Effect of the land spreading technique on ammonia volatilization from different pig slurries applied on wheat stubble

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Abstract
Field experiments were carried out in Brittany (Western France) in 2012 to measure and compare the ammonia losses after surface and incorporation application of fattening and farrowing-gestating pig slurry. Experiments were conducted on wheat stubble. Ammonia emissions were measured by using wind tunnels method. The results show a reduction of the ammonia emission by incorporation compared to the broadcast spreading whatever the slurry. However, the reduction of ammonia volatilization by incorporation technique is lower with the farrowing/gestating (65% of reduction) compared to the fattening slurry (97% of reduction). This lower reduction was associated with a lower Total Ammonia Nitrogen emissions in farrowing slurry (16% of the $N\text{-}NH_4^+$ applied) compared to the fattening slurry (74% of the $N\text{-}NH_4^+$ applied). The lower ammonia emission were attributed to low dry matter content and ammonium level in farrowing/gestating compared to the fattening slurry.

Introduction
This study is part of the European Interreg BatFarm project (www.batfarm.eu) and aimed to assess the efficiency of the easily applicable soil incorporation technique to reduce ammonia emission after the land spreading of pig slurries under French conditions. Indeed, there are a lot of studies demonstrating the efficiency of the incorporation of manure in reducing ammonia emissions [1] but there are very few French data. Moreover there is considerable variation in the efficiencies reported due to difference among manures or between sites [1-3]. In this framework there is a need to have data obtained under the farm conditions in order to assess the efficiency of a spreading in reducing ammonia emissions. Two slurries differencing in characteristics (farrowing/gestating and fattening pigs) were applied on wheat stubble at a rate of 45 m^3 ha^{-1}. The NH_3 emission was measured using the wind tunnel technique after applying slurries with closed-slot injector technique (fitted with tanker, Pichon Industries, France) and broadcast technique (manually simulated) under field conditions. Measurements were carried out in end of summer. Although there are discussions about the effect of the wind tunnel technique of an overestimation on ammonia emissions [4-5], this method suits well for small-plot comparative measurements [6].

Material and Methods
Two trials were carried out at a farrowing-fattening farm with 200 sows during two subsequent weeks in the end of august 2012. The first trial was dedicated to the farrowing/gestating sow slurry and the second run dedicated to fattening pigs slurry. The different pig slurries were applied on wheat stubble by closed-slot injection and by manually broadcast application (manually simulated).

Manure characteristic
At each trial, and just before spreading, a representative manure sample (1–2 L) was collected from the manure load trailer to determine manure pH, percentage dry matter (DM), N, and the total ammoniacal N (TAN) of each of the slurries applied. Table 1 summarizes the main characteristics of the two slurries.

Manure application
The spreading experiment was carried out on a crop plot belonging to the pig farmer. Whatever the spreading technique, the slurry was applied on wheat stubble at a rate of 45 m^3 ha^{-1}. The slurry was spread and incorporated to soil using a commercial closed-slot injection device fitted with a tanker (one opening disc and one closing disc per raw/disposal pipe, 7 injection rows spaced by 70 cm given a spread width of 4,7 m). The spreading rate was monitor with an electronic device integrating the tractor's velocity meter and manure flow meter information; the quantity of applied slurry was verified by comparing the surface area that received slurry and the difference of slurry mass before and after

spreading. We assumed the velocity of the tractor equal for the 2 runs and did not affect trials. The broadcast spreading was simulated by applying the slurry manually (4.5 liters of slurry per square meter of surface) using a simulated splash-plate spreading technique (watering can with spoon). The slurry was spread in three different areas given 3 replicates by spreading technique in order to take account of the likely spatial variability of the NH_3 emissions, as an incidence of spreading and soil variability.

Table 1: Main characteristics of the slurries applied on wheat stubble

Run	Type of slurry	Rate (m^3 ha^{-1})	Dry matter (% of raw slurry)	pH	Ntotal (mg kg^{-1})	$N\text{-}NH_4$+ (mg kg^{-1})
1	Farrowing/gestating sows	45	1.2	7.7	2.1	1.7
2	Fattening pigs	45	3.1	7.7	4.1	2.9

Ammonia measurement after manure spreading

The effect of the spreading technique on the ammonia emissions following the surface-application of slurry was measured for 3 days using the wind tunnel method already described [7-9]. Each NH_3 emissions monitoring session included a set of 6 wind tunnels: 3 plots of incorporated slurry (3 replicates) and 3 plots of surface applied slurry (3 replicates). Background ammonia concentration in air was measured at the entrance of one of the 3 Wind Tunnels for each spreading method, using an trapping flask containing 50 ml H_2SO_4 (0.25 N). Ammonia concentrations in the air outlet of the wind tunnels were measured using the same trapping method. The cumulative ammonia emission was determined for each application technique by collecting and replacing frequently the acid at 2, 5, 9, 15, 22 h after manure application for the first day and every 12-18h for the two remaining days.

Results

The recorded mean air temperature at the soil surface was more and less similar for the farrowing/gestating and the fattening trials, 21 and 19◦C respectively during the day and 14.2◦C during the night. Whatever the technique and the slurry NH_3 emissions were higher in the first 6 h after application, and quickly decreased to negligible levels after 73 h. Cumulative percentages of NH_3-N volatilized (as a percentage of applied TAN in slurry or in g m^{-2} of applied surface) during each experiment are given in Table 2. The results show a reduction of the ammonia emission by incorporation compared to the broadcast spreading whatever the slurry. We also measured a high variation in ammonia loss between the three wind tunnels (replicates of similar slurry) with the incorporation technique compared to the broadcast technique (figure 1). It is recognized that NH_3 volatilization from field-applied manure may be affected by weather conditions, manure characteristics, soil conditions and crop cover. Nevertheless we attributed this variation (99.2% for the slurry of farrowing/gestating sow and 54.2% for the slurry of fattening pig) to micro spatial variation during the incorporation of the slurry with the disc. Indeed, we observed after incorporation some slurry remaining at the surface of the soil. This variation between wind tunnels was less with the broadcast (4.9% for the slurry of farrowing/gestating sow and 8.3% for the slurry of fattening pig value). A hypothesis is that factors influencing slurry infiltration into the soil (e.g. hydraulic loading rate, slurry solids content, soil moisture status) influence the effective reductions achieved through bandspread or shallow injection compared with surface broadcast application [10]. Differences between the techniques were large and significant. However, the reduction of ammonia volatilization by incorporation technique is lower with the farrowing/gestating (65% of reduction) compared to the fattening slurry (97% of reduction). This lower reduction was associated with lower Total Ammonia Nitrogen emissions from farrowing slurry (16% of the $N\text{-}NH_4^+$ applied) compared to the fattening slurry (75% of the N- NH_4^+ applied). The lower ammonia emission were also attributed to low dry matter content and ammonium level in farrowing/gestating compared to the fattening slurry. The results are in the higher range for fattening slurry or lower for farrowing slurry than those published [8] under French conditions (37-45% of TAN of pig on wheat stubble in summer at a rate of 40 m^3 ha^{-1}). Nevertheless it is difficult to compare the different EF's found in the literature because ammonia losses after manure spreading vary greatly depending of various influencing parameters (manure and soil characteristics, type of crop, climatic conditions, measurement technique). It would be interesting to compare our experimental results with predicted emissions using modelling approaches, but that was not the aim of this study.

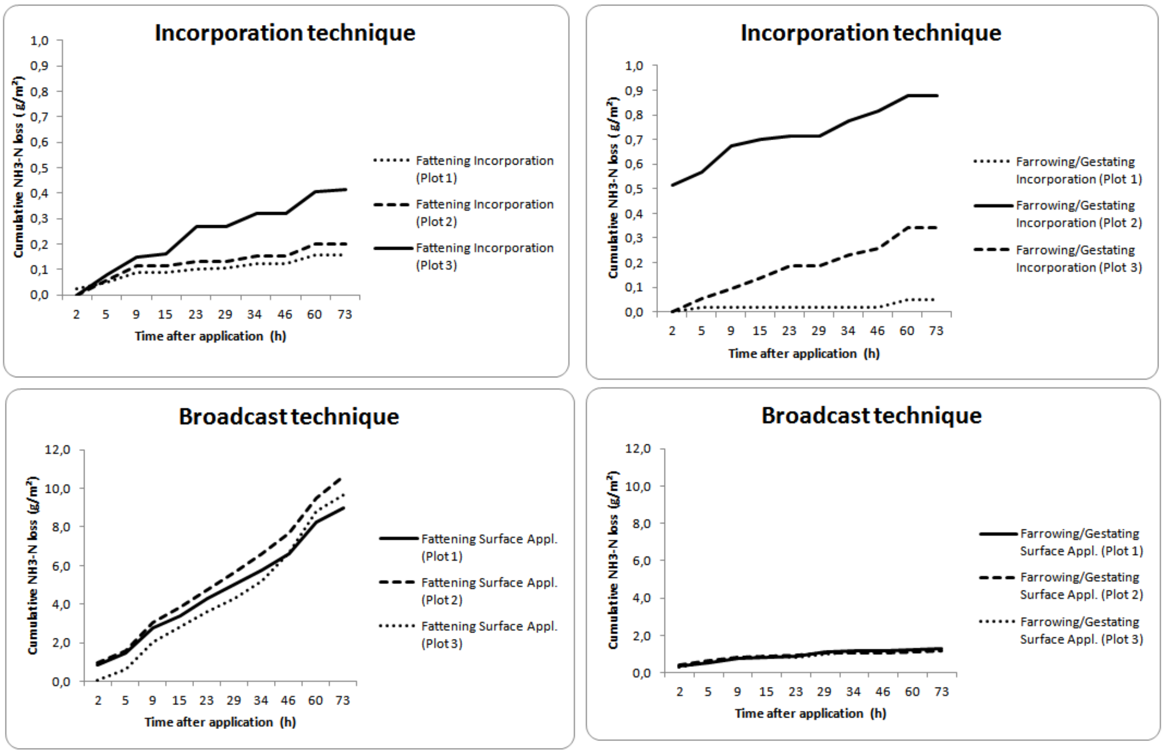

Figure 1. Cumulative NH_3 (in g m^{-2} of applied surface) following application of pig slurries (45 m^3 ha^{-1}) on wheat stubble

Table 2: Cumulative loss of NH_3 after spreading of 45 m^3 ha^{-1} of different pig slurry (mean of 3 replicates)

	Application Rate	Volatilisation			
		Incorporation		Broadcast	
	TAN Applied (g NH_3-N/m²)	g NH_3-N/m²	% TAN applied	g NH_3-N/m²	% TAN applied
Farrowing/gestating sows	7.6	0.42	5.7	1.21	16.2
		CV: 99.2%		CV: 4.9%	
Fattening pigs	13.5	0.26	2.0	9.75	74.7
		CV: 54.2%		CV: 8.3%	

CV: coefficient of variation

Conclusion and perspectives

The results of this study confirm that the incorporation of pig slurry is a technique to reduces the ammonia emissions. However, the level of reduction is linked to the characteristics of the slurry applied that influence the ammonia volatilization. We also observed a heterogeneity of slurry incorporation that impacted the ammonia reduction by the technique.

References

[1] Webb, J., Pain, B., Bittman, S., Morgan, J., 2010. The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response--A review. Agriculture, Ecosystems & Environment 137, 39-46.

[2] Misselbrook, T.H., Nicholson, F.A., Chambers, B.J., 2005a. Predicting ammonia losses following the application of livestock manure to land. Bioresource Technology 96, 159-168.
[3] Huijsmans, J.F.M., Hol, J.M.G., Vermeulen, G.D., 2003. Effect of application method, manure characteristics, weather and field conditions on ammonia volatilization from manure applied to arable land. Atmospheric Environment 37, 3669-3680.
[4] Sommer, S.G., Génermont, S., Cellier, P., Hutchings, N.J., Olesen, J.E., Morvan, T., 2003. Processes controlling ammonia emission from livestock slurry in the field. European Journal of Agronomy 19, 465-486.
[5] Sintermann, J., Neftel, A., Ammann, C., Häni, C., Hensen, A., Loubet, B., Flechard, C.R., 2011. Are ammonia emissions from field-applied slurry substantially over-estimated in European emission inventories? Biogeosciences 8, 10069-10118.
[6] Misselbrook, T.H., Nicholson, F.A., Chambers, B.J., Johnson, R.A., 2005b. Measuring ammonia emissions from land applied manure: an intercomparison of commonly used samplers and techniques. Environmental Pollution 135, 389-397.
[7] Lockyer, D.R., 1984. A system for the measurement in the field of losses of ammonia through volatilisation. Journal of the Science of Food and Agriculture 35, 837-848.
[8] Moal, J.F., Martinez, J., Guiziou, F., Coste, C.M., 1995. Ammonia volatilization following surface-applied pig and cattle slurry in France. *Journal of Agriculture Science* 125, 245-252.
[9] Portejoie, S., Martinez, J., Guiziou, F., Coste, C.M., 2003. Effect of covering pig slurry stores on the ammonia emission processes. Bioresource Technology 87, 199-207.
[10] Misselbrook, T.H., Gilhespy, S.L., Yamulki, S.C., V., Donovan, N., Bulmer, N., Retter, A., Williams, J., Chambers, B., Sagoo, E., Thorman, R.E., 2006. Influence of application rate and method on nitrogen losses from slurry applied to grassland Proceedings of the 12th International Conference of the Ramiran Network, 281-283.