EVALUATION OF A DYNAMIC RUMEN MODEL FOR PREDICTION OF FORAGE INTAKE OF GRAZING RUMINANTS

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Story in Brief

A first step of a research program to assist in management of stocker cattle enterprises in Oklahoma requires development of a model to predict forage intake and weight gains. In this study, a dynamic rumen model was evaluated to determine the effect of digestion and passage of various dietary components on intake. Model sensitivity was tested for each of the parameter values and dietary components. The model is sensitive to dietary changes in degradable or non-degradable protein and beta-hexose and not sensitive to changes in alpha-hexose and water soluble carbohydrates. Model behavior was insensitive to changes in fixed parameters for microbial composition and growth and rate constants for degradation of alpha-hexose, beta-hexose and protein. Supplementation of the reference forage with a corn supplement resulted in decreased forage intake, however, total intake remained constant indicating complete substitution of forage for corn. Protein supplementation caused intake to decrease more rapidly due to the large supply of available nitrogen in the forage. The model will be useful in quantifying effects of supplementation on forage intake of stocker cattle.

(Key Words: Dynamic Rumen Model, Forage Intake, Stocker Cattle)

Introduction

Performance of grazing ruminants is difficult to predict due primarily to variation in forage intake in different grazing situations. This variation is often due to forage quality and availability factors; however, these interact with animal factors such as physiological state and rumen fill to determine intake. Several approaches have been used to predict intake of grazing ruminants. These span the scale from simple empirical relationships relating feed quality to intake (Conrad, 1966) to complex mechanistic models which integrate both physical and metabolic controls (Bywater, 1984). Regardless of the approach, supplementation programs add a complicating factor to accurate prediction. In order to quantify the effects of various supplementation programs on the grazing ruminant, it is necessary to account for effects of rumen fermentation, digestion and passage on intake during grazing. Therefore, the objective of this research was to evaluate a dynamic rumen model of intermediate complexity and determine if model behavior concurs with previously validated biological concepts influencing intake.

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Materials and Methods.

A dynamic rumen model (France et al., 1984) parameterized for sheep was used as a basis for evaluation. The model is relatively aggregated, containing nine state variables and was initially developed for mature wether sheep consuming Italian ryegrass. The state variables in the model include rumen metabolic volume, rumen degradable beta-hexose pool, rumen non-degradable beta-hexose, alpha hexose, water soluble carbohydrates, rumen degradable protein, rumen non-degradable protein, and non-protein nitrogen. Inputs into the rumen are intake of the above mentioned dietary components, water content of the forage and salivary flow and composition. Salivary flow is calculated as a function of both dry matter intake and diet composition. Differential equations describe the rate of change of each state variable. Fixed values in the model include microbial composition and growth parameters, rate constants for microbial degradation of alpha-hexose, beta-hexose and protein, microbial catabolism and growth parameters, a constant determining dependence of microbial catabolism on microbial growth rate and a conversion efficiency of substrate carbohydrate into microbial carbohydrate. An integration interval of .002 days is employed in the dynamic model.

Model validation was accomplished using a reference diet of ryegrass (Table 1) at an intake level of 1.5% of the sheep's body weight. Corn and protein supplements were also evaluated and their nutrient compositions are shown in Table 1.

To estimate intake using the rumen model, intake is assumed to be limited by rumen fill. Maximum rumen fill for the reference diet was assumed to be the sum of the concentrations of each of the dietary components in the rumen. Initial maximum rumen fill was 24.8 g/L. Dietary intake is then determined by an iterative procedure to achieve this fill, after 3 days on the diet.

Results and Discussion

Sensitivity to changes in rumen fill is shown in Figure 1. Forage intake increased linearly to rumen fill values of about 31 g/l and then leveled off.

Table 1. Nutrient proportions of feeds (DM basis).

	Italian Ryegrass (%)	Rolled Corn (%)	Cottonseed Meal (%)
Alpha-hexose	2.66	65.0	8.18
Degradable b-hexose	49.37	0	17.53
Non-degradable b-hexose	6.73	3.5	14.03
Water soluble carbohydrates	21.5	15.0	1.17
Degradable protein	7.29	7.0	41.73
Non-degradable protein	2.43	3.0	4.91
Non-protein nitrogen	4.22	.005	2.45

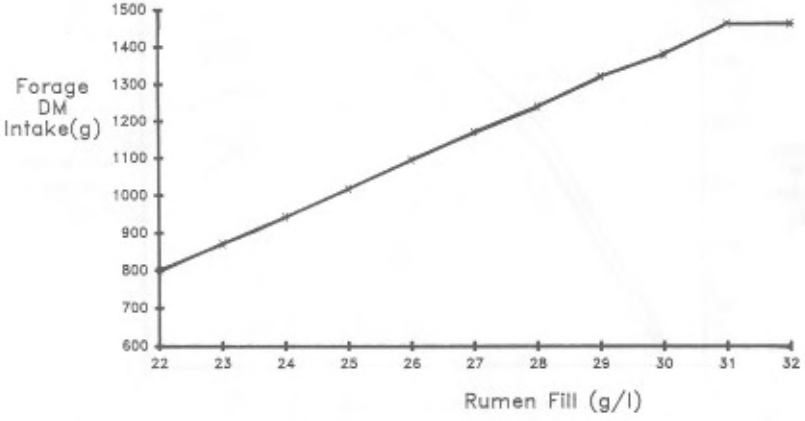

Figure 1. Sensitivity of forage dry matter intake to changes in maximum rumen fill.

Metabolic volume is determined as the effective volume of the rumen and is closely related to aqueous volume of rumen contents (France et al., 1984). The model is sensitive to changes in rumen volume below the reference level of 5 liters (Figure 2), given that all other factors are constant. However, model behavior is relatively insensitive to changes in rumen volume above this point.

Sensitivity of the model for each of the rate constants and parameter values was tested. In general, intake was insensitive to small incremental changes in microbial growth, composition and nutrient use parameters. However, model behavior is quite sensitive to changes of the dietary proportions of protein. Figure 3 illustrates sensitivity

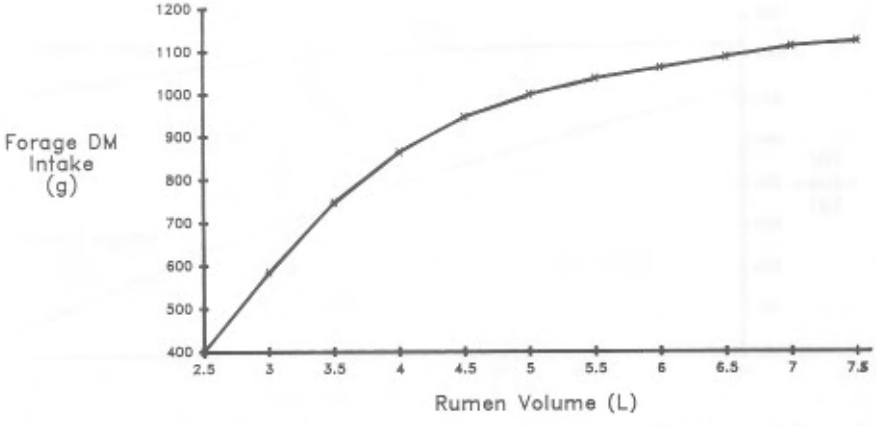

Figure 2. Sensitivity of forage dry matter intake to changes in the aqueous volume of rumen contents.

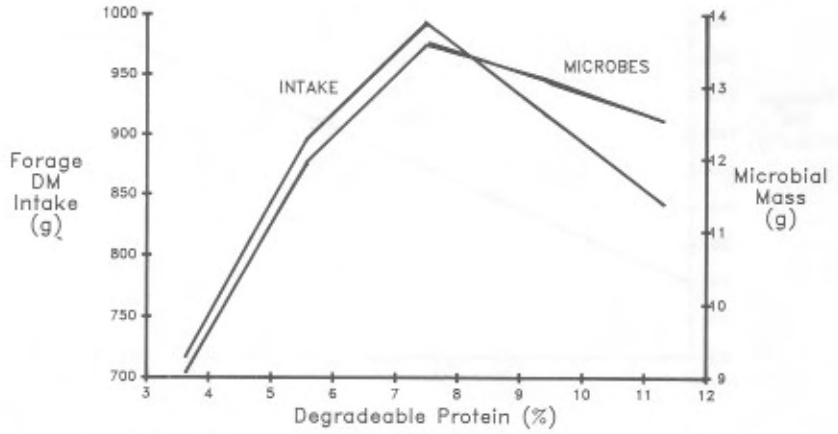

Figure 3. Sensitivity of forage intake to changes in the degradable protein portion of the diet and subsequent changes in the microbial mass in the rumen.

of forage intake to the degradable protein in the diet. Intake decreased when degradable protein in the forage was above 7.5 %. Rumen microbial mass appears to follow the same trend indicating that further evaluation is needed concerning ammonia use in the rumen.

Supplementation of the reference forage diet with an energy supplement (dry rolled corn) resulted in nearly complete substitution between forage and supplement (Figure 4). The substitution effect observed would be in agreement with results of previous studies when corn is fed at low levels (<20% of the diet); however, as the amount of the supplement in the diet increases above 20% (>200g), total intake

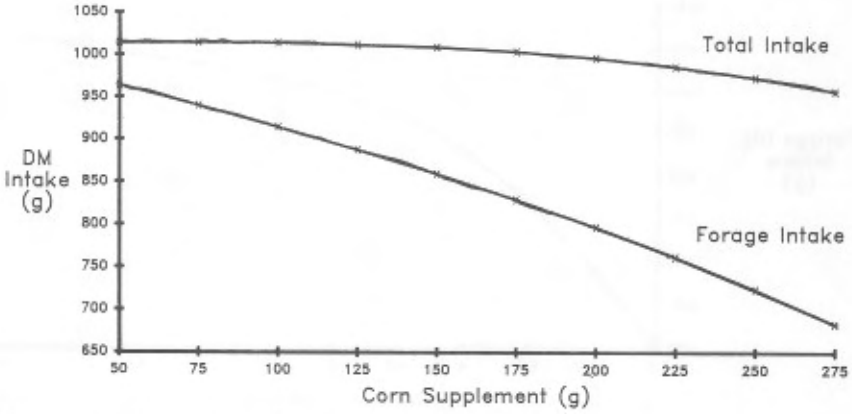

Figure 4. The effect of various levels energy supplementation on forage and total dry matter intake.

Figure 5. The effects of various levels protein supplementation on forage and total dry matter intake.

decreased. Protein supplementation with cottonseed meal decreased both forage and total intake (Figure 5). This is a result of the high protein content in the reference forage.

In conclusion, model behavior is in general agreement with previously validated rumen concepts. The problems associated with nitrogen or ammonia are not new, and similar problems have been observed for other rumen models (Baldwin et al., 1977). Initial evaluation indicates correct behavior with regard to energy supplementation. However, further work is needed to evaluate the model with regard to protein supplementation on low to medium quality forages. Future efforts will be directed toward parameterizing the model for beef cattle grazing forages in Oklahama.

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