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Relationships Among Manure Nitrogen Output and Dietary and Animal Factors in Lactating Dairy Cows

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ABSTRACT

A large data set derived from total diet digestibility assessments on lactating dairy cows (535 Holstein-Friesian and 29 Norwegian) was used to examine effects of dietary and animal factors on manure (feces and urine) nitrogen (N) output and to develop mitigation strategies and prediction equations for manure N output in lactating dairy cows. Manure N output was positively and significantly related to live weight, milk yield, dietary crude protein (CP) concentration, dry matter intake, and N intake. Reducing the dietary CP concentration or increasing the milk yield decreased manure N output per kilogram of milk yield. Prediction equations for manure N output using live weight and milk yield, either alone or combined, had relatively low R^2 (0.227 to 0.474) and large standard error (70.6 to 85.6) values. Addition of dietary CP concentration to these relationships considerably increased R^2 to 0.754 and reduced the standard error to 48.2. Relating manure N output to N intake produced a very high r^2 (0.901) and a very low standard error (30.6). The addition of live weight and milk yield to this relationship as supporting predictors only marginally increased R^2 to 0.910 and reduced the standard error to 29.3. The internal validation of these equations revealed that use of N intake as the primary predictor produced a very accurate prediction of manure N output. In situations in which data on N intake are not available, prediction equations based on dietary CP concentration, live weight, and milk yield together can produce a relatively accurate assessment of manure N output.
Key words: dairy cow, manure nitrogen output, nitrogen intake, prediction equation

INTRODUCTION

Nitrogen is of primary environmental concern at present because of losses of ammonia to the air and nitrate contamination of surface water and groundwater (Tamminga, 1992; Van Horn et al., 1994). Every year large amounts of N are brought onto dairy farms, and much of this N remains on the farm rather than being incorporated into milk, animal tissue, and crops that are sold off the farm (Korevaar, 1992; Klausner, 1993). The overall efficiency of utilization of dietary N in European dairy farming was estimated to be less than 20% and in many situations is still decreasing (Bruchem et al., 1991). Consequently, dairy production contributes to environmental pollution from N as ammonia N and nitrous oxides in air and as nitrate in soil and groundwater (Tamminga, 1992). In 1991, the European Union introduced the Nitrates Directive, (European Union, 1991) which aims to prevent the pollution of groundwater and surface water by nitrates arising from agricultural sources. The Directive stipulates mandatory measures that must be included in an action program, one of which involves a limit on the amount of livestock manure (feces and urine) that may be applied to land each year, set at 170 kg of organic N (manure N) per hectare. This limit will have very significant implications for stocking rates on livestock farms. Therefore, there is increasing interest in developing approaches to mitigate manure N output in animal production. From 1990 to 2002, a large number of lactating dairy cows were used in total diet digestibility measurements at the Agricultural Research Institute of Northern Ireland. The objectives of the present study were to use these digestibility data to examine effects of dietary and animal factors on the efficiency of utilization of dietary N and then to develop mitigation strategies and prediction equations for manure N output in lactating dairy cows.

MATERIALS AND METHODS

Animals and Diets

The data set used in the present study was obtained from 564 lactating dairy cows (535 Holstein-Friesian and 29 Norwegian breed) in 26 total diet digestibility studies undertaken at the Agricultural Research Institute of Northern Ireland from 1990 to 2002. The animals used were of various genetic merits (low to high) and different stages of lactation, with milk yields during

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Table 1. Summary statistics of animal and dietary variables and nitrogen intake, excretion, and retention data used in model development

Variable	No.	Mean	SD	Minimum	Maximum
Animal and dietary data					
Age, mo	477	55	21.4	25	126
Live weight, kg	564	564	65.3	385	781
BCS	248	2.57	0.454	1.75	4.25
Lactation number	477	3	1.8	1	9
DIM	477	151	68.8	16	422
Milk yield, kg/d	564	21.4	6.61	6.1	49.1
Total DMI, kg/d	564	16.4	3.02	7.5	24.3
Forage proportion, g/kg of DM	564	579	183.4	211	1,000
CP concentration, g/kg of DM	564	183	25.9	106	271
Nitrogen utilization data, g/d					
Nitrogen intake	564	486	129.6	155	874
Fecal nitrogen	564	142	36.1	48	241
Urine nitrogen	564	209	69.1	70	452
Milk nitrogen	564	109	33.0	24	231
Retained nitrogen	564	26	35.0	–75	150

digestibility measurements ranging from 6.1 to 49.1 kg/d. A total of 477 cows had records of lactation number and DIM at the commencement of digestibility studies, of which 92, 152, and 233 cows were in the first, second, and third lactation or above, respectively; and 118, 303, and 56 cows were in 0 to 100, 101 to 200, and above 200 DIM, respectively. Table 1 presents the mean, standard deviation, and range of data for age, live weight, BCS, lactation number, and DIM.

A total of 71 perennial ryegrass silages, 3 types of fresh grass, and one fodder beet were examined over the 26 experiments. The grass silages encompassed primary growth and first and second regrowth material. The grass was either unwilted or wilted prior to ensiling and ensiled with or without application of silage additives. A total of 49 cows were offered forage as the sole diet, but otherwise all other cattle (n = 515) were offered forages with a range of proportions of concentrates from 211 to 876 (g/kg of DM) with a mean of 539 (SD 135.4). The concentrates used in each of the studies included a mineral-vitamin supplement and some of the following ingredients: cereal grains (barley, wheat, or corn), by-products (corn gluten meal, molassed or unmolassed sugar-beet pulp, citrus pulp, or molasses), and protein supplements (fish meal, soybean meal, or rapeseed meal). The concentrate portion of the diet was offered either in a complete diet mixed with the grass silage or as a feed separate from the silage. All animals were offered either silage or the complete diet ad libitum. Data on the mean, standard deviation, and range for DMI, proportion of dietary forage, and dietary CP concentration are presented in Table 1.

Digestibility Measurements

Prior to commencing the digestibility studies, all cows were housed in loose housing using cubicles and were offered experimental diets for at least 20 d. Animals had free access to water. Animals were then transferred to metabolism units and housed for 8 d with total collection of feces and urine during the final 6 d. Feces and urine outputs were recorded and sampled daily as a

Table 2. Correlation coefficients (r) for the linear relationships between nitrogen variables and dietary and animal factors[1]

	N intake, output and retention, g/d				As a proportion of N intake, g/kg		
Variable	Intake	Manure	Milk	Retained	Manure N	Milk N	Retained N
	(Correlation coefficients)						
Live weight, kg	0.45	0.48	0.19	0.16	0.11	–0.28	0.10
DIM	–0.18	–0.12	–0.53	0.17	0.18	–0.51	0.20
Milk yield, kg/d	0.66	0.56	0.95		–0.25	0.46	–0.10
DMI, kg/d	0.90	0.83	0.74	0.30	–0.14		0.19
Gross energy intake, MJ/d	0.89	0.83	0.71	0.32	–0.13	–0.12	0.20
N intake, g/d	—	0.95	0.71	0.40	–0.10	–0.25	0.26
Proportion of dietary forage, g/kg of DM	–0.45	–0.41	–0.55			–0.18	
Dietary CP concentration, g/kg of DM	0.77	0.75	0.42	0.38		–0.35	0.30

[1]When r = [0.10] to [0.11], $P < 0.05$; r = [0.12] to [0.13], $P < 0.01$; r ≥ [0.13], $P < 0.001$.

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