

Nitrogen losses and transformations within farmyard manure storage

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Introduction

All losses of nitrogen from the point of excretion by livestock onwards need to be fully accounted for to accurately predict and model ammonia and nitrous oxide emissions at each stage of manure management. The relative proportions of readily available nitrogen and organic nitrogen at each stage will influence the potential losses, so the transformation of nitrogen between these forms needs to be accounted for. These losses and transformations of nitrogen are particularly important in the management of solid manures, where excreta are intimately mixed with bedding materials. The objective of this project was to test our hypothesis that nitrous oxide and ammonia losses during solid manure storage are related to the amounts of ammonium-N, rather than total N, contained in the manures when they enter storage.

Materials and methods

The storage bunkers

The experiment was conducted using six storage bunkers at the North Wyke site, similar to those described by Chadwick [1]. The farmyard manure (FYM) stores were 4.4 x 3.4 x 1.0 m high with a storage capacity of ca. 15 m³. The front wall was constructed of a steel framed door that could be removed at times of filling and emptying of the bunkers. The floor of each bunker sloped to a central drain, covered with a plastic drain cover. The drain from each bunker led to an outlet pipe where the volume of leachate could be collected and measured. Approximately 4 tonnes of manure (fresh weight) was weighed into the replicate storage bunkers, 3 filled with pig manure and 3 with beef cattle manure, using a randomised design. The storage period was from July to September, with an average ambient air temperature of 13.7 °C and cumulative rainfall of 76 mm.

FYM composition

The weight of fresh pig or beef cattle manure placed in each storage bunker was recorded. Representative samples of FYM were taken as each storage bunker was filled, with 3 replicate samples per bunker. The samples were analysed for dry matter content, pH, total N, NH₄-N, NO₃-N and total P. At the end of the storage period, the FYM was weighed out of each storage bunker and representative sub samples taken from each heap and the analyses repeated. Temperature measurements were taken at intervals through the storage period. Leachate samples were collected periodically from the individual collection tanks from each manure heap. The total volume leached was measured and samples analysed for dry matter content, pH, total N, NH₄-N, NO₃-N and total P.

Gaseous measurements

Ammonia measurements were achieved using two large dynamic chambers (emission hoods), each attached to a steel trolley that was rolled back and forth along steel runners across the top of the storage bunkers, and lowered on to each storage bunker in turn. The base of the frame supporting the emission hood was fitted with a neoprene seal at the base, forming an airtight seal when lowered onto the bunker walls.

Each emission hood had a semi-circular cross section with a maximum height of 1.35 m. The volume of the emission hood was ca. 12 m³. An adjustable speed fan was attached to the outlet end of the emission hood. The air flow used in the study (0.12m³ s⁻¹) resulted in ca. 1.7 air changes per minute. A 40 cm long honeycomb section on the outside of the fan resulted in laminar airflow to a multipoint

cross-sectional air sampler. This allowed hood exhaust air to be sampled from the entire cross of the fan ducting. A plastic flap was rolled down to within 25cm of the base of the emission hood at the inlet end and allowed clean air to be drawn through the emission hood by the fan. Air samples from the inlet and outlet of the hood were passed through separate absorption flasks containing 100ml of orthophosphoric acid (0.02M) at a rate of 4 l min⁻¹ to trap NH₃. The ammonium-N content of the acid solution was measured by discrete photometric analysis. Measurements were made from each heap over at least a 1-hour period on days, 1, 2, 3, 6, 7, 10, 15, 17, 22, 29, 36, 50 and 77. Nitrous oxide measurements from the FYM storage bunkers were taken on the same days as ammonia emissions were quantified, by taking 60 ml gas samples from the inlet and outlet of the emission hood at ca.120 minutes. Samples were stored in evacuated 22 ml vials prior to analysis by gas chromatography (GC) (Perkin Elmer, Claurus 580GC, Turbo matrix 110headspace autosampler).

The ratio of N₂O to N₂ emissions was estimated using the acetylene inhibition technique, replicated three times per heap on days 3, 8, 21, 28, 42, 56 and 85. About 800 g fresh weight of FYM was taken from the manure heap, and divided between two Kilner jars. Once the lids were fitted, 60 ml of the headspace was removed from one of the pair of Kilner jars and replaced with 60ml of acetylene. The other jar of the pair was left unaltered. Gas samples (30 ml) were removed from the headspace of each Kilner jar at 0, 30 and 60 minutes after closing the lids. After the removal of the gas sample, 30 ml of ambient air was injected into the jar. During the 60 minute incubation, the Kilner jars were placed in insulated boxes to maintain the temperature of the manure at the temperature of the heap. Samples were stored in evacuated 22 ml vials prior to analysis by gas chromatography (GC) (Perkin Elmer, Claurus 580GC, Turbo matrix 110headspace autosampler).

Results

FYM composition

The composition of the pig and cattle FYM at the start and end of the 3 month storage period is given in Table 1. There was a 35-40% loss of manure fresh weight over the period, similar for both the pig and cattle FYM. Manure DM contents were similar (slightly higher for pig FYM) and did not change greatly from start to end of storage. Total N and NH₄⁺-N concentrations in the manure decreased over the storage period. The pig FYM had a much greater NH₄⁺-N to total N ratio at the start of storage, and the cattle FYM had very little NH₄⁺-N remaining at the end of storage. Compositional measurements from the start and end of storage indicated that approximately 40% of the initial organic N was mineralised during the storage period.

Table 1. FYM composition at the start and end of the storage period

	Fresh weight (kg)	DM (%)	pH	Total N (g kg ⁻¹)	Ammonium-N (g kg ⁻¹)	Nitrate-N (g kg ⁻¹)	Ratio ammonium-N/total N
<u>Start storage</u>							
Pig FYM	4180	24.8	8.6	7.41	2.32	0.00	0.31
Cattle FYM	2993	21.4	8.9	5.20	0.58	0.00	0.11
<u>End storage</u>							
Pig FYM	2550	22.7	8.3	6.47	0.93	0.06	0.14
Cattle FYM	1880	19.4	8.2	4.33	0.09	0.09	0.02

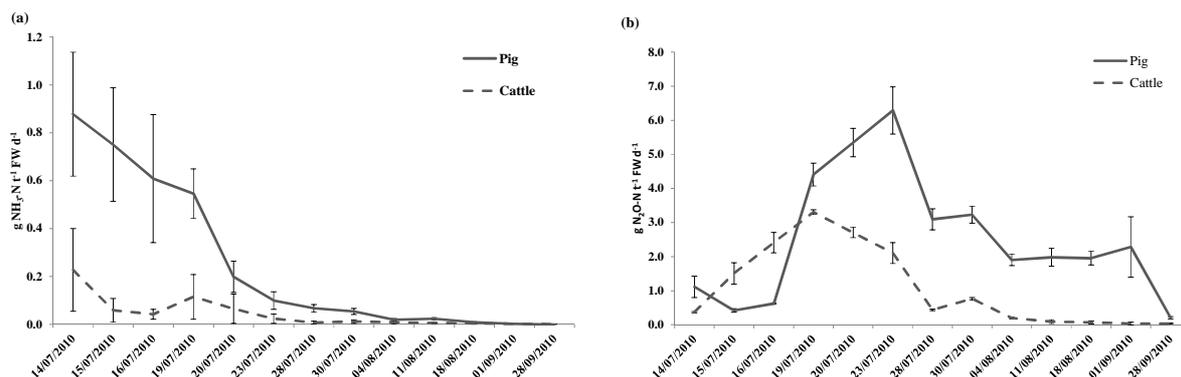


Figure 1. Ammonia (a) and nitrous oxide (b) emission rates during the 2 month storage of pig and cattle FYM

Ammonia emission rates were greatest immediately after storage heaps were created and declined rapidly over the first 1-2 weeks (Fig. 1a). Emission rates were significantly greater and remained above background level for longer for the pig FYM. Peak N_2O emission rates were observed at 7-10 d following heap establishment, with that for pig FYM being two-fold greater than that for cattle FYM (Fig. 1b). In cattle FYM, N_2O emission rates declined to background levels after approximately 1 month, while for pig FYM rates were consistently above background for at least 2 months following heap establishment. The patterns of emission rates for both gases are similar to those reported previously for summer FYM storage [1, 2]. Peak NH_3 emission rates were much lower than those reported by Chadwick [1] or Moral et al. [2] who observed peak values of 12 and 48 $\text{g NH}_3\text{-N t}^{-1} \text{FW d}^{-1}$, respectively for cattle FYM. Peak N_2O emissions were in the range of those reported by Chadwick [1] and Moral et al. [2].

Cumulative emissions of NH_3 were numerically, but not significantly ($P>0.05$) greater from the pig FYM (Figure 2a). Similarly, when expressed as a percentage of initial manure total N and $\text{NH}_4^+\text{-N}$, cumulative losses were numerically, but not significantly ($P>0.05$) greater from pig FYM (Figure 2b). Cumulative losses of initial total N content as NH_3 were similar to those reported by Moral et al. [2] and at the lower range of those reported elsewhere (2 – 30% of the initial N content, [3]).

Cumulative N_2O emissions were significantly greater ($P<0.05$) from pig FYM in absolute terms and when expressed as a percentage of initial heap N content (Figure 2). However, when expressed as a percentage of the initial heap $\text{NH}_4^+\text{-N}$ content, losses were not significantly different ($P>0.05$), although numerically greater for pig FYM. For both pig and cattle FYM, the derived emission factor ($\text{N}_2\text{O-N}$ emission as a percentage of initial heap total N content) was greater than the IPCC default value of 0.5% (IPCC 2006 Reporting Guidelines), but in the range of those reported elsewhere [4].

Estimates of cumulative N_2O emission derived from the jar incubations were greater than those from the dynamic chamber measurements by a factor of 6 and 7 for pig and cattle FYM, respectively. The pattern of N_2O flux was similar for the jar and hood measurements for cattle FYM, but showed a later peak in emissions from the jar incubation measurements for pig FYM (data not shown). Estimated cumulative N_2 emissions from the jar incubation measurements were greater than the N_2O emissions. The ratio of cumulative N_2 to N_2O emission was numerically, but not significantly ($P>0.05$) greater for cattle than pig FYM, with respective ratios of 2.8 and 1.5. Applying these ratios to the cumulative $\text{N}_2\text{O-N}$ emissions derived from the dynamic chamber measurements gave estimates of cumulative N_2 emission of 350 and 140 $\text{g N}_2\text{-N t}^{-1} \text{FW}$. For this study therefore, total N losses via denitrification (bearing in mind that there may have been additional losses as nitric oxide that were not measured) were more important than those via NH_3 volatilisation.

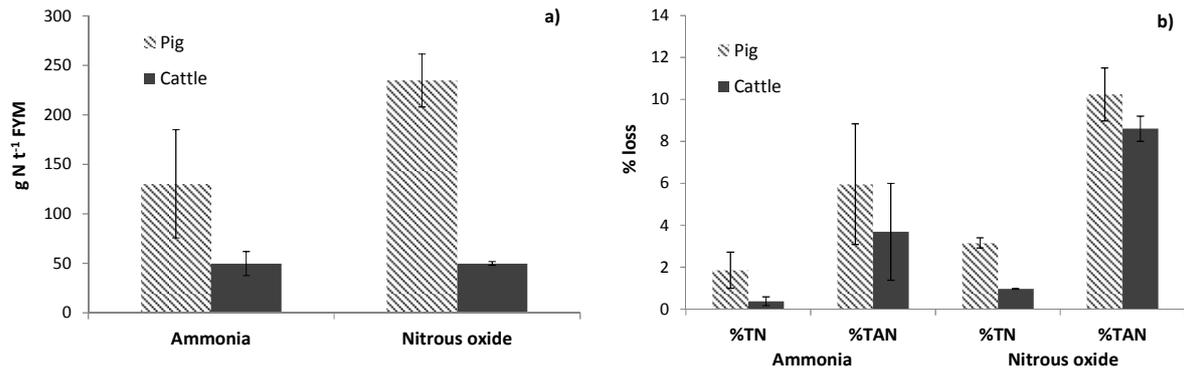


Figure 2. Cumulative emissions of ammonia and nitrous oxide from pig and cattle FYM over the 2 month storage period expressed as: (a) g N per tonne initial heap fresh weight; and (b) percentage of initial heap total N (TN) and total ammoniacal N (TAN) content. Error bars show ± 1 standard error.

Conclusions and perspectives

Gaseous nitrogen emissions (as NH_3 , N_2O and N_2) were greater in this study from stored pig FYM than cattle FYM, agreeing with the hypothesis that losses would be greater from the manure with the higher initial available N content. Losses via NH_3 volatilisation were low in this study in comparison with other studies and N losses via denitrification were greater than those via NH_3 volatilisation. Significant mineralisation of organic N occurred during the FYM storage period.

Further measurements are required of emissions from pig and cattle FYM storage at different times of year to confirm the hypothesis of this study and to generate robust emission factors for gaseous emissions and parameters for N transformations during manure storage.

Acknowledgements

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