Utilization of nitrogen from cattle slurry applied to grassland as affected by diet composition

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Introduction

Increasing slurry C:N ratio through dietary adjustments has been suggested as a means to reduce N losses from dairy systems. It has been shown that a reduction of the protein content of dairy cow diets, resulting in lower ammonium and total N contents in the slurry, reduces slurry N volatilization (Paul et al., 1998; Külling et al. 2001). At the same time, slurry is an important source of N for grassland production. Sørensen et al. (2003) showed that the short-term fertilizer N value of slurry was negatively related to its C:N ratio in an experiment with barley. On the long term, application of dairy cattle slurry will result in a significant amount of residual organic N, increasing the long-term fertilizer N value. As organic matter and organic N accumulation are determined by the input of C rather than the input of N (Hassink, 1994), slurry C:N ratio can also affect its long term fertilizer N value.
This paper investigates whether there are differences in fertilizer N value of slurries from non-lactating dairy cows, that have been fed diets with combinations of extremely high and low protein and energy levels, when applied to grassland in a one-year experiment. In addition, the effect of long-term application of cattle slurries varying in C:N ratio on the time course of soil organic C and N content and soil N mineralization was estimated using a simulation model.

Material & Methods

Slurry production and grassland experiment

Eight pairs of non-lactating dairy cows were fed diets with extremely high and low levels of dietary energy and protein (Table 1). C:N ratio of the experimental slurries ranged from 5.1 to 11.4 (Table 1) and the largest part of the variation in C:N ratio could be explained by a combination of the CP (84 %) and NDF (12 %) content of the diet (P=0.001). The produced slurries (n=8) and slurries from commercial farms with variable composition (n=4), were slit injected on two grassland fields on the same sandy soil type with differences in age to evaluate their short-term fertilizer N value. One field (NEW) was recently established and characterized by lower soil OM, N and moisture contents, less herbs and more modern grass varieties compared to the other (OLD) that had been under grassland for at least 38 years. Slurry was applied in spring (100 kg N ha^{-1}) and after the first cut (80 kg N ha^{-1}) while in total four cuts were harvested. Inorganic fertilizer N treatments were included in the experiment to calculate the Mineral Fertilizer Equivalent (MFE) of slurry N.

Table 1 *Selection of dietary and slurry characteristics of the slurries used in the grassland experiment*

Slurry	Forage type *	*Diets (kg^{-1} dm)* NEL** (kJ)	CP (g)	*Slurry characteristics* NH_4-N ($g\ kg^{-1}$ dm)	C:N ratio	C:Norg ratio
GMH	60 % MS & 40 % HDGS	6700	182	48	5.9	19.1
GYH	100 % HDGS	6679	200	45	5.1	12.4
GOH	100 % LDGS	5513	185	38	6.4	17.8
SH	100 % STR	5327	187	48	6.8	25.2
GML	60 % MS & 40 % HDGS	6693	115	27	8.4	18.7
ML	100 % MS	6700	101	28	9.6	23.8
GOL	100 % LDGS	5327	110	17	11.4	22.9
SL	100 % STR	5251	105	26	10.1	27.0
COM1				13	11.2	18.6
COM2				24	9.1	18.6
COM3				21	9.1	16.7
COM4				34	7.2	17.1

* *MS= Maize Silage; HDGS= High Digestible Grass Silage; LDGS= Low Digestible Grass Silage; STR= Straw*

** *According to Dutch standards for net energy lactation*

Model simulations

Long-term effects of application of different slurries on the time course of soil N content of the top 25 cm and subsequent mineralization were simulated for the experimental slurries with highest and lowest C/N ratio (GYH and GOL) for both fields (OLD and NEW) based on the equations described by Groot et al. (2003), extended with explicit modeling of carbon additions in manure and a soil carbon pool.

Results & Discussion

Grassland experiment

The OLD field showed a higher total N uptake whereas DM yields were similar for the two fields. Total N uptake of the fertilized plots was linearly related to N application with artificial fertilizer for both fields, which allowed for the calculation of the MFE. Ranges in slurry MFE were high for both the NEW (37-78%) and the OLD field (36-65%). Average MFE of the slurries on the OLD field (47 %) was lower than on the NEW field (56 %), probably as a result of denitrification of slurry N during wet conditions in spring. Slurries from high crude protein diets showed a significantly higher MFE ($p<0.05$) compared to low crude protein diets. No significant differences in MFE were observed between slurries from high and low energy diets. On both fields, MFE appeared to be positively linearly related to the ammonium content (in DM) ($P<0.001$) and negatively to the C:N ratio of the slurry ($P=0.001$) (Figure 1). These relations show great similarity with findings of Sørensen et al. (2003) in an experiment with barley.

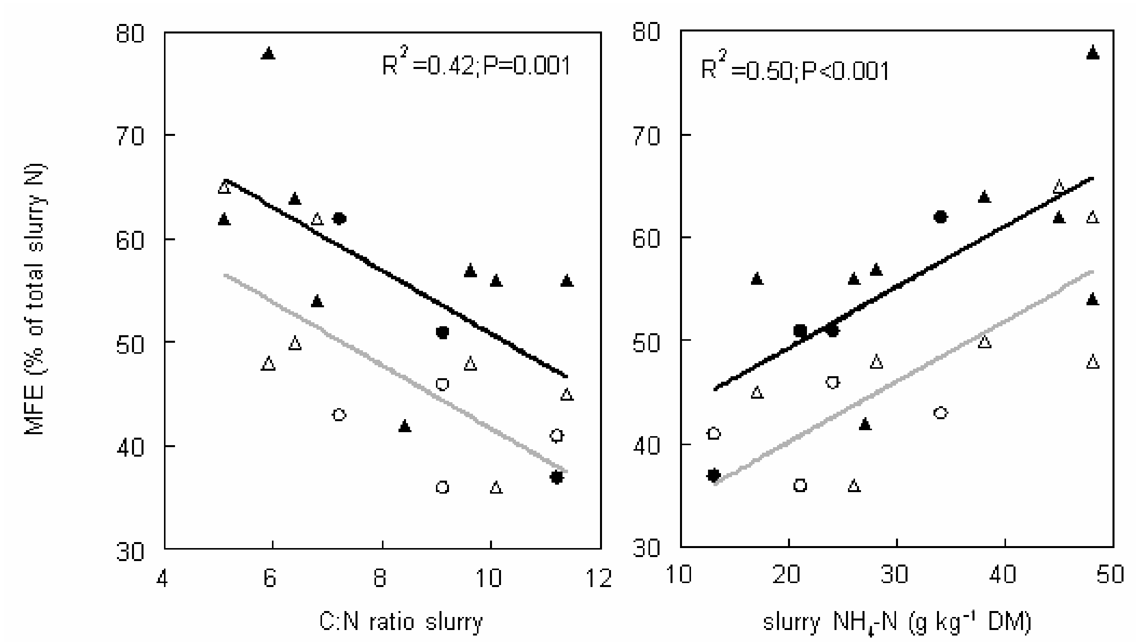

Figure 1. *Relation between the average mineral fertilizer equivalent (MFE) of experimental (▲NEW and Δ OLD) and commercial (● NEW and ○ OLD) cattle slurries on a NEW and OLD grassland and A) the C:N ratio of the slurry and B) the ammonium (N-NH4) content in DM of the slurry*

Model simulations

Simulation of the effect of long-term annual application of 180 kg N ha^{-1} with highest and lowest C:N ratio suggested that both slurries would lead to an increase in annual soil N mineralization. Both, soil N mineralization and SOC are substantially higher in equilibrium state for the slurry with the highest C:N ratio. In equilibrium state (200 year) soil N mineralization was approximately 150 kg N ha^{-1} for slurry GYH and 180 kg N ha^{-1} for slurry GOL on both fields. This implies an increase of the yearly soil N mineralization as a result of slurry application of 50 kg N ha^{-1} for slurry GYH and 80 kg N ha^{-1} for slurry GOL on the NEW field, of which the largest part comes within the first 50 years.

The lower availability of inorganic and organic slurry N of slurry GOL will be compensated by the increase of soil N mineralization only at the very long term (Figure 2). These results imply that, if ammonia losses can be limited, slurries with a low C:N ratio will give higher yields and a higher N utilization in the short and medium term. However, as the experiment was only performed for a one-year period and the effects of C addition on soil properties and soil biological functioning were not taken into account in the simulation model, longer terms trials are needed to confirm the results.

Conclusions

In a one-year grassland experiment, average one-year N availability compared to fertilizer (MFE) of dairy slurries with a wide range in C:N ratio, resulting from dietary differences was negatively related to the slurry C:N ratio. From model simulations it is concluded that with the use of 180 kg slurry N in a situation with slit injection, the reduced one-year N availability of slurry with a high C:N ratio will only be compensated for by soil N mineralization at the very long term.

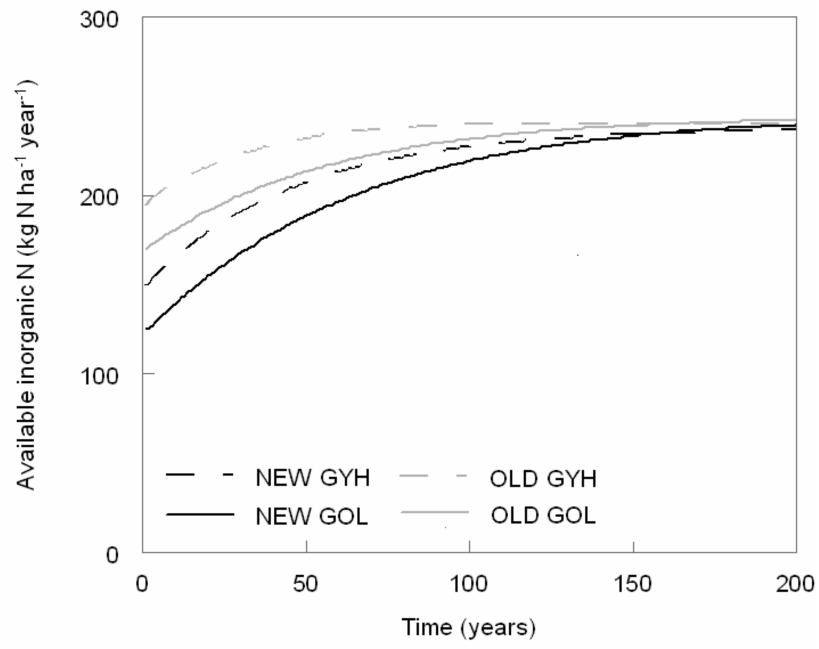

Figure 2. *Simulated time course of annual availability of inorganic N from slurry (inorganic and mineralized N) and soil mineralization after long-term annual application of 180 kg N ha^{-1} from slurry with a low (GYH) and a high (GOL) C:N ratio on a NEW and an OLD grassland*

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