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Prediction of urinary nitrogen and urinary urea nitrogen excretion by lactating dairy cattle in northwestern Europe and North America: A meta-analysis

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ABSTRACT

A meta-analysis was conducted on the effect of dietary and animal factors on the excretion of total urinary nitrogen (UN) and urinary urea nitrogen (UUN) in lactating dairy cattle in North America (NA) and northwestern Europe (EU). Mean treatment data were used from 47 trials carried out in NA and EU. Mixed model analysis was used with experiment included as a random effect and all other factors, consisting of dietary and animal characteristics, included as fixed effects. Fixed factors were nested within continent (EU or NA). A distinction was made between urinary excretions based on either urine spot samples or calculated assuming a zero N balance, and excretions that were determined by total collection of urine only. Moreover, with the subset of data based on total collection of urine, a new data set was created by calculating urinary N excretion assuming a zero N balance. Comparison with the original subset of data allowed for examining the effect of such an assumption on the relationship established between milk urea N (MUN) concentration and UN. Of all single dietary and animal factors evaluated to predict N excretion in urine, MUN and dietary crude protein (CP) concentration were by far the best predictors. Urinary N excretion was best predicted by the combination of MUN, CP, and dry matter intake, whereas UUN was best predicted by the combination of MUN and CP. All other factors did not improve or only marginally improved the prediction of UN or UUN. The relationship between UN and MUN differed between NA and EU, with higher estimated regression coefficients for MUN for the NA data set. Precision of UN and UUN prediction improved substantially when only UN or UUN data based on total collection of urine were used. The relationship between UN and MUN for the NA data set, but not for the EU data set, was substantially altered when UN was calculated assuming a zero N balance instead of being based on the total collection of urine. According to results of the present meta-analysis, UN and UUN are best predicted by the combination of MUN and CP and that, in regard to precision and accuracy, prediction equations for UN and UUN should be derived from the total collection of urine.

Key words: milk urea nitrogen, urinary nitrogen, dairy cattle, meta-analysis

INTRODUCTION

Nitrogen (N) losses via excreted feces and urine in dairy cattle are associated with losses of N from the farming system through ammonia volatilization, nitrate leaching, and dissipation of N as N_2O, NO, and NO_2 (de Vries et al., 2001). With regard to such environmental concerns, great interest has been noted in investigating the potential of specific on-farm measures to reduce N losses, preferably without reducing milk production. Nitrogen digested and not excreted as milk protein is, in large part, excreted as urea N in urine. On-farm indicators including MUN concentration (mg of N/dL) may be attractive to monitor the excretion of urinary urea N (**UUN**; g of N/d) or total urinary N (**UN**; g of N/d). Several studies focused on the relationship between MUN and UN (Jonker et al., 1998; Kauffman and St-Pierre, 2001; Nousiainen et al., 2004; Zhai et al., 2005; Zhai et al., 2007). Jonker et al. (1998) and Nousiainen et al. (2004) performed meta-analyses analyzing the relationship between MUN and UN on data sets containing data from multiple trials. Published meta-analyses have either been based solely on data from North America (**NA**) or data from northwestern European countries (**EU**). Jonker et al. (1998) based their analysis on 3 NA trials, whereas Nousiainen et al. (2004) based their analysis on a large data set of 50 EU trials with grass-silage-based diets. In all trials used by Nousiainen et al. (2004), concentrates were offered at a flat rate irrespective of milk yield and UN was not based on total collection of urine but calculated from the difference between N intake and excretion of N in feces and milk, assuming a zero N balance. However, it is known from various studies in lactating dairy cows (Spanghero and Kowalski, 1997; Eriksson et al., 2004; Colmenero and Broderick, 2006), mice (Costa et al.,

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1968), and humans (Young et al., 1981) that the N balance in general is positive due to losses of N from the organism not measured in urine, milk, and feces. Furthermore, differences in the MUN-UN relationships established in these studies might be related to differences in herd management, climatic conditions, type of diet, concentrate to roughage ratio of the diet, genetic makeup of the cows, or differences in techniques used to measure UN and UUN. Recently, the effect of such factors has been reviewed by Spek et al. (2013). During the last decade, more attention has been paid to the relationship between MUN and UUN instead of UN, because UUN is most strongly related to ammonia emission (Burgos et al., 2007). At present, only a few studies (Burgos et al., 2007; Powell et al., 2011) have focused on prediction of UUN by MUN. No studies have been published on the prediction of UUN from multiple animal- and dietary-related factors. For the present study, we hypothesized that the prediction accuracy of UN and UUN may be improved by selection of only those trials where UN and UUN are analyzed based on total collection of urine, instead of estimating UN and UUN based on the difference between N intake and excretion of N in milk and feces, or based on analysis of UN and UUN in urine spot samples with daily volume of urine estimated from creatinine levels in the same urine spot samples. For practical and animal welfare reasons, it might be argued to determine UN based on the difference between N intake and N excreted in feces and milk instead of using indwelling urine catheters. However, no studies have been carried out that have tested whether the relationship between MUN and UN is actually similar for UN derived from total collection of urine, or for UN calculated as the difference between N intake and N excreted in feces and milk.

The first objective of this study was to quantify the relationship between various dietary and animal factors and UN or UUN for either EU or NA data sets and to compare their respective prediction equations. The second objective of this study was to test whether the accuracy and precision of UN and UUN prediction equations are affected by the method of measuring UN and UUN, namely, estimation of UN and UUN from urine spot samples or by calculations assuming a zero N balance, versus UN and UUN determined by total collection of urine only.

MATERIALS AND METHODS

Data Set Selection

Studies were selected that contained at least information on (1) the partitioning of N excretion in urine, feces, and milk, (2) MUN, (3) DMI (kg/d) and composition of the ration, and (4) milk production and fat and protein content in milk. Mean treatment data (n = 200) from 47 trials carried out in NA (n = 118) and EU (n = 82) were used. A description of this data set (referred to as complete data set) is presented in Table 1 and contained 193 observations on UN (n = 111 for NA and n = 82 for EU) and 98 observations on UUN (n = 57 for NA and n = 41 for NA). The appendix provides a reference list of 41 studies describing these 47 trials. Some studies described multiple trials, which explains the presence of more trials than studies. In several studies, excretion of UN and UUN was determined based on spot samples taken from the urine, or based on the calculation of UN as the difference between N intake and excretion of N in milk and feces (i.e., zero N balance). A reduced data set (referred to as reduced data set) was developed including only observations on UN or UUN from studies where urine was collected quantitatively. This reduced data set contained 123 observations on UN (n = 55 for NA and n = 68 for EU) and 63 observations on UUN (n = 22 for NA and n = 41 for EU). The number of observations in the reduced data set where both UN and UUN were measured was 56 (n = 15 for NA and n = 41 for EU). To evaluate the effect of the assumption of a zero N balance on the results obtained, a new data set (number of data hence identical to that of the reduced data set) was created from the reduced data set in which data on urine N excretion were replaced by values calculated under assumption of a zero N balance.

Independent and Dependent Factors

The list of independent factors that were tested for their capacity to explain observed variation in UN and UUN included animal factors and dietary factors. These independent factors are presented in Table 1 under the headings Animal factors and Dietary factors. The dependent factors in the data set were UUN and UN. Some dietary values were missing with respect to ash, starch, and NDF. These missing values were predicted based on typical composition using the Dutch feeding tables (CVB, 2007). For all diets, values were predicted for RDP, RUP, rumen-undegradable starch, digestible protein available in the small intestine (**DVE**), rumen-degradable protein balance (**OEB**), and NE_L using the Dutch feeding tables (CVB, 2007).

Statistical Procedure

Multiple regression analyses were carried out with the MIXED procedure in SAS (SAS Institute Inc., Cary, NC) with trial included as random effect and all other factors as fixed effects. Fixed effects were nested