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Estimating ruminal nitrogen-to-energy balance with in situ disappearance data

STACEY A. GUNTER, MICHAEL L. GALYEAN, AND F. TED MCCOLLUM III

Authors are state livestock specialist, Maine Cooperative Extension, Department of Animal, Veterinary, and Aquatic Sciences, University of Maine, Orono 04469-5735; professor, Department of Animal and Range Sciences, Clayton Livestock Research Center, New Mexico State University, Clayton 88415-9501; and professor, Animal Science Department, Oklahoma State University, Stillwater 74078-0425.

Abstract

Microbial growth in the rumen is a pivotal part of any ruminant protein system, and there is an optimal balance between available nitrogen (N) and energy in the rumen. When the nitrogen-to-energy balance in the rumen is optimal, apparent ruminal N digestion (percentage of intake) equals 0. In situ digestion can be used to estimate the ruminally degraded N:ruminally degraded organic matter (OM; g/kg) ratio. The relationship between in vivo apparent ruminal N digestion and dietary N concentration (percentage of OM), dietary N concentration relative to in vitro digestible OM (IVDOM; percentage of IVDOM), and the ruminally degraded N:ruminally degraded OM ratio were evaluated with data from 10 studies in which cattle consumed forage diets. A moderate relationship ($r^2 = 0.49$) was noted between apparent ruminal N digestion (Y) and dietary N (X; % of OM; Y = 42.94X - 110.54); this equation predicted that apparent ruminal N digestion would equal 0 at a N concentration of 2.57 ± 0.95% of OM. There was a weak relationship ($r^2 = 0.14$) between apparent ruminal N digestion (Y) and the N:IVDOM ratio (X; Y = 21.64X - 97.77); this equation predicted that apparent ruminal N digestion would equal 0 at a N concentration of 4.57% of IVDOM. A strong relationship ($r^2 = 0.67$) was noted between apparent ruminal N digestion (Y) and ruminally degraded N:ruminally degraded OM (X; Y = 4.327X - 117.04); this equation predicted that apparent ruminal N digestion would equal 0 at a ruminally degraded N:ruminally degraded OM ratio of 27.03 ± 0.71 g/kg. The ruminally degraded N:ruminally degraded OM ratio was a better predictor of apparent ruminal N digestion than dietary N concentration expressed relative to either OM or IVDOM. The ruminally degraded N:ruminally degraded OM ratio seems to be a useful tool for predicting apparent ruminal N digestion and managing the nutrition of forage-fed cattle.

Key Words: in situ digestion, ruminally degraded nitrogen, ruminally degraded organic matter, diet quality techniques, forages

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When decisions are made regarding the type and amount of supplement for cattle consuming forages, an estimate of ruminal nitrogen-to-energy balance is necessary. If the rumen is nitrogen (N) deficient (e.g., straw), a ruminally degraded N source would be needed (Nocek and Russell 1988). However, if ruminally degraded N is not limiting (e.g., vegetative wheat pasture [*Triticum aestivum* L.]), high-starch or digestible fiber supplements would be the most beneficial (Nocek and Russell 1988). Researchers and nutritional consultants have a limited number of in vitro and in situ methods to determine needs for supplemental ruminally degraded N and the ruminally degraded organic matter (OM) requirement of ruminants.

Microbial protein synthesis is driven by available energy in the rumen (ARC 1980, NRC 1984, 1985); however, if ruminally degraded N is limiting, microbial protein yield and ruminal carbohydrate digestion will decrease (Nocek and Russell 1988, Clark et al. 1992). The National Research Council (1985) estimated that the proper balance between nitrogen and ruminally degraded OM to optimize microbial yield is 26.13 ± 1.3 g of ruminally available N (ruminally degraded N plus recycled N) per kilogram of ruminally degraded OM. Apparent ruminal N digestion is indicative of the ruminal nitrogen-to-energy balance, with balance assumed to be optimal when apparent ruminal N digestion (percentage of intake) equals 0 (ARC 1980, NRC 1984, 1985). Because in vivo apparent ruminal N digestion for a particular forage cannot be determined in production situations, a rapid in situ method should prove useful.

Extent of ruminal OM and N disappearance can be estimated with in situ methods. Gunter and McCollum (1991) suggested that the ruminally degraded N:ruminally degraded OM ratio based on in situ data could be used to estimate the ruminal nitrogen-to-energy balance. We evaluated experimental data to estimate the relationship between apparent ruminal N digestion and dietary N concentration (percentage of OM), dietary nitrogen concentration relative to in vitro digestible OM (IVDOM; percentage of IVDOM), and the in situ ruminally degraded N:ruminally degraded OM ratio (g/kg).

Material and Methods

Published (Zorrilla-Rios et al. 1985a, 1985b, Campbell 1989,

Van Vuuren et al. 1992, Caton et al. 1993, Gunter 1993, Gunter et al. 1993, Olson et al. 1994a, 1994b) and unpublished data (J. S. Caton, North Dakota State University) were used to construct the experimental data set. There were a total of 10 studies in the data set, and all data were from cattle that had ad libitum access to forage diets (both pen-fed and grazing studies). Each mean for forage type or maturity within a study was considered to be an experimental observation (n = 44).

In all of the studies cited, in situ N and organic matter disappearance was estimated by placing at least 3 g of forage dry matter (ground to pass either a 2 or 3-mm screen) in polyester in situ bags, and incubating the bags in the rumen of ruminally cannulated cattle for discrete times between 2 and 96 hours. After in situ bags were removed, bags were washed in cold water until effluent water remained clear, dried in a forced-air oven to determine dry matter loss, and then analyzed for dry matter, ash, and Kjeldahl nitrogen.

The data base included the variables ruminally degraded N:ruminally degraded OM, apparent ruminal N digestion, dietary N concentration, and IVDOM. The ruminally degraded N:ruminally degraded OM ratio was calculated as described by Gunter and McCollum (1991; [dietary N g kg^{-1} * ruminally degraded N (%)]/ruminally degraded OM [%]). Ruminally degraded N:ruminally degraded OM ranged from 7.57 to 46.82 g/kg, apparent ruminal N digestion ranged from –108.50 to 65.20% of intake, dietary N concentration ranged from 1.01 to 4.39% of OM, and IVDOM ranged from 40.34 to 83.60%. The relationships between apparent ruminal N digestion and dietary N concentration (percentage of OM), dietary N concentration relative to IVOMD (N:IVDOM, percentage of IVDOM), and the ruminally degraded N:ruminally degraded OM ratio (g/kg) were evaluated by regression analyses (Neter et al. 1989). Quadratic effects were included in the model if they were significant ($P < 0.10$; Neter et al. 1989).

Table 1. The relationship between apparent ruminal nitrogen digestion (Y; % of intake) and dietary nitrogen concentration relative to organic matter (OM) or in vitro digestible OM (IVDOM) in cattle consuming forages.

Independent variable (X)	β_0	β_1	r^2	$S_{x.y}$	n
Dietary nitrogen concentration					
Percentage of OM	-110.45	42.94	0.49	30.33	44
Percentage of IVDOM	-97.77	21.64	0.14	35.57	42

Results and Discussion

Dietary N accounted for 49% of the variation in apparent ruminal N digestion (Table 1). Based on the relationship between dietary N and apparent ruminal N digestion, ruminal nitrogen-to-energy balance (apparent ruminal N digestion = 0% of intake) would occur at a N concentration of 2.57 ± 0.94% of OM. This estimate is similar to the range (1.76 to 2.08% of dry matter) suggested by the National Research Council (1984). The N:IVDOM ratio accounted for only 14% of the variation associated with apparent ruminal N digestion (Table 1). With our equation, ruminal nitrogen-to-energy balance would occur at a dietary N concentration of 4.52% of IVDOM. Hogan and Weston (1970) reported that ruminal nitrogen-to-energy balance occurred at a dietary N concentration of approximately 4.00% of IVDOM in sheep fed various forages.

The ruminally degraded N:ruminally degraded OM ratio accounted for 37% more of the variation associated with apparent ruminal N digestion ($r^2 = 0.67$, Fig. 1) than dietary N concentration (% of OM). This result reflects the fact that, unlike dietary N concentration, the ruminally degraded N:ruminally degraded OM ratio accounts for differences in the ruminal availability of the nutrients. This equation predicted that apparent ruminal N diges-

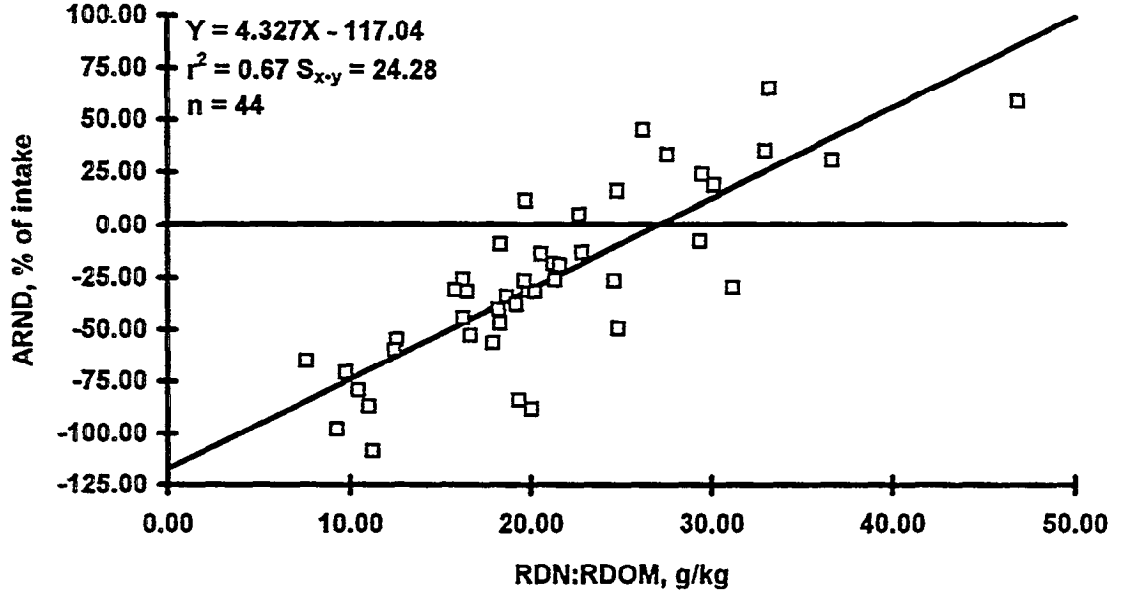

Fig. 1. The relationship between apparent ruminal nitrogen digestion (ARND, % of intake) and the in situ ruminally degraded nitrogen:ruminally degraded organic matter (RDN:RDOM, g/kg) ratio in cattle consuming forages.

tion would equal 0 at a ruminally degraded N:ruminally degraded OM ratio of 27.03 ± 0.71 g/kg, which is similar to estimates suggested by the National Research Council (1985, 26.13 ± 1.3 g of ruminally degraded N/kg of ruminally degraded OM).

An example of the use of the ruminally degraded N:ruminally degraded OM ratio to design supplements for cattle fed forages as the basal diet is presented in Table 2. The body weight and desired performance of the steer in this example is typical for cattle grazing rangeland in northcentral Oklahoma in August. In Step 2, the extent of in vitro OM disappearance was assumed to be equal the extent of ruminally degraded OM. In support of this assumption, cattle grazing tallgrass prairie across four stages of maturity and over 2 years, in vitro OM disappearance was 98.8% of the percentage of OM truly fermented in the rumen (Campbell 1989). In Step 6, the N requirement of the steer was compared with the total N intake (forage plus supplement). In this example, total (forage plus supplement) N intake exceeded the N requirement of the steer for the desired level of performance. If ruminally degraded N:ruminally degraded OM had been balanced, but total N intake was less than the animal requirement, a source of ruminal escape protein would be required. With forages like vegetative perennial ryegrass pasture (*Lolium perenne* L.), the ruminally degraded N:ruminally degraded OM ratio may exceed 26.13 g/kg (Van Vuuren et al. 1992), and a source of supplemental RDOM would be necessary to balance the ruminal nitrogen-to-energy status.

In summary, the ruminally degraded N:ruminally degraded OM ratio estimated from in situ digestion was a better predictor of apparent ruminal N digestion than dietary N concentration relative to OM. However, if in situ degradability of OM and N can not be measured, dietary N concentration (relative to OM) was the next best estimator of apparent ruminal N digestion. Although further research and field application are needed, the ruminally degraded N:ruminally degraded OM ratio seems to be a simple, useful tool for predicting apparent ruminal N digestion that should be helpful in managing the nutrition of forage-fed cattle.

Table 2. An example calculation of the supplemental nitrogen (N) requirement using the RDN:RDOM[1] ratio for a steer gaining 0.68 kg/d grazing tallgrass prairie in northcentral Oklahoma.

Steer description		Reference
Body weight (BW)	272 kg	———
Desired BW gain	0.68 kg/d	———
N requirement	102.6 g/d	NRC 1984
Fecal organic matter (OM) output	10.1 g/kg of BW	Campbell 1989
IVOMD[2]	51.6%	Campbell 1989
RDN:RDOM requirement	27.0 g/kg	Fig. 1
Dietary RDN:RDOM	14.5 g/kg	Gunter and McCollum 1991

1. OM intake
   (272 kg of BW) * (fecal output = 10.1 g/kg of BW)/(1 - .516 IVOMD) = 5.676 kg/d
2. RDOM intake
   (5.676 kg of OM) * (51.6% IVOMD)[3] = 2.93 kg
3. Supplemental RDN requirement
   (2.93 kg of RDOM) * (27.0 - 14.5 g of RDN/kg of RDOM) = 36.6 g of RDN
4. Supplemental soybean meal required to meet the microbial requirement
   36.6 g of RDN/(7.98% N * 72.0% RDN) = 637.0 g of soybean meal
5. Total N intake
   (5,676 g of forage OM * 1.20% N) + (637.0 g of soybean meal * 7.98% N) = 118.9 g of N
6. Animal N status
   118.9 g of intake N - 102.6 g of N required = +16.3 g of N

[1]RDN = ruminally degraded N, RDOM = ruminally degraded organic matter.
[2]IVOMD = in vitro organic matter disappearance.
[3]IVOMD is assumed to equal RDOM.

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