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Evaluation of Models to Predict Dry Matter Intake of Forage Based Diets

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Summary with Implications

Dry matter intake (DMI) data from growing cattle experiments at the Eastern Nebraska Research and Extension Center were summarized in order to evaluate the accuracy of model predicted DMI. Cattle were fed individually (n = 78) or in pens (n = 15) and predicted DMI using the Beef Cattle Nutrient Requirements Model (BCNRM, 2016) was compared to observed DMI. The model over predicted DMI when total digestible nutrients (TDN) was less than 64%, under predicted DMI when dietary TDN was greater than 64%, and had a low accuracy, explaining less than 22% of the variation in DMI. An equation to predict DMI was developed using dietary neutral detergent fiber (NDF), energy (NEm), and calf shrunk body weight. The inclusion of dietary NDF concentration improved the prediction precision of DMI for growing cattle consuming low-energy, forage-based diets. Intake may be limited due to rumen fill as well as decreased passage rate from the high NDF concentration of the diets. Including the additional variable of dietary NDF could allow for more precise predictions of DMI and animal performance resulting in more accurate dietary formulations.

Introduction

The concept of modeling is to use previous data to create a tool that can predict dry matter intake (DMI), protein and energy requirements, along with performance of growing cattle. The current Beef Cattle Nutrient Requirements Model (BCNRM, 2016) equation for predicting DMI focuses on the use of dietary NEm concentration. The hypothesis was that the data used to build the current BCNRM was based primarily on studies consisting of medium- to high-energy growing or finishing diets, and these data were extrapolated to fit low-energy, high-forage diets. Thus, the objective was to evaluate the BCNRM's ability to predict DMI in low-energy, high-forage diets and to develop a more robust prediction equation for growing calves fed these diets in the western corn belt. These data are an update to the *2021 Nebraska Beef Cattle Report* (pp. 36–37).

Procedure

All experiments were conducted at the Eastern Nebraska Research and Extension Center, near Mead, NE, utilizing similar protocols. In each experiment, cattle were individually fed or pen-fed. Individually fed calves used the Calan gate system with 6 to 24 replications per treatment. Pen-fed cattle had 8 to 12 head per pen with 4 to 8 replications per treatment. Overall, there were 93 treatment means with 78 of those being individually fed calves and 15 of those being pen-fed calves.

Treatment means were sorted into categories dependent on the type of forage that was fed. Originally there were 9 categories which were separated based on forage type and whether distillers grains (DG) or other corn byproducts were included in the diet. These categories included: (1) grass hay or sorghum silage-based diets without DG (controls), (2) controls + DG, (3) ensiled corn residue-based, (4) corn silage-based, (5) corn silage + DG, (6) dry corn residue, (7) reconstituted corn residue, (8) corn residue + DG, and (9) ensiled residue + DG. After evaluation of the data, cattle fed corn residue had considerably lower intakes and it appears the mechanism controlling DMI on residue-based diets was different than other forage types (*2021 Nebraska Beef Cattle Report,* pp. 33–35); therefore, these treatments were excluded from evaluation of the model. The remaining treatment means in the data set included control (n = 24), control + DG (n = 31), corn silage (n = 28) and corn silage + DG (n = 10).

Actual shrunk BW and dietary NEm (determined through digestion experiments) for each treatment mean was entered into the BCNRM (2016) equation to predict intake of the cattle during the experimental period. Implant status was included in the model, however the effect of ionophore was not included. The predicted intake was compared with the observed intake of the cattle to determine the accuracy of the prediction model.

Statistical Analysis

All statistical analysis was conducted using the GLM and REG procedures of SAS (SAS Inst. Inc., Cary, NC). Equations were developed to predict DMI as a % of BW. Variables were considered that were previously included in the NRC (1996) and BCNRM (2016) equations such as metabolic BW, average BW, and dietary NEm concentration. Other considerations included dietary concentration measures that could contribute to varied DMI such as dietary NDF concentration, dietary TDN, and fecal excretion (FE) as calculated from the current database. Variables were then selected using a backwards step-wise regression technique.

Validation of developed equations was done by regressing observed DMI on predicted DMI for each equation. The strength of the relationship between observed and predicted DMI was obtained through the coefficient of determination (r^2).

Results

Evaluation of the BCNRM

Observed and predicted intake as a % of BW were plotted across calculated TDN values to evaluate their relationship (Figure 1). As TDN increased, the observed DMI increased linearly, while the predicted DMI slope slightly decreased linearly. The difference in the slope of the lines suggests

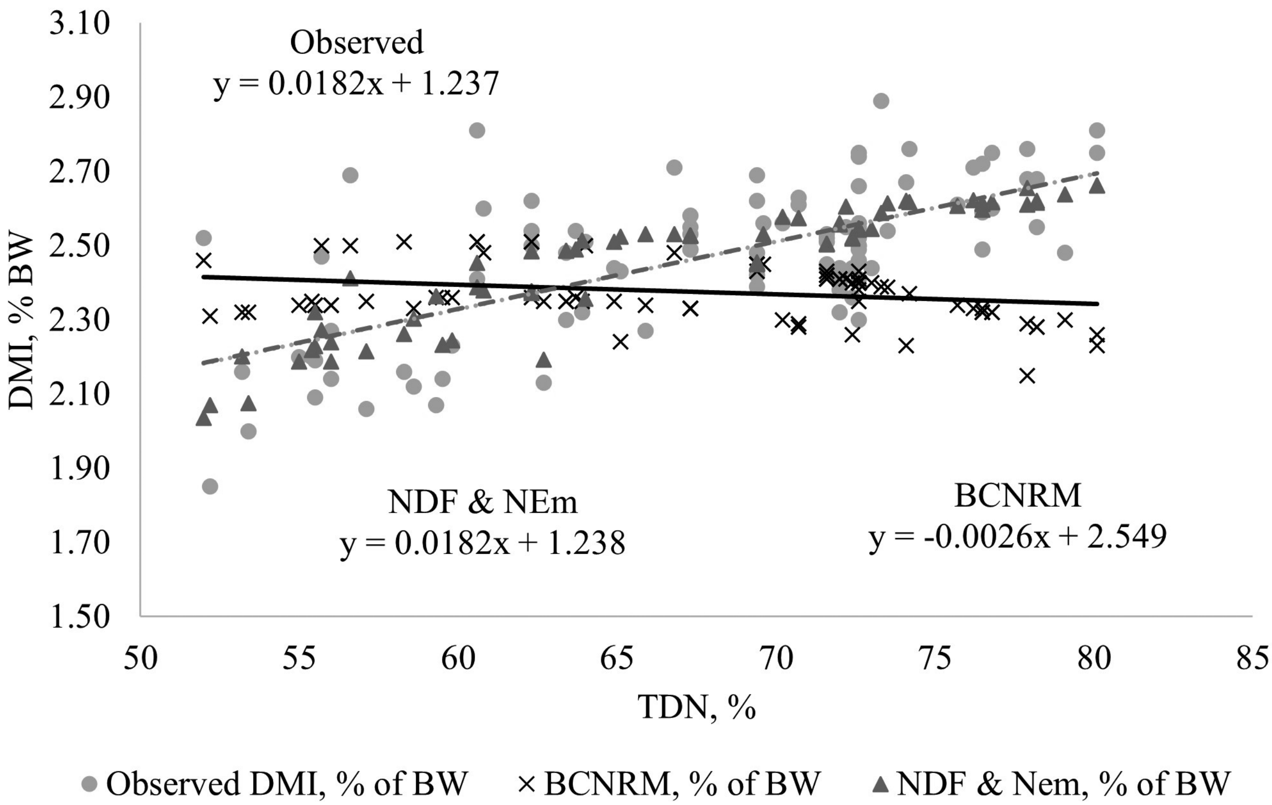

Figure 1. Observed, BCNRM, and new NDF & NEm equation predicting dry matter intake (DMI) as a % of body weight (BW). Plot of (93 treatment means) for forage-based diets (hay or corn silage-based with and without distillers grains) with TDN of 52 to 82%. Observed = light gray short dashed line and circles; BCNRM predicted = Solid black line and x's; NDF & NEm predicted = dark gray long dashed line and triangles.

the BCNRM may not correctly account for differences in diet type or there are other factors controlling intake than what is used in the BCNRM (2016) equation. When TDN was low (< 64%) in the dataset, the predicted intake was greater than that of the observed. As TDN increased, observed DMI increased at a greater rate than the predicted DMI. The intersection of when predicted intake over or under predicted DMI was approximately 64% TDN. Diets consisting of 64 to 82% TDN would be considered as medium to high energy diets. Because the BCNRM (2016) only uses NEm to predict DMI, it was assumed that energy is considered the limiting factor of DMI at any energy level. However, the observed data would conflict with this assumption because DMI increased with increasing TDN for the current data set. At 52 and 82% dietary TDN, the BCNRM (2016) predicted calves would consume 2.41 and 2.33% of BW, respectively. The observed DMI's were 2.18 and 2.73% of BW for calves fed 52 and 82% TDN diets, respectively. Because the BCNRM (2016) had a negative slope for predicted intake and the observed intake slope was positive, there must be another factor controlling DMI in low-energy, forage-based diets.

Equation Development

An effort was made to predict DMI as a % of BW in order to reduce the impact of animal body weight. The equations developed included both dietary NDF and NEm concentration together and then evaluated both variables separately to predict DMI as a % of BW. Figure 1 shows the relationship of observed DMI and predicted DMI using the BCNRM and the newly developed model on a % BW basis. The newly developed model has similar slope and intercept as the observed DMI, suggesting it is more precisely predicting DMI. This was expected as the same dataset was used to develop the equations.

While the use of a single variable may not be able to predict intake accurately and precisely, the use of multiple variables to predict DMI can greatly improve the use of the model. Due to the current data set being forage-based diets with low-energy content (average NEm = 0.71 Mcal/lb DMI), the use of NDF content of the diet greatly improved the precision of the prediction models. Improved precision may be due to the greater NDF content creating a partial limit in DMI due to gut fill and a decreased passage rate, which would limit intake compared with strictly using an NEm based equation. The observed DMI from the current data set increased as a % of BW with increasing energy concentration, at least up to 82% dietary TDN.

The difference between observed DMI and BCNRM (2016) predicted DMI, as a % of BW, were plotted relative to TDN concentration of the diet (Figure 2). As TDN increased from 52 to 82%, the difference between observed and predicted intake

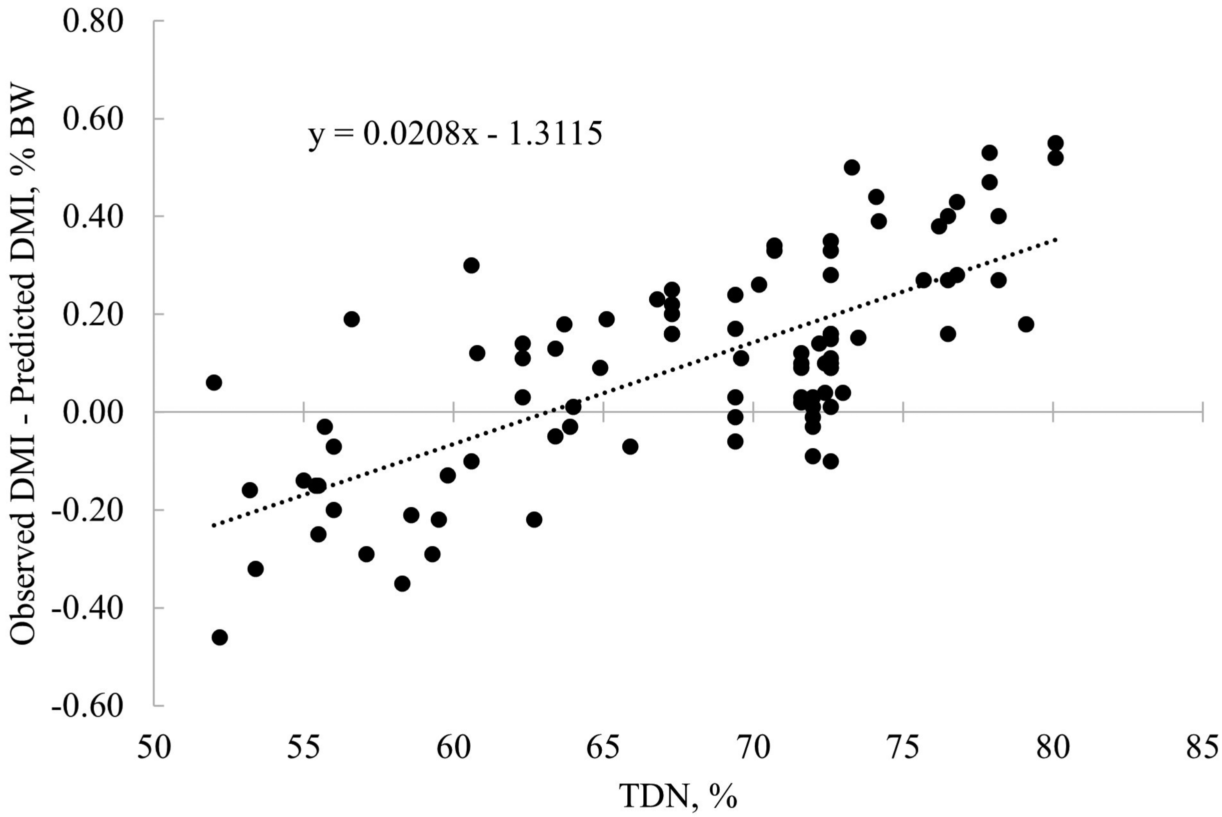

Figure 2. Plot of observed (93 treatments means) dry matter intake (DMI) minus BCNRM (2016) predicted DMI for forage-based diets (hay or corn silage-based with or without distillers grains) with TDN of 52 to 82%

Table 1. Observed versus predicted DMI as a % of BW of different diet types[1]

	Observed	Predicted	*P*-Value	r^2
Overall Means[2]	2.47	2.37	0.02	0.0802
Control[3]	2.30	2.35	0.08	0.2185
Control DG[4]	2.52	2.37	0.15	0.1267
Corn Silage[5]	2.54	2.39	0.05	0.1577

[1]Comparison of observed versus predicted dry matter intake (DMI) using the BCNRM (2016) model on a % body weight (BW) basis

[2]All treatment means developed, n = 93

[3]Traditional forage-based diets with no distillers grains n = 24

[4]Traditional forage-based diets with distillers grains, n = 31

[5]Corn silage-based diets with and without distillers grains, n =38

increased linearly ($P < 0.01$) at 0.021% of BW with each 1% unit increase in TDN. At approximately 64% TDN, Observed DMI—Predicted DMI = 0; therefore, the model over predicted DMI for TDN < 64% and under predicted DMI in diets greater than 64% TDN.

In Table 1, the strength of the BCNRM model and the correlation between predicted and actual intake, as a % of BW, are shown for the overall treatment means and the different categories of diets. While the BCNRM model was considered significant, it was not precise in predicting intake of the overall means ($r^2 = 0.0802$; $P = 0.02$). The explanation of variation became greater (r^2 values improved) with individual diet types, but the significance of the model (*P*-values) did not improve. The BCNRM (2016) explained 0.2185 of the variation in DMI with a *P*-value of 0.08 for the control diets. Control diets that included DG had a lower r^2 value of 0.1267 and a *P*-value of 0.15. Corn silage diets with or without DG had the strongest significance at *P*-value = 0.05 but the explanation of variation was very poor ($r^2 = 0.1577$). The BCNRM model had relatively low r^2 values for all categories, suggesting it was not precise in predicting DMI as a % of BW of growing calves on these forage-based diets.

The lack of precision could be due to a lack of data points using low-energy, forage-based diets to develop the model. The current data set had an average dietary NEm concentration of 0.71 Mcal/lb, compared to 0.92 Mcal/lb in the BCNRM dataset. Extrapolation from more energy dense diets did not provide the same accuracy due to differences in the mechanisms that control rumen fill and satiation.

Comparison of BCNRM with Developed Prediction Equations

The range in observed and predicted DMI as % of BW is presented in Table 2. Using the BCNRM resulted in a tighter

Table 2. Mean and range of observed and predicted DMI as a % of BW[1]

Measure	Observed	BCNRM	NDF and NEm
Mean	2.47	2.37	2.47
Minimum	1.85	2.15	2.04
Maximum	2.89	2.51	2.66

[1]Values shown are observed and predicted dry matter intake (DMI) as a % of body weight (BW) using the Beef Cattle Nutrient Requirements model (BCNRM) or a newly developed equation based on dietary fiber (NDF) and energy (NEm).

range of predicted DMI as a % of BW (2.15 to 2.51%) compared to the observed (1.85 to 2.89%). The range in predicted DMI as a % of BW when using the equation including both dietary NDF and NEm as predictors was 2.04 to 2.66% of BW. The range in predicted DMI for any equation was not as large as the range in observed DMI.

The inability of the equations to predict the extreme data points in the current data set demonstrates the challenge in predicting the outliers. Individual calves are affected differently by forage type and energy content of the diet and therefore outliers were kept in the dataset.

Prediction of DMI as a % of BW was improved on the current data set by including dietary NDF as a means of estimating rumen fill. While this is encouraging for accurately predicting DMI in low-energy, forage-based diets of growing calves, the new equations must be validated on additional data sets with similar performance goals to be considered valuable to the industry.

Conclusion

The current model that included dietary fiber (NDF) as a proxy for rumen fill, along with dietary energy (NEm) concentration increased the explanation of variation by approximately 50% when predicting DMI as a % of BW. This model improved DMI predictions for cattle fed Eastern Nebraska forage-based diets but needs to be further evaluated using additional validation datasets to determine robustness with additional forage and cattle types.

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