and 2a, respectively).

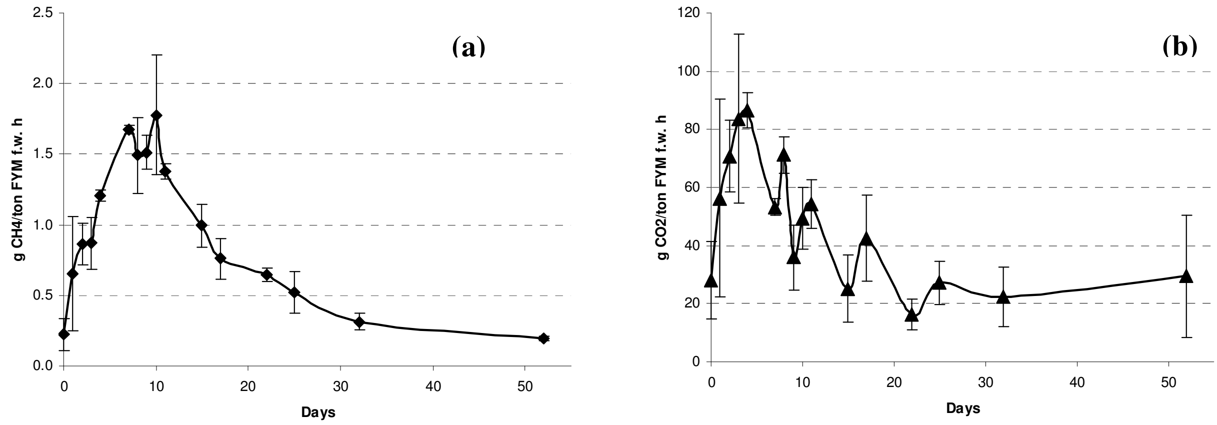

FIGURE 1 **Methane (a) and carbon dioxide emissions (b) throughout the experiment.**

The CO_2 emission profile was more variable, with a linear increase in the emission rate at the beginning of the storage period, which was probably due to the presence of easily available C in the heap and the increase of the heap temperature values. Peak emission rate was reached after 5 days, followed by a decline back to initial emission rates after 20 days.

The cumulative CH_4-C and C-CO_2 emission trends are displayed in Figure 2b. The cumulative CH_4-C emission was about 537 g C ton^{-1} initial fresh weight, around 0.6% of the total C in the heap at the beginning of FYM storage. In case of CO_2-C, the cumulative emission was 8742 mg C ton^{-1} initial fresh weight, representing around 9.75% of the total initial heap C content.

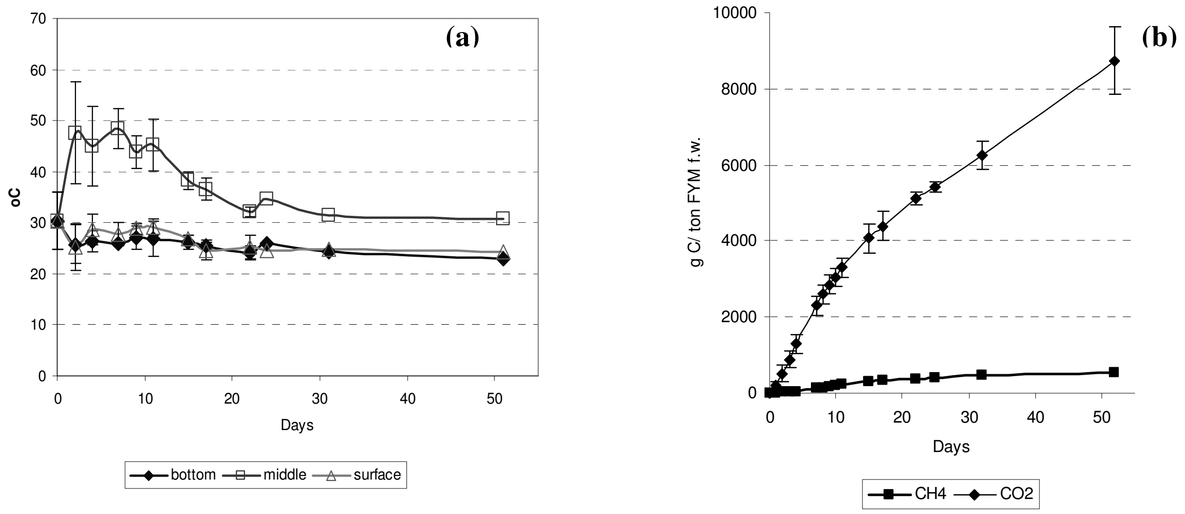

FIGURE 2 **Evolution of the temperature in the heaps (a) and cumulative emissions of methane and carbon dioxide (b) during the storage of cattle farmyard manure.**

Table 2 shows the summary of the C balance of FYM. A C balance was made to ascertain if any C remained unaccounted for and to check if the measurements of C emissions could account for all C losses. This balance is based on the determination of the proportion of the mass of C lost, defined as the mass of C in the heap at the beginning of the storage period minus the mass of C remaining in the heaps at the end of the experiment (determined by chemical analysis of the FYM samples), and accounting for total C-CH_4 and total CO_2-C emissions and total C leaching.

A potential source of error in this estimation is the representativeness of the FYM sub-samples. However, the reliability of sub-sampling may be checked by calculating the P balance, since P is not volatilised and little is lost by leaching (Petersen et al., 1998). No significant changes were observed in total P per heap, showing the representativeness of FYM sampling (Table 1).

TABLE 2 **Summary of C balance for cattle farmyard manure storage.**

C balance						
Initial C content (kg)	Total CH_4-C emission (kg)	Total CO_2-C emission (kg)	Total C in leachate (kg)	Total C losses measured (kg)	Final C content heap (kg)	C unaccounted (%)
423.1	2.53	41.26	2.11	45.9	319.8	13.6

Based on C balance, for the storage period, 13.6% of the initial C in the FYM heaps was unaccounted for and the CH_4-C emission constituted approximately 6% of CO_2-C emission (Table 2). The imbalance between mass of carbon emitted and the carbon loss determined by the mass balance method is expected to be caused by the inaccuracy of the mass balance method and to a lesser degree by emission of carbon monoxide (CO) (Hellebrand and Kalk, 2001). Total losses of CH_4-C were 0.6% of the total C in FYM, similar to those observed by Chadwick (2005) (ranged from 0.4% to 9.7% of the total C) and considerably higher than those observed by Sommer (2001) in a stored deep litter (CH_4 emission values between 0.01 and 0.03% of the C).

4 CONCLUSIONS

From the results, it can be concluded that the main CH_4-C and CO_2-C emissions during conventional storage of FYM were generated in the first week of storage, when the heaps reached the greatest temperatures. The main losses related to C were from CO_2, representing around 10% of the total initial heap C content, with losses via CH_4 and leachate each accounting for <1 % initial heap C content.

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