Predicting N excretion in commercial grazing system dairy farms

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Abstract
Improving nitrogen (N) management on dairy farms is best facilitated through management of dairy cow dietary N intakes, due to strong associations between intakes, nutrient use efficiencies and N excretion. Milk urea N (MUN) has also been used as an indicator of excess N in dairy systems. While a number of predictive relationships between these parameters have been developed for confinement based systems, less information is available for grazing dairy systems. Feed intake, N excretion and MUN data were determined from samples collected at five quarterly visits over a year on 43 commercial grazing-based dairy farms representing a range of production systems (n=227). Relationships were developed between feed N intake, excreted N, feed N use efficiency (NUE) and MUN using these data. The regression relationships were generally similar to the prediction equations reported in the literature for confinement-based dairy systems. The coefficient of determination for the relationship between excreted N and N intake (ExcrN = 0.84NIn - 23.6; R^2=0.97) was greater than the literature, probably due to the method of estimating excreted N. Lactating cow N use efficiency declined with N intake (NUE = -0.009NIn + 25.9; R^2=0.08), but the relationship to crude protein concentration was stronger (NUE = -0.79CP + 35.9; R^2=0.50). Mean MUN for these grazing system dairy cows (12.7 mg/dL) was similar to levels reported for commercial herd and significant relationships were observed between MUN and crude protein (R^2=0.19), N use efficiency (R^2=0.10) and excreted N (R^2=0.17). The weaker relationships observed were most likely due to the range of breeds, milk production and feeding systems used by these farmers, in contrast to the experimental herds and confinement systems reported elsewhere. Despite the lower R^2, these relationships suggest that prediction of N intake and excretion could improve nutrient management in grazing systems.

Key Words
Milk urea nitrogen, nitrogen excretion, N use efficiency, dietary crude protein

Introduction

Large N surpluses have been reported for dairy production systems worldwide, with an ongoing challenge to improve N management and minimise the impact of reactive N on the environment. A key recommendation is the reduction in N excretion by animals on commercial farms, due to the observed relationship between N surplus and N in animal manure (Børsting *et al.* 2003). Faecal N excretion and milk N secretion were shown to increase linearly with dietary N intake, while urine N increased exponentially (Castillo *et al.* 2000). Consequently, various research groups have developed prediction equations for N excretion to assist with the development of nutrient and manure management plans for confinement based systems (Nennich *et al.* 2005; Knowlton *et al.* 2010).

Urinary N excretion occurs when un-utilised dietary CP is converted to urea, which then equalises across cell membranes into milk during transport in blood to the kidneys. Hence, milk urea N (MUN) is considered an indicator of excess dietary CP and is monitored to manage protein intake in confinement dairy herd diets for reproductive and environmental N management (Broderick and Huhtanen 2007). In grazing systems MUN has typically been measured to understand its relationship to cow fertility (Carlsson and Pehrson 1993; Wittwer *et al.* 1999; Smith *et al.* 2001), with fewer reports assessing the association with dietary CP (Gourley *et al.* 2012; Powell *et al.* 2012). In confinement systems under experimental conditions, Jonker et al. (1999) developed regression relationships between MUN and milk production to predict N intake and utilisation efficiencies, while positive relationships between MUN and CP were also reported (e.g. Nousiainen *et al.* 2004). A strong relationship between MUN and CP intake was also observed for 29 grazing and confinement dairy farms (Gourley *et al.* 2012). However, MUN was not related to dietary CP in four grazing system farms studied in Australia (Powell *et al.* 2012), perhaps due to low milk yields and poor diet formulations in these systems. Furthermore, differences between bulk tank and individual animal MUN could have contributed to the differences in the relationships between MUN and CP. The objective of this study was to develop predictive relationships between N excretion, N use efficiency (NUE), and MUN using data readily collected on a variety of commercial grazing system dairy farms. We then compared these relationships with those reported in the literature for confinement based systems.

Methods

Intake, excretion and milk data

Milk production, herd lactation characteristics and diet data were collected from 42 commercial farms that represent the range of dairy grazing systems in Australia on five separate occasions over a year to calculate N intakes and excretion (see Aarons *et al.* 2016a; and Aarons *et al.* 2016b in this proceedings). These farms were located in all major dairy producing regions, ranging from temperate systems in Tasmania to sub-tropical dairy farms in far north Queensland, and including the Mediterranean regions in West Australia and South Australia. Briefly, pasture dry matter intake (DMI) for each herd on each farm at each survey was calculated based on the metabolic requirements of the animals on each date surveyed. Nitrogen intakes were then calculated from supplement and pasture N concentrations and total DMI. N excretion was simply milk N subtracted from N intake, and feed NUE was a measure of the efficiency by which intake nutrients were converted to milk. Milk urea N was measured in bulk tank samples collected from the milk vat containing both morning and evening milkings, with one sample collected on each farm for each where more than one herd was milked separately.

Sample analysis

All pasture and fodder, supplementary feeds and milk samples were stored at 4°C, returned promptly to the laboratory. The feeds were dried (105°C, 24 hours) for DM calculations or dried and ground (65°C, 72 hours; <2mm) for chemical analysis. Milk samples were stored frozen until analysis. All samples were analysed at Westons Laboratories. See Aarons et al. (2016b) for more details.

Predictive relationships

Linear regression relationships were calculated between estimated excreted N or NUE and N intake or milk N secretion. Relationships were also calculated between MUN and dietary CP or NUE. The slopes and coefficients of determination of the relationships were compared with those previously published in literature.

Results

Energy corrected milk averaged 22 kg/cow/day on the 42 farms over the five occasions, ranging from a minimum of 9 (Farm 1) where all cows in the herd were in late lactation at the autumn visit, to a maximum of 36 kg/cow/day (Farm 29) where cows were milked thrice daily (Table 1). Total N intakes were generally higher than the 400 g/cow/day recommended by Castillo et al. (2000) and consequently calculated excreted N was also high. Excreted N was strongly related to total N intake concentration, but less so for dietary pasture or supplement N concentrations (Figure 1). A very strong positive relationship (R^2=0.97) was observed between excreted N and total N intake, compared with published regression relationships (Table 2). The NUE ranged from 11 to 39%, and as expected declined as excreted N increased (data not shown).

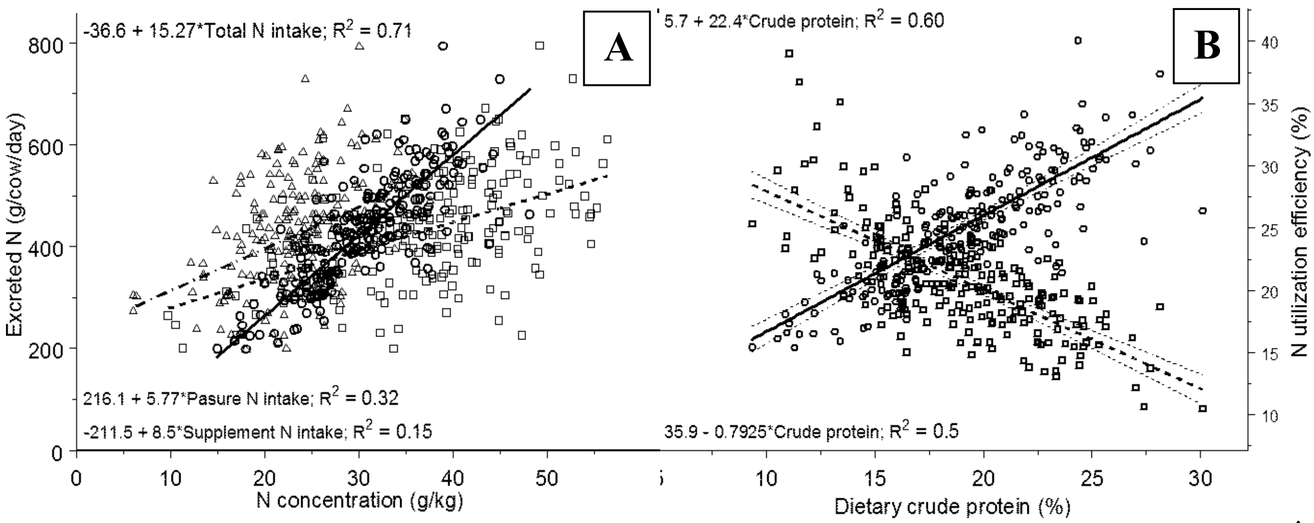

Figure 1. Relationships between excreted N and (A) total (——,○) pasture (----, □) or supplement (– · –,△) N intake concentrations, and (B) between excreted N (——,○) or NUE (---- , □) and dietary CP intake showing 95% confidence bounds

Table 1. Energy corrected milk yield (ECM; kg/cow/day), total N intake (g/cow/day), dietary crude protein concentration (CP; %), excreted N (g/cow/day), milk urea N (MUN; mg/dL) and N utilisation efficiency (NUE; %) for the herds on each interview date on three of the grazing system dairy farms, including the farm average (CV).

Region[a]	Farm	Herd	Interview	ECM	Total N intake	CP	Excreted N	MUN	NUE
Tasmania									
	1	1	Summer	14	367	16	299	8	19
	1	2	Summer	14	378	16	309	8	18
	1	1	Autumn	9	453	27	405	17	11
	1	1	Winter	16	510	22	437	9	14
	1	1	Spring	15	572	23	495	15	13
	1	2	Spring	15	632	27	555	15	12
				14 (17)	478 (19)	22 (19)	411 (21)	12 (31)	14 (19)
Queensland									
	6	1	Summer	23	405	14	294	5	27
	6	1	Autumn	25	412	15	289	11	30
	6	1	Winter	21	337	14	237	3	30
	6	1	Spring	21	407	16	302	7	26
				22 (7)	391 (8)	15 (6)	282 (9)	6 (44)	28 (6)
Victoria									
	29	1	Summer	32	788	20	621	21	21
	29	2	Summer	32	788	20	621	21	21
	29	1	Autumn	32	770	21	603	17	22
	29	2	Autumn	32	770	21	603	17	22
	29	1	Winter	34	983	24	793	9	19
	29	2	Winter	34	983	24	793	9	19
	29	1	Spring	35	621	14	435	17	30
	29	2	Spring	35	621	14	435	17	30
				34 (5)	791 (15)	20 (19)	612 (20)	15 (27)	23 (17)

[a]Tasmania farm had low dietary supplement use; Queensland farm was organic; Victoria farm milked thrice daily and used total mixed rations

Table 2. Regression equations comparing i) N excretion with N intake, ii) N use efficiency (NUE) with N intake or dietary crude protein (CP), and iii) CP, NUE, excreted N with milk urea N (MUN), from the literature[a] and using data from this study.

Regression equations	R^2 (*P value*)	Source
i) N excretion (g/cow/day)		
N_{Exc} = 0.55Int + 43 (below 400 g/c/d)	0.78	Castillo et al. 2000
N_{Exc}=0.90Int-89 (above 400 g/c/d)	0.87	Castillo et al. 2000
Manure N output = 0.710NI + 7	0.894	Yan et al. 2006
$N_{excret\ ion}$ = 30 + 0.62(NI)	0.78	Kebreab et al. 2001
Manure N output = 0.8NI − 19.8	0.698	Arriaga et al. 2009
ExcrN = 0.84N_{In} -23.6	0.97 (*P*<0.001)	This study
ii) N use efficiency (%)		
Milk N/N intake = −0.672 CPc + 350	0.13	Yan et al. 2006
NUE = -0.009376N_{In} + 25.9	0.08 (*P*<0.001)	This study
NUE = -0.7925CP + 35.8792	0.5 (*P*<0.001)	This study
iii) Milk urea N (mg/dL)		
CP = 0.269 MUN + 13.7	0.839	Broderick and Clayton 1997
CP = 9.98 + 0.45MUN	0.779	Nousiainen et al. 2004
CP = 0.41 MUN + 13.8	0.19 (*P*<0.001)	This study
N Efficiency = –0.004 MUN + 0.309	0.626	Broderick and Clayton 1997
N Utilization = 37.8 - 0.73MUN	0.768	Nousiainen et al. 2004
NUE = -0.34MUN + 25.2	0.1 (*P*<0.001)	This study
Excess N intake = 11.0 MUN + 313	0.772	Broderick and Clayton 1997
ExcrN = 11.13MUN + 289.62	0.17 (*P*<0.001)	This study

[a]Equations given are as provided in each citation. ExcrN – excreted N for this study.

The relationship between NUE and total N intake although significant, was weaker than that described by Castillo et al. (2000), while NUE was more strongly related to CP concentrations than observed by Yan et al. (2006). Milk urea N for these grazing system cows averaged 13 mg/dL virtually identical to that observed on 372 commercial dairy farms (Jonker *et al.* 2002) and higher than bulk tank MUN from 176 herds (Arunvipas *et al.* 2004). While, prediction relationships between MUN and CP, NUE and excreted N were significant (*P<0.001*) and similar to the literature (Table 2), the coefficients of determination were lower than for experimental and commercial feeding studies of confinement based herds; most likely due to variability in herd and grazing management and to bulk tank sampling (Arunvipas *et al.* 2004).

Conclusion

The significant egression relationships between N intake, N excretion and NUE, as well as MUN measured in milk samples from grazing system lactating herds were generally similar to those reported for feeding experiments in confinement dairy systems. The similarity of the relationships indicates that the animal performance method was suitable for calculation of dry matter and nutrient intake and excretion in these grazing systems, where direct measurements of animal intake are difficult. These results also indicate that MUN could be used as both an indicator of excess dietary N and to assist in managing N intakes in grazing system herds. Further research is required to explore the impact of bulk tank versus individual animal sampling, and to investigate the relationships between MUN and urinary N excretion.

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