Cattle slurry treatment by mechanical and chemical separation: effect on N_2O emissions, mineral N dynamics and grass yields after application to grassland

D. Fangueiro[1] and D. Chadwick[2]*
[1] Department of Plant Science and Agricultural Engineering, UTAD, Ap. 1013, 5001-801 Vila Real, Portugal.
[2]Institute of Grassland and Environmental Research, North Wyke Research Station, Okehampton, Devon, EX20 2SB, UK
[*]corresponding author: email: dfangueiro@utad.pt

Introduction

Intensive dairy farming in NW Portugal is based on zero-grazing with all the dairy cattle housed in covered concrete yards/buidlings. As a consequence, large quantities of cattle slurry are produced. All this slurry is stored and then applied to fields in either Spring or Autumn before maize and ryegrass sowing, respectively. Such agricultural practices have a direct effect on global warming since nitrous oxide (N_2O), one of the main greenhouse gases (IPCC, 2001), is emitted during storage and after application of cattle slurry to soil (Oenema et al., 2007). Furthermore, the rainfall generally observed in Autumn may lead to significant nitrate leaching (Ryan et al., 2006). All these N losses have a strong impact on environment but also decrease the amount of nitrogen available for the plants.

Slurry storage facilities are expensive to construct and there is also a cost associated with slurry spreading. Furthermore, the available land area may not be sufficient to apply all the slurry produced on the farm and it may be necessary to export this surplus. Slurry treatment offers a solution to improve slurry management and reduce its environmental impact (Amon et al., 2006; Fangueiro et al., 2008a). Indeed, slurry separation by mechanical and chemical methods reduces the volume of slurry requiring storage and results in valuable slurry fractions that can be applied to field or used for fertigation, used to generate compost or used for biogas production.

In this study, five fractions of dairy cattle slurry were obtained using a combined separation system and applied to grassland in order to compare the effect of each fraction relative to the untreated slurry (US) on the nitrous oxide (N_2O) emissions, soil mineral N (soil N_{min}) dynamics and the grass yield.

Methods

The untreated cattle slurry, obtained from a commercial dairy farm, was first subjected to mechanical separation with a farm screw press separator (FAN model S650, BAUER) to obtain a solid (SF) and a liquid fraction (LF). The LF was then subjected to chemically enhanced settling for 48 hours after addition of 200 mg l^{-1} of a flocculating agent, the cationic polyacrylamide (VTAF94®), generating two more fractions: a supernatant (PAM-sup) and a sediment (PAM-sed) fraction (Fangueiro et al., 2008a). The solid fraction was used in a fresh form (FSF) and a composted form (OSF) of the solid fraction was obtained from the same dairy farm. The main characteristics of the US and slurry fractions are shown in Table 1.

These 5 slurry fractions and the US were applied manually to small plots (1 m by 1 m) set up on an established sward of perennial ryegrass (*Lolium perenne* L) at equal application rates of 40 m^3 ha^{-1} for the liquid effluent and 40 ton ha^{-1} for the solid effluent. Four replicates of each treatment and control (non amended soil) were performed.

Fluxes of N_2O were measured using the closed-chamber technique in conjunction with a photoacoustic infrared spectrometer/ trace gas analyser (Fangueiro et al., 2008b). Soil samples (0-15 cm depth) were taken from each plot on days 1, 3, 8, 10 and 14 after application and analysed for NH_4^+ and NO_3^- content. For this, 100 g (fresh weight) of sieved soil was shaken with 200 ml of 2M KCl for 2 hours. The suspension was then filtered through No. 4 filter papers and the extract analyzed for NH_4^+ and NO_3^- content by automated segmented-flow spectrophotometric methods (Houba et al., 1989). The remaining soil sample was used to determine soil moisture content after drying at 105°C for 24 h.

To estimate the agronomic effect of each fraction, the grass yield was determined in each treatment. In all plots, the grass was harvested manually two month after application of the slurry fractions to estimate the yields.

Table 1: Characteristics of the untreated slurry and slurry fractions used (on a fresh weight basis); mean ± standard error (N=4) (from Fangueiro et al., 2008b)

	Total N (g/kg)	NH_4^+-N (mg/ kg)	NO_3^--N (mg/kg)	C:N	Dry matter (%)	pH
US	*1.13 ± 0.03^c	556.5 ± 10.6^a	2.8 ± 2.0^b	18.2 ± 0.9^a	5.8 ± 0.1^c	6.5 ± 0.0^c
FSF	14.15 ± 1.05^b	394.5 ± 28.5^c	23.0 ± 4.0^b	6.5 ± 0.7^c	24.8 ± 0.3^b	7.2 ± 0.3^{ab}
OSF	28.78 ± 1.05^a	469.8 ± 38.5^b	2620.0 ± 133.4^a	3.4 ± 0.2^d	26.0 ± 0.1^a	7.4 ± 0.2^a
LF	1.05 ± 0.03^c	553.5 ± 7.0^a	0.8 ± 0.1^b	16.3 ± 0.6^a	4.9 ± 0.1^d	7.1 ± 0.0^b
Pam-sup	0.80 ± 0.00^d	457.0 ± 18.0^b	0.8 ± 0.1^b	12.9 ± 0.4^b	3.9 ± 0.2^e	7.1 ± 0.0^{ab}
Pam-sed	0.88 ± 0.03^d	486.3 ± 8.2^b	0.8 ± 0.1^b	16.7 ± 1.1^a	4.6 ± 0.1^d	7.3 ± 0.1^{ab}

*Values with different letters are statistically different at $P<0.05$.

Results and Discussion

Application of the US and slurry fractions to soil led to an immediate increase of the soil N_{min} content in all treatments relative to the control but such increases were statistically significant ($P<0.05$) only in the case of LF, PAM-sup and OSF (Figure 1). Furthermore, higher contents of soil N_{min} relative to the US treatment were observed in treatments amended with LF, OSF and PAM-sup during the first 10 days, whereas similar soil N_{min} concentrations were found in the US and FSF treatment. Fangueiro *et al*. (2008c) showed that the smallest slurry particles led to organic N mineralization whereas immobilization occurs in the coarser slurry fraction. It may explain the high soil N_{min} content observed in the LF and PAM-sup treatments whereas, in the case of the OSF, the increase of the soil N_{min} concentration should be due mainly to its high nitrate content. Indeed, in terms of NO_3^-N, soil concentrations were similar in all treatments except the OSF where significantly ($P<0.05$) higher amounts were found. Hence, it may be concluded that OSF applications increase the risk of nitrate leaching which is the main source of nitrogen losses and has a strong environmental impact (McGechan and Wu, 1998). After day 10, the N_{min} concentration increased slightly in all treatments probably due to nitrification of applied NH_4^+-N.

An increase of the N_2O emissions relative to the control was observed immediately after application of the US and liquid slurry fractions (LF, PAM-sed and PAM-sup) whereas no effect was observed with the solid fractions (Figure 2). Nevertheless, the N_2O emissions from the LF, PAM-sed and PAM-sup treatments were lower than those from the US. The N_2O emissions observed here were lower than those reported by other authors (Groenigen et al., 2004; Rhode et al., 2006) and it was probably the result of the low amounts of total N and N_{min} applied (Fangueiro et al., 2008b). The low N_2O emissions after FSF and OSF applications relative to other treatments may be related to their high DM content which limits their soil infiltration and interaction with soil microorganisms (Fangueiro et al., 2008b).

Nevertheless, a large peak in N_2O emissions was observed in the OSF treatment on day 7, probably due to denitrification of the large amounts of NO_3^--N applied in this treatment.

Figure 1: Soil mineral nitrogen contents during the 14 days after application of slurry and slurry fractions; mean of 4 replicates. Standard errors removed for clarity

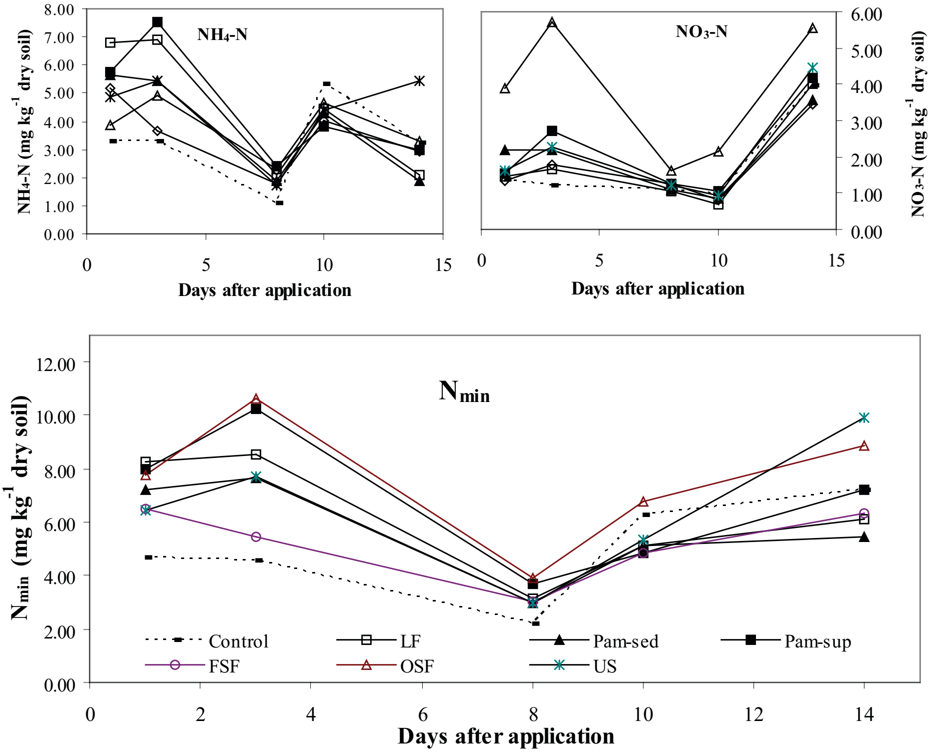
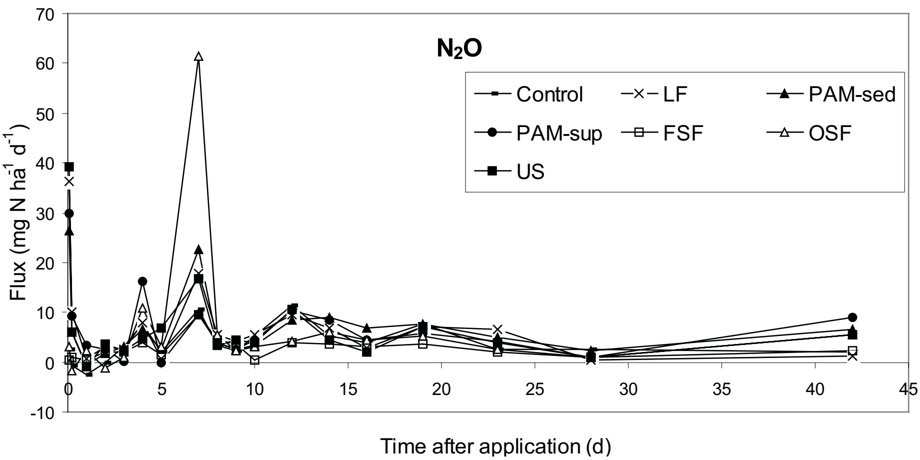


Figure 2: Average gaseous emissions rates following application to soil of untreated slurry and slurry fractions (N=4). Standard errors removed for clarity (from Fangueiro et al., 2008b)



The grass yields obtained two months after application were significantly higher after PAM-sup and OSF application than in the US treatment (Table 2). All other slurry fractions led to yields similar to those obtained in the US treatment. Hence it can be concluded that the application of slurry fractions does not induce any yield decrease relative to the US. Similarly, Matilla et al. (2003) observed no significant differences in yield after application of US or slurry fractions.

Table 2: Herbage yields obtained after application of untreated slurry and slurry fractions – mean values of 4 replicates. (from Fangueiro et al., 2008b)

	Control	US	FSF	OSF	LF	PAM-sup	PAM-sed
Yield (t ha^{-1} DM	*3.10 ^{c}	3.33 ^{c}	3.02 ^{c}	5.43 ^{ab}	3.72 ^{bc}	6.02 ^{a}	3.90 ^{bc}

*Values with different letters are statistically different at $P<0.05$

It can be concluded that slurry separation is a good tool for slurry management since it generated fractions with different characteristics that could be applied at different times according to crop needs. Furthermore, slurry fractions application did not increase emissions of N_2O relative to the US and may lead, in some cases (PAM-sup and LF) to higher N_{min} concentrations in soil. Grass yields may be improved by application of PAM-sup and OSF even if the high nitrate content of the OSF limits its application to dry seasons.

References

Amon, B., Kryvoruchko, V., Amon, T., Zechmeister-Boltenstern, S., 2006. Methane, nitrous oxide and ammonia emissions during storage and after application of dairy cattle slurry and influence of slurry treatment. Agric. Ecosyst. Environ. 112, 153-162.

Fangueiro, D., Pereira, J., Chadwick, D., Coutinho, J., Moreira, N., Trindade, H., 2008a. Laboratory assessment of the effect of cattle slurry pre-treatment on organic N degradation after soil application and N_2O and N_2 emissions. Nutrient Cycling in Agroecosystems, 80, 107-120.

Fangueiro, D., Senbayran, M., Trindade, H., Chadwick, D. 2008b Cattle slurry treatment by screw press separation and chemically enhanced settling: Effect on greenhouse gas emissions after land spreading and grass yield. Bioresource Technology, doi:10.1016/j.biortech.2007.12.069.

Fangueiro, D., Chadwick, D., Bol, R. 2008c. Assessment of the potential N mineralization of different particle size fractions in two dairy cattle slurries. Journal of Plant Nutrition and Soil science, In press.

Groenigen, J.W., Kasper, G.J., Velthof, G.L., van den Pol-van Dasselaar A., Kuikman, P.J., 2004. Nitrous oxide emissions from silage maize fields under different mineral nitrogen fertilizer and slurry applications. Plant and Soil 263, 101-111.

Houba, V. J., Lee, J. J., Novozamsky, I., Walling, I., 1989. Soil and Plant Analysis, Part 5. Soil Analysis Procedures. Wageningen.

IPCC, 2001. Good practise guidance and uncertainty management in national greenhouse gas inventories. In: Penman, J. et al. (Eds). IPCC national greenhouse gas inventories programme, Technical support unit, Hayama, Japan.

Mattila, P.K., Joki-Tokola, E.,Tanni, R. 2003. Effect of treatment and application technique of cattle slurry on its utilization by ley: II. Recovery of nitrogen and composition of herbage yield. Nutrient Cycling in Agroecosystems 65: 231–242.

McGechan, M.B., Wu, L. 1998 Environmental and Economic Implications of some slurry management options. Journal of Agricultural Engeneering Research, 71, 273-283.

Oenema, O., Oudendag, D., Velthof, G.L. 2007. Nutrient losses from manure management in the European Union. Livestock Science, 112 261–272.

Rhode, L., Pell, M., Yamulki, S., 2006. Nitrous oxide, methane and ammonia emissions following slurry spreading on grassland. Soil Use Manag. 22: 229-237.

Ryan, M., Brophy, C., Connolly, J., McNamara, K., Carton, O.T. (2006) Monitoring of nitrogen leaching on a dairy farm during four drainage seasons. Irish Journal of Agricultural and Food research, 45 (2): 115-134