Acidification of slurry in barns, stores and during application: review of Danish research, trials and experience

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Abstract
Acidification is recognised as a method for reduction of ammonia volatilisation of manure. During the last two to three years acidification of slurry has become common in Denmark. In 2012 it has been estimated that about 11 % of all applied slurry in Denmark was acidified, and in 2013 it is expected that up to 20 % will be acidified. In all cases sulphuric acid is used for acidification, because sulphuric acid is a very strong acid, it is relatively cheap and it contributes significantly to the content of sulphur in the slurry. Acidification can take place in the barn, in the slurry tank or during application of the slurry in the field. Recent Danish research and trials have shown a significant reduction of ammonia volatilisation after application of the slurry in the field (typically a 50 % reduction compared to untreated slurry) and a subsequent increase of yield due to a higher amount of nitrogen available to the crop.

Introduction
Acidification of slurry has long been recognised as a potential method for reduction of ammonia emissions from animal slurry. By adding acid, pH in the slurry is reduced and the equilibrium between ammonia and ammonium will be pushed towards ammonium. However, so far acidification has not been used to any larger extend in practice due to practical problems and difficulties in meeting the basic safety rules. During the latest few years a major breakthrough has been experienced in Denmark and today commercial equipment is available for acidification under the slats in the barn, in the slurry tank during storage and on the slurry trailer during application in the field.

Techniques used
Basically three different techniques are used. Common for all techniques is that the acid used is concentrated sulphuric acid. Sulphuric acid is relatively inexpensive and the slurry is added sulphur, which increases the fertiliser value of the slurry.

Technique	Description
Acidification in barns	A tank of acid is placed nearby the pretank just outside the barn. On a daily basis acid is mixed into the slurry in the pretank, and the acidified slurry is pumped back into the barn. The slurry under the slats is kept under the pH of 5.5 at any time.
Acidification in slurry tanks	Prior to application the slurry in the tank is mixed thoroughly with a mechanical mixer. During mixing acid is slowly mixed into the slurry until pH reaches a level of about 5.5 - 6.
Acidification during application	A standard pallet tank is carried in the front lift of the tractor. The tank is protected by a break proof “cage”. The acid is pumped to the slurry trailer through a solid hose, and pH is continuously measured. The acid is injected into the slurry immediately before the slurry is applied.

Distribution in Danish agriculture
Acidification in barns has been used for at least ten years, while commercial systems for acidification in slurry tanks and during application were introduced in 2012 and 2011, respectively. However, these two methods are today widely distributed and generally recognised as available and efficient methods. A recent survey shows that 112 units for barn acidification are installed, and 37 units for tank acidification and 56 units for slurry tanker acidification are sold. Most of the units for tank acidification and slurry trailer acidification are owned by contractors and have a very large capacity. The survey estimates that about 11 % of all slurry in Denmark was acidified in 2012 (Toft, 2012).

Trials and experience

Intensive research by the University of Aarhus and field trials carried out by the Knowledge Centre for Agriculture show that acidification reduced the ammonia emission about 50 per cent, harvest yield is increased and in many cases the increased yield will pay for the treatment.

The Knowledge Centre for Agriculture has done field trials with acidified slurry in cereal and grassland with clover in the period 2001-2012. In the trials, untreated slurry was compared to acidified slurry applied with trailing hoses.

The effect of acidification is measured in the trials by calculating the Mineral Fertiliser Equivalent (MFE) of nitrogen in the slurry compared to plots fertilised with mineral fertilizer only.

$$MFE = ((N_{yield(s)} - N_{yield(0N)})/A - N_{fertiliser}) / N_{total} \times 100$$

where:
$N_{yield(s)}$ = N-yield of plot, fertilised with slurry (yield of dry matter x raw protein),
$N_{yield(0N)}$ = N-yield of plot with no nitrogen application,
A = the slope of the N-yield curve of increasing mineral fertilised plots,
$N_{fertilizer}$ = applied mineral fertilizer-N to plot with slurry and
N_{total} = total amount of nitrogen applied in slurry in plot with tested slurry

The MFE is calculated for plots with untreated and acidified slurry and is shown for clover grassland and for cereals in figure 1 (15 trials in winter wheat and one trial in spring barley). Because of clover, the N-response varies a lot in the grass land trials, and there is no clear coherence between acidification and MFE. In average, the MFE has increased by nine units by acidification. In cereals the yield response of N-application is higher and shows an increase in MFE of acidification of 14 units.

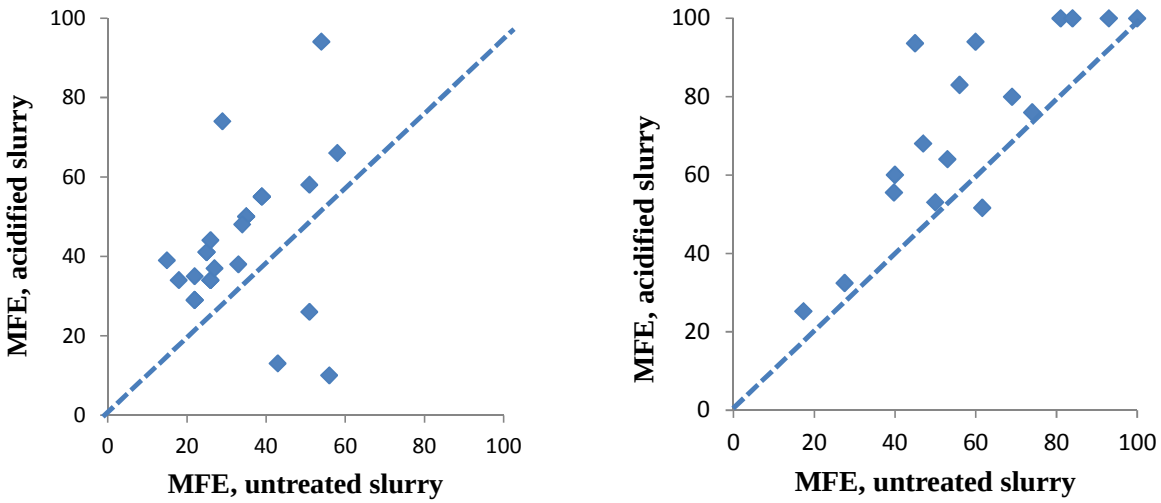

Figure 1: MFE of untreated and acidified slurry to grassland with clover (to the left) and cereal (to the right). The dotted line is X=Y.

From 2007 to 2012 55 field trials with increasing amounts of nitrogen to winter wheat show that the average yield response of nitrogen is 12 kg of grain per kg nitrogen applied (Pedersen, 2012). With an increased MFE of 14 units by acidification of slurry, the average yield increase per 100 kg total nitrogen in slurry applied will be 0.17 tonne of grain per hectare.

In 2011 four field trials with acidification of slurry to winter wheat were made (Pedersen, 2011). The pH of the slurry was reduced from 7.4 to 5.9 during application. Application of sulphuric acid has supplied 30 kg of plant available sulphur per hectare. The weather conditions after application of slur-

ry were warm, with high radiation and no precipitation, which are the conditions to expect a high ammonia volatilisation from surface applied manure. Results are showed in table 1.

Table 1. Yield effect of application of acidified pig slurry to winter wheat. Average of four trials.

	Raw protein in dry matter [%]	Yield [kg N in grain per ha]	Yield [tonne of grain per ha]
1. 50 + 100 N, mineral fertiliser	10.9	125	7.69
2. 50 N + 100 NH_4-N in pig slurry	10.0	108	7.25
3. 50 N + 100 NH_4-N in acidified pig slutty	10.5	121	7.75
LSD	-	12	ns

Economic calculations

Economic calculations have been made for the different types of acidification. In Denmark, acidification in the field and in the slurry tank is often done by the contractor, and the capacity of the acidification is high. To the same pH-level, the two types of acidification have approximately the same costs of 1-2 euros per ton slurry acidified. Acidification in the barn has shown to reduce ammonia volatilization from the barn by 65 % (Kai *et al*., 2008) compared to untreated slurry. That will increase the amount of plant available nitrogen 10-12 %, which explains the increase of MFE, as shown in figure 1. With the current prices of protein and grain, the increased yield can pay for the cost of acidification.

Acidification in the stable is the most expensive method, since the investment costs is high and the capacity is low. For cattle and milk production, the investment costs are particular high and, therefore, it is normally only due to environmental considerations that acidification in the barn is done. In pig production the investment is lower, and a calculation has shown a cost of 3-3.5 euros per ton slurry acidified. The N-effect is rather high, since ammonia loss from barn, tank and during application is reduced. Acidification in barns for pigs, therefore results in more than 20 per cent more plant available nitrogen per pig, than from untreated slurry. In times of high prices of protein and grain, increase of yield will pay the costs of acidification.

Experiences from practice

Since about 10 % of the slurry was acidified in 2012 a lot of observations were made in practice. It was observed that winter wheat and grass that was fertilised with acidified slurry visually appeared darker green than wheat and grass fertilised with untreated slurry (figure 2). It was also observed that roots appeared denser after application of acidified slurry (figure 3). The understanding of these observations is still not fully understood. More trials and observations are to be done in 2013.

Figure 2. Acidified slurry in winter wheat to the right, untreated slurry to left.

Figure 3. Winter wheat roots from crop fertilised acidified slurry to the right and untreated slurry to the left.

References

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