Evaluation of NRC (2000) model energy requirement and DMI equation accuracy and precision for wintering beef cows in western Canada

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Block, H. C., Bourne, J. L., Lardner, H. A. and McKinnon, J. J. 2010. **Evaluation of NRC (2000) model energy requirement and DMI equation accuracy and precision for wintering beef cows in western Canada.** Can. J. Anim. Sci. **90**: 245–258. Three years of winter feeding trials using 90 Angus cows (15 pens of six cows) fed typical western Canadian wintering diets formulated to stage of pregnancy were used to evaluate National Research Council (NRC 2000) energy requirement and dry matter intake (DMI) equation accuracy and precision. Data collection included pen DMI, individual cow weights, body condition scores, calving dates and weights, and daily environmental temperature. Diet energy density was estimated from nutrient analysis of composited weekly feed samples. Equation evaluations compared observed and predicted DMI and conceptus corrected average daily gain (ADG) for the second and third trimesters using regression, means comparison, concordance correlation coefficient (CCC), and total deviation index (TDI) methods. Across all 3 yr, second trimester DMI was over-predicted ($P<0.01$) with low precision (CCC = 0.24, TDI_{90} = n/a) using actual environmental conditions, but not ($P=0.34$) when assuming thermal neutral (TN) conditions, although precision remained low (CCC = 0.25, $\mathrm{TDI}_{90}=1.91$ kg d^{-1}). Third trimester DMI over the 3 yr was also over-predicted ($P<0.01$) with low precision (CCC = 0.12, $\mathrm{TDI}_{90}=1.57$ kg d^{-1}) using actual environmental conditions, but was largely under-predicted ($P<0.01$) with lower precision (CCC = −0.01, $\mathrm{TDI}_{90}=2.34$ kg d^{-1}) when assuming TN conditions. Across all 3 yr, second trimester ADG was largely under-predicted ($P<0.01$) with low precision (CCC = 0.50, $\mathrm{TDI}_{90}=0.58$ kg) using actual environmental conditions, but over-predicted ($P<0.01$) with similar precision (CCC = 0.51, $\mathrm{TDI}_{90}=0.50$ kg) when assuming TN conditions. Third trimester ADG predictions using actual environmental conditions were inaccurate ($P<0.01$) with low precision (CCC = 0.20, $\mathrm{TDI}_{90}=0.38$ kg) using actual conditions and lower precision (CCC = −0.01, TDI_{90} = n/a) when assuming TN conditions where ADG was over-predicted ($P<0.01$). These results indicate a lack of accuracy and precision with the current NRC (2000) model energy requirement and DMI equations that was not addressed by assuming TN conditions. Future research should be targeted at alternate DMI equations and refinements to maintenance and gain requirements.

Key words: NRC evaluation, nutrient requirements, wintering beef cows

Block, H. C., Bourne, J. L., Lardner, H. A. et McKinnon, J. J. 2010. **Évaluation de l'exactitude et de la précision de l'équation du modèle du NRC (2000) prévoyant les besoins énergétiques et l'ingestion de matière sèche pour les vaches de boucherie de l'Ouest canadien durant leur hivernage.** Can. J. Anim. Sci. **90**: 245–258. Trois années durant, les auteurs ont effectué des essais hivernaux sur 90 vaches Angus (15 enclos de six) en leur procurant des rations typiques de l'Ouest canadien, préparées en fonction du stade de gestation. Le but consistait à vérifier l'exactitude et la précision de l'équation du modèle du NRC (2000) servant à prévoir les besoins énergétiques et l'ingestion de matière sèche (IMS) des animaux. Les données recueillies comprenaient les suivantes : IMS par enclos, poids des vaches, note d'état corporel, date de vêlage et poids à la mise bas, et température ambiante quotidienne. L'énergie volumique des rations a été estimée par analyse des éléments nutritifs des échantillons d'aliments préparés hebdomadairement. L'évaluation reposait sur la comparaison entre l'IMS relevée et prévue, et sur le gain quotidien moyen (GQM) au deuxième et au troisième trimestre de gestation, corrigé pour la date de fécondation, par régression, par comparaison des moyennes, par concordance des coefficients de corrélation (CCC) et d'après l'indice d'écart global (TDI). Au cours des trois ans, l'équation a surestimé ($P<0.01$) l'IMS

Abbreviations: **ADG,** average daily gain; **ADF,** acid detergent fibre; **ADIN,** acid detergent insoluble nitrogen; **ADL,** acid detergent lignin; **CCC,** concordance correlation coefficient; **CP,** crude protein; **DMI,** dry matter intake; **EE,** ether extract; **NDF,** neutral detergent fibre; **$\mathbf{NE_m}$,** net energy maintenance; **NRC,** national research council; **$\mathbf{TDI_{90}}$,** 90% total deviation index; **TDN,** total digestible nutrients; **TN,** thermal neutral

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du deuxième trimestre avec une faible précision (CCC = 0,24, 90 % TDI = n/d) dans les conditions environnementales réelles, mais pas ($P = 0{,}34$) dans des conditions thermiques neutres, bien que le degré de précision soit demeuré faible (CCC = 0,25, 90 % TDI = 1,91 kg par jour). L'équation a aussi surestimé ($P < 0.01$) le GQM du troisième trimestre durant les trois années de l'étude, avec un faible degré de précision (CCC = 0,12, 90 % TDI = 1,57 kg par jour) dans les conditions environnementales réelles, tandis qu'elle a fortement sous-estimé ($P < 0.01$) ce paramètre avec une précision plus faible (CCC = −0,01, 90 % TDI = 2,34 kg par jour) dans des conditions thermiques neutres. La prévision du GQM du troisième trimestre est inexacte ($P < 0.01$) avec un faible degré de précision (CCC = 0,20, 90 % TDI = 0,38 kg) dans les conditions environnementales réelles et la précision est plus faible encore (CCC = −0,01, 90 % TDI = n/d) dans les conditions thermiques neutres, avec surestimation du GQM ($P < 0.01$)Ces résultats indiquent que les équations du modèle actuel du NRC (2000) servant à évaluer les besoins énergétiques et l'IMS manquent d'exactitude et de précision, car on ne les a pas élaborées en tenant compte de conditions thermiques neutres. Il faudrait entreprendre plus de recherches pour trouver d'autres équations qui serviront à prévoir l'IMS ou perfectionner les équations existantes afin d'établir les besoins énergétiques relatifs à l'entretien et à l'engraissement des bêtes.

Mots clés: Evaluation du NRC, besoins nutritifs, hivernage des vaches de boucherie

The cost of wintering beef cows in western Canada is the single largest cost of beef production, accounting for 60–65% of the total cost of production in a cow–calf operation (Kaliel and Kotowich 2002). Providing wintering beef cows enough feed to meet their nutrient requirements while avoiding waste resulting from overfeeding provides a means of controlling and reducing these costs. In order to meet this objective, beef cattle producers need accurate and precise estimates of wintering cow nutrient requirements. The National Research Council (NRC 2000) beef model provides a means of estimating the nutrient requirements of cattle under diverse production and environmental conditions. Previous evaluations of the NRC (2000) beef model (Block et al. 2001, 2006) found the model to lack accuracy, but were focused on evaluation of feedlot cattle performance. Evaluations of model intake and gain predictions for wintering beef cows are not readily available. The objective of this project was to evaluate the NRC (2000) beef model DMI and energy requirement equations with regard to their ability to predict the voluntary feed intake and weight gain of beef cows during the winter feeding period.

MATERIALS AND METHODS

The data used in this evaluation are from 2002–2003, 2003–2004, and 2004–2005 winter feeding trials conducted at the Western Beef Development Centre Termuende Research Farm near Lanigan, SK. Each of these winter feeding trials began with 15 pens of six mature commercial Angus cows. At the start of the study the cows averaged 39 ± 1.5 mo of age, 5.4 ± 0.2 body condition score (nine-point scale) and 584.5 ± 9.2 kg body weight. The same animals were used for each year of the study, unless culled for injury or failure to conceive, in which case a similar replacement was brought in from within the herd.

All cows were pregnancy checked at the beginning of the trial, which allowed the cows to be managed in early, mid, and late calving groups. This was carried out to reduce the pen variation in days of pregnancy, in order to more precisely deliver the required nutrients for conceptus growth and for division of the winter feeding stage into the two evaluation periods. The first period corresponded to the 2nd trimester and began on Nov. 05 in 2002–2003, Nov. 04 in 2003–2004, and Nov. 09 in 2004–2005 with all winter feeding trials and ending approximately 8 wk before calving. The second period corresponded to the 3rd trimester and began approximately 8 wk before calving and ended approximately 2 wk before calving. Third trimester evaluation period end dates varied with pen due to stage of pregnancy and ranged from Mar. 23 to May 05 in each of the respective years.

Housing and Feeding

All cows were housed in outdoor 7.4 m by 24.5 m pens with a feed bunk running along the shorter southern edge of each pen, and a 20% porosity windbreak 2.4 m beyond the northern edge of the pens. Cattle were bedded twice weekly with woodchips. On three occasions over the 3 yr, straw bedding was used due to extreme conditions.

Cows were fed total mixed rations formulated to meet nutrient requirements for maintenance and pregnancy (NRC 2000) once daily. Expected ad libitum intake of the total mixed rations should have resulted in zero weight gain beyond that associated with fetal growth. Feed supplied was 5 to 10% in excess of this amount. Feed bunks were cleaned weekly to account for feed refusals. An early gestation ration based on barley green feed and oat straw, and a late gestation ration based on alfalfa hay, barley grain, and oat straw were fed, and cows had ad libitum access to mineral supplements (Table 1). Analyzed nutrient content of diets are also presented in Table 1 and were used to estimate diet total digestible nutrients (TDN) according to Weiss et al. (1992).

Cows were weighed individually before feeding on 2 consecutive days at the beginning and end of the trial, and every 3 wk during the course of the trial. Cow weights were adjusted for actual conceptus weight according to NRC (2000) before determining ADG or shrunk body weights for model inputs. A Microsoft

Table 1. Ingredient and nutrient content of rations fed to wintering beef cows[z]

	2002–2003		2003–2004		2004–2005	
	2nd trimester	3rd trimester	2nd trimester	3rd trimester	2nd trimester	3rd trimester
Ration ingredients (% of DM)						
Alfalfa hay	–	63.1	–	61.5	–	25
Barley grain	–	12.7	–	13.4	–	6
Barley green feed	55.9	–	55.1	–	53	25
Oat straw	44.1	24.2	44.9	25.2	47	44
Nutrient content						
NDF (% of DM)	69.3	60.2	69.2	68.8	64.0	67.6
ADF (% of DM)	45.4	42.8	44.6	44.0	39.0	42.9
ADL (% of NDF)	7.0	8.3	7.7	7.5	8.53	9.68
CP (% of DM)	7.7	9.6	6.6	7.6	7.7	7.3
NDIN (% of CP)	42.9	49.0	45.5	61.8	18.1	22.9
ADIN (% of CP)	31.2	28.1	25.8	28.9	16.5	23.1
EE (% of DM)	1.4	1.8	1.6	1.7	2.8	2.5
Ash (% of DM)	8.0	8.2	7.6	6.9	5.9	6.3

[z] Commercial 1:1 mineral (Feed-Rite Hi C-N-Z with selenium, Feed-Rite Ltd., Humboldt, SK) containing 160 g kg^{-1} Ca, 160 g kg^{-1} P, 450 mg kg^{-1} Fe, 125 mg kg^{-1} I, 5300 mg kg^{-1} Mn, 4000 mg kg^{-1} Cu, 40 mg kg^{-1} Co, 10 000 mg kg^{-1} Zn, 2000 mg kg^{-1} F, 200 000 IU kg^{-1} vitamin A, 45 000 IU kg^{-1} vitamin D, and 40 IU kg^{-1} vitamin E, and cobalt iodized salt (Feed-Rite cobalt iodized salt, Feed-Rite Ltd., Humboldt, SK) containing 390 g kg^{-1} Na, 600 g kg^{-1} Cl, 150 mg kg^{-1} I, and 100 mg kg^{-1} Co were provided ad libitum.

Excel (Microsoft Corporation, Redmond, WA) spreadsheet containing the energy requirement and DMI equations related to pregnant, non-lactating, wintering beef cows was developed to evaluate NRC (2000). Table 2 illustrates the steps followed to arrive at these calculations.

Model Inputs

As all cattle in these studies were non-lactating Angus cows, there was no need to input the breed, lactation, and gender modifiers to estimate NE$_m$ requirements. Required dietary inputs consisted of information on DMI, TDN, and if an ionophore was used. Diet CP data were not used as the NRC (2000) equations focus first on energy then on protein requirements. Both DMI and TDN data are summarized in Table 3. None of the diets fed contained an ionophore.

Table 2. Summary of steps involved in developing spreadsheet for prediction of dry matter intake and energy requirements of pregnant, non-lactating cows using equations of NRC (2000)

1. Conversion of dietary TDN values to NE$_m$ values.
2. Estimation of NE$_m$, intake of non-lactating pregnant cows in their last two-thirds of pregnancy, subject to the limitation that if diet NE$_{ma}$ is <1.00 Mcal kg^{-1}, then diet NE$_{ma}$ is set at 0.95 Mcal kg^{-1}.
3. Estimation of NE$_m$ requirements without accounting for acute cold stress effects.
4. Estimation of the NE$_m$ required for pregnancy.
5. Estimation of the lower critical temperature of the cattle based on surface area and normal heat production calculations relative to cattle external and tissue insulation. and determining additional energy required to offset acute cold stress.
6. NE$_m$ requirements for maintenance without cold stress, pregnancy, and any effect of cold stress can be subtracted from total NE$_m$ intake.
7. Weight gain or loss can be estimated based on any surpluses or deficiencies in energy intake.
8. In the case of a predicted deficient energy intake, the prediction of ADG is modified to reflect the lower efficiency of mobilizing tissue reserves to meet NE$_m$ requirements by dividing negative predictions of ADG by 0.8.

Required environmental information included existence of night cooling to offset heat stress, pen mud depth as a modifier of intake, previous and current temperature, wind speed, effective hair depth, and effect of hide condition and thickness on external and tissue insulation. With these winter feeding trials, night cooling to offset heat stress was not a factor in the model predictions. Likewise, frozen pen conditions removed pen mud depth as a modifier of intake. Previous temperatures are summarized in Table 3 and were taken as the average temperature for a time period of the same duration as the 2nd or 3rd trimester evaluation periods, but starting 28 d earlier. Current temperatures and wind speed were the averages over the feeding periods and are also summarized in Table 3. Temperatures were taken on site, adjacent to the pens daily with a min/max thermometer (TaylorUSA, OakBrooks, Il). The average of the daily minimum and maximum temperatures were used for model evaluation. Wind speeds for cattle housed in western Canada in 20% porosity fenced pens and fed over winter were based on Block et al. (2001). Effective hair depth was set to the NRC (2000) model suggested default of 1.27 cm. With Angus cattle, hide thickness does not affect model prediction of tissue insulation, and with these feeding trials occurring in a dry environment with temperatures below freezing, cows remained clean and dry removing hide condition as a modifier of external insulation. Evaluations were also carried out assuming thermal neutral conditions by using previous and current temperatures of 20°C and a wind speed of 0 km/h.

Table 3. Summary of DMI and ADG prediction inputs (average ± SD) for the 15 pens in each evaluation periodof the data set

	2002–2003		2003–2004		2004–2005	
	2nd trimester	3rd trimester	2nd trimester	3rd trimester	2nd trimester	3rd trimester
Shrunk body weight (kg)	584.5 ± 9.2	589.7 ± 10.3	590.1 ± 6.4	599.6 ± 7.4	628.7 ± 16.9	639.7 ± 23.6
Observed DMI (kg d^{-1})	10.93 ± 0.44	12.70 ± 0.90	11.52 ± 0.78	13.63 ± 0.53	13.10 ± 1.03	12.74 ± 0.63
TDN^{z} (%)	51.74 ± NA	56.38 ± NA	49.75 ± NA	56.38 ± NA	55.56 ± NA	61.05 ± 0.97
Temperature (°C)						
Previous	−7.2 ± 0.3	−13.8 ± 2.2	−10.9 ± 0.1	−10.2 ± 1.5	1.0 ± 0.0	−15.5 ± 1.1
Current	−9.6 ± 1.4	−10.1 ± 2.6	−11.6 ± 1.3	−8.2 ± 1.1	−11.7 ± 0.5	−5.4 ± 1.8
Wind speed (km $h^{-1})^{y}$	5.0 ± NA	5.0 ± NA	5.0 ± NA	5.0 ± NA	5.0 ± NA	5.0 ± NA
Body condition score, 9-point	5.4 ± 0.2	5.4 ± 0.2	4.7 ± 0.3	5.1 ± 0.3	5.7 ± 0.5	5.7 ± 0.5
Days pregnant	158 ± 5	237 ± 5	164 ± 8	243 ± 4	152 ± 8	233 ± 5
Calf birth weight (kg)	45.1 ± 1.7		44.3 ± 2.2		50.0 ± 3.1	
Observed ADG (kg)	0.13 ± 0.09	0.00 ± 0.12	0.07 ± 0.12	0.15 ± 0.14	0.39 ± 0.15	−0.12 ± 0.13

[z] Calculated according to Weiss et al. (1992).
[y] Taken from Block et al. (2001).

Within the NRC (2000) model, tissue insulation value changes with animal age up to one year, after which cattle of all ages are dealt with similarly. With this study focusing on mature cows, exact animal age would not affect predictions of intake or gain. Shrunk body weights after adjusting for conceptus weight, body condition scores (9-point scale), stage of pregnancy, and calf birth weights are summarized in Table 3. The shrunk body weight, body condition scores, and stage of pregnancy data represent averages over the evaluation period. Conceptus corrected observed ADG are presented in Table 3.

Statistical Analyses

For all analysis, the pen was the unit of measurement. A variety of methods were used to address the challenges of statistically analyzing the accuracy and precision of the NRC (2000) model DMI and ADG predictions. Evaluation of accuracy began with regression of observed and predicted DMI or ADG and tested for equality to the isopleth. Additionally, mean square error of prediction was determined and partitioned into bias (difference between means), slope (difference from unity), and residual (random error or lack of correlation) components as described by Rice and Cochran (1984). If there was no relationship ($P > 0.05$) between observed and predicted, residuals (predicted – observed) were regressed on predicted DMI and ADG and tested for equality to the X-axis. If there was no relationship ($P > 0.05$) between residuals and predicted, observed and predicted DMI or ADG means were compared.

Evaluation of precision involved the concordance correlation coefficient (CCC), the 90% total deviation index (TDI_{90}), and coverage probability tests as described by Lin (1992, 2000) and Lin et al. (2002). The CCC is the product of accuracy (deviation from the isopleth) and precision (Pearson correlation coefficient) coefficients and will have a value of 1 when observed and predicted values are in perfect agreement and -1 when they are in perfect disagreement. For these evaluations, arbitrarily selected coverage probability limits were 1.0 kg d^{-1} for DMI and 0.25 kg for ADG as it was deemed that predictions unable to meet these levels of precision would have little practical applicability for beef cattle producers. To protect against type II errors, both the TDI_{90} and coverage probability statistics are considered appropriate only if the relative bias square statistic is ≤ 1.

All analyses except the mean square error partitioning were carried out using SAS software (SAS Institute, Inc., Cary, NC) regression or mixed models procedures or a macro provided by L. Lin (Baxter Health Care Corp., Round Lake, IL).

RESULTS AND DISCUSSION

Dry matter intake and performance results are presented for each year of the study as well as collectively for the 3 yr. Discussion will focus on the 3-yr average results unless a significant deviation occurred in a given year.

Accuracy and Precision of DMI Predictions for the 2nd Trimester Evaluation Period

Regression analysis indicated that when DMI data were evaluated over all 3 yr of the trial using actual environmental conditions (Table 4, Fig. 1), predicted DMI explained 69% of the variation in observed DMI with a $s_{y.x}$ of 0.68 kg d^{-1}. However, the fitted regression differed from the isopleth ($P < 0.01$), indicating inaccurate prediction with a general over-prediction of DMI (1.47 kg d^{-1}). Similar results were observed in each of the 3 yr of the study (Table 4). Mean square error of prediction partitioning indicated that 74% of the inaccuracy was due to bias, 10% due to slope, and 16% due to residual sources. The agreement between observed and predicted DMI was weak, with a CCC of 0.24, while the relative bias square of 2.83 exceeded 1 and invalidated the TDI_{90} and coverage probability statistics. One possible cause of the over-prediction of

Table 4. Accuracy and precision evaluation results for the 2nd trimester predictions of DMI made using actual and thermal neutral environmental conditions

	Actual environment				Thermal neutral			
	2002–2003	2003–2004	2004–2005	All	2002–2003	2003–2004	2004–2005	All
N	15	15	15	45	15	15	15	45
Regression of observed vs. predicted								
Intercept	3.83	−2.46	−23.57	−16.06	12.90	−2.46	−23.59	3.15
SE[z]	10.08	26.05	10.09	2.88	1.73	26.05	9.95	3.66
Slope	0.55	1.07	2.63	2.10	−0.17	1.24	3.06	0.75
SE[z]	0.78	1.99	0.73	0.22	0.15	2.31	0.83	0.31
P value for regression[y]	0.49	0.60	<0.01	<0.01	0.27	0.60	<0.01	0.02
R^2	0.04	0.02	0.50	0.69	0.09	0.02	0.51	0.12
$s_{y.x}$, (kg d^{-1})	0.45	0.80	0.75	0.68	0.43	0.80	0.75	1.14
P value for isopleth[x]	<0.01	<0.01	<0.01	<0.01	<0.01	0.53	<0.01	0.34
Bias (kg d^{-1})	2.01	1.57	0.82	1.47	0.70	0.24	1.10	0.21
Mean square error of prediction	4.50	3.23	1.46	2.92	1.52	0.65	2.06	1.35
Bias (%)	96	80	48	74	33	8	61	3
Slope (%)	0	0	14	10	56	0	13	1
Correlation (%)	4	20	38	16	12	92	26	96
Regression of residual vs. predicted								
Intercept	−3.83	2.46	23.57	16.06	−12.90	2.46	23.59	−3.15
SE	10.08	26.05	10.09	2.88	1.73	26.05	9.95	3.66
Slope	0.45	−0.07	−1.63	−1.10	1.17	−0.24	−2.06	0.25
SE[z]	0.78	1.99	0.73	0.22	0.15	2.31	0.83	0.31
P value for regression[y]	0.57	0.97	0.04	<0.01	<0.01	0.92	0.03	0.43
R^2	0.03	<0.01	0.28	0.37	0.83	<0.01	0.32	0.01
$s_{y.x}$ (kg d^{-1})	0.45	0.80	0.75	0.68	0.43	0.80	0.75	1.14
Means comparison								
Observed (kg d^{-1})	10.93	11.52	13.10	11.85	10.93	11.52	13.10	11.85
Predicted (kg d^{-1})	12.93	13.09	13.92	13.31	11.62	11.29	12.00	11.64
SE[z]	0.08	0.14	0.20	0.14	0.16	0.14	0.19	0.14
P value	<0.01	<0.01	0.01	<0.01	0.01	0.25	<0.01	0.28
Concordance correlation coefficient	0.01	0.01	0.22	0.24	−0.16	0.03	0.15	0.25
Precision coefficient	0.19	0.15	0.71	0.83	−0.30	0.15	0.72	0.34
Accuracy coefficient	0.03	0.05	0.31	0.30	0.52	0.21	0.21	0.74
Total deviation index (90%) (kg d^{-1})	3.49	2.96	1.99	2.81	2.03	1.32	2.36	1.91
Coverage probability,%	2	24	55	29	55	75	45	60
Relative bias square[w]	18.18	3.59	0.79	2.83	0.41	0.08	1.35	0.03

[z] Standard error of the intercept, slope, or least square means.
[y] Significance of the regression relationship between observed or residual and predicted values.
[x] Significance of the test for equality between the fitted regression equation and the isopleth.
[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

DMI for the 2nd trimester evaluation period is that the predicted DMI from the NRC (2000) model incorporates a series of adjustment factors that increase DMI as temperature progressively decreases below 5°C. For the 2nd trimester evaluation period, this would have resulted in a 16% increase in predicted DMI for all 3 yr of the winter feeding trials. Re-evaluating the DMI predictions under the assumption of thermal neutral conditions removes the effect of this adjuster.

When the data from all 3 yr were re-evaluated under the assumption of thermal neutral environmental conditions (Table 4), there was a relationship ($P = 0.02$) between observed and predicted DMI with predicted DMI explaining 12% of the variation in observed DMI with a $s_{y.x}$ of 1.14 kg d^{-1}. This regression relationship did not differ ($P = 0.34$) from the isopleth allowing for the conclusion of accurate prediction. Of the inaccuracy that did exist, mean square error of prediction partitioning found 3% was due to bias, 1% due to slope, and 96% due to residual sources related to lack of correlation. However, the CCC of 0.25 suggests quite low agreement between observed and predicted DMI, and was supported by the large TDI_{90} of 1.91 kg d^{-1} and that only 60% of the pens of cows would be expected to have a difference between observed and predicted DMI of less than 1 kg d^{-1}. Independent evaluation of the 3 yr of data under the assumption of thermal neutral conditions found DMI to be over-predicted in the first and third years, but accurate in the second year of the study (Table 4).

Removing the temperature-based adjustments to DMI predictions for the 2nd trimester evaluation period by assuming thermal neutral conditions did reduce the over-prediction of DMI observed when actual environmental

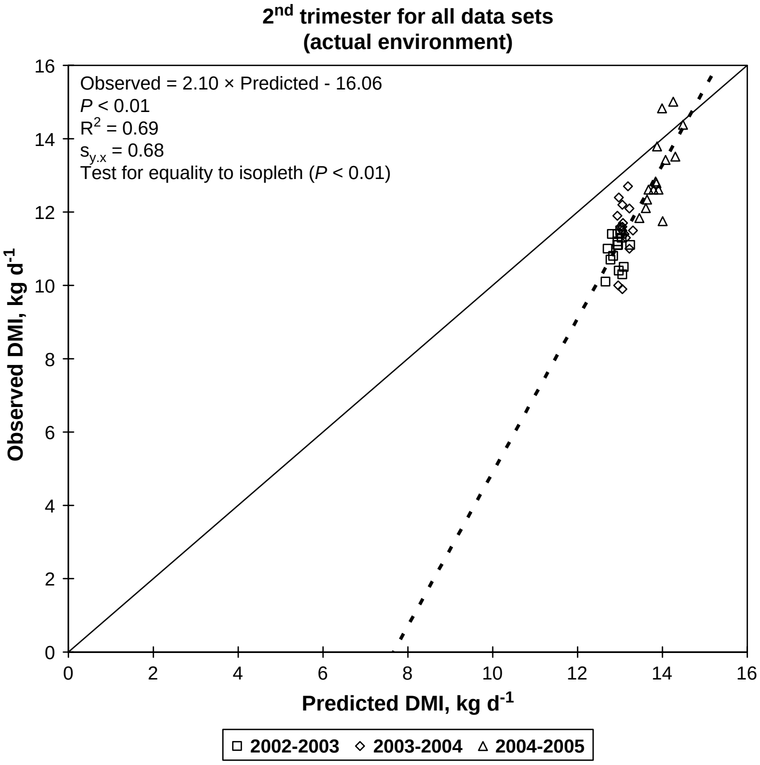

Fig. 1. Evaluation the NRC (2000) model DMI equation accuracy under the actual environmental conditions of the 2nd trimester evaluation period for the 2002–2003, 2003–2004, and 2004–2005 winter feeding trials. Each point represents one pen of six cows. The solid line represents the isopleth (Y = X) line that would indicate accurate prediction. The dashed line represents the fitted regression equation for which the equation, fit statistics, and test for equality to the isopleth are shown.

conditions were used. However, poor precision and agreement between observed and predicted DMI still limits the practical application of the NRC (2000) model predictions of DMI for wintering beef cows. Improvements in prediction accuracy were achieved by removal of the environmental effect components of the DMI prediction equation. This suggests these adjustments are a substantial cause of the inaccurate prediction of DMI during the 2nd trimester; however, it should be noted that in this evaluation process we have only focused on the environmental adjustment.

The NRC (2000) model DMI prediction equation is based on SBW and diet energy density with diet energy values being set to fixed values with low energy diets (NE_{ma} is set at 0.95 Mcal kg^{-1} if diet NE_{ma} is <1.00 Mcal kg^{-1}). In the case of the 2nd trimester evaluation period, diet energy values were low enough that NE_{ma} would be set to 0.95 Mcal kg^{-1} with the result being that predicted DMI stops responding to changes in diet energy density and begins to be based on SBW only. While the NRC (2000) model incorporates the theory that intake of high energy diets is limited by chemo-osmotic factors, there is no transition to any other form of prediction equation when diet energy density decreases to the point where DMI is limited by physical factors including rumen fill or feed mastication time effects (Troelsen and Bigsby 1964; Mertens 1987, 1994; Van Soest 1994; Allen 1996; NRC 2000). This observation suggests further research be directed to development or selection of intake prediction equations based on factors other than diet energy density, especially in the case of wintering beef cows where chemo-osmotic factors are not expected to limit feed intake.

Accuracy and Precision of DMI Predictions for the 3rd Trimester Evaluation Period

When the 3rd trimester DMI data were evaluated collectively (Table 5; Fig. 2), there was no relationship ($P = 0.12$) between observed and predicted DMI, with predicted DMI explaining only 5% of the variation in observed DMI with a $s_{y.x}$ of 0.80 kg d^{-1}. Similar results were noted for the first 2 yr of the study ($P = 0.21$ and 0.72). For the 3rd trimester of the 2004–2005 winter feeding period, there was a relationship ($P = 0.02$) between observed and predicted DMI with predicted DMI explaining 35% of the variation in observed DMI with a $s_{y.x}$ of 0.53 kg d^{-1}. However, the fitted relationship differed ($P < 0.01$) from the isopleth with a general over-prediction of DMI. Of the inaccuracy observed, mean square error of prediction partitioning found 79% was due to bias, 1% due to slope, and 20% due

Table 5. Accuracy and precision evaluation results for the 3rd trimester predictions of DMI made using actual and thermal neutral environmental conditions

	Actual environment				Thermal neutral			
	2002–2003	2003–2004	2004–2005	All	2002–2003	2003–2004	2004–2005	All
N	15	15	15	45	15	15	15	45
Regression of observed vs. predicted								
Intercept	−11.10	19.52	2.18	5.59	7.07	19.52	7.21	13.20
SE[z]	17.92	15.85	4.04	4.74	3.17	15.85	4.88	2.17
Slope	1.78	−0.44	0.77	0.55	0.47	−0.51	0.44	−0.01
SE[z]	1.34	1.17	0.29	0.35	0.26	1.36	0.38	0.18
P value for regression[y]	0.21	0.72	0.02	0.12	0.10	0.72	0.28	0.94
R^2	0.12	0.01	0.35	0.05	0.20	0.01	0.09	<0.01
$s_{y.x}$ (kg d^{-1})	0.88	0.55	0.53	0.80	0.84	0.55	0.62	0.82
P value for isopleth[x]	0.04	0.34	<0.01	<0.01	0.01	<0.01	0.35	<0.01
Bias (kg d^{-1})	0.64	0.13	1.02	0.51	0.71	1.99	0.06	0.92
Mean square error of prediction	1.17	0.33	1.39	0.92	1.40	4.55	0.42	2.03
Bias (%)	35	6	79	28	37	92	1	43
Slope (%)	2	9	1	3	15	1	14	25
Correlation (%)	63	85	20	69	48	7	85	33
Regression of residual vs. predicted								
Intercept	11.10	−19.52	−2.18	−5.59	−7.07	−19.52	−7.21	−13.20
SE[z]	17.92	15.85	4.04	4.74	3.17	15.85	4.88	2.17
Slope	−0.78	1.44	0.23	0.45	0.53	1.51	0.56	1.01
SE[z]	1.34	1.17	0.29	0.35	0.26	1.36	0.38	0.18
P value for regression[y]	0.57	0.24	0.44	0.21	0.07	0.29	0.17	<0.01
R^2	0.03	0.10	0.05	0.04	0.24	0.09	0.14	0.43
$s_{y.x}$ (kg d^{-1})	0.88	0.55	0.53	0.80	0.84	0.55	0.62	0.82
Means comparison								
Observed (kg d^{-1})	12.70	13.63	12.74	13.02	12.70	13.63	12.74	13.02
Predicted (kg d^{-1})	13.34	13.50	13.76	13.53	11.99	11.64	12.67	12.10
SE[z]	0.17	0.10	0.14	0.09	0.23	0.10	0.14	0.11
P value	0.01	0.36	<0.01	<0.01	0.03	<0.01	0.75	<0.01
Concordance correlation coefficient	0.09	−0.04	0.20	0.12	0.33	−0.01	0.28	−0.01
Precision coefficient	0.35	−0.10	0.59	0.23	0.44	−0.10	0.30	−0.01
Accuracy coefficient	0.25	0.42	0.35	0.54	0.74	0.02	0.93	0.56
Total deviation index (90%) (kg d^{-1})	1.78	0.94	1.94	1.57	1.95	3.51	1.07	2.34
Coverage probability (%)	61	90	49	69	57	5	85	49
Relative bias square[w]	0.47	0.05	3.30	0.38	0.51	11.24	0.01	0.70

[z] Standard error of the intercept, slope, or least square means.
[y] Significance of the regression relationship between observed or residual and predicted values.
[x] Significance of the test for equality between the fitted regression equation and the isopleth.
[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

to residual sources. Agreement between observed and predicted DMI was low with a CCC of 0.20. The relative bias square of 3.30 was >1 invalidating the TDI_{90} and coverage probability statistics.

Over the 3 yr of the study, there was also no relationship ($P = 0.21$) between residual and predicted DMI (Table 5). Means comparison found DMI to be over-predicted ($P < 0.01$) by 4%. The CCC of 0.12 suggests no relationship between observed and predicted DMI, and the relative large TDI_{90} of 1.57 kg d^{-1}, and the fact that <70% of the pens of cows evaluated would be expected to have observed and predicted DMI agreeing within 1 kg d^{-1} indicates that there is opportunity and need to improve the DMI predictions. This observation is supported by independent evaluation of the 3 yr of the data, which found DMI to be over-predicted in the first ($P = 0.01$) and third ($P < 0.01$) years of the study, whereas the second year was deemed accurate ($P = 0.36$) (Table 5).

In this study, cows experienced similar temperatures in both the 2nd and 3rd trimester evaluation periods of the first 2 yr of the winter-feeding trials whereas cows in the third year of the winter feeding trial experienced warmer temperatures for the 3rd than the 2nd trimester evaluation period. The temperatures these cows were exposed to result in the NRC (2000) model intake equation increasing predicted DMI by 16% for all evaluation periods except the 3rd trimester of 2004–2005 where intake predictions were increased by only 5%. As with the 2nd trimester evaluation period results, DMI predictions for the 3rd trimester of the winter feeding trials were re-evaluated under the assumption of thermal

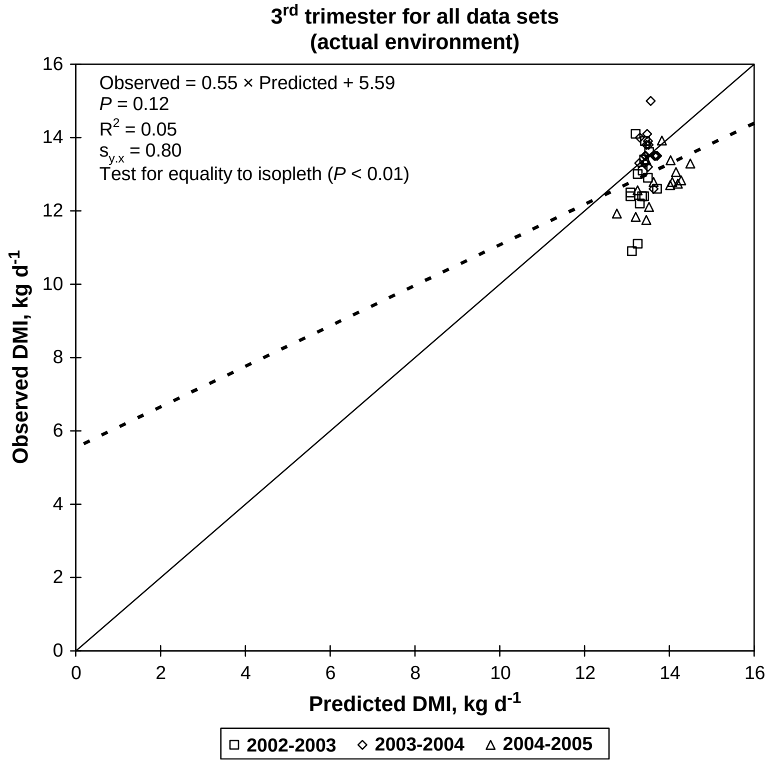

Fig. 2. Evaluation the NRC (2000) model DMI equation accuracy under the actual environmental conditions of the 3rd trimester evaluation period for the 2002–2003, 2003–2004, and 2004–2005 winter feeding trials. Each point represents one pen of six cows. The solid line represents the isopleth (Y = X) line that would indicate accurate prediction. The dashed line represents the fitted regression equation for which the equation, fit statistics, and test for equality to the isopleth are shown.

neutral conditions to remove the effect of these adjusters and determine if this would result in more accurate and precise estimates of DMI by wintering beef cows (Table 5). Under this scenario, no relationship ($P = 0.94$) was found between observed and predicted DMI (Table 5). Predicted DMI explained < 1% of the variation in observed DMI with a $s_{y.x}$ of 0.82 kg d^{-1}. There was a relationship ($P < 0.01$) between residual and predicted DMI indicating inaccurate prediction of DMI. Intake was generally under-predicted with predicted DMI being able to explain 43% of the variation in DMI prediction error. The CCC of -0.01 indicates little agreement between observed and predicted DMI, and is supported by the TDI_{90} of 2.34 kg d^{-1} and the coverage probability of 49%. Independent evaluation of the 3 yr of data under thermal neutral conditions supports the collective results with predicted DMI in the first year going from being over- to under-predicted, from accurate to under-predicted in the second year and in the third year from over-predicted to accurate (Table 5).

The accuracy and precision of DMI predictions made for the 3rd trimester with actual environmental conditions were variable and would limit the practical application of these predictions. This situation was not improved with the assumption of thermal neutral conditions and removal of the temperature adjustments, having the net impact of switching from over- to under-prediction of DMI. This contrasts with the 2nd trimester evaluations, where removing the effect of the temperature-based adjusters by assuming thermal neutral conditions improved DMI predictions. This suggests the inaccuracies and imprecision observed in DMI prediction cannot be attributed solely to the temperature-based adjusters, as removal of these adjusters should have improved the accuracy of the predictions. Several differences existed between the 2nd and 3rd trimester evaluation periods that may explain the differences in observed accuracy and precision of DMI predictions and the differing results achieved by assuming thermal neutral conditions. The cows were in a more advanced stage of pregnancy, diets had been reformulated to supply more energy, and in at least 1 of the 3 yr of data, the cows were experiencing temperatures that were sufficiently warmer than the 2nd trimester evaluation, such that the degree of temperature related adjustment applied by the NRC (2000) model to predicted DMI was altered. Any of these factors could have contributed to the difference in prediction accuracy between the two trimesters. Although it is tempting to presume that the increased energy density of the 3rd trimester evaluation period diets was sufficient to remove the fill effect limitations on DMI and that other factors would then be responsible for the inaccuracies in DMI prediction, there is no conclusive evidence that fill effects did not limit DMI. The possibility for fill effect to persist as a DMI limiting factor may be particularly appropriate with late gestation cows where conceptus growth may begin to impact rumen volume.

Accuracy and Precision of ADG Predictions for the 2nd Trimester Evaluation Period

Figure 3 is a plot of observed vs. predicted ADG under actual environmental conditions for the 2nd trimester evaluation period of all three trials. Both observed and predicted ADG reflect weight gain by cows in addition to the gain expected due to conceptus growth with advancing pregnancy. When the 2nd trimester data of all three winter feeding trials were evaluated collectively (Table 6), there was a relationship ($P < 0.01$) between observed and predicted ADG with predicted ADG explaining 69% of the variation in observed ADG with a $s_{y.x}$ of 0.10 kg. However, this relationship differed ($P < 0.01$) from the isopleth indicating inaccurate prediction of ADG. Of the inaccuracy observed, 42% was attributed to bias, 50% to slope, and 8% to residual error components. There was a general under-prediction of ADG. The only exception being the third year of the study where predictions were inaccurate ($P < 0.01$) but predicted and observed means were similar ($P = 0.17$). The CCC of 0.50 supports moderate agreement between observed and predicted ADG. However, the TDI_{90} of 0.58 kg and the observation that <50% of the pens of cows would be expected to have observed and predicted ADG agree within 0.25 kg would limit practical application of these predictions. There are several possible reasons why ADG would be under-predicted for wintering beef cows during the 2nd trimester evaluation period. Block et al. (2001) have suggested that with feedlot cattle the adjustments made to maintenance energy requirements in response to colder environmental conditions appear to be in excess of the cold stress experienced by cattle and would lead to over-estimation of maintenance energy requirements and subsequent under-estimation of ADG. In their evaluations of feedlot cattle, Block et al. (2001) found that assuming thermal neutral conditions and removing the impact of environment on the maintenance energy requirements of steers did result in predictions of ADG that were closer to observed values. However, although the NRC (2000) model equations addressing the impact of environment on maintenance energy requirement do appear to be suspect, the observations of Block et al. (2001) do not provide conclusive proof that this is a

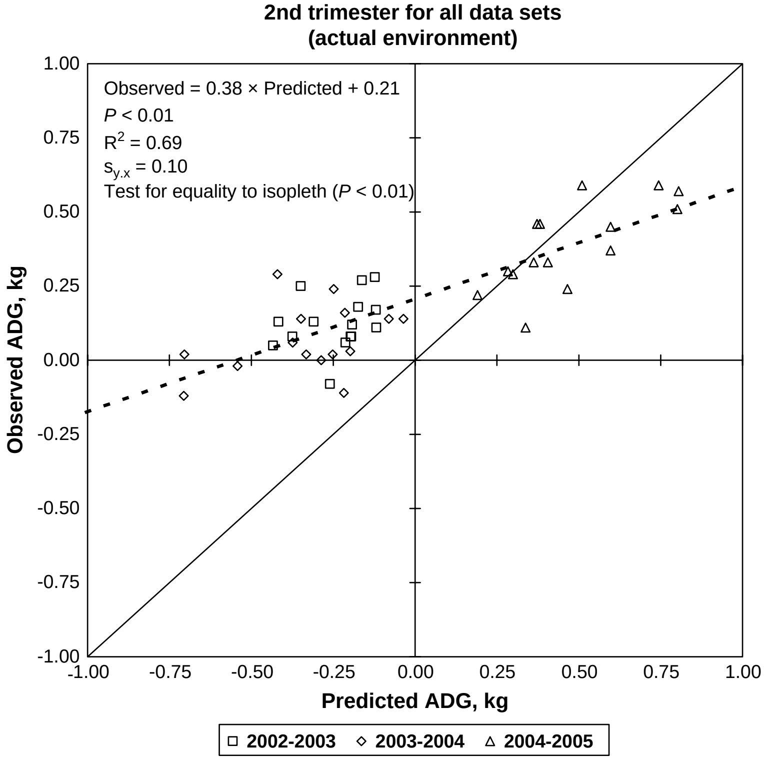

Fig. 3. Evaluation the NRC (2000) model ADG equation accuracy under the actual environmental conditions of the 3rd trimester evaluation period for the 2002–2003, 2003–2004, and 2004–2005 winter feeding trials. Each point represents one pen of six cows. The solid line represents the isopleth (Y = X) line that would indicate accurate prediction. The dashed line represents the fitted regression equation for which the equation, fit statistics, and test for equality to the isopleth are shown.

Table 6. Accuracy and precision evaluation results for the 2nd trimester predictions of ADG made using actual and thermal neutral environmental conditions

	Actual environment				Thermal neutral			
	2002–2003	2003–2004	2004–2005	All	2002–2003	2003–2004	2004–2005	All
N	15	15	15	45	15	15	15	45
Regression of observed vs. predicted								
Intercept	0.19	0.14	0.13	0.21	0.13	−0.02	−0.04	0.06
SE[z]	0.06	0.06	0.07	0.02	0.03	0.05	0.11	0.03
Slope	0.25	0.22	0.54	0.38	−0.06	0.40	0.56	0.38
SE[z]	0.23	0.15	0.15	0.04	0.11	0.22	0.14	0.05
P-value for regression[y]	0.30	0.18	<0.01	<0.01	0.62	0.09	<0.01	<0.01
R^2	0.08	0.14	0.52	0.69	0.02	0.20	0.54	0.54
$s_{y.x}$ (kg d^{-1})	0.09	0.11	0.10	0.10	0.10	0.11	0.10	0.13
P-value for isopleth[x]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bias (kg)	0.37	0.40	0.09	0.23	0.04	0.15	0.39	0.16
Mean square error of prediction	0.16	0.21	0.03	0.13	0.07	0.04	0.18	0.09
Bias (%)	91	82	30	42	3	55	90	30
Slope (%)	4	12	30	50	85	17	4	53
Correlation (%)	5	6	39	8	12	28	6	17
Regression of residual vs. predicted								
Intercept	−0.19	−0.14	−0.13	−0.21	−0.13	0.02	0.04	−0.06
SE[z]	0.06	0.06	0.07	0.02	0.03	0.05	0.11	0.03
Slope	0.75	0.78	0.46	0.62	1.06	0.60	0.44	0.62
SE[z]	0.23	0.15	0.15	0.04	0.11	0.22	0.14	0.05
P value for regression[y]	0.01	<0.01	0.01	<0.01	<0.01	0.02	0.01	<0.01
R^2	0.45	0.67	0.43	0.86	0.87	0.36	0.43	0.76
$s_{y.x}$ (kg d^{-1})	0.09	0.11	0.10	0.10	0.10	0.11	0.10	0.13
Means comparison								
Observed (kg)	0.13	0.07	0.39	0.19	0.13	0.07	0.39	0.19
Predicted (kg)	−0.24	−0.33	0.48	−0.03	0.09	0.21	0.78	0.36
SE[z]	0.03	0.04	0.04	0.05	0.05	0.03	0.04	0.04
P value	<0.01	<0.01	0.17	<0.01	0.52	<0.01	<0.01	0.01
Concordance correlation coefficient	0.03	0.08	0.60	0.50	−0.10	0.26	0.19	0.51
Precision coefficient	0.29	0.37	0.72	0.83	−0.14	0.45	0.74	0.73
Accuracy coefficient	0.12	0.21	0.84	0.60	0.68	0.57	0.25	0.70
Total deviation index (90%) (kg)	0.66	0.75	0.27	0.58	0.43	0.33	0.70	0.50
Coverage probability (%)	18	23	86	49	61	77	16	57
Relative bias square[w]	7.95	3.82	0.37	0.67	0.02	1.07	7.62	0.40

[z] Standard error of the intercept, slope, or least square means.
[y] Significance of the regression relationship between observed or residual and predicted values.
[x] Significance of the test for equality between the fitted regression equation and the isopleth.
[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

problem with ADG predictions, or that it is the only problem with these predictions.

The net energy system used by the NRC (2000) model is based on California feedlot steer data (Lofgreen and Garrett 1968; Garrett 1980) and the base maintenance energy requirements were originally based on empty body weight. The NRC (2000) model maintenance equations use shrunk body weight. No adjustments were made to adjust the maintenance energy equations to use shrunk body weight, and there has not been any evaluation specifically regarding the appropriateness of using maintenance energy equations derived from steer data for cows. These issues allow the equation for determining the maintenance energy requirement of cows to be called into question, independently of whether the impact of environment on maintenance energy requirements is estimated correctly.

Both of the two previous mentioned possible explanations for inaccurate ADG prediction affect predicted ADG only through their impact on maintenance energy requirements and subsequently the energy available for gain. There is also the potential that the equations predicting ADG from intake energy surplus to maintenance requirements could be flawed. With feedlot cattle, the ADG prediction equations take into account changes in the composition of gain that occur as cattle fatten, by increasing the energy content of gain with increasing body weight and with more rapid rates of gain, to reflect the increased fat content of gain occurring in these situations (NRC 2000). The equations predicting ADG of mature cows do not reflect any changes in body composition or the composition of gain. All mature cows are expected to gain 1 kg of SBW for every 5.82 Mcal of NE_m available in excess of maintenance, pregnancy, and lactation requirements (NRC 2000). This expectation has obvious potential to contribute to inaccurate prediction of ADG with wintering beef cows.

With the previous feedlot based evaluations of ADG predictions (Block et al. 2001, 2006) the relatively large observed and predicted ADG provided limited ability to narrow down possible causes of inaccurate ADG prediction because both observed and predicted ADG remained positive. However, with the current evaluation using wintering cows with substantially lower ADG than growing cattle, it was possible to specifically identify a problem with the prediction maintenance requirements when using actual environmental conditions. This stems from the observation that predicted ADG means for the 2002–2003 and 2003–2004 winter feeding trials were negative whereas observed ADG means were positive (Table 6). While this does not exclude a possible issue with the accuracy of the equation relating surplus energy intake to ADG, the only way in which cows can demonstrate positive ADG while being predicted to have negative ADG is for there to be an error in predicting the amount of feed required for maintenance, or in the amount of energy available from the diet. With the diet energy values used in this evaluation being based on the diet nutrient content according to Weiss et al. (1992), large errors in diet energy value estimation are not expected. Additionally, initial evaluations on the first two years of data also made use of ADF based equations from Pennsylvania State for predicting TDN (National Forage Testing Association 1993) and steer digestibility trial results to estimate diet energy values (data not presented). Both of these other approaches resulted in lower estimated diet energy values than the Weiss et al (1992) approach, and would have led to further under-prediction of ADG. Consequently, neither of these alternate approaches supports the concept that under-prediction of ADG resulted from under-estimation of diet energy availability.

Re-evaluation of 2nd trimester ADG predictions under the assumption of thermal neutral conditions (Table 6) has the effect of removing the impact of the suspect environmental effect equations. When all three years of 2nd trimester ADG data were evaluated collectively under the assumption of thermal neutral conditions, there was a relationship ($P < 0.01$) between observed and predicted ADG with predicted ADG explaining 54% of the variation in ADG with a $s_{y.x}$ of 0.13 kg. This relationship, however did differ ($P < 0.05$) from the isopleth indicating inaccurate prediction of ADG with 30% of the inaccuracy due to bias, 53% due to slope, and 17% due to residual error components. Gains were generally over-predicted, although to a lesser degree than the under- prediction that occurred when using actual environmental conditions (Table 6). The CCC of 0.51 indicates moderate agreement between observed and predicted ADG and is supported by the TDI_{90} of 0.50 kg and the expectation that only 57% of the pens of cows would have predicted and observed ADG agree within 0.25 kg. These results suggest that there is a limit to the practical application of these predictions and that refinement to the prediction equations is required.

The assumption of thermal neutral conditions for the 2nd trimester of the winter feeding trials resulted in predictions of ADG that were closer to observed ADG although they still lacked accuracy and precision. In many cases where ADG was under-predicted when using actual environmental conditions, ADG became over-predicted when thermal neutral conditions were assumed. This suggests that the cows were affected by environmental conditions, but not as severely as suggested by the model equations. Unfortunately, from a model evaluation viewpoint, when thermal neutral conditions were assumed, all observed and predicted ADG means were positive. Had any of the prediction means remained negative while the cows demonstrated positive gains, it would have been clear evidence that the base maintenance energy requirement equations were inaccurate. As this did not occur, no firm conclusions can be made regarding whether the inaccuracy in estimating maintenance energy requirements lies with the base maintenance equations, or the environment-based adjustments.

Accuracy and Precision of ADG Predictions for the 3rd Trimester Evaluation Period

Figure 4 is a plot of observed vs. predicted ADG under actual environmental conditions for the 3rd trimester evaluation period of all three trials. As with the 2nd trimester, both observed and predicted ADG reflect weight gain by cows occurring after the gain expected due to conceptus growth with advancing pregnancy was accounted for. When all 3 yr of 3rd trimester ADG data were evaluated collectively, there was no relationship ($P = 0.18$) between predicted and observed ADG, with predicted ADG explaining only 4% of the variation in observed ADG with a $s_{y.x}$ of 0.17 kg. There was a relationship ($P < 0.01$) between residual and predicted ADG indicating inaccurate prediction. Predicted ADG was able to explain 49% of the variation in predicted ADG error. Observed and predicted ADG means were quite similar (Table 7) with ADG being under-predicted with low predictions and over-predicted with high predictions (Fig. 4). When combined with the observation that the range in actual ADG was less variable than predicted ADG, this suggests that the NRC (2000) model equations were sensitive to inputs that the cows were not experiencing (Fig. 4). The CCC of 0.20 indicates very weak relationship between observed and predicted ADG with the large TDI_{90} of 0.38 and coverage probability of 70% indicating a lack of precision in ADG prediction. When the 3 yr of data were evaluated independently, ADG in the first year was under-predicted; very similar but inaccurate in the second year with low predicted ADG being

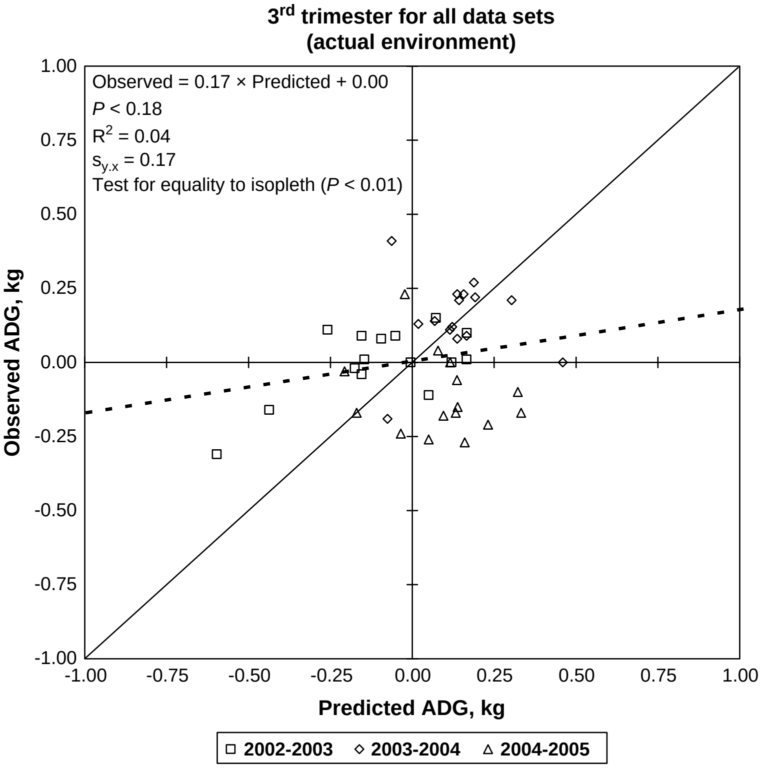

Fig. 4. Evaluation the NRC (2000) model ADG equation accuracy under the actual environmental conditions of the 3rd trimester evaluation period for the 2002–2003, 2003–2004, and 2004–2005 winter feeding trials. Each point represents one pen of six cows. The solid line represents the isopleth (Y = X) line that would indicate accurate prediction. The dashed line represents the fitted regression equation for which the equation, fit statistics, and test for equality to the isopleth are shown.

under-predicted and high predicted ADG being over-predicted indicating the model was more sensitive than the cows; and the third year being over-predicted (Table 7).

Overall, during the 3rd trimester, ADG predictions made using actual environmental conditions were positive. The only exception was 2002/2003, when the prediction was slightly negative. As such, this set of data cannot be used to provide any additional support to the idea that part of the error in ADG predictions can be specifically attributed to errors in maintenance energy requirement determinations. Additionally, with ADG predicted using actual environmental conditions being either very similar to observed ADG or over-predicted, removing the effect of cold environments on the prediction of ADG is not expected to result in improved ADG prediction accuracy or precision. This was the case for all 3 yr (Table 7) with no relationship ($P = 0.67$) between observed and predicted ADG, with predicted ADG explaining $<1\%$ of variation in observed ADG with a $s_{y.x}$ of 0.17 kg. Inaccurate prediction was identified based on a relationship ($P < 0.01$) between residual and predicted ADG with predicted ADG explaining 67% of the variation in ADG prediction error. Gain was generally over-predicted with CCC of -0.01 indicating no relationship between observed and predicted ADG, while a relative bias square value of 2.84 invalidating the TDI_{90} and coverage probability statistics. A similar over prediction of gain was noted for each year of the study when thermal neutral conditions were assumed (Table 7).

The authors recognize that the NRC (2000) approach to modeling intake and performance of cattle is based on a continuum of research that has led to refinement and improvement of the equations and that the approach by NRC (2000) is widely adopted by industry. However, the results of the evaluations carried out in this study indicate that the DMI and energy requirement equations show a lack of precision and accuracy for mature beef cows housed under western Canadian environmental conditions. This lack of precision and accuracy limits their use under commercial conditions and indicates that further research is required to improve their prediction accuracy. The most important components of the evaluations carried out in this study are the suggestions for model refinement that result. These include investigation into development of alternative DMI prediction equations to reflect intake limiting factors other than diet energy density, a more thorough evaluation of the effects of environment on energy requirements, a re-evaluation of maintenance requirement equations for pregnant, non-lactating cows,

Table 7. Accuracy and precision evaluation results for the 3rd trimester predictions of ADG made using actual environmental conditions

	Actual environment				Thermal neutral			
	2002–2003	2003–2004	2004–2005	All	2002–2003	2003–2004	2004–2005	All
N	15	15	15	45	15	15	15	45
Regression of observed vs. predicted								
Intercept	0.04	0.15	−0.10	0.00	−0.01	0.12	−0.02	0.04
SE[z]	0.03	0.05	0.04	0.03	0.06	0.18	0.17	0.06
Slope	0.36	−0.02	−0.19	0.17	0.03	0.05	−0.14	−0.05
SE[z]	0.12	0.28	0.24	0.13	0.15	0.31	0.26	0.11
P value for regression[y]	0.01	0.96	0.44	0.18	0.85	0.87	0.60	0.67
R^2	0.41	<0.01	0.05	0.04	<0.01	<0.01	0.02	<0.01
$s_{y.x}$ (kg d^{-1})	0.10	0.14	0.14	0.17	0.12	0.14	0.14	0.17
P value for isopleth[x]	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bias (kg)	0.10	0.01	0.21	0.03	0.30	0.43	0.77	0.50
Mean square error of prediction	0.04	0.04	0.10	0.06	0.16	0.23	0.69	0.34
Bias (%)	26	0	48	2	59	85	93	75
Slope (%)	51	50	37	48	31	6	4	17
Correlation (%)	23	50	19	50	10	9	3	8
Regression of residual vs. predicted								
Intercept	−0.04	−0.15	0.10	0.00	0.01	−0.12	0.02	−0.04
SE[z]	0.03	0.05	0.04	0.03	0.06	0.18	0.17	0.06
Slope	0.64	1.02	1.19	0.83	0.97	0.95	1.14	1.05
SE[z]	0.64	1.02	1.19	0.83	0.97	0.95	0.26	0.11
P value for regression[y]	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
R^2	0.69	0.49	0.66	0.49	0.77	0.42	0.60	0.67
$s_{y.x}$ (kg d^{-1})	0.10	0.14	0.14	0.17	0.12	0.14	0.14	0.17
Means comparison								
Observed (kg)	0.00	0.15	−0.12	0.01	0.00	0.15	−0.12	0.01
Predicted (kg)	−0.10	0.14	0.09	0.04	0.30	0.58	0.66	0.51
SE[z]	0.05	0.03	0.04	0.03	0.05	0.03	0.04	0.03
P value	0.13	0.80	<0.01	0.42	<0.01	<0.01	<0.01	<0.01
Concordance correlation coefficient	0.46	−0.01	−0.10	0.20	0.02	0.01	−0.01	−0.01
Precision coefficient	0.64	−0.01	−0.22	0.20	0.05	0.05	−0.15	−0.06
Accuracy coefficient	0.72	0.99	0.47	0.97	0.34	0.14	0.06	0.23
Total deviation index (90%) (kg)	0.32	0.31	0.51	0.38	0.65	0.79	1.36	0.96
Coverage probability (%)	77	78	54	70	41	17	1	19
Relative bias square[w]	0.31	0.00	0.73	0.02	1.25	5.06	11.79	2.84

[z] Standard error of the intercept, slope, or least square means.

[y] Significance of the regression relationship between observed or residual and predicted values.

[x] Significance of the test for equality between the fitted regression equation and the isopleth.

[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

and refinement of ADG prediction equations to reflect changes in body composition. As a consequence of the current evaluation being focused on the animal side of the equations, these suggestions for improvements have also focused on the animal side of the equations. This is not meant to imply that the energy supply equations involved in conversion of TDN to NE_m are beyond consideration and not deserving of closer scrutiny, only that the current evaluation provides little insight in this area. In addition to the suggestions for model refinement, and perhaps equally important for future model use is an indication of what level of accuracy and precision can be expected from application of a model and how this compares with the requirements for practical application. This was a challenge in the current evaluation and was the reason for arbitrarily selecting 1 kg d^{-1} for DMI and 0.25 kg for ADG coverage probability limits and use of a 90% TDI. Future models containing refinements intended to improve functionality would benefit from having an indication of the level of precision that can be expected, and the conditions under which these expectations are appropriate.

CONCLUSIONS

The lack of accuracy and precision found in the NRC (2000) predictions of energy requirements and DMI of wintering beef cows in western Canada in this evaluation and the failure to resolve these deficiencies by assuming thermal neutral conditions call into question the practical applicability of this model for use in beef cow feeding management. Improvements in predictions may be possible through development of alternate intake equations that reflect the different factors that limit feed intake, maintenance requirement equations that are specific to cows and not feedlot cattle, and gain equations that reflect changes in the composition of gain. The inability of the current equations to accurately and precisely predict intake and gain of wintering beef cows should not be viewed as a failure, but rather represents a success in providing direction for future research. For practical application as a management tool, additional research is needed that is focused specifically at addressing the currently identified limitations of the NRC (2000) model DMI and energy requirement equations.

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