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Effects of different diets on utilization of nitrogen from cattle slurry applied to grassland on a sandy soil in The Netherlands

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Abstract

Dietary adjustments have been suggested as a means to reduce N losses from dairy systems. Differences in fertilizing value of dairy slurry as a result of dietary adjustments were evaluated in a 1-year grassland experiment and by long-term modelling. Slurry composition of non-lactating dairy cows was manipulated by feeding diets with extreme high and low levels of dietary protein and energy. $C{:}N_{total}$ ratio of the produced slurries ranged from 5.1 to 11.4. To evaluate their short-term fertilizer N value, the experimental slurries ($n = 8$) and slurries from commercial farms with variable composition ($n = 4$), were slit-injected in two grassland fields on the same sandy soil series in the north of The Netherlands (53°10′N, 6°04′E), with differences in sward age and ground water level. The recently established grassland field (NEW) was characterized by lower soil OM, N and moisture contents, less herbs and more modern grass varieties compared to the older grassland field (OLD). 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. Artificial fertilizer N treatments were included in the experiment to calculate the mineral fertilizer equivalent (MFE) of slurry N. The OLD field showed a higher total N uptake whereas DM yields were similar for the two fields. 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 related to the ammonium content ($P < 0.001$) and negatively to the $C{:}N_{total}$ ratio of the slurry DM ($P = 0.001$). Simulation of the effect of long-term annual application of 180 kg N ha^{-1} with highest and lowest $C{:}N_{total}$ ratio suggested that both slurries would lead to an increase in annual soil N mineralization. Both soil N mineralization and SOC appeared to be substantially higher in equilibrium state for the slurry with the highest $C{:}N_{total}$ ratio. It is concluded that in a situation with slit-injection, the reduced first-year N availability of slurry with a high $C{:}N_{total}$ ratio as observed in the grassland experiment will only be compensated for by soil N mineralization on the very long term.

Keywords: Cattle slurry; C:N ratio; Nitrogen utilization; Fertilizing value; Grassland; Diet composition

1. Introduction

Increasing the efficiency of nitrogen (N) use in dairy cow feeding is an important tool for decreasing environmental pollution (Castillo et al., 2000; Børsting et al., 2003). Cattle slurry is a mixture of urine and faeces added with substances like bedding material and cleaning water. The N in slurry is particularly susceptible to volatilization and represents a major source for atmospheric pollution (Bussink and Oenema, 1998). This volatilization can be reduced by technical means such as adjustments of storage facilities and by using

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low-emission techniques, but also by a reduction of the protein content of dairy cow diets, resulting in lower total N contents in the slurry (Paul et al., 1998; Külling et al., 2001). In a number of pilot projects efficient protein feeding is applied as a means to increase farm N efficiency on commercial farms (Oenema et al., 2001; Reijs et al., 2004). Phillips et al. (1999) reviewed different approaches for reducing ammonia emission from livestock buildings and identified dietary manipulation and generous use of bedding material to increase the C:N_{total} ratio of slurry as the most promising options.

At the same time, slurry is an important source of N for grassland production. After anaerobic slurry storage, slurry N is mainly found as ammonium N and organic N (Kirchmann and Witter, 1992). Ammonium N is directly available to plants and it contributes to the fertilizer nitrogen value of slurry. A reduction of feed protein content reduces the proportion of N excreted with urine, resulting in a decrease of ammonium N in the slurry. Consequently, the fertilizer N value of slurry is negatively correlated with the dietary protein content (Paul et al., 1998; Sørensen et al., 2003).

Organic slurry N has to be mineralized before it is available for plant uptake. During microbial decomposition of organic compounds in applied slurry, part of the ammonium N will be immobilized in the soil (Sørensen and Jensen, 1995). The N mineralization/immobilization processes are influenced by the slurry composition and affect the fertilizing value of slurry. Janssen (1996) showed that for substances with equal decomposability, net mineralization linearly decreased with increasing C:N ratio of the organic material. Van Faassen and Van Dijk (1987) and Chadwick et al. (2000) reported a decrease of N mineralization from several types of organic manure, being related to the C:N_{org} ratio of the manure. Ruminant faecal N concentration has been shown to decrease with diet digestibility (Kyvsgaard et al., 2000; Sørensen et al., 2003). Therefore, diet digestibility is probably a determining factor for the C:N_{org} ratio of slurry. Kyvsgaard et al. (2000) showed indeed that the turnover of faecal N was influenced by the digestibility of the feed for sheep. In addition, Sørensen et al. (2003) showed a negative relationship between the crude fibre (CF) and neutral detergent fibre (NDF) content and the fertilizer value of slurry.

Also long-term effects of slurry can be affected by diet composition. Application of cattle slurry will result in considerable amounts of residual organic N which contribute to the accumulation of organic N in the soil (Sørensen and Amato, 2002; Hao et al., 2003) and consequently to its

Table 1
Average (data from two collection periods) diet composition, dietary characteristics and calculated OM digestibility of the eight diets fed

No.	Code	Type	Dietary components[a]	C:N ratio	Intake (kg DM cow^{-1} day^{-1})	Dietary characteristics (kg^{-1} DM)					
						NEL[b] (kJ)	CP (g)	OM (g)	NDF (g)	ADF (g)	Dig. OM (%)
1	GMH	Forages	60% MS and 40% HDGS	23.0	12.2	6700	182	930	376	238	72.1
		Concentrates	90% SO and 10% MA		3.6						
2	GYH	Forages	100% HDGS	14.5	12.4	6679	200	905	405	247	79.9
		Concentrates	40% SO and 60% MA		3.3						
3	GOH	Forages	100% LDGS	26.3	7.1	5513	185	878	487	327	68.0
		Concentrates	100% SO		2.7						
4	SH	Forages	100% STR	55.1	4.7	5327	187	945	502	336	61.3
		Concentrates	75% SO and 25% MA		4.1						
5	GML	Forages	60% MS and 40% HDGS	23.0	9.9	6693	115	931	397	240	72.5
		Concentrates	55% MA and 45% BP		3.0						
6	ML	Forages	100% MS	38.0	11.9	6700	101	953	371	233	73.6
		Concentrates	43% SO, 21% MA and 36% BP		2.4						
7	GOL	Forages	100% LDGS	26.3	6.9	5327	110	869	549	353	64.0
		Concentrates	19% SO and 81% BP		2.5						
8	SL	Forages	100% STR	55.1	4.0	5251	105	932	559	353	64.0
		Concentrates	21% SO, 21% MA and 58% BP		4.1						

[a] MS: maize silage; HDGS: high digestible grass silage; LDGS: low digestible grass silage; STR: straw; SO: soya; MA: maize; BP: beet pulp.
[b] According to Dutch standards for net energy lactation (Anonymous, 2005).