A RUMINAL FILL MODEL TO PREDICT FORAGE INTAKE OF CATTLE GRAZING NATIVE RANGELANDS

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Story in Brief

A model with a limited number of commonly measured dietary inputs was developed to predict forage intake in cattle grazing native rangeland. Intake was considered to be limited by the ruminal fill of potentially digestible (PDNDF) and indigestible (INDF) neutral detergent fiber. The ruminal pool of PDNDF was assumed to disappear by digestion (rate constant k_d) and passage (rate constant k_p). The INDF pool disappears only by passage (k_p). A pool of potentially degradable nitrogen was used to adjust k_d and ruminal fill. Intake predictions from the model support the hypothesis that ruminal NDF fill is an important intake control mechanism in grazing ruminants. Although the model responded to protein supplementation in an expected manner, the magnitude of increased intake with protein supplementation was small and less than expected.

(Key Words: Digestion Models, Forage Intake, Neutral Detergent Fiber)

Introduction

Recent New Mexico studies (Krysl et al., 1987) suggested that the fill of non-digested dry matter in the gastrointestinal tract of cattle grazing blue grama rangeland was fairly constant across the year. These results can be interpreted to suggest that ruminal fill is an important factor in the long-term control of forage intake by grazing cattle. Previously, Hyer and Oltjen (1987) evaluated a dynamic rumen model and found the model to be sensitive only to degradable and non-degradable beta-hexose and nitrogen inputs. A potential problem with this previous model is that data for dietary inputs required by the model are not available on many forages, particularly native range forages that would be important in stocker programs. Moreover, while the model responded to carbohydrate (grain) supplementation in an expected manner, it did not adequately predict the response to protein supplementation. The nitrogen (N) content of forages is an important factor affecting digestion. Supplementation of N to high-fiber forages that are low in N content results in increased intake and associated changes in digestion and passage (McCollum and Galyean, 1985). Based on the model of ruminal cellulose digestion proposed by Waldo et al. (1972), we report herein a new model that was devised with simple and commonly measured dietary inputs.

Materials and Methods

Basic features of the model are depicted in Figure 1. Neutral detergent fiber (NDF) was chosen as a major input variable because of

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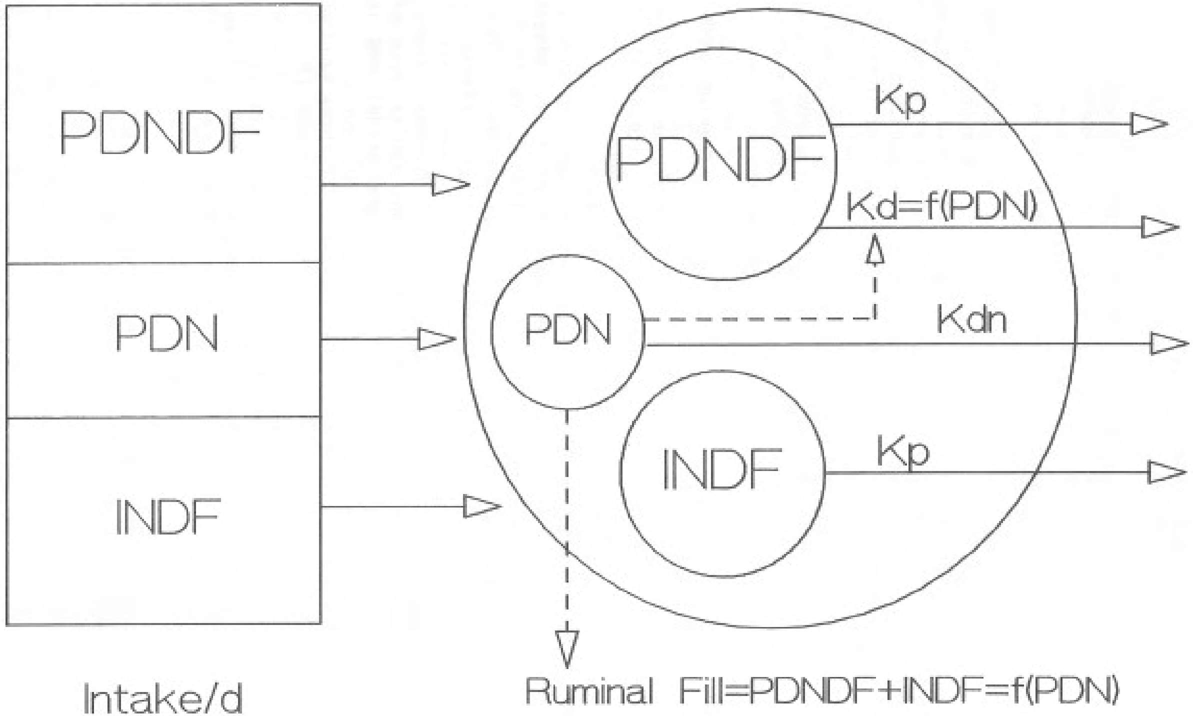

Figure 1. Schematic representation of the ruminal fill model. PDNDF is potentially digestible neutral detergent fiber (NDF), INDF is indigestible NDF and PDN is potentially degradable nitrogen. Rate constants are designated by k and functions are designated by f().

the feed constituents commonly measured, NDF is the most highly related to the fill effect of the diet (Mertens, 1987). Conceptually and analytically, NDF can be considered to consist of fractions that are potentially digested (PDNDF) and indigestible (INDF) in the rumen. Potentially digested NDF can leave the rumen by two routes: by passage at a specific rate (k_p) and by digestion at a specific rate (k_d). The INDF fraction disappears only by passage (k_p). Under steady-state conditions, the intake of PDNDF equals the fill or pool size of PDNDF multiplied by the sum of k_p and k_d. Likewise, intake of INDF equals the pool size multiplied by k_p. Ruminal fill was considered to be the sum of PDNDF and INDF pools divided by body weight.

In the model, k_d of PDNDF and ruminal fill were considered functions of potentially degradable N (PDN). Dietary concentration of PDN was defined as percent total N minus percent acid detergent insoluble N. The PDN pool in the rumen was considered to disappear by passage and digestion, and a combined disappearance rate constant (k_{dn}) was set at .07 h^{-1}. Ruminal fill was adjusted by the PDN pool through a simple linear regression equation with the restriction that fill could not exceed 15 g/kg of body weight. The adjustment of k_d by PDN took the form of a Michaelis-Menten equation with a maximum k_d and a PDN fill at half maximal k_d (k), such that k_d was equal to (k_{dmax} x PDN)/(k + PDN). Values for k_p in the model were scaled by a linear regression equation, such that k_p was adjusted relative to the mean intake by a mature (750 kg) steer of all the native range forages used to develop model parameters.

Given the maximal fill calculated from the PDN pool, an iterative procedure was used to determine forage organic matter intake at steady state after 3 days (integration interval .02 day). Model parameters were estimated using the simplex method of Nelder and Mead (1965).

Data from three studies conducted at New Mexico State University with steers grazing blue grama rangeland in south-central New Mexico (McCollum et al., 1985; Krysl et al., 1987) and northeast New Mexico (Funk et al., 1987) were used to develop model parameters. These studies provided 24 intake estimates, obtained at varying stages of forage growth and maturity, that were averages of measurements with at least four Hereford x Angus or Hereford x Angus x Brahman steers. Organic matter intake was determined from fecal output (pulse dose of ytterbium-labeled forage or continuous dose of chromic oxide) and in vitro organic matter indigestibility. Esophageal-fistulated cows or steers were used to collect samples of grazed forage. All three studies measured forage neutral detergent fiber (NDF), total nitrogen (N) and acid detergent insoluble N. Either in vitro 48-h digestion (McCollum et al., 1985; Krysl et al., 1987) or in situ 72-h digestion (Funk et al., 1987) were used to estimate potential degradeability of NDF. Forage composition and intake estimates for the 24 data points are shown in Table 1.

Results and Discussion

Parameter estimates and their asymptotic standard errors are shown in Table 2. All estimates were within ranges typically observed in experiments that have measured digesta kinetics in grazing cattle. Error sum of squares was 34.71, indicating forage organic matter intake could be predicted with a standard error of 1.4 kg (.37% body weight). Actual vs predicted forage intake is shown in Figure 2. Although substantial over- and under-estimations were apparent for a few points,

Table 1. Steer body weights, forage organic matter intake and nutrient composition for the data points used in development of the model.

Body wt, kg	Organic matter intake, kg	Percent of organic matter PDNDF[a]	INDF	PDN	Stage of growth[b]
221.0	2.97	30.05	52.35	.87	D
270.0	6.48	49.81	25.09	2.56	G
293.0	5.89	47.83	27.97	2.40	G
307.0	5.34	36.07	33.83	1.54	G
342.0	7.14	31.09	33.81	1.20	ED
308.0	4.68	33.78	47.42	1.33	D
385.0	7.09	37.59	41.21	2.50	G
413.0	10.57	49.15	31.55	1.80	G
411.0	7.89	39.57	36.23	1.30	ED
425.0	8.12	41.32	36.78	.70	D
505.0	12.37	60.98	22.32	1.90	G
541.0	11.58	49.27	26.53	1.70	G
620.0	12.15	44.36	26.84	1.00	ED
374.0	8.60	42.99	24.71	4.10	G
392.0	8.98	40.37	32.23	2.40	G
396.0	7.48	41.53	37.87	2.30	ED
433.0	9.33	36.73	37.77	1.30	D
471.0	12.29	57.20	23.70	2.50	G
512.0	12.70	57.08	23.32	1.90	G
585.0	9.08	39.48	37.32	1.10	ED
232.2	5.78	44.54	23.56	1.60	G
248.8	6.59	50.83	28.97	1.10	SD
271.9	7.04	52.23	26.67	.94	SD
296.1	7.97	52.73	26.57	1.58	G

[a]PDNDF is potentially digestible neutral detergent fiber (NDF), INDF is indigestible NDF and PDN is potentially degradable nitrogen.
[b]Stage of forage growth: G is growing, ED is early dormancy, D is dormancy and SD is summer dormancy (drought).

which increased the fitted sum of squares, the model reasonably fit most observations. It is important to also consider that the actual forage intake observations are subject to substantial error because of the techniques used to measure fecal output and forage indigestibility (Galyean et al., 1987). Thus, these results support the hypothesis that ruminal fill of NDF is a major factor regulating intake of native range forage.

Supplemental feeds, particularly protein meals and grains, are often provided to grazing cattle. As developed, the model would not be sensitive to fermentable carbohydrate (grain) supplementation. However, the PDN component of the model should allow prediction of intake responses to the provision of protein supplements. To test the ability of the model to respond to protein supplementation, iterations were performed with or without inclusion of 1 kg of cottonseed meal. This level of supplementation has been shown to increase intake and rate of passage in steers fed prairie hay similar in composition to many of the range forages used in the present data set (McCollum and Galyean, 1985). Changes in forage intake with cottonseed meal supplementation relative to basal forage PDN are shown in Figure 3. The model responded in an

Table 2. Parameter equations and estimates (± standard errors) developed with the 24 data points.

Equation[a]	Parameter estimate
$k_d = (PDN \times k_{dmax}) / (k + PDN)$ where PDN is the potentially degradable N pool (g)	k_{dmax} = .044 ± .004 k = 17.7 ± 1.1
$k_p = k_{pp} \times (bk_0 + bk_1 \times OMI/(16584 \times BW/750))$ where bk_0 is $(1-bk_1)$, OMI is organic matter intake (kg) and BW is body weight (kg)	k_{pp} = .033 ± .002 bk_1 = .19 ± .04
$RFBW = b_0 + b_1 \times (PDN \times k_{dn} \times 24)$ where k_{dn} is .07 h^{-1}	b_0 = 13.59 ± 1.13 b_1 = .0019 ± .0003

[a] k_d is rate of digestion (h^{-1}), k_p is rate of passage (h^{-1}) and RFBW is ruminal neutral detergent fiber fill/body weight (g/kg).

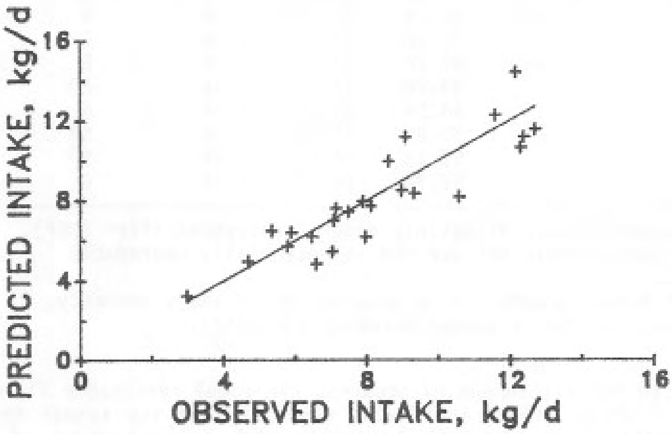

Figure 2. Organic matter intake versus model-predicted intake. The solid line represents the ideal situation of perfect agreement between actual and predicted data.

appropriate manner, in that forages low in PDN showed the greatest increase in intake with supplemental cottonseed meal, and forages adequate in PDN showed little change. However, increases in intake with supplementation were much lower than expected, rarely exceeding 5%.

Based on observations in the literature, one might expect intake of forages with less than 1% PDN to increase by 20% or more with protein supplementation. Additional parameters may be needed in the model to account for the positive effects that protein supplementation has on ruminal digestion and passage of NDF. Conversely, intake changes with protein supplementation may result in part from metabolic changes

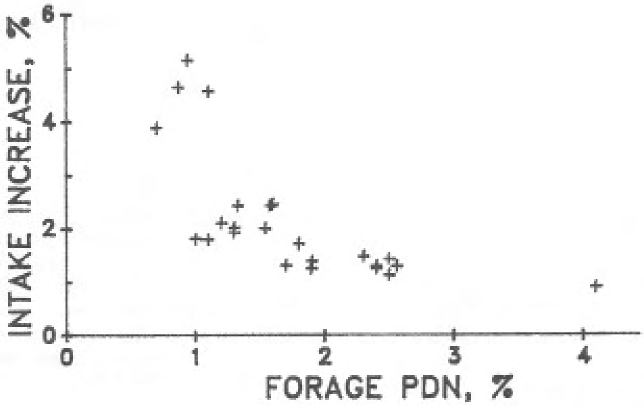

Figure 3. Increase in model-predicted intake with supplementation of 1 kg of cottonseed meal (CSM) versus potentially degradable nitrogen (PDN) content of the forage.

associated with postruminal protein supply that are not accounted for adequately by a ruminal model. Further evaluation of the model with regard to protein supplementation is needed.

In general, these results suggest a simple model based on fill of potentially digestible and indigestible NDF can be used to predict forage intake of cattle grazing native rangelands. Further work with the model will involve the use of forage intake estimates from other locations in an effort to assess its general potential for predicting forage intake.

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