Prediction of urinary nitrogen excretion in urine from lactating dairy cattle in Western Europe: A meta-analysis

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Introduction

An accurate indicator of urinary nitrogen excretion (UN; g N/d) is required to minimize UN and N losses by on farm feeding management. Because of the relationship between milk urea N concentration (MUN; mg N/dL) and UN (Ciszuk and Gebregziabher, 1994), MUN is regarded as an potential on farm indicator of UN. The objective of this meta-analysis study was to develop prediction equations for UN under Western European conditions based on MUN, but also on other factors such as milk production (MILK; kg d), dry matter intake (DMI; kg/d), N intake, and dietary factors like crude protein content (CP; % DM), energy level, and rumen degradable protein balance.

Materials and Methods

Data originated from 17 studies describing 22 trials with together 105 treatment means that were carried out in Europe. Most diets were based on fresh grass, grass silage, legumes, or a mixture of these. Trials were selected on the basis that they had to contain information on DMI, dietary N intake, milk production, MUN, and excretion of N into milk, urine, and faeces. Furthermore, the data set contained 41 observations from 7 studies on excretion of urinary urea N excretion (UUN; g N/d). Analysis of data was carried out on the complete dataset and on a reduced dataset with MUN values lower than 15 mg/dL. This reduced dataset was composed to account for the fact that MUN values on most dairy farms are below 15 mg/dL. Data were analysed with the PROC MIXED procedure of SAS with trial included as a random factor (St-Pierre, 2001). Because the observations within trial were considered to be independent from each other the covariance structure was modelled as compound symmetry. The coefficient of determination (R^2) of each model was obtained from regressing the predicted values from the fixed part of the mixed model on the observed values.

Results

In the complete dataset UN was highly related to MUN (R^2=0.83, model 1) and CP (R^2=0.87, model 2), and multiple regression of UN on MUN and CP resulted in an improved model fit (R^2=0.90, model 3). Addition of the factors DMI and MILK (model 4) further improved the model fit. In the reduced dataset correlation coefficients between UN and MUN and between UN and CP were 0.32 (model 5) and 0.51 (model 6) respectively, and multiple regression of UN on MUN and CP yielded an R^2 value of 0.53 (model 7). Addition of the factors DMI and MILK improved the model fit (R^2=0.70, model 8) substantially. The regression coefficient for MUN predicting UN was 12.61 for the whole dataset whereas this was 10.63 for the reduced dataset. Likewise, a lower regression coefficient for CP was found of 21.96 for the reduced model in comparison to the regression coefficient of 25.82 for the complete dataset.
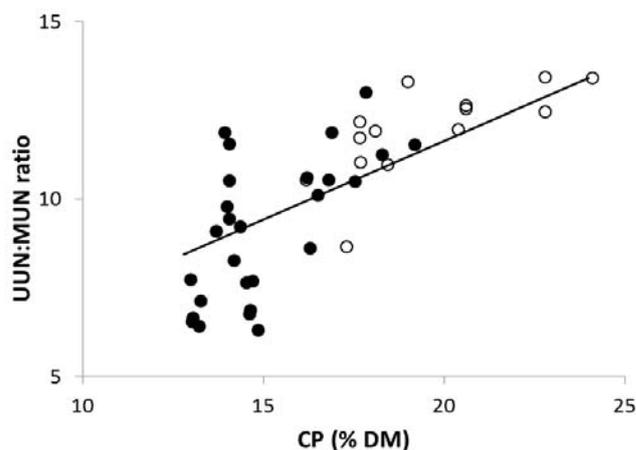

Figure 1. Relationship between dietary crude protein (CP, %DM) and the ratio between urinary urea nitrogen excretion (UUN; g N/d) and milk urea nitrogen content (MUN; mg N/dL); UUN:MUN = 2.75 ±1.366 + 0.444 ±0.0764 × CP; R^2 = 0.60. Closed and open circles represent values where MUN is smaller or larger than 15.

Discussion and conclusion

Compared to the complete data set, the lower regression coefficients for MUN and CP in the reduced data set suggest that the relationship between UN and CP or MUN is not linear over the whole range and as levels of CP and MUN increase the quantity of UN per unit of MUN or CP increases as well. It is proposed that this nonlinearity is caused by an increase in renal urea reabsorption at decreased CP levels in order to retain urea for rumen microbial protein synthesis. An increase in renal urea reabsorption when dietary CP content decreases has been observed by Schmidt-Nielsen and Osaki (1958) in sheep and by Eriksson and Valtonen (1982) in goats. This increase in renal reabsorption of urea might affect the ratio of excreted urea in urine per unit of MUN or CP. Indeed the present study reveals a positive relationship between the quantity of UUN per unit of MUN and the level of CP (Fig. 1). The low predictive capacity of MUN in the reduced dataset and the improvement in model fit after addition of the factors CP, DMI, and MILK indicates the limited use of MUN alone in predicting UN within a more narrow range, and necessitates other factors such as CP, DMI, and MILK to be included as well to achieve a reasonable prediction. Moreover, the prediction accuracy in the practical range of interest on dairy farms (MUN < 15 mg/dl) is much smaller than when the full MUN range is considered.

Table 1. Model predictions of urinary nitrogen excretion (g N/d) for the complete data set and for the reduced data set (MUN < 15 mg/dL) based on milk urea nitrogen content (MUN; mg N/dL), dietary crude protein content (CP; % DM), dry matter intake (DMI; kg/d) and milk production (MILK; kg/d)[1].

Model	Intercept SE	MUN SE	CP SE	DMI	MILK	N	AIC	RMSE	R^2
1 Complete	32.6 9.63	12.61 0.515				105	965	33.62	0.83
2 Complete	-227.3 17.31		25.82 0.976			105	949	29.88	0.87
3 Complete	-126.0 22.17	5.94 0.972	14.92 1.919			105	915	26.19	0.90
4 Complete	-245.5 25.93	5.85 0.794	15.66 1.606	11.58 1.627	-4.37 0.888	105	869	21.56	0.93
5 Reduced	45.9 10.33	10.63 0.811				71	605	28.11	0.32
6 Reduced	-176.6 24.26		21.96 1.568			71	595	24.94	0.51
7 Reduced	-99.6 31.15	4.92 1.364	13.52 2.771			71	581	23.37	0.53
8 Reduced	-202.3 27.39	4.74 1.024	14.45 2.139	9.00 1.332	-3.16 0.743	71	538	18.41	0.70

[1]Based on mixed models with trial included as random factor. The fixed part of the model is presented here. The root mean square error (RMSE) and the coefficient of determination (R^2) of each model was obtained from regression results of values predicted by the fixed part of the mixed model on the observed values. AIC=Akaike Information Criterion (a smaller value means a better fit).

References

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