AMMONIA VOLATILIZATION AFTER APPLICATION OF DIGESTED BIOGAS SLURRIES IN A COASTAL MARSH REGION OF NORTHERN GERMANY

Quakernack R.[1], Techow A.[2], Herrmann A.[2], Taube F.[2], Kage H.[1], Pacholski A.[1]
Institute of Crop Science and Plant Breeding, Hermann-Rodewald-Straße 9, 24118 Kiel, Germany.
Tel:++49 431 8804398. quakernack@pflanzenbau.uni-kiel.de
[1] Agronomy and Crop Science
[2] Grass and Forage Science/Organic Agriculture

1 INTRODUCTION

Biogas plays an important role in the German bio-energy production and has increased rapidly within the last years. There exists a subsidy for use of crops (silage maize etc.) in biogas fermentation. As a result new types of biogas slurries are produced with high crop biomass contents resulting in physico-chemical characteristics different from conventional animal and digested biogas slurries. The nitrogen (N)-fertiliser-value of these substrates as well as their contribution to unwanted emissions of ammonia (NH_3) and greenhouse gases (GHG) and N losses as nitrate leaching, has not been studied in detail up to now. NH_3-emissions are among the main sources of acidifying and eutrophying atmospheric compounds and are considered as indirect greenhouse gas emissions. Crucial factors for NH_3volatilization are application technique, pH-value of digested biogas slurry and climate conditions. Furthermore N-loss by NH_3 volatilization of organic fertilisers can reduce the N-fertilisation value up to a yield-relevant level (Sommer and Hutchings, 2001). The coastal marsh region of the federal state of Schleswig-Holstein in Northern Germany is characterized by very particular growing conditions because of shallow groundwater levels, heavy, silt-clayey soils (Fluvimollic Gleysol) and high wind speeds. These conditions are also potentially favourable for high NH_3 losses. However, NH_3losses in the marshland have not been studied in detail yet, also with respect to conventional animal slurries. Therefore, a field study was established to determine NH_3losses by volatilization after application of digested biogas slurries (BGS) in different crop rotations grown on a marshland soil and to study the effect of NH_3 losses on the fertiliser N-value of BGS with respect to yield level.

2 MATERIALS AND METHODS

Ammonia losses after application of digested biogas slurries with trail hoses were determined in a multi-plot field trial including a bi-annual energy crop rotation consisting of maize (*Zea mays L.*), spring wheat (*Triticum aestivum L.*) and Italian ryegrass (*Lolium multiflorum L.*) as intercrop and the monocultures of maize and perennial ryegrass (*Lolium perenne L.)*. The latter was cut four times. Investigations were carried out in the marshland of Schleswig-Holstein, Northern Germany, in the year 2009 and included three different N-treatments for every crop type (control; moderate; high) by comparing organic and mineral N-fertilisers: co-fermented digested biogas slurries (BGS) and calcium ammonium nitrate (CAN) as mineral N-fertiliser. Ammonia volatilization after BGS application was measured by using the micrometeorological backwards Lagrangian stochastic dispersion technique (bLS, Sommer et al., 2005) on larger field sites of grassland (one plot per fertilisation) and a combination of passive flux samplers and a calibrated dynamic chamber method (DSM, Pacholski *et al.*, 2009) in the multi-plot field trial. The bLS-plot size of each fertilisation date depended on the working width of the trail hoses which varied between the different dates of fertilisation (plot sizes at investigated application dates: 07.04.09: 48x48m; 28.05.09: 54x54m) and were carried out on the same date and with the same N-supply of the moderate N-treatment as in the multi-plot field trial on grassland. Plot size of the multi-plot field trial was 12x12m with four replicates for each treatment. Moderate (360 kg N ha^{-1}) and high (480 kg N ha^{-1}) treatment in Perennial ryegrass were subdivided in four doses whereas for wheat (moderate: 180 kg N ha^{-1}; high: 240 kg N ha^{-1}) the fertilisers were applied in two doses. For maize (moderate: 150 kg N ha^{-1}; high: 200 kg N ha^{-1}) one biogas slurry application was given besides mineral side-dressing at sowing. Ammonia losses from mineral fertilisation (CAN) were considered as negligible. Yield [t DM ha^{-1}] of every plot in the multi-plot field trial was determined by machine harvest of a subplot [27 m²]. Statistical analyses of yield were done by using two-way ANOVA including N-form and N-levels as treatment factors.

3 RESULTS AND DISCUSSION

Nitrogen losses by NH_3-volatilization differed between dates of fertiliser application. Figure 1 shows the cumulative and the relative NH_3 losses after BGS application on grassland determined in 2 experimental campaigns measured by bLS- and DSM-technique.

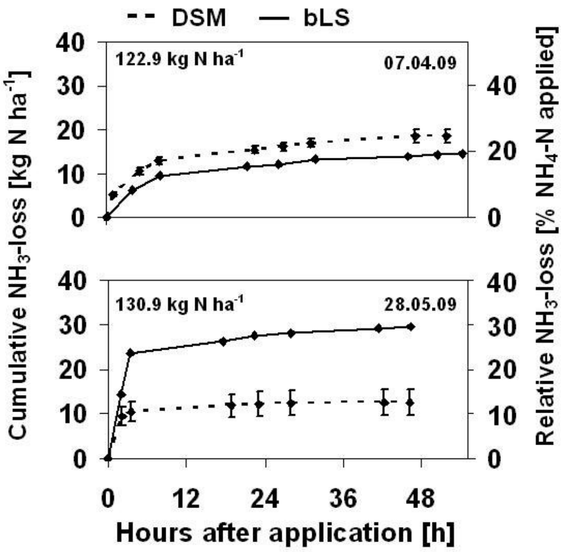

FIGURE 1 **Cumulative and relative N-loss by NH_3-volatilization after application of digested biogas slurry in moderate N level, perennial ryegrass (*Lolium perenne L.*), marsh region of Schleswig-Holstein, micrometeorological bLS-technique and combined passive flux samplers/ calibrated dynamic chamber method (DSM), 2 dates during spring 2009. Error bars indicate standard error (SD), n=4**

After N-application relative losses of about 20% of NH_4-N applied could be observed on the application date 7th April whereas on the 28th May NH_3-losses were higher than 30% of supplied NH_4-N for bLS-method. The higher relative losses were probably due to strong wind on the 28th May, which is one of the main driving factors for NH_3-volatilization. Average wind speed at a height of 2 meters for the first few hours after application was 7.4 m s^{-1}, much higher than on the 7th April (3.6 m s^{-1}). Compared to bLS-technique the combination of passive flux samplers and a calibrated dynamic chamber method (DSM) showed similar relative NH_3-losses in grassland of about 22% on the 7th April. On the 28th May the DSM-method strongly underestimated NH_3-losses which may due to high wind speed at this date. Strong wind can cause problems for dynamic chamber measurement with respect to calibration of the DSM-method (Figure 1). In general wind conditions complied with the requirements for the application of the DSM, so that in general a good agreement between the methods can by assumed. However, for the date with the strong deviation of the DSM from bLS measurements the results of the bLS technique were used in the calculation of the total NH_3-losses (Table 1).

TABLE 1 **Total N-supply and total/relative NH_3-losses by volatilization after application of digested biogas slurries on a multi-plot field trial including grass (four applications), wheat (two applications) and maize (one application) in the marshlands of Schleswig-Holstein, Germany, 2009, measured by a combination of passive flux samplers and a calibrated dynamic chamber method (SCM) and bLS technique.** Except from one application date (28.05., results of bLS measurement) in grass, for each crop type NH_3-loss determination after application: n=4

	N-treatment	Total-N applied [kg N ha^{-1}]	NH_4-N applied [kg N ha^{-1}]	Total NH_3-loss [kg N ha^{-1}]	Relative NH_3-loss [% NH_4-N]
	Moderate	374	254	56 ± 8	19 - 25
Grass	High	497	338	74 ± 9	19 - 25
	Moderate	196	133	31 ± 6	19 - 28
Wheat	High	261	177	40 ± 7	19 - 27
	Moderate	108	74	15 ± 5	14 - 27
Maize	High	162	110	15 ± 4	10 - 17

Relative NH_3-losses after BGS application on wheat (19-28%) were on a similar level to those on grassland (19-25%). Different levels of relative NH_3-volatilization losses were observed between moderate (14-27% NH_4-N applied) and high (10-17% NH_4-N applied) N-treatment in maize. Highest amount of N-loss by NH_3-volatilization was determined in grassland, followed by wheat and maize cropping systems (Table 1). Due to the suitable agreement between the two NH_3 loss measurement techniques, the combined dynamic chamber and passive flux sampler method is considered as an alternative to the micrometeorological bLS-technique for sampling and quantifying NH_3-emissions after organic fertiliser supply. NH_3-volatilization losses after slurry application with trail hoses in the marsh were about two fold higher than in other landscapes of Schleswig-Holstein (Pacholski *et al.*, 2009).

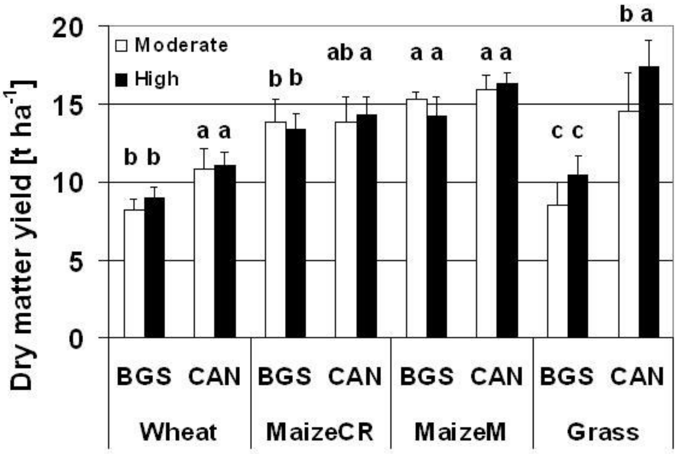

FIGURE 2 **Dry matter yield [t ha^{-1}] of wheat, maize in crop rotation system (MaizeCR), maize in monoculture (MaizeM) and perennial ryegrass, cut 4 times a year, at a moderate and a high level of N fertilisation with digested biogas slurry and mineral N-fertiliser (CAN) in the marsh region of Schleswig-Holstein.** Values with different letters are statistically different for each crop type at *P<0.05* (Tukey-test, n=4)

Yield of every crop type was lower in the BGS treatment as compared to mineral fertilisation. No interactions between N fertiliser and N level were observed (Figure 2). As a result the highest differences in yield-level could be observed in ryegrass. The total yield decreased from 14.5 t DM ha^{-1} (CAN) to 8.5 t DM ha^{-1} (BGS) by about 42% under the moderate N level and from 17.3 t DM ha^{-1} (CAN) to 10.4 t DM ha^{-1} (BGS) by about 40% in the high N level. In both rotations no significant differences in maize yield in connection with N-treatment were observed. This can be explained by the comparatively low N fertilisation demand of maize and the high N-mineralization level at the study site as indicated by high DM yields in the control treatment (11.2-12.5 t DM ha^{-1}). For wheat the yields differed significantly with respect to fertiliser type. The data suggest that N-losses by NH_3-volatilization were one of the main factors for high differences in yield levels between the two N-fertilisers in grassland and wheat. In addition, lower yields under biogas slurry fertilisation in grass is also attributed to the low NH_4-N level in BGS as compared to CAN and slow mineralization of the organic N compound in BGS which did not suffice to meet the high N demand of this crop. Other negative yield effects could also be due to ammonium adsorption and fixation in the soil characterized by high clay contents (about 40%), nitrous oxide (N_2O)-losses by microorganisms or N-leaching. Besides environmental impact like acidification and eutrophication NH_3-volatilization can thus also strongly influence the N-fertilisation value of biogas slurry. Nevertheless, a yield of 14.5 t DM ha^{-1} for grass with mineral fertilisation was competitive to the yield of dominant biogas crop maize at this site.

4 CONCLUSIONS

Fertilisation of BGS with trail hoses can lead to high N-losses by NH_3-volatilization with high environmental impact under conditions of the marshland in Northern Germany. Losses were even higher than 30% of NH_4-N applied in case of strong winds. Those losses substantially contributed to strongly decreased yields of perennial ryegrass and wheat. Application of biogas slurry as organic N fertilizer had a reduced fertilizer N value for grass and wheat as compared to CAN while no effect was observed for maize probably due to the lower N fertilisation demand of this crop.

REFERENCES

Pacholski A, Gericke D, Kage H 2009. Measurement and modelling of NH3 emissions from field-applied biogas residues in North German energy crop rotations. In: Grignani, C., Acutis, M., Zavattaro, L., Bechini, L., Bertora, C., Marino Gallina, P. and Sacco, D. (eds.) *Proceedings of the 16th Nitrogen Workshop - Connecting different scales of nitrogen use in agriculture*. 28th June – 1st July 2009, Turin, Facolta di Agraria, Turin, Italy. pp. 189 - 190

Sommer S G, Huchtings N J 2001. Ammonia emission from field manure and its reduction – invited paper, European Journal of Agronomy 15, 1-15.

Sommer S G, McGinn S M, Flesch T K 2005. Simple use of the backwards Langrangian stochastic dispersion technique for measuring ammonia emission from small field-plots. European Journal of Agronomy 23, 1-7.