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Nitrogen fertilizer value of digestates from anaerobic digestion of animal manures and crops

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Introduction

After anaerobic digestion (AD) of manures for biogas production the concentration of ammonium-N is increased and the concentration of decomposable carbon in manure is decreased. That implies that the first year fertilizer value of the manure can be increased by the treatment. However, pH is also increased by AD thereby increasing the risk of ammonia losses while the lowered dry matter content on the other hand improves the manure infiltration in soil and reduces the risk of ammonia loss. Therefore the effects of AD on plant N availability can be expected to interact with the manure application method used.

In stockless organic farming it has been suggested that nitrogen utilization can be improved by using AD of plant-based green manures, but the information about the fertilizing value of such manures is scarce. Such a practice also provides renewable energy on the farm.

We have compared nitrogen fertilizer values of 1) pig and cattle slurries before and after AD and of 2) digested plant-based manures. Mineral fertilizer replacement values (MFRV) were determined after direct injection to barley and oats crops and after surface-banding in a winter wheat crop.

Materials and methods

The manures were digested in continuously fed pilot digesters with an active volume of 130 liters at thermophilic conditions (47- 53°C) as described by Møller et al. (2007). The average hydraulic retention time was about 20 days. When plant-based manures were digested the digesters initially contained digested manure based on animal manure as an inoculum but only plant material was applied to the digester. So in the end the plant-based digestates only contained traces of animal manure. The three tested plant-based manures derived from crops of either grass clover, yellow lupine or a triticale-winter vetch mixture grown at organic farms. The composition of the manures is shown in Table 1. The cattle slurry 1 also derived from an organic farm. The manures were applied to small framed plots and grain yields and N uptake were compared to plots receiving increasing amounts of mineral N fertilizer as described by Sørensen and Eriksen (2009). The frames consisted of 30 cm diameter cylinders inserted in spring either over two plant rows in an established winter wheat crop or on bare soil before sowing spring barley or oats. In winter wheat the manure (150 kg total N ha^{-1}) was applied in a band on the crop simulating a trailing hose application. In barley and oats plots the manure (80 kg total N ha^{-1}) was applied in a band at 10 cm depth simulating a direct injection before sowing. Manure-treated plots received no other N applications. The experiments were placed in two fields at Research Centre Foulum, Denmark on a loamy sandy soil.

Table 1. Chemical composition of digestates and corresponding raw liquid manures.

Manure	Total N	NH4-N	NH4/total N	DM	VS	pH
	kg N/t	kg N/t	%	%	%	
Clover-grass digestate	4.53	2.75	61	5.18	3.65	7.81
Lupine digestate	2.78	1.90	68	3.50	2.34	7.71
Triticale-vetch digestate	2.69	1.58	59	5.25	4.06	7.48
Cattle slurry 1 (organic farm)	2.92	1.44	49	6.95	5.09	8.17
Cattle slurry 1 digestate	2.94	1.81	61	4.65	3.08	8.09
Cattle slurry 2	3.00	1.63	54	6.43	5.26	6.72
Cattle slurry 2 digestate	3.05	2.03	67	4.82	3.60	7.52
Pig slurry	2.81	2.18	78	3.45	2.50	7.71
Pig slurry digestate	2.57	2.45	95	1.46	0.73	8.40

DM: dry matter; VS: volatile solids (“organic matter”)

Results and discussion

After AD of the slurries the proportion of total N on ammonium form increased as expected (table 1). The MFRV of total N in two different injected cattle slurries applied to barley increased from 58-75% to 69-82% after AD (Fig. 1). Similar MFRV of the slurries were obtained after application to oats. The MFRV of cattle slurry after surface-banding in winter wheat was much lower: 30-37% for untreated slurry and 38-49% after AD. The low availability after surface-banding can be ascribed to high ammonia volatilization. The MFRV of injected pig slurry was high and similar with and without AD: 89-91%. After surface banding of pig slurry MFRV was 75% for untreated and 87% for digested pig slurry. Thus, the reduced fertilizer value after surface banding was most significant for the manures with the highest dry matter content. This is in accordance with the general finding that ammonia emission (as % of NH_4-N) increases with manure dry matter content.

The plant-based manures contained a high proportion of ammonium-N (59-68% of total N) after AD and the MFRVs of total manure N were comparable to the digested cattle slurries: 73-77% after injection, but only 43-57% after surface-banding of the manure. The fertilizer value of the digested plant materials was significantly higher than normally found for similar untreated material. This shows that on stockless organic farms it is possible to produce plant-based manures with an N availability of about 75% for the first crop.

The use of plant material in biogas plants is becoming more common, and the present results indicate that the plant availability of N of the digested plant material is similar to that of digested cattle slurry.

The influence of AD of manure on N turnover in soil has also been evaluated in a soil incubation study with some of the same manures, and the differences between untreated and digested manures were more distinct in this incubation study than the observed differences in fertilizer value (Sørensen and Møller, 2009). Sørensen and Møller (2009) found an increase in net N mineralization after digestion equivalent to 15-20 % of total N in cattle and pig slurry. Some of the differences between the laboratory and the field study can be ascribed to ammonia losses in the field, but effects of plant N uptake on turnover of manure N may also have an effect.

The measured MFRV of injected pig slurry was higher than expected from measured N mineralization in the corresponding soil incubation study. Sørensen and Eriksen (2009) similarly found an unexpected high fertilizer replacement value of injected pig slurry for unknown reasons. This may be the reason why no effect of AD was detectable on the N fertilizer value of the pig slurry.

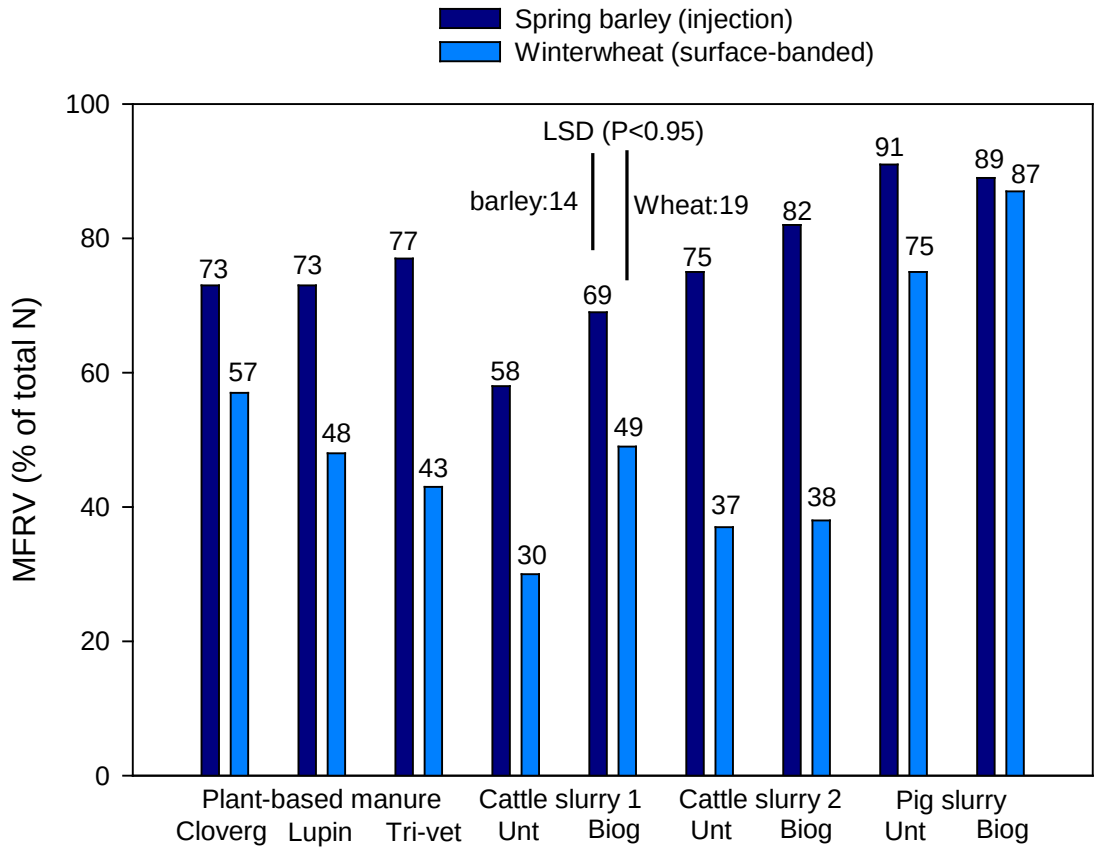

Figure 1. Mineral N fertilizer replacement values (MFRV) of digested plant-based manures and digested (biog) and untreated (Unt) cattle and pig slurries applied to spring barley and winter wheat. LSD is least significant difference (n=4).

Conclusion

We conclude that the potential plant availability of pig and cattle slurry can be increased by 10-15% points after AD. However, after surface-banding of digested manures rich in fibers, such as cattle and plant-based manures, significant ammonia loss can be expected resulting in relative poor N utilization. Anaerobic digestion of plant-based manures (e.g. on stockless organic farms) may produce organic fertilizers with a high N availability of about 75% of the total N content.

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