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Evaluation in Appalachian pasture systems 1996 NRC model for weaning cattle

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Evaluation in Appalachian pasture systems of the 1996 (update 2000) National Research Council model for weaning cattle[1,2]

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ABSTRACT: This study was conducted to evaluate the accuracy of the National Research Council's (2000) Nutrient Requirements of Beef Cattle computer model when used to predict calf performance during on-farm pasture or dry-lot weaning and backgrounding. Calf performance was measured on 22 farms in 2002 and 8 farms in 2003 that participated in West Virginia Beef Quality Assurance Sale marketing pools. Calves were weaned on pasture (25 farms) or dry-lot (5 farms) and fed supplemental hay, haylage, ground shell corn, soybean hulls, or a commercial concentrate. Concentrates were fed at a rate of 0.0 to 1.5% of BW. The National Research Council (2000) model was used to predict ADG of each group of calves observed on each farm. The model error was measured by calculating residuals (the difference between predicted ADG minus observed ADG). Predicted animal performance was determined using level 1 of the model. Results show that, when using normal on-farm pasture sampling and forage analysis methods, the model error for ADG is high and did not accurately predict the performance of steers or heifers fed high-forage pasture-based diets; the predicted ADG was lower ($P < 0.05$) than the observed ADG. The estimated intake of low-producing animals was similar to the expected DMI, but for the greater-producing animals it was not. The NRC (2000) beef model may more accurately predict on-farm animal performance in pastured situations if feed analysis values reflect the energy value of the feed, account for selective grazing, and relate empty BW and shrunk BW to NDF.

Key words: beef cattle, computer model, forage, performance

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INTRODUCTION

Accurate prediction models of animal response to environment and management are valuable tools for managers evaluating alternative production and marketing options. The National Research Council's (**NRC**) Nutritional Requirements of Beef Cattle (2000 update) includes a computer model that allows user description of cattle type, ration components, and environment to predict animal performance. Based on previous research (Rayburn and Fox, 1990), we know that the current equation set used in the NRC beef system predicts feedlot gain of animals well, determined by the accuracy of the description of the animals and ration modeled. The seventh edition includes requirements that are given for the energy allowable ADG when cattle are fed a particular ration and consume the ration at a given DMI. The effect of diet quality and animal state has been defined more precisely compared with the previous edition.

The West Virginia Quality Assurance Feeder calf marketing program offers a valuable resource of cattle and livestock managers dedicated to producing a safe, high-quality product. The updated NRC model could be a valuable tool for these beef producers to predict and evaluate cattle performance under varying management situations. The objective of this project was to evaluate the accuracy of the NRC (2000) beef model (level 1) on farms when used for calves backgrounded on a variety of pasture- and dry-lot-based systems using

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practical pasture sampling techniques and forage analyses available to producers.

MATERIALS AND METHODS

Calf performance was measured on 22 farms in 2002 and 8 farms in 2003 that participated in West Virginia Beef Quality Assurance Sale marketing pools. Calves were born between January and May, the normal calving season in West Virginia. Calf age at weaning ranged from 5 to 8 mo. Individual calf performance was evaluated each year, beginning at the end of August, when animals were weaned, until mid-October, when animals were sold.

The NRC (2000) beef model has 2 levels. Level 1 is empirical and designed to predict animal performance, whereas Level 2 is more mechanistic and designed for developing an understanding of the nutrient digestion process (NRC, 2000). For the purpose of this study, level 1 was used. Data collected to characterize the animals included: weaning date, initial shrunk body weight (**SBW**; overnight off feed and water), weaning BCS, weaning date, sale day SBW, sex, birth date, breed of sire, breed of dam, supplement consumed ($kg \cdot animal^{-1} \cdot d^{-1}$), number of calves in each lot, and number of days backgrounded on pasture or dry-lot.

For input into the model, animal weights, ages, and BCS were averaged by sex within year by farm. The average SBW by calf group (steer or heifer) over the backgrounding period was calculated by averaging the group weaning SBW and the group sale SBW. This resulted in a sample size (n) of 55 calf groups, 41 groups from the 22 farms in 2002 and 14 groups from the 8 farms in 2003. Most of the farms had both sex groups, whereas 5 farms had only 1 sex group. There were 21 and 7 heifer groups and 20 and 7 steer groups in 2002 and 2003, respectively. The average number of steers per group was 29 and 32 for 2002 and 2003, respectively. The average number of heifers per group was 22 and 25, for 2002 and 2003, respectively. The total number of animals over the 2 yr was 1,386. All male calves were castrated shortly after birth. Cattle breeds included Angus, Angus-cross, Angus × Limousin cross, Red Angus, Angus × Limousin × Hereford cross, Angus × Gelbvieh cross, Angus × Hereford cross, and Angus × polled Hereford cross.

Gut fill as a percentage of BW was estimated for each group of animals using the prediction equation for gut fill as a function of dietary forage NDF developed by Williams et al. (1992). From these percentages, we calculated the kilograms of gut fill for the shrunk animals at weaning and at sale. Empty BW (**EBW**), defined as BW minus digesta, which was completely removed from the animal gastrointestinal tract at slaughter (Owens et al., 1995), was estimated as the difference between SBW and the calculated gut fill weight.

Calves were weaned on pasture (25 farms) or dry-lot (5 farms) and fed supplemental hay, haylage, ground shell corn, soybean hulls, or a commercial concentrate. Concentrates were fed at the rate of 0.0 to 1.5% of BW. Pasture height was measured using a falling plate meter (Rayburn and Rayburn, 1998), and herbage mass was estimated from the average sward plate height using local calibrations of plate height to forage mass from pastures of similar botanical composition, management, and season of growth. The equation used for forage mass (FM) was: $FM = ([651 \times \text{Pasture height}] - [32 \times \{\text{Past.HT}\}^2])$. Pasture quality was evaluated before animals entered each pasture and on a weekly basis (August to mid-October) using hand-plucked samples representing the grazed horizon. Hay bales from each farm were randomly sampled by 1 person using an electric drill and a Penn State forage sampler (Nasco Agricultural Sciences, Fort Atkinson, WI).

The same commercial supplement was used for all farms and was from the same lot within each year. Supplement samples were collected from 2 farms selected randomly. Corn samples were collected from each farm that fed corn. Samples were placed in plastic bags and transported in ice-filled coolers to the lab. Feed samples were placed in forced-air ovens (65°C), dried to a constant weight, and allowed to air-equilibrate. Samples were ground in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) through a 1-mm screen, subsampled, and stored in plastic bags until sent to a commercial forage testing laboratory (Dairy One, Inc., Ithaca, NY) for analyses. Chemical composition of samples was determined using near-infrared reflectance spectroscopy (AOAC 991.03). Analysis of these samples included DM, CP, ADF, NDF, nonstructural carbohydrates, ash, lignin, sugar, crude fat, TDN, NE_m, NE_g, and minerals (Ca, P, Mg, K, and S). Results from analyses of pasture forages were averaged across pastures for each farm within each year.

Seven farms used scales certified by the West Virginia Department of Agriculture. Sixteen farms used Tru-test scales (Tru Test Limited, Auckland, New Zealand) mounted on concrete, which were accurate within 1% as specified by the manufacturer. To take the weights at weaning, calves were gathered from the pastures in the morning. Calves were vaccinated and weighed individually, then placed in weaning pastures or dry-lot. The weighing conditions at sale were on scales certified by the West Virginia Department of Agriculture. The BW at weaning was adjusted by using a 4% pencil shrink to get SBW, and at sale the animals were shrunk overnight (i.e., kept off feed and water) and transported to the certified scale for weighing at the delivery point of the marketing pool. The average number of days for the backgrounding period for all groups was 50.

The NRC model was used to predict ADG of each group of calves by sex using the group average BW, as defined previously. Predicted ADG (**ADG_{pred}**) was compared with observed ADG (**ADG_{obs}**) for each group of animals. Model error was measured by calculating the model residuals (i.e., ADG_{pred} minus ADG_{obs}).

Table 1. Chemical composition of feeds, DM basis[1]

Item	SBH (2)[2, 3]	C. Suppl.[3] (9)	Haylage (1)	Hay (30)	Corn (2)	Pasture (192)
	% DM					
DM	90.4 ± 1.7	89.6 ± 1.9	92.2	92.8 ± 1.5	88.1 ± 2.3	32.4 ± 8.6
CP	12.1 ± 1.4	17.4 ± 0.5	10.9	13.2 ± 8.5	10.5 ± 2.7	18.6 ± 3.3
NDF	62.6 ± 4.6	42.1 ± 4.3	67.7	63.7 ± 6.8	7.1 ± 0.6	54.3 ± 4.3
ADF	46.2 ± 4.7	22.2 ± 2.0	44.3	40.7 ± 4.3	2.1 ± 0.2	31.2 ± 3.2
TDN	66.7 ± 5.2	75.5 ± 0.6	52.0	54.6 ± 4.1	88.0	59.2 ± 2.4
Ca	0.7 ± 0.0	1.2 ± 0.2	0.7	0.6 ± 0.3	0.0	0.8 ± 0.1
P	0.1 ± 0.5	0.7 ± 0.1	0.3	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.0

[1]Means ± SD.
[2]Number of samples analyzed is indicated in parentheses.
[3]SBH = soybean hulls; C. Suppl. = commercial supplement.

Rations used in the model were formulated using the NRC (2000) DMI calf equation for the initial estimate of DMI. From this estimate, the amount of supplement and hay consumed was subtracted to obtain the DMI from pasture. The DMI required to cause the model prediction to achieve the ADG_{obs} was also calculated. Predicted animal performance was determined using level 1 in the NRC (2000) model. The model requires the user to describe those observable and measurable factors known to influence cattle DMI under field conditions. The mature SBW used were 545, 568, 591, or 614 kg for Angus, Angus × Hereford cross, Angus × Gelbvieh cross, or Angus × Hereford × Limousin cross cattle, respectively, based on the breed of the sires and dams of the group. The grading system used was finishing animals at choice or AAA, representing 27.8% body fat. The BCS used at weaning was based on visual appraisal of the calves and ranged from 3.8 to 6. Weather data were obtained from the Morgantown Municipal Airport as a representation of the regional weather. Previous and current temperatures (19.8 to 11.5, and 21.8 to 11.0°C, for 2002 and 2003, respectively) were calculated from the previous month (August) and the month of the backgrounding period (October). Wind speed was assumed to be 5 miles per hour. Animal hide and hair conditions were specified as clean and dry.

Statistical analysis of the modeled animal performance and the model residuals were performed using correlation and regression analyses (NCSS, 2001). Correlations between variables and model residuals were computed. Variables that were correlated to the model residuals were used in a stepwise regression to determine those that would ultimately enter into a residual regression analysis.

RESULTS AND DISCUSSION

The composition of feeds used in this study is shown in Table 1, averaged across farm and year. Forage and palatable weed species present in pastures were mainly orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* L.), and clover (*Trifolium repens* and *pretenses* L.), and in lower proportions Kentucky bluegrass (*Poa pratensis* L.), timothy (*Phleum pretense* L.), alfalfa (*Medicago sativa* L.), milkweed (*Asclepias* L.), dock (*Rumex* spp.), barnyard grass (*Echinochloa crus-galli* L.), fox tail (*Setaria* spp.), buckhorn plantain (*Plantago lanceolata* L.), common plantain (*Plantago rugerii* L.), and dandelion (*Taxacum officinale* L.). The hays and haylages contained the same species as the pastures.

Table 2 presents a summary of the observed values for DMI of pasture, hay, and supplements offered to calves during the backgrounding period. In all but 4 cases forage mass exceeded 1,150 kg/ha, below which cool season pasture DMI is expected to be limited by forage availability (NRC, 2000). For these cases, animal's pasture DMI was proportionally adjusted down to the level expected due to low forage mass limiting pasture DMI (NRC, 2000).

Observed values (mean ± SD) for initial SBW, final SBW, and weight gained by calves during the backgrounding period were: 220 ± 18 kg, 265 ± 23 kg, and 44 ± 13 kg, respectively (n = 55). The large SD shows the variability of animal gain due to ration and environment across farms. This range is of value when testing the model's performance across the normal variability of animal and pasture quality occurring on farms.

Mean and SD of ADG_{obs} and ADG_{pred} were: 0.94 ± 0.29 kg and 0.60 ± 0.24 kg, respectively; whereas the mean and SD of DMI required for ADG_{obs} and model DMI output were: 7.27 ± 1.64, and 5.63 ± 0.43, respectively (n = 55). The DMI required for ADG_{obs} was greater than the model output DMI. This may be explained by

Table 2. Observed pasture characteristics, and amounts of hay, haylage, and supplements offered to calves

Item	N	Mean	SD
Pasture height, cm	45	8.7	2.3
Forage mass, kg of DM/ha	45	1,929	523
Hay, kg·animal^{-1}·d^{-1}	55	1.7	1.2
Haylage, kg·animal^{-1}·d^{-1}	2	0.2	0.00
Commercial supplement, kg·animal^{-1}·d^{-1}	53	1.0	0.6
Corn, kg·animal^{-1}·d^{-1}	12	1.2	0.6
Soybean hulls, kg·animal^{-1}·d^{-1}	4	1.1	0.1

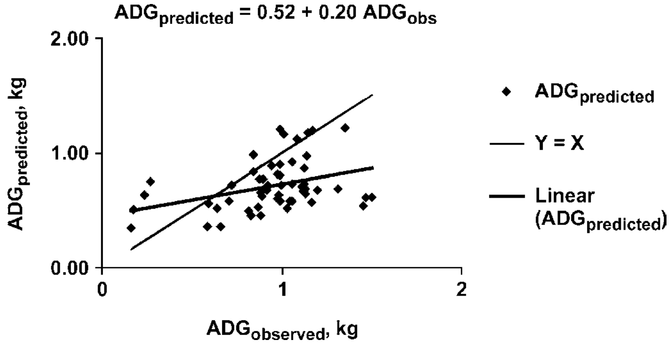

Figure 1. A comparison of ADG observed (ADG_{obs}) and ADG predicted (ADG_{pred}). Each point represents the mean of a farm group.

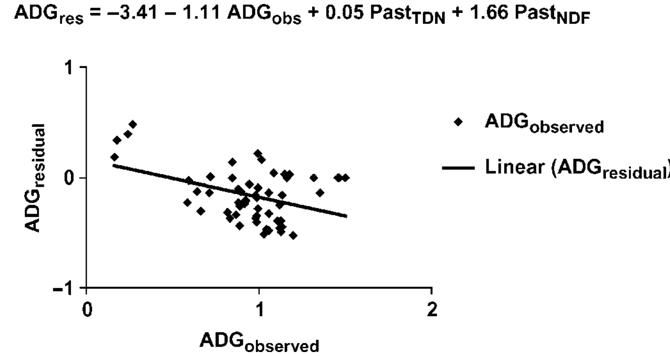

Figure 2. A comparison of ADG observed (ADG_{obs}) and ADG residuals ($ADG_{res} = ADG_{pred} - ADG_{obs}$). Each point represents the mean of a farm group.

the animals selectively grazing the pasture, which can increase the value of the NE intake by as much as 10%, thus decreasing the required DMI for a given ADG. Macoon et al. (2003) indicated that the animal performance method for estimating forage intake was one of the best methods when evaluating lactating dairy cows grazing pasture. This method was comparable to our calculation of DMI required for ADG_{obs}, which was used because no direct measure of DMI was employed.

Figure 1 shows ADG_{pred} plotted against ADG_{obs} when using NRC model predicted DMI. It indicates that the model did not accurately predict ADG for calves on pasture and that it underpredicted in most cases.

When ADG_{pred} was regressed against ADG_{obs} ($P <$ 0.05), it resulted in the following equation:

$$ADG_{pred} = 0.52 + 0.20ADG_{obs};$$
$$r^2 = 0.08, SD = 0.21 \ (P < 0.05).$$

The ADG_{pred} for 4 groups of calves on pasture with low forage mass was overpredicted by the model. It is likely these calves on short pastures were not able to get enough pasture DMI even though input was adjusted for low forage mass (NRC, 2000). Some of the high gaining animal groups may have exhibited compensatory gain because these animals began on test at about 200 kg with a BCS of 4 and came off at 268 kg with an ADG of 1.16 kg. The chemical composition of feeds was analyzed by near-infrared reflectance spectroscopy with digestibility estimated using a summative equation developed for dairy cattle (Weiss, 1995). High-producing dairy cattle have a greater rate of passage there by reducing feed digestibility. Beef cattle consuming the same feed would obtain greater digestibility. Greater digestibility values entered into the model would result in greater predicted ADG and would improve model performance.

When the model residuals were plotted against the ADG_{obs}, the model predicted ADG within 0.5 kg and that most error was from underpredicting ADG because most residuals were negative (Figure 2). When using stepwise regression of variables against ADG residuals (**ADG_{res}**), the independent variables related to the model error were ADG_{obs} ($P < 0.001$), pasture TDN percentage (**$Past_{TDN}$**, $P < 0.001$), and pasture NDF (**$Past_{NDF}$**; $P = 0.049$). Multiple regression analysis was used with these independent variables, and as ADG_{obs} increased the model residual became more negative and increasingly underpredicted ADG; and that when $Past_{TDN}$ and $Past_{NDF}$ increased the model residual was less negative.

$$ADG_{res} = -3.41 - 1.11 \ ADG_{obs} + 0.05 \ Past_{TDN} + 1.66 \ Past_{NDF};$$
$$r^2 = 0.83, SD = 0.11.$$

Because the P-value of $Past_{NDF}$ was close to 0.049, we reran the regression analyses without this variable and obtained the following equation with no change in P-values for the retained variables.

$$ADG_{res} = -1.32 - 1.11 \ ADG_{obs} + 0.03 \ Past_{TDN};$$
$$r^2 = 0.81, SD = 0.11.$$

The fact that ADG_{res} were negatively related to ADG_{obs} indicates systematic error in the model, which may be due to the model not accurately predicting DMI or a systematic error in evaluating feed digestibility. This may also be related to selective grazing because across a range of similar pastures using a method similar to Macoon et al. (2003), we showed that apparent intake of forage was about 10% greater in NE_m than that of the pasture average (E. B. Rayburn, unpublished data). As $Past_{TDN}$ increased, ADG_{res} became less negative. The observation that ADG_{res} became less negative with increasing $Past_{NDF}$ may relate to greater gut fill in these animal groups resulting in greater ADG_{obs} compared with EBW gain, whereas the model is predicting EBW gain. Gut fill (in kilograms) at sale was used in

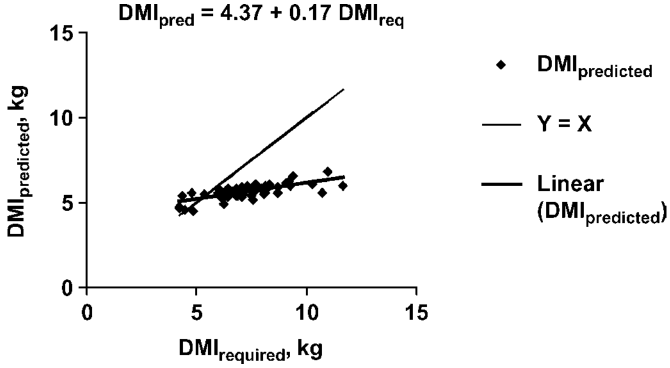

Figure 3. A comparison of DMI predicted (DMI_{pred}) and DMI required (DMI_{req}) for ADG observed (ADG_{obs}). Each point represents the mean of a farm group.

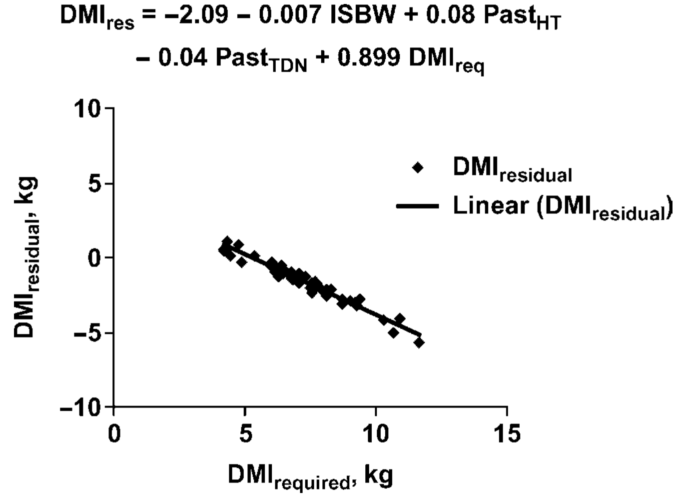

Figure 4. A comparison of DMI required (DMI_{req}) for ADG observed (ADG_{obs}) and DMI residuals (DMI_{res} = DMI_{pred} − DMI_{req}). Each point represents the mean of a farm group. ISBW = initial shrunk BW; $Past_{HT}$ = pasture height; $Past_{TDN}$ = pasture TDN.

the residual analyses for ADG but was not a significant variable.

When using the NRC model predicted DMI to predict ADG on dry-lot, stepwise regression of variables against ADG_{res} indicated that the independent variables related to the model error were ADG_{obs} and ration NE_g ($P < 0.001$). Multiple regression analyses using these independent variables showed that as ADG_{obs} increased the residual became more negative, suggesting that the model increasingly underpredicted ADG as ADG_{obs} increased. The negative relation between ADG_{obs} and ADG_{res} is similar to what was observed with the pasture cattle. This residual analysis also showed that as NE_g increased, the residual became more negative similar to the pastured cattle response to pasture TDN level.

$$ADG_{res} = -0.98\ ADG_{obs} + 1.03\ NE_g;$$
$$r^2 = 0.93,\ SD = 0.10.$$

When the NRC (1996) beef model was evaluated using bulls (Duynisveld and Charmley, 2001) and feedlot backgrounding, and finishing steers (Block et al., 2001), the model increasingly underpredicted ADG as ADG increased. For the Duynisveld and Charmley (2001) study, as forage inclusion increased in the ration, ADG_{pred} decreased. They speculated that the 1996 NRC beef model assumes a lower energy value for greater forage diets than occurs. Rayburn and Fox (1990) showed that the NRC (1984) beef model accurately predicted performance of dry-lot fed Holstein steers. The model bias for ADG predicted was to underestimate ADG by 1.2%. Fox et al. (1995) indicated that the NRC (1984) medium-frame steer equation could be used as a base to accurately predict the energy and protein requirements of growing and finishing steers.

A comparison of NRC model predicted DMI and DMI required for ADG_{obs} (**DMI_{req}**) is shown in Figure 3. The NRC model predicted DMI for low intake animals was similar to DMI required for ADG ($P < 0.001$), but for the greater-producing animals, it was not.

$$DMI_{pred} = 4.37 + 0.17\ DMI_{req};$$
$$r^2 = 0.47,\ SD = 0.32.$$

Regression analyses using this variable related to the model error showed that as DMI required for ADG increased, the DMI_{pred} increased also.

For pasture-fed calves when the model DMI residuals were plotted against the DMI_{req}, the model predicted accurately ($P < 0.001$) when DMI required for ADG_{obs} was low (residual values equal to zero) and underpredicted when DMI required for ADG_{obs} was high (residual values were negative; Figure 4).

Stepwise regression using DMI residuals (DMI_{res}) predicted by NRC indicated that the independent variables related to the model error for pasture calves were initial shrunk BW (**ISBW**), pasture height ($Past_{HT}$), pasture TDN ($Past_{TDN}$), and DMI_{req} ($P < 0.001$).

$$DMI_{res} = -2.09 + 0.007\ ISBW + 0.08\ Past_{HT}$$
$$+ 0.04\ Past_{TDN} - 0.899\ DMI_{req};$$
$$r^2 = 0.99,\ SD = 0.15.$$

Regression analyses using these variables related to the model error showed that as DMI required for ADG increased, the residual decreased; and as ISBW, $Past_{HT}$, and $Past_{TDN}$ increased, the residual increased. For dry-lot calves, stepwise regression using DMI_{res} predicted by NRC indicated that the independent variables related to the model error were ISBW and DMI_{req} ($P < 0.001$).

$$DMI_{res} = -2.17 + 0.007\ SIBW - 0.975\ DMI_{req};$$
$$r^2 = 0.99,\ SD = 0.05.$$

Regression analyses using this variable showed, as for pasture calves, that as DMI_{req} increased the residual decreased and that as ISBW increased the residual increased also. The fact that DMI residual increases as ISBW increases may be related to a greater ruminal capacity of the animal to ingest more feed material. There is a positive relationship between intake and BW in growing animals, and also there is a positive relationship between intake and mature animals of different skeletal size (Forbes, 1986). Several authors have published the results of studies involving the relationship between the live-weight of grazing animals and their consumption of herbage (Conrad et al., 1964; Hodgson and Wilkinson, 1967; Taylor et al., 1986; Illus, 1989). In some cases it was assumed that herbage intake was proportional to the live weight to the 0.73 power (Conrad et al., 1964; Illus, 1989). Other workers calculated that the exponent that best fit their results varied between 0.53 to 1 (Hodgson and Wilkinson, 1967; Taylor et al., 1986). Conrad et al. (1964) found that feed intake of lactating dairy cows, eating forage or mixed diets in 114 different trials, varied in direct proportion to live weight when digestibility of DM was less than 66%. For diets of greater nutritive value (DMD > 66%), food intake varied with the 0.73 power of live weight. Finally, Conrad et al. (1964) indicated a correlation coefficient of 0.99 relating DMI to BW.

When the NRC 1984 beef model was analyzed for DMI prediction, Rayburn and Fox (1990) and Fox et al. (1992) reported an accurate prediction of DMI in their evaluation. Rayburn and Fox (1990) indicated that 93% of the variability in DMI was accounted for by the 1984 Beef model and a variance of 0.58 kg of the predicted values. Fox et al. (1992) observed r^2 values of 0.64 and 0.94 for steers and heifers, respectively. On the other hand, other research has shown that the 1996 NRC model underestimated DMI (Duynisveld and Charmley, 2001; Knaus et al., 2001).

Results of this study showed that the NRC (2000) beef model predicted the performance of backgrounding steers and heifers under grazing and dry-lot conditions within 0.5 kg/d. The model prediction DMI was most accurate for low-producing animals. The backgrounding period for calves can be stressful even under the best of conditions, and animal health and environment play a major role in animal performance. The NRC model uses constants for adjustment between EBW and SBW, which are adjusted according to feed-lot cattle (NRC, 2000) and does not reflect what happens over a range of dietary NDF levels that occurs in supplemented high forage systems. It is possible that the NRC (2000) Beef Model may more accurately predict on-farm animal performance in pasture situations if feed analysis values reflect the energy value of the feed to beef cattle, account for selective grazing, and relate EBW and SBW to NDF.

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