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Evaluation of equations predicting the net portal appearance of amino acid nitrogen in ruminants

R. Martineau,* C. Côrtes,† I. Ortigues-Marty,‡ D. R. Ouellet,* and H. Lapierre*[1]
*Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, Sherbrooke, Québec, J1M 0C8, Canada
†Département de Productions Animales, Unité de Recherche Systèmes d'Élevage, École Supérieure d'Agriculture d'Angers, Angers, 49007, France
‡Institut National de la Recherche Agronomique, UMR1213 Herbivores, Theix, 63122 St Genès Champanelle, France

ABSTRACT

A better assessment of digestible protein and AA flows is required to improve the predictions of animal performance in ruminants (e.g., growth and yields of milk and milk protein). In that respect, 2 recent meta-analyses were conducted in our laboratory to establish the relationships between net portal appearance of AA nitrogen (NPA-AAN) and dietary characteristics either from the National Research Council (Washington, DC) or Institut National de la Recherche Agronomique (INRA; St Genès Champanelle, France). Three prediction equations were selected from these meta-analyses: one equation based only on N intake (NI) and 2 equations based on NI, the intake of neutral detergent fiber, plus the dietary concentration of either total digestible nutrients or digestible organic matter. In the current meta-analysis, 2 new equations were developed to predict NPA-AAN from the estimated supply of metabolizable protein (MP) and the protein truly digestible in the intestine (PDI). The reliability of these 5 equations to predict NPA-AAN was evaluated using an independent database. On average, NPA-AAN predictions based on the supply of MP or PDI had the highest coefficient of determination and the lowest root of mean square prediction error and mean and regression biases compared with predictions based on dietary characteristics, suggesting better reliability with the former. No major difference was detected between NPA-AAN predictions based on parameters from the National Research Council or INRA, except that predictions based on MP had the lowest mean and regression biases. In each equation, mean of residual NPA-AAN (observed NPA-AAN minus predicted values) was lowest and negative for sheep compared with dairy cows, suggesting that NPA-AAN were overpredicted in sheep. Many continuous variables biased NPA-AAN predictions based on NI only, but none of the tested variables biased the predictions based on the supply of MP or PDI, corroborating the better reliability for the prediction equations based on the supply of digestible protein. Of the tested continuous variables, only the dietary concentration of crude protein (CP) biased NPA-AAN predictions based on NI plus dietary characteristics. The NPA-AAN responses to dietary CP concentration were overpredicted as dietary CP concentration increased and underpredicted as CP decreased, suggesting that ruminants were more efficient at converting ingested N into digestible protein when fed low-CP diets compared with high-CP diets.
Key words: portal, amino acid, meta-analysis, ruminant

INTRODUCTION

Over the last decades, feeding evaluation systems of ruminants have evolved from estimations of protein requirements and supply based on the dietary concentrations of CP or RDP plus RUP toward more refined models based on the supply of digestible protein (e.g., MP of NRC, 2001) and the protein truly digestible in the intestine (**PDI**) of Institut National de la Recherche Agronomique (**INRA**, 2007; INRAtion software, version 4.0; INRA, Paris, France). Estimations of the supply of digestible protein might differ between feeding evaluation systems because of differences in the estimations of rumen protein outflows and intestinal digestibilities. Furthermore, NRC (2001) explicitly adds an endogenous component to the digestible protein flow from the undegraded feed protein and the microbial protein, but INRA (2007) does not. The ability of a feeding evaluation system to accurately predict the supply of digestible protein might be indirectly evaluated by its accuracy to predict a zootechnical performance (e.g., milk yield being one the easiest to measure with precision). Yan et al. (2003) used production data of 838 lactating dairy cows drawn from 12 long-term studies and reported that Australian and French systems had a better prediction of milk yield compared with other systems, including NRC (2001). Indeed, a bet-

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[1]Corresponding author: Helene.Lapierre@agr.gc.ca

ter prediction of milk yield could be associated with a better prediction of the supply of digestible protein, given that the mammary gland is the primary net user of the absorbed AA in dairy cows (Lapierre et al., 2012). One way to estimate the supply of digestible protein is to measure the net transfer of AA across the portal-drained viscera (**PDV**; gut, spleen, pancreas, and associated mesenteric fat), acknowledging that this measurement already excludes AA utilization by the PDV (Lapierre et al., 2006). The net portal appearance of AA nitrogen (**NPA-AAN**) has been related to the intakes of N (**NI**) and NDF (**NDFi**) and to the dietary concentration of TDN or digestible OM (**dOM**) in 2 recent meta-analyses: Martineau et al. (2011) and Côrtes et al. [C. Côrtes, R. Martineau, D. R. Ouellet, D. Sauvant (AgroParisTech INRA, Paris, France), J. Vernet (INRA, Theix, St Genès Champanelle, France), I. Ortigues-Marty, P. Nozière (INRA, Theix, St Genès Champanelle, France), and H. Lapierre; hereafter, Côrtes et al., unpublished data]. The relationship between NPA-AAN and the supply of digestible protein has not been established yet.

Acknowledging that the supply of digestible protein is ultimately driving NPA-AAN and based on the findings of Yan et al. (2003), we hypothesized that (1) predictions of NPA-AAN based on the supply of digestible protein would be more accurate compared with predictions based on dietary characteristics and (2) predictions of NPA-AAN based on INRA (2007) parameters (e.g., dOM and PDI) would be more accurate compared with predictions based on NRC (2001) parameters (e.g., TDN and MP). Therefore, the objectives of this study were first, to develop 2 new equations predicting NPA-AAN based on the supply of MP (**MP_{supply}**) or PDI (**PDI_{supply}**); second, to evaluate and compare these 2 prediction equations based on the supply of digestible protein with the 3 equations based on dietary characteristics; and finally, to examine if systematic biases were influencing NPA-AAN predictions.

MATERIALS AND METHODS

Equations Predicting NPA-AAN

All equations tested in the current study were developed by meta-analysis using the same database, hereafter referred to as the development database, and the methodology outlined in Martineau et al. (2011). The reference list of studies used in the development database is reported in the Supplemental Reference List (http://dx.doi.org/10.3168/jds.2013-7249). Briefly, the chemical composition (CP, NDF, and ash) of each feed ingredient was used when reported; if missing, table values from the library of each feed evaluation system were used to yield the value reported for the experimental diet. Nitrogen intake and dietary concentration of CP were reported in all studies; however, dietary concentrations of NDF and ash were reported in less than half the studies (Martineau et al., 2011). To account for the difference in BW of species in the database [i.e., sheep, cattle, and dairy cows; see Martineau et al. (2011) for description of species], NPA-AAN was reported on a BW basis, as nutrient digestion and absorption have been shown to be similar between sheep and cattle when expressed as a function of $BW^{1.0}$ (Vernet et al., 2005; Sauvant et al., 2006). Further details on the inclusion criteria and the methodology used to develop the equations are provided in Martineau et al. (2011).

Among the 5 prediction equations tested in the current study, 3 equations predict NPA-AAN based on dietary characteristics and 2 new equations predict NPA-AAN based on the supply of digestible protein [i.e., MP_{supply} from NRC (2001) or PDI_{supply} from INRA (2007)]. Among the 3 equations that predict NPA-AAN based on dietary characteristics, 1 equation is the simplest prediction of NPA-AAN as a function solely of NI, whereas the other 2 equations are more complex and include the following independent variables: NI plus the ingestion of a fiber factor (i.e., NDFi) and the dietary concentration of an energy factor [i.e., either TDN (NRC, 2001) or dOM (INRA, 2007)]. The 5 equations that predict NPA-AAN are as follows (SE in parentheses and *P*-value in superscript):

$$\text{NPA-AAN (mg of N/d per kg of BW)} = 461^{<0.01} (\pm 54.6) \times \text{NI} - 25^{0.49} (\pm 35.6); \quad [1]$$

$$603^{<0.01} (\pm 48.3) \times \text{NI} - 5^{0.05} (\pm 2.7) \times \text{NDFi} + 0.3^{0.02} (\pm 0.12) \times \text{TDN} - 237^{0.01} (\pm 91.5); \quad [2]$$

$$598^{<0.01} (\pm 59.3) \times \text{NI} - 6^{0.07} (\pm 3.1) \times \text{NDFi} + 0.2^{0.08} (\pm 0.10) \times \text{dOM} - 167^{0.03} (\pm 76.3); \quad [3]$$

$$0.85^{<0.01} (\pm 0.065) \times \text{MP}_{supply} - 71^{<0.01} (\pm 22.4); \quad [4]$$

$$0.77^{<0.01} (\pm 0.070) \times \text{PDI}_{supply} - 55^{0.04} (\pm 25.7), \quad [5]$$

where NI and NDFi are in grams per day per kilogram of BW, TDN and dOM are in grams per kilogram of DM, and MP_{supply} and PDI_{supply} are in milligrams of N per day per kilogram of BW.

Note that NI is an obligatory covariate in Equations [1] to [3], but NI is not included in Equations [4] and [5]. Tests of significance were conducted on the parameter estimates derived from each species. In Equation [1],