TC-P_05 Impact of cattle-slurry treatment by separation and acidification on gaseous emissions after soil application

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1. Objectives

Cattle-slurry management became a priority in many livestock farms and slurry treatment is used to increase the fertilizer value of slurry and/or minimize its environmental impact. Indeed, significant emissions of ammonia (NH_3) and greenhouse gases (GHG) as nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) can occur during and after slurry application to soil. Application of acidified slurry or liquid fraction (LF) obtained by solid-liquid separation are two alternatives to raw slurry application that have proven to be efficient to minimize ammonia emissions. However, few is known about its effect on GHG emissions.

The aim of the present work was to assess the efficiency of cattle slurry treatment by acidification and/or solid liquid separation to mitigate ammonia (NH_3) and greenhouse gases (GHG) emissions following surface application to a sandy loam soil.

2. Methodology

Raw slurry (S) from a commercial dairy farm located close to Lisbon (Portugal) was first treated by centrifugation to obtain a liquid fraction (LF). Half of S and LF were then acidified to pH 5.5 by addition of concentrated sulphuric acid leading to acidified slurry (AS) and an acidified liquid fraction (ALF). Slurries' composition is presented in Table 1. These slurries were then applied to a Portuguese sandy loam soil (39º 49' 17'' N 07º 27' 44'' W; Haplic Cambisol; 38% coarse sand, 38% fine sand, 15% silt and 9% clay) at a rate of 80 mg N kg^{-1} dry soil (equivalent to 240 kg N ha^{-1}) and an aerobic incubation was performed during 92 days at 25 ºC in 2 L kilner jars.

Table 1: Composition of the slurries used and amounts applied to soil (*N* = 3).

Parameters	Slurries			
	S	**AS**	**LF**	**ALF**
Slurry composition				
pH (H_2O)	7.2[a]	5.5[b]	7.2[a]	5.5[b]
Dry matter (g kg^{-1})	113[a]	116[a]	21[b]	25[b]
Total C (g C kg^{-1})	74.7[a]	76.0[a]	15.4[b]	16.5[b]
Total N (g kg^{-1})	3.8[a]	3.3[b]	2.5[c]	2.2[c]
NH_4^+-N (g N kg^{-1})	1.3[a]	1.3[a]	1.2[a]	1.2[a]
NO_3^--N (mg N kg^{-1})	0.1[b]	1.6[ab]	0.9[ab]	2.1[a]
Application rate				
mg C kg^{-1} dry soil	1570[b]	1869[a]	498[d]	588[c]

Within rows, values presented with different superscripts are significantly different ($P < 0.05$) by Tukey test.

Six treatments three times replicated were carried out: 1. soil only (Control); 2. surface application of S followed by soil incorporation (S-I); 3. band application of S (S-S); 4. band application of AS (AS-S); 5. band application of LF (LF-S); 6. band application of ALF (ALF-S).

Two independent incubations were performed to follow NH_3 and GHG emissions.

- NH_3 fluxes: Kilner jars (L = 100 mm, H = 210 mm) were filled with 0.75 kg dry soil (H = 70 mm) and treatments were then applied as above described. Water holding capacity was adjusted at 60% and controlled regularly. Ammonia fluxes were measured during the first 14 days of incubation using the acid traps, containing 50 mL of 0.05 M orthophosphoric acid. Acid traps in each jar were replaced after 5, 22, 29, 45, 69, 94, 166, 220 and 333 hours of the beginning of the experiment.
- GHG fluxes: a second independent set of Kilner jars was prepared to measure the GHG emissions in each treatment following the same procedure described for the measurement of NH_3 fluxes. Methane, N_2O and CO_2 were measured using the close chamber technique followed by quantification by gas chromatography, using a GC-2014 (Shimadzu, Japan). Gas measurements were carried out at days 1, 3, 4, 5, 8, then every two days up to day 36 and once a week up to day 92.

Cumulative emissions were estimated by averaging the flux between two sampling occasions and multiplying by the time interval between the measurements. More information about the experimental protocol can be obtained in [1].

3. Results and discussion

3.1 Nitrogen emissions

Significantly higher ($P < 0.05$) NH_3 emissions were observed in S-S treatment relative to all other amended treatments during all the measurement period (Figure 1). Incorporation of raw slurry led to a significant decrease of NH_3 emissions relative to S-S treatment but the lowest NH_3 emissions were observed in treatments amended with acidified slurry, LF or acidified LF. The cumulative NH_3 emissions from AS-S were significantly lower ($P < 0.05$) in 86% relative to S-S treatment (Figure 1). During the measurement period, the daily NH_3 fluxes from LF-S treatment were similar ($P > 0.05$) to those observed in Control. No differences ($P > 0.05$) were observed between ALF-S and LF-S treatment relative to NH_3 emissions indicating that LF acidification is not required since raw LF application already minimizes NH_3 emissions relative to raw slurry. As observed here, lower NH_3 emissions from LF amended soil than raw slurry were reported by other authors and they attributed this difference to a greater infiltration of LF in soil [2, 3]. Furthermore, a significant immobilization of NH_4^+ ions derived from LF might have occurred leading to a lower NH_3 volatilization [4]. As previously reported [5, 6], slurry acidification seems to have a strong potential to minimize NH_3 emissions after soil application.

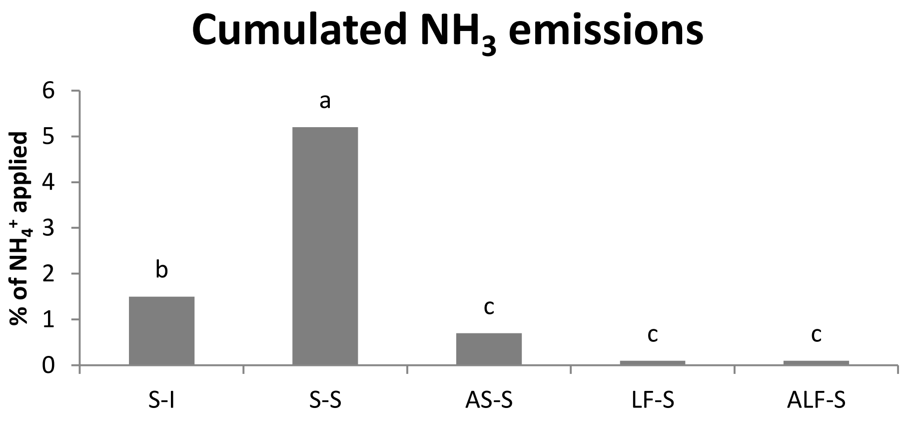

Figure 1: Mean value of the cumulated amount of ammonia emitted during the experiment ($N = 3$). Values quoted with different letters are significantly different ($P < 0.05$) by Tukey test.

Lower N_2O fluxes were observed in acidified treatments (AS-S and ALF-S) relative to non-acidified (S-S and LF-S, respectively) treatments. Significantly higher or similar N_2O emissions were observed in S-I treatments relative to S-S indicating that slurry incorporation might enhance N_2O emissions. The highest values of cumulative N_2O emissions were obtained in S-I, LF-S and

ALF-S treatments (Figure 2). It is to refer that the total amount of N_2O released from ALF-S was significantly higher than in S-S and AS-S. Application of acidified slurry led to the lowest N_2O emissions, namely a significant ($P < 0.05$) decrease of N_2O emissions relative to S-I. This result is in line with a previous study [7] using acidified pig slurry and a delay or inhibition of the nitrification process might be the main reason for such decrease.

The N losses (NH_3 + N_2O) by gaseous emissions were significantly reduced by 59% in acidified cattle-slurry comparatively to non-acidified cattle-slurry. However, a combined treatment - separation + acidification - did not bring any benefit relative to NH_3 and N_2O emissions since similar results were observed in acidified LF and non-acidified LF. Soil application of acidified cattle-slurry rather than non-acidified LF might be motivated by the lower costs associated to acidification compared to solid-liquid separation.

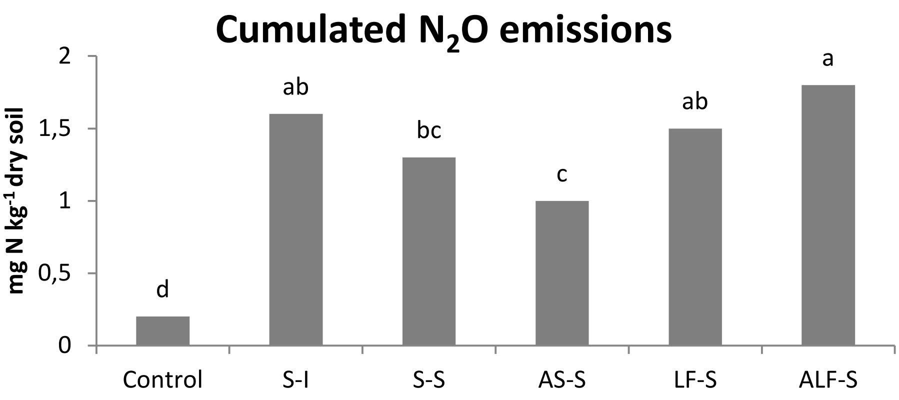

Figure 2. Mean value of the cumulated amount of nitrous oxide emitted during the experiment ($N = 3$). Values quoted with different letters are significantly different ($P < 0.05$) by Tukey test.

3.2 Carbon emissions

Higher CO_2 fluxes were observed over the first 8 days of the experiment in all treatments, with 26 and 45% of the total CO_2 emissions occurring during this period, followed by a reduction until the end of the measurements. Cumulative CO_2 emissions were lower in 32% when S-S was applied relative to LF-S (Figure 3). Also, the cumulative CO_2 emissions were lower ($P < 0.05$) in 52% when ALF-S was applied relative to LF-S amended treatment (Figure 3). More than 60% of the applied C was released as CO_2 in the LF-S treatment whereas in all the other amended treatments, less than 35% of the applied C was released.

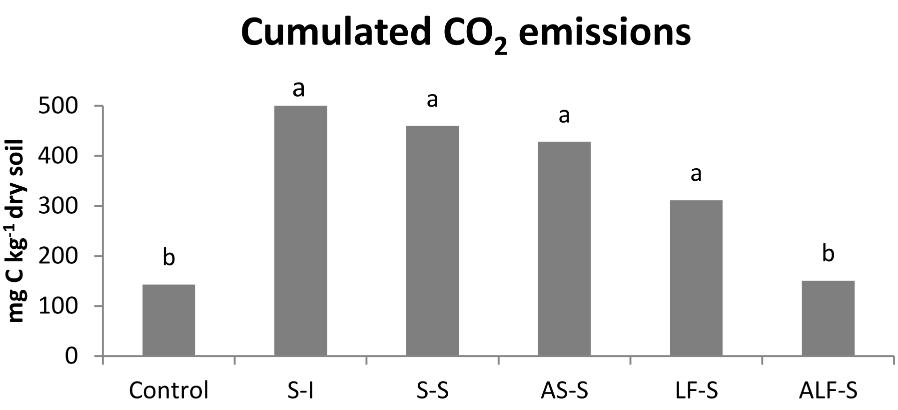

Figure 3. Mean value of the cumulated amount of carbon dioxide emitted during the experiment ($N = 3$). Values quoted with different letters are significantly different ($P < 0.05$) by Tukey test.

Cattle-slurry application increases the soil microbial activity and consequently CO_2 emissions after amendment due the organic matter decomposition. Compared with non-acidified slurries, slurry acidification reduced CO_2 emissions because it decreases microbial activity and consequently oxygen consumption, sulphate reduction and methanogenesis [8].

Methane emissions were only observed in S-I and S-S treatments during the first 4 days following soil application, being in agreement with previous studies [9] who reported that CH_4 emissions occurred during a short period. Furthermore, it is generally assumed that most of CH_4 released from slurry amended soil is due to the volatilisation of the CH_4 dissolved in the cattle-slurry (produced during storage). It has been seen that slurry acidification reduces the methanogenesis and consequently CH_4 production and emissions during slurry storage [6], what justifies the lower CH_4 emissions observed in AS-S relative to S-S. Most of the dissolved CH_4 initially present in S and AS should have been released during the separation process explaining the absence of CH_4 emissions in LF-S or ALF-S treatments.

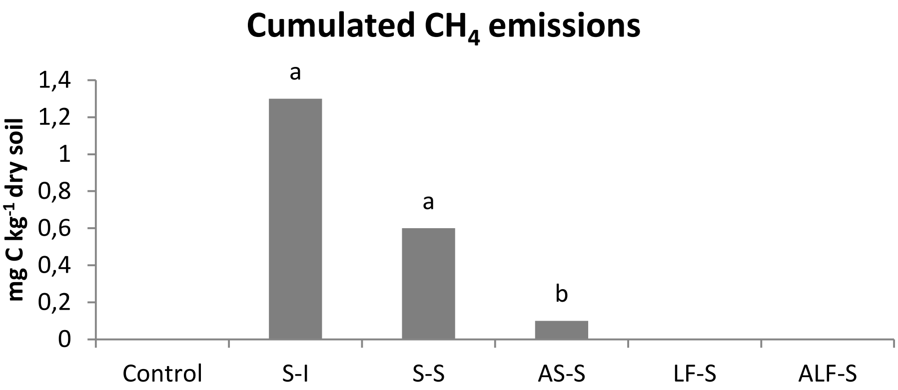

Figure 3. Mean value of the cumulated amount of methane emitted during the experiment (N = 3). Values quoted with different letters are significantly different (P < 0.05) by Tukey test

4. Conclusions

Our results showed that slurry acidification is a good solution to minimize NH_3, N_2O and CH_4 emissions following soil application. Furthermore, LF application rather than raw slurry led to a significant decrease of NH_3 emissions but has no impact on N_2O emissions. However, acidification of LF has no positive impact on gaseous emissions. Further studies at farm scale are required to validate our results and, on the other hand, a more safe and cost- effective solution for slurry acidification needs to be developed.

Acknowledgements

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