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Evaluation of Dry Matter Intake and Average Daily Gain Predicted by the Cornell Net Carbohydrate and Protein System in Crossbred Growing Bulls Kept in a Traditionally Confined Feeding System in China*

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ABSTRACT : Two separate animal trials were conducted to evaluate the coincidence of dry matter intake (DMI) and average daily gain (ADG) predicted by the Cornell Net Carbohydrate and Protein System (CNCPS) and observed actually in crossbred growing bulls kept in a traditionally confined feeding system in China. In Trial 1, 45 growing Simmental×Mongolia crossbred F1 bulls were assigned to three treatments (T1-3) with 15 animals in each treatment. Trial 2 was conducted with 60 Limousin×Fuzhou crossbred F2 bulls allocated to 4 treatments (t1-4). All of the animals were confined in individual stalls. DMI and ADG for each bull were measured as a mean of each treatment. All of the data about animals, environment, management and feeds required by the CNCPS model were collected, and model predictions were generated for animals on each treatment. Subsequently, model-predicted DMI and ADG were compared with the actually recorded results. In the three treatments in Trial 1, 93.3, 80.0 and 73.3% of points fell within the range from -0.4 to 0.4 kg/d for DMI mean bias; similarly, in the four treatments in Trial 2, about 86.7, 73.3, 73.3 and 80.0% of points fell within the same range. These results indicate that the CNCPS model can accurately predict DMI of crossbred bulls in the traditionally confined feeding system in China. There were no significant differences between predicted and observed ADG for T1 ($p = 0.06$) and T2 ($p = 0.09$) in Trial 1, and for t1 ($p = 0.07$), t2 ($p = 0.14$) and t4 ($p = 0.83$) in Trial 2. However, significant differences between predicted and observed ADG values were observed for T3 in Trial 1 ($p<0.01$) and for t3 in Trial 2 ($p = 0.04$). By regression analysis, a statistically different value of intercept from zero for the regression equation of DMI ($p<0.01$) or an identical value of ADG ($p = 0.06$) were obtained, whereas the slopes were significantly different ($p<0.01$) from unity for both DMI and ADG. Additionally, small root mean square error (RMSE) values were obtained for the unbiased estimator of the two variances (DMI and ADG). Thus, the present results indicated that the CNCPS model can give acceptable estimates of DMI and ADG of crossbred growing bulls kept in a traditionally confined feeding system in China. (**Key Words :** CNCPS Model, Dry Matter Intake, Average Daily Gain, Growing Bulls)

INTRODUCTION

Cattle are utilized to convert feed nutrients to human food and are a major source of human nutrients (Beermann and Fox, 1998). By accounting for farm-specific management, environmental and feed characteristics, more accurate predictions of the growth and milk production of cattle and nutrient excretion in diverse production situations have been possible (Fox et al., 2004). Also, an accurate prediction of animal performance including dry matter intake, average daily gain and feed conversion efficiency will help animal producers to obtain maximum returns (Zhao et al., 2008).

The Cornell Net Carbohydrate and Protein System (CNCPS) is a mathematical model to evaluate diet and animal performance that was developed from basic principles of rumen function, microbial growth, feed digestion and passage and animal physiology (Fox et al., 2004). Also, the CNCPS model contains a biologically based structure to evaluate diets for all classes of cattle (i.e. beef, dairy, and dual purpose) based on consideration of the

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existing animals, feeds, management and environmental conditions. Researchers have investigated the DMI predictions of the CNCPS with Holstein and dual-purpose lactating cattle in the tropics (Molina et al., 2004). Tedeschi and Fox (2001) also concluded that the CNCPS can be used to describe animal requirements and the biological values of tropical feeds for cattle kept in the tropics for developing feeding recommendations in specific production situations. However, such conditions as the environment to which the animals are exposed, composition of rations fed to animals, and cattle breeds vary in different countries or regions. In China, using local breeds of beef cattle kept in a pen-feeding system, Zhao et al. (2008) found that the CNCPS model was an acceptable model to predict dietary DMI and ADG of the local breeds of Chinese beef cattle. Nevertheless, the confined feeding system is very popular in China as a beef cattle feeding practice, and the data about evaluation of prediction of DMI or ADG by the CNCPS model in beef cattle kept in this traditional system is rather scarce. Therefore, the purpose of the present study was to evaluate the coincidence of DMI and ADG values predicted by CNCPS v5.0 and observed actually in growing crossbred bulls kept in the confined feeding system in China.

MATERIALS AND METHODS

In the present study, two separate animal trials were conducted using different growing bulls kept in the traditional confined feeding system in China. All of the information was actually collected on-site and entered into the CNCPS v5.0 and the predicted outcomes were compared with the feeding results. The two trials were all conducted at China Agricultural University Beef Experiment and Demonstration Center located in Daxing District, Beijing. All bulls were de-wormed before the feeding trials started.

Trial design

The selected animals were blocked on the basis of body weight (BW) and ages (months) as follows:

In Trial 1, 45 growing Simmental×Mongolia crossbred F1 bulls (14 months age, 388±32 kg average BW) were assigned to three treatments, with 15 animals in each treatment, in a completely randomised design according to BW so that differences and variances in initial BW among treatment groups were minimized. All of the bulls were housed individually in stalls. Three isonitrogenous diets (Table 1) were formulated with different levels of palm kernel cake (PKC) and fed to bulls. Animals in Treatment 1 (T1) were fed on a maize grain and maize stalk silage-based diet with no PKC included, while the animals in Treatments 2 (T2) and 3 (T3) were fed the same diet including 12 or 24% PKC (DM basis), respectively. Rations were mixed as TMR diets which were fed *ad libtium* to animals and daily intake of individual bulls was accurately recorded by quantitative collection of daily orts. Fresh water was freely accessible to animals. During the experimental period, the bulls were offered their test diets *ad libitum* for a 12 d adjustment period, followed by an 84-d data collection period. The trial lasted for a total of 96 d from February 2008 to May 2008.

In Trial 2, 60 Limousin×Fuzhou crossbred F2 bulls (13 months age, 345±23 kg average BW) were assigned randomly to four treatments according to BW, with 15 animals in each treatment. The animals were confined individually in stalls similar to Trial 1. All animals were fed with the same basal diet (Table 1) with the exception of supplemental lysine (a commercial rumen-protected lysine product purchased from Libao Chemical Technology Co, Ltd., Jinan, China). Animals were supplemented individually with lysine at levels of 0, 5, 10 and 15 g/d in treatment 1 (t1), treatment 2 (t2), treatment 3 (t3) and treatment 4 (t4), respectively. During the trials, the bulls were offered the treatment diet *ad libitum* for a 14 d adjustment period and a 112 d data collection period. The trial lasted for a total of 126 d from June 2008 to October 2008.

The average temperature and other environment inputs are listed in Table 2 (descriptions of the model inputs were common to all the animals within the trial).

Sampling and analytical procedures

Diets provided to each animal in the two trials were accurately weighed and recorded before morning feeding and feed orts were collected and weighed 1 h after evening feeding. Both feed and orts samples were collected daily and brought to the laboratory for DM determination. The remainder was refrigerated (-4°C) until chemical analyses. Feed samples were analyzed mainly following the CNCPS recommended procedures as described by Zhao et al. (2008).

Feed compositions based on the CNCPS model were described as carbohydrate and protein fractions and their digestion rates, which were used to compute the amount of structural carbohydrates (SC) and non-structural carbohydrates (NSC) available for each of two microbial pools (Sniffen et al., 1992). Data were entered into the CNCPS v5.0 User-Created Feed Database. Values including NDICP, ADICP, peNDF, degradation rates and intestinal digestion rates were calculated based on the CNCPS v5.0 Temperate Feeds Library using either i) direct comparison of the feeds from the CNCPS v5.0 Temperate Feeds Library, or ii) the CNCPS v5.0 Temperate feeds with the lowest deviation of NDF, lignin (Lig) and CP values, as shown by Eq. (1):

Table 1. Ingredient and composition of the diets fed to cattle in Trial 1 and Trial 2[a]

Item	Trial 1			Trial 2			
	T1	T2	T3	t1	t2	t3	t4
Ingredient (% DM)							
Maize	30.0	21.0	12.0	33.0	33.0	33.0	33.0
Soybean meal	6.0	3.0	0.0	-	-	-	-
PKC [b]	0.0	12.0	24.0	-	-	-	-
Cottonseed meal	5.3	6.5	8.0	3.4	3.4	3.4	3.4
Brewers dried grain	15.9	14.9	13.6	10.9	10.9	10.9	10.9
Maize stalk silage	40.0	40.0	40.0	50.0	50.0	50.0	50.0
Limestone	0.3	0.4	0.5	0.8	0.8	0.8	0.8
Di-calcium phosphate	0.6	0.3	0.0	-	-	-	-
Sodium bicarbonate	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Vitamin/trace mineral premix [c]	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Rumen protected Lys (g/d) [d]	-	-	-	0	5	10	15
Composition[e]							
ME (MJ/kg DM)	10.7	9.7	8.7	10.1	10.1	10.1	10.1
NE_m (MJ/kg DM)	6.9	6.1	5.1	6.4	6.4	6.4	6.4
NE_g (MJ/kg DM)	4.4	3.6	2.8	3.9	3.9	3.9	3.9
CP (% DM)[f]	12.7	12.6	12.7	11.2	11.2	11.2	11.2
NDF (% DM)	38.9	45.3	51.6				
ADF (% DM)	28.2	32.1	36.0				
C_a (% DM)	0.62	0.62	0.61	0.5	0.5	0.5	0.5
P (% DM)	0.49	0.49	0.4	0.3	0.3	0.3	0.3

[a] Trials 1and Trial 2 were conducted on the same beef feedlot farm.
[b] PKC = Palm kernel cake.
[c] Contain 10,000 mg/kg Fe; 2400 mg/kg Cu; 8400 mg/kg Mn; 13,000 mg/kg Zn; 160 mg/kg I; 70 mg/kg Se; 100 mg/kg Co; 960,000 IU/kg VA; 200,000 IU/kg VD3; and 7,500 mg/kg VE.
[d] Treatments in Trial 2 are different only in the lysine supplement. t1 was no lysine added, and t2, 3 and 4 were lysine added at 5, 10, 15 g/d to each animal, respectively.
[e] ME, NEm and NEg were calculated from CNCPS model. CP, aNDF, ADF, Ca, and P are actually analyzed values. ME = Metabolizable energy; NEg = Net energy for growth; NEm = Net energy for maintenance; CP = Crude protein; aNDF = Neutral detergent fibre; ADF = Acid detergent fibre.
[f] Values are actually analyzed results from the basal diets, without considering the supplemental rumen-protected lysine.

$$\text{Deviation} = \frac{\sqrt{(NDF_{CNCPS} - NDF_{Feed})^2}}{NDF_{CNCPS}} + \frac{\sqrt{(Lig_{CNCPS} - Lig_{Feed})^2}}{Lig_{CNCPS}} + \frac{\sqrt{(CP_{CNCPS} - CP_{Feed})^2}}{CP_{CNCPS}} \quad (1)$$

The above two calculations (by direct comparison and Eq. (1)) ensured that the feed with the most similar fiber and protein content within a feed category was selected to provide the missing values (Tedeschi et al., 2002).

Measurement of animal performance

Before morning feeding in both trials, animal body weights were measured twice on the final 2 consecutive days of both adjustment and total periods. The average and initial body weights were entered in the CNCPS model V5.0. As shown in Table 2, the mature body weight of the bulls was assumed as 550 kg (shrunk body weight), which should represent an average level of body weight in the current beef finishing system in China (Zhao et al., 2008).

Model inputs and outputs

Environmental temperature and relative humidity were recorded twice daily at 4:00 and 16:00 using a hygrothermograph (EA-WSD, Huarui Corporation, Beijing).

All data and observed information were entered into the model. The descriptions of model inputs used for the evaluation of DMI and ADG predictions by CNCPS are listed in Table 2 and 3. For each bull, individual body weight records over the 84 d period in Trial 1 and the 112 d period in Trial 2 were used to generate predicted DMI. Additionally, the actual DMI was used to predict ADG.

ME values of the diets were evaluated by the CNCPS v5.0 computer model (level 2) and the results are listed in Table 1. Other parameters were calculated by the CNCPS v5.0 computer model using the inputs. ADG values were

Table 2. Description of the model inputs common to all the animals, within each trial group, used for evaluation of the DMI and ADG predictions by the CNCPS model

Item	Trial 1	Trial 2
Initial date	2,008.2	2,008.6
Duration (d)	84	112
Animal description		
Breed	Simmental×Mongolia Crossbred F1	Limousin×Fuzhou Crossbred F2
Animal type	growing	growing
Sex	Bull	Bull
Grading system	250 g/kg body fat	250 g/kg body fat
Body weight at 250 g/kg body fat (kg)	550	550
Management		
Additive	None	None
Added fat in diet	No	No
Environment		
Average temperature (°C)	-0.5	19.5
Average relative humidity (%)	50	60.5
Wind speed (km/h)	1.6 (default)	1.6 (default)
Previous temperature (°C)	-2	17
Previous relative humidity (%)	46	63
Storm exposure	No	No
Hair depth (cm)	0.64 (default)	0.64 (default)
Mud depth (cm)	No	No
Cattle panting	None	None
Minimum night temperature (°C)	-12	-6
Activity	Confined by stalling	Confined by stalling

predicted based on ingested metabolizable energy allowance automatically calculated by the computer model. The equations used are not included here, and can be found in the literature (Fox et al., 2004).

Statistical evaluation criteria

When developing and evaluating a model, one should incorporate important variables despite the foreseeable confines of our scientific knowledge and current modeling techniques. The adequacy tests of the model should be designed to evaluate the model and identify weaknesses that need to be addressed. Adequate statistical analysis is an indispensable step especially for predictive models (Tedeschi, 2006).

Model predictions were evaluated for accuracy and precision. Accuracy measures how closely model-predicted values are to the true values, while precision measures how close individual model-predicted values are to each other. In other words, accuracy is the model's ability to predict the right values and precision is the ability of the model to predict similar values consistently (Tedeschi, 2006).

Model-predicted performance was also evaluated using analysis of linear regression between the observed and the model-predicted values. The model-predicted values were plotted in the *X*-axis while the observed values were plotted in the *Y*-axis because the observed values contain natural

Table 3. Description of the model inputs used for the DMI and ADG predictions by the CNCPS

	Trial 1			Trial 2			
	T1	T2	T3	t1	t2	t3	t4
Animal description							
Age (months)	14	14	14	13	13	13	13
No. in group	15	15	15	15	15	15	15
Initial body weight (kg)	386.7±34.7	392.7±33.1	384.8±28.4	338.3±17.6	347.8±25.8	347.0±29.0	345.6±16.6
Final body weight (kg)	492.0±38.5	504.6±42.1	487.7±35.4	472.7±30.7	473.9±32.3	486.1±31.7	466.8±27.2
ADG (kg/d)[a]	1.25±0.21	1.33±0.24	1.23±0.19	1.20±0.18	1.13±0.14	1.24±0.18	1.08±0.15

[a] ADG = Average daily gain (kg/d).

Table 4. Comparison between observed DMI and CNCPS-predicted DMI (kg/d)[a]

	Trial 1			Trial 2			
	T1	T2	T3	t1	t2	t3	t4
No. in treatments	15	15	15	15	15	15	15
CNCPS-predicted DMI	8.60±0.41	8.79±0.48	8.74±0.40	8.55±0.32	8.73±0.47	8.76±0.52	8.69±0.35
Observed DMI	8.53±0.42	8.60±0.39	8.61±0.22	8.44±0.12	8.52±0.25	8.51±0.39	8.48±0.22
Mean bias[b]	0.07	0.18	0.13	0.12	0.19	0.25	0. 21
RMSPE[c]	0.16	0.24	0.13	0.11	0.19	0.19	0.14

[a] Observed and predicted DMI values as *Y*- and *X*- variates, respectively.
[b] Mean bias is the average of CNCPS-predicted minus observed DMI.
[c] RMSPE = Root mean square prediction error.

variability whereas the model-predicted values are deterministic with no random variation (Mayer and Butler, 1993). In this plot format, data points lying below and above the $Y = X$ line indicate over- and under-prediction by the mathematical model, respectively (Tedeschi, 2006). As the model was universally applied to the two trials, we analysed the data of the two trials in one regression. The reported R^2 and mean square error (MSE) were obtained from the linear regression.

Mitchell (1997) and Mitchell and Sheehy (1997) proposed an empirical evaluation method. In this case, the deviations (model-predicted minus observed values) are plotted against the observed values and the percentage of points lying within an acceptable range is based on the purpose of the model; usually the limits of 95% confidence interval of the observed values are used as a guideline. Ultimately, the differences between observed and model-predicted values provide adequate information on the extent to which the model fails to simulate the system (Tedeschi, 2006). In the current study, two trials were conducted in the same feedlots using two beef cattle breeds purchased from different areas of the northern part of China. Body fat at 250 g/kg (trace of marbling) was set as the target, and mature shrunk body weight (MSBW, expected finished weight at the target body fat) was set at 550 kg, which should represent an average level of body fat in the current confined beef finishing system in China. At the same time, a limit of -0.4 and 0.4 kg/d for DMI comparisons and a limit of -0.1 and 0.1 kg/d for ADG comparisons were established. This range approximates the values delimiting a 95% confidence interval of DMI and ADG means observed in the trials (Zhao et al., 2008).

The mean bias, the mean square prediction error (MSPE) (Bibby and Toutenburg, 1997), and the statistical measures of model performance (Mitchell and Sheehy, 1997) were calculated as described by Tedeschi et al. (2000).

All statistical analyses were performed using SAS Version 8.02. Estimates of regression values were obtained using the statement of PROC REG, and the statistical comparison between predicted and observed values was performed using the two-sample *t*-test.

RESULTS

Comparisons between CNCPS model-predicted and observed DMI are presented in Table 4. The mean biases between the model-predicted and observed DMI in the two trials were smaller than 0.25 kg/d. However, less bias was observed in Trial 1 than in Trial 2. For Trial 1, the least mean bias was observed in T1 (0.07 kg/d) and the RMSPE in T3 (0.13), while for Trial2 the most accurate prediction was observed in t1 with the least mean bias (0.12 kg/d) and lowest RMSPE values (0.11). Correspondingly, the least accurate prediction was observed in t3 of Trial 2 with a mean bias of 0.25 kg/d and a RMSPE of 0.19, which revealed much more scattered values than in other treatments.

A plot of CNCPS model-predicted *versus* observed DMI for the two trials had an even distribution of points along the unity line and did not have any systematic prediction error (Figure 1A). It should be noted that all the points were gathered based on their own trials in the plot. Consequently, the proportion of deviation points lying between -0.4 and 0.4 kg/d (a 95% confidence interval as shown in Materials and Methods section) was high (82.2 and 78.3% for Trial 1 and 2, respectively) (Figure 1B), which would be a recommended limit for practical acceptance.

A comparison between CNCPS model-predicted and observed ADG is shown in Table 5. Mean biases between predicted and observed ADG in overall treatments were very low, suggesting little variation of predicted ADG between animals within the treatment. The lower ADG mean bias in Trial 2 compared with Trial 1 indicated a better (ADG) prediction of CNCPS for Trial 2.

The relationship between CNCPS predicted and observed ADG for Trials 1 and 2 is illustrated in Figure 2. From the asymmetric distributions of points along the unity line, a small systematic prediction error was observed (Figure 2A).

Estimates of regression parameters including DMI and ADG between observation and CNCPS-prediction are presented in Table 6. The regression equation between observed (*Y* variate) and predicted (*X* variate) DMI was:

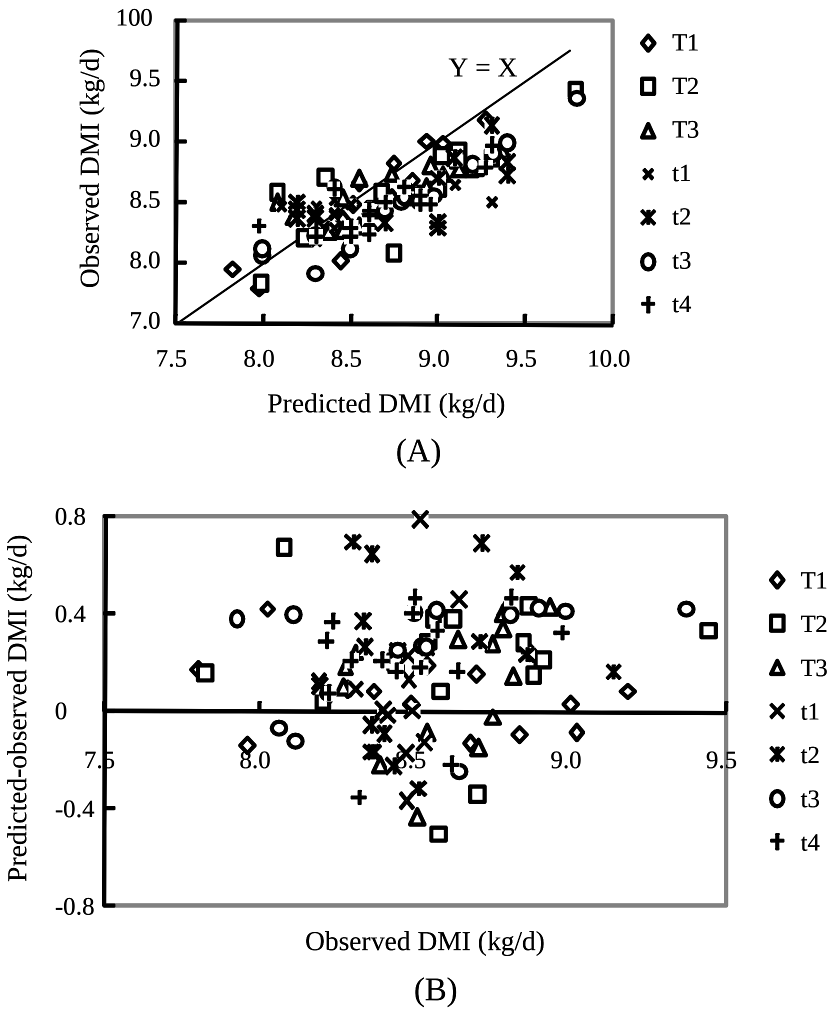
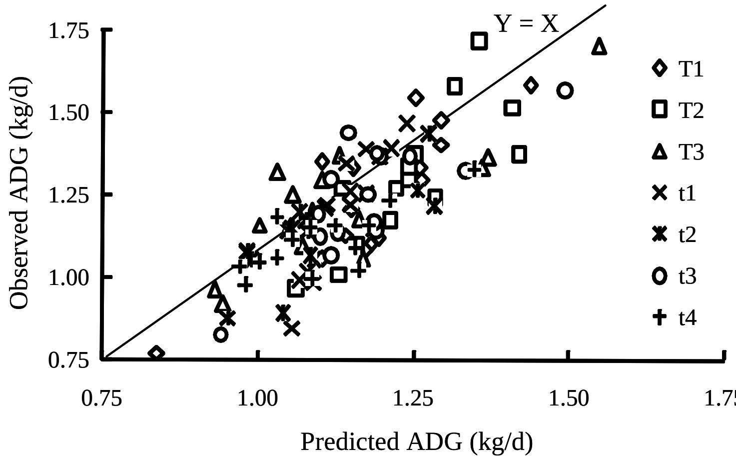


Figure 1. Prediction of DMI by CNCPS. Relationship between observed DMI and predicted DMI (A) and between observed DMI and predicted minus observed DMI (B). All data are from Trials 1 and 2. Variation of CNCPS-predicted minus observed DMI vs. observed DMI indicated that about 82.2% (93.3, 80.0 and 73.3% for T1, T2 and T3 in Trial 1, respectively) and 78.3% (86.7, 73.3, 73.3 and 80.0% for t1, t2, t3 and t4 in Trial 2, respectively) of the points are within the range -0.4 to 0.4 kg/d for Trials 1 and 2, respectively.

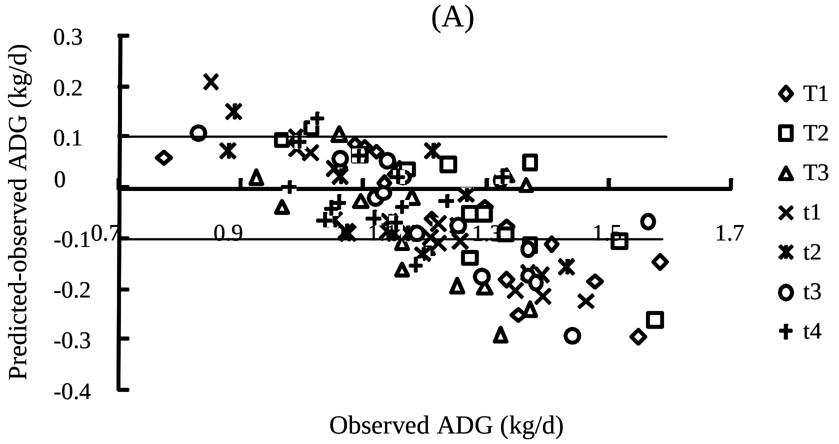
Table 5. Comparison between observed ADG and CNCPS-predicted ADG (kg/d)[a]

Item	Trial 1			Trial 2			
	T1	T2	T3	t1	t2	t3	t4
No. in treatment	15	15	15	15	15	15	15
CNCPS-predicted ADG	1.19±0.13	1.26±0.12	1.13±0.17	1.14±0.06	1.09±0.11	1.18±0.12	1.08±0.14
Observed ADG	1.25±0.21	1.33±0.24	1.23±0.19	1.20±0.18	1.13±0.14	1.24±0.18	1.08±0.15
Mean bias[b]	-0.06	-0.07	-0.09	-0.06	-0.03	-0.06	-0. 004
RMSPE [c]	0.12	0.12	0.12	0.07	0.09	0.11	0.08

[a] Observed and predicted ADG values as Y- and X- variates, respectively.
[b] Mean bias is the average of CNCPS-predicted minus observed ADG.
[c] RMSPE = Root mean square prediction error.



(A)



(B)

Figure 2. Prediction of ADG by CNCPS. Relationship between observed ADG and CNCPS-predicted ADG (A) and between observed ADG and predicted minus observed ADG (B). All data are from Trial 1 and 2. Variation of CNCPS-predicted minus observed ADG vs. observed ADG indicated that about 51.1% (60.0, 53.3 and 40.0% for T1, T2 and T3 in Trial 1) and 66.7% (40.0, 80.0, 60.0 and 86.7% for t1, t2, t3 and t4 in Trial 2) of the points are within the range -0.1 to 0.1 kg/d for Trials 1 and 2, respectively.

$Y_{OBS} = 0.57X_{CNCPS}+3.59$ ($R^2 = 0.79$; $p<0.01$). The regression equation between observed (*Y* variate) and predicted (*X* variate) ADG was: $Y_{OBS} = 1.20X_{CNCPS}-0.18$ ($R^2 = 0.83$; $p<0.01$).

DISCUSSION

CNCPS v5.0 was designed to work with multiple groups to allow for evaluations of herd nutrient excretion and herd feed requirements (Fox et al., 2003). Although there was more than one treatment in each of the present trials, the comparison of this study was concerned with the differences between CNCPS predicted and observed values. Therefore, we could take into account the treatments in one trial. All rations in the current study were well balanced with respect to recommendations of NRC (2000) and no adjustment was made before entering the CNCPS model. After the feed database was built for entering CNCPS, ME and NEm values of the rations used in each trial were predicted by CNCPS v5.0 and are listed in Table 1. CNCPS-predicted DMI and ADG values were based on the available information, such as animal source factors, weather conditions, dietary nutrient density, feed available energy level and others (Zhao et al., 2008). In fact, there was no significant treatment effect in the present study.

It was noted that the average ages of the bulls in the two

Table 6. Regression of observed upon CNCPS-predicted DMI and of observed upon CNCPS-predicted ADG (kg/d)

	Intercept	Slope	R^2	RMSE[a]
DMI (kg/d)	3.59±0.37[b]	0.57±0.04[b]	0.79	0.18
ADG (kg/d)	-0.18±0.09	1.20±0.084[b]	0.83	0.11

[a] RMSE = Root mean square error. [b] Statistically different from 0 (intercept) or 1 (slope) at p = 0.01.

trials were 13 to 14 months (see Table 3). The inputs of initial body weight, dietary ME level and weather conditions differed greatly between the two trials, but other factors were quite similar between the trials. The animal, dietary and weather conditions used in this study could well represent the prevailing conditions in Northern China.

The initial body weights and other data of each bull were input to the CNCPS model to obtain predicted individual DMI and ADG values. In addition, the actual DMI was used in prediction of the latter for each animal. The actual DMI and ADG values of each animal were measured and calculated individually, and then pooled to be expressed as an average per treatment. All of the average parameters for each treatment are presented in Table 4 and 5.

Evaluation of CNCPS-predicted DMI

The judgment of model adequacy always has to be made on relative comparisons and is subject to the suitability of the model given its objectives (Tedeschi, 2006). In general, greater values were obtained in Trial 1 for both the actual and CNCPS-predicted DMI than those in Trial 2 (Table 4). Because the animals were under similar management conditions and within the same feedlot, the discrepancy in model-predicted DMI between the two trials is probably due to the differences in initial body weight of animals (Table 3) and environmental temperature. Mean biases (model-predicted minus observed DMI) of T1, T3, and t1 were quite low, suggesting an accurate predicted performance by the CNCPS model. However, the model-predicted DM intakes for T2, t2, t3, and t4 were not as accurate as those for the animals in T1, T3, and t1 because of the greater biases (Table 4). These positive values of mean bias, derived from the two trials, revealed that DM intakes were over-predicted by the CNCPS model in this study. In our previous work, three of ten treatments showed positive values, whereas the others were negative (Zhao et al., 2008). Similarly, other experiments (Kolver et al., 1996; Molina et al., 2004) also presented an under-predicted DMI by CNCPS. The under-predicted DMI, in general, seems to be related to the bias of the CNCPS model predictions. Data from trials with lactating dairy cows (149 period observations of DMI 0f 1,284 Holstein cows in 28 experiments) showed that the CNCPS intake equation had an average under-prediction bias of 5% (Fox et al., 1992). In a study of the CNCPS model (version 3.0) using four grazing and four indoor feeding experiments with dairy cattle, Kolver et al. (1996) found that DMI was under-predicted by the model with an 11% bias. Although the range in DMI was small in our trials, the pattern observed for the animals was completely different from other studies (Molina et al., 2004). The high content of ether extract (8% DM) in palm kernel cake (PKC) in Trial 1 and of dietary essential amino acids in Trial 2 (e.g., lysine) may be partly responsible for this difference in the present study.

As stated by Tedeschi (2006), the estimate of coefficient of determination (R^2) for the regression is a good indicator of precision: the higher the R^2 the higher the precision. Additionally, the regression estimates of the intercept and the slope are good indicators of accuracy; when these are simultaneously closer to zero and unity, respectively, the higher the accuracy. Lower root mean square prediction errors (RMSPE) of the model-predicted DMI were obtained in T3, t1 and t4 than in other treatments, indicating a high accuracy of the model predictions (Table 4). Although these equations of the CNCPS model used to predict DMI were developed in typical North American conditions and for purebred bulls fed high levels of supplements, this may be not the case for the crossbred breeds and feeding in the confined system used in our study. Nevertheless, the very small mean bias value in T1 (0.07 kg/d) and RMSPE value in t1 (0.11) suggest that the CNCPS model can be satisfactorily used for the prediction of DMI for crossbred beef cattle fed in the confined feeding system in China.

When a linear regression is performed for comparing the predicted and observed DMI, an ideal model needs to meet three criteria: i) high R^2 value (>0.75 as a reference), ii) intercept close to (not different from) zero, and iii) slope being close to 1 (Zhao et al., 2008). Analysis of the regression between observed (*Y* variate) and predicted (*X* variate) DMI values indicated that the intercept and slope differed from zero (p<0.01) and unity (p<0.01), respectively. Likewise, a higher R^2 value than 0.75 (R^2 = 0.79) (Table 6) was obtained. These results indicate that CNCPS model could give an acceptable prediction of dietary DMI of crossbred bulls fed in the confined feeding system in China.

Finally, it is necessary to recognize that prediction of intake is often difficult because of the many interactions (e.g., animal and diet) involved in the regulation of intake by ruminant animals (Forbes, 1996; Molina et al., 2004).

Evaluation of CNCPS-predicted ADG

For growing cattle, prediction of daily gain is dependent on accurate prediction of NE available for gain (NE_g), which in turn depends on accurate assessment of maintenance requirements and feed energy values (Fox et al., 1992). ADG prediction with CNCPS v5.0 in this study was directly dependent upon the amount of retained energy (RE) and equivalent shrunk body weight (EQSBW) of the animals. The RE was equal to NE_g values of the daily ration predicted by CNCPS level 2 based on feed chemical analysis. Moreover, shrunk body weight (SBW) is adjusted to a weight equivalent to that of a standard reference animal at the same stage of growth and the EQSBW was calculated by the following equation described by Fox et al. (2004).

$$\mathrm{EQSBW} = \mathrm{SBW}\left(\frac{SRW}{AFBW}\right) \qquad (2)$$

Where SRW is the mature BW of the standard reference animal and AFBW is expected mature shrunk BW. For growing cattle to be harvested for beef, mature BW is the expected BW at the target body composition. The SRW of growing and finishing steers, heifers, or bulls is 400, 435, 462, or 478 kg when the harvest target is 22, 25, 27%, or 28% body fat, respectively.

On average, the bulls in Trial 2 gained less weight daily than those in Trial 1 (Table 5). The lower initial body weight and lower DMI of the animals in Trial 2, combined with heat stress because of the sweltering weather during this trial period, could have caused the differences. As shown in Table 3, the standard deviations of the initial body weight within a treatment were less than 34.7 kg, indicating that the prediction of the CNCPS model is not so sensitive to a small variance of body weights. In Trial 1, a higher ADG in T2 than in the other two treatments indicated that the appropriate percentage of palm kernel cake fed to animals may be 12%. However, no significant differences were observed between these treatments ($p>0.05$). In Trial 2, animals in four treatments were fed on the same rations with the exception of different lysine supplement (Table 1). Therefore, the variations occurring in predicted ADG were probably caused by the difference in dietary essential amino acid supply.

Low values of RMSPE seemed to reflect a higher accuracy of model predictions (Table 5). Although the ADG points from interaction between the observed and predicted values were gathered based on individual trials as shown in Figure 2, the overall data from treatments within Trial 1 or Trial 2 pooled together could cover the normal range of ADG occurring commonly in beef breeds in Northern China, suggesting that the CNCPS model for prediction of ADG performance is well representative of the current Chinese confined feeding situation.

The regression between observed (*Y* variate) and predicted (*X* variate) ADG (Table 6) had an intercept not different ($p = 0.06$) from zero, but slope different ($p<0.01$) from 1 (Table 6). This observation implies that the CNCPS model can be acceptable to predict body weight gain of crossbred bulls fed in the confined feeding system in China.

Consideration of systematic adjustment of CNCPS model for DMI and ADG prediction

Either the positive DMI mean bias values (CNCPS predicted minus observed DMI, Table 4) or the negative ADG values (CNCPS predicted minus observed ADG, Table 5) indicated that a systematic adjustment to the CNCPS prediction for performance was necessary. For all cattle types (beef cattle, dual purpose cattle and dairy cattle), DMI is adjusted for the effect of temperature, and the predicted DMI is adjusted for lot mud depth because animals become increasingly reluctant to approach the feed bunker as mud depth increases (Fox et al., 2004). Besides, adjustments for the N-limitation, which reduced the over-prediction of the animal ADG and DMI by CNCPS v4.0 (Tedeschi et al., 2000), and beef breed factor (Zhao et al., 2008) should also be included. Beef breed factor seemed to be an important factor and beef cattle in China are usually different in body size and marbling characteristics compared to North American breeds. As no data were available on Chinese beef cattle breeds in the CNCPS system, the Holstein cattle breed was chosen as a default breed input. This may have affected DMI and ADG predictions, and more research is therefore needed to create appropriate breed adjustment factors for DMI and ADG prediction for Chinese crossbred beef cattle.

Amend feed fractionation scheme and feedstuffs database

The CNCPS v5.0 accounts for effects of variation in feed fractions on predicted feed ME supply, rumen N, and AA balances when developing diets to meet cattle nutrient requirements. However, several limitations of its feed fractionation scheme have become apparent because these fractions are not precisely defined or analyzed (Offner and Sauvant, 2004; Lanzas et al., 2007). In the original CNCPS fractionation scheme (Sniffen et al., 1992), the CA fraction (the A fraction of carbohydrates) represents the rapidly fermented (1-3 h^{-1}) water soluble CHO fraction, and is the sugar content of feed. In contrast, in the new scheme (Lanzas et al., 2007), the CA is divided into four fractions: volatile fatty acids (VFA), lactic acid, other organic acids and sugars. It is a more detailed scheme for practical application. That is also highlighted as an area that needs further improvement to accurately predict the growth performance of crossbred bulls fed in the confined feeding system in China. For example, cornstalk silage, in which the VFA and lactic acid content is often high, is fed to animals widely in China. Usually, we analyze the sugar content only and therefore an improper input is used. So it is necessary to amend the feed fractionation scheme according to the latest methods (Lanzas et al., 2007).

Accuracy of prediction of nutrient requirements and performance under specific conditions depends on accuracy of description of feedstuff composition and DMI (Fox et al., 2003). Feeds vary widely in their amount and composition of carbohydrate and protein fractions, and these fractions differ in rate and extent of fermentation, products of fermentation, and contribution to microbial CP production (Hall and Herejk, 2001), and, therefore, to animal performance. The use of the CNCPS model for prediction of DMI and performance in China is just at the primary stage. The lack of basic feed information suitable for the CNCPS has restricted application of the model in practice (Zhao et al., 2008). In the present study, only a few indices (CP, NDF, ADF, etc.; Table 1) were analyzed actually and the values, including NDICP, ADICP, peNDF, degradation rates and intestinal digestion rates, were calculated based on the CNCPS v5.0 Temperate Feeds Library. The use of tabulated feed data rather than actual laboratory determinations may have caused prediction errors in this study. It is important to create a useful database with indices required by the CNCPS model suitable for locally available Chinese feedstuffs.

CONCLUSIONS

Results indicate that the DMI and ADG prediction of the CNCPS v5.0 model is acceptable for growing bulls kept in the traditionally confined feeding system in China. Because of the slight over-prediction of DMI and under-prediction of ADG, further studies are warranted to give systematic adjustment of the model under conditions in China. It is also important to develop a feeds database suitable to Chinese conditions for the potential application of the CNCPS model.

REFERENCES

Beermann, D. H. and D. G. Fox. 1998. Use of feed and water by livestock in the United States. Cornell CALS news, May 1995.

Bibby, J. and H. Toutenburg. 1997. Prediction and improved estimation in linear models. John Wiley & Sons Publishers, Berlin, Germany.

Forbes, J. M. 1996. Integration of regulatory signals controlling forage intake in ruminants. J. Anim. Sci. 74:3029-3035.

Fox, D. G., C. J. Sniffen, J. D. O'Connor, J. B. Russell and P. J. Van Soest. 1992. A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy. J. Anim. Sci. 70:3578-3596.

Fox, D. G., L. O. Tedeschi, T. P. Tylutki, J. B. Russell, M. E. Van Amburgh, L. E. Chase, A. N. Pell and T. R. Overton. 2004. The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion. Anim. Feed Sci. Technol. 112:29-78.

Fox, D. G., T. P. Tylutki, L. O. Tedeschi, M. E. Van Amburgh, L. E. Chase, A. N. Pell, T. R. Overton and J. B. Russell. 2003. The net carbohydrate and protein system for evaluating herd nutrition and nutrient excretion. CNCPS version 5.0, Model Documentation. Ithaca, NY, USA.

Hall, M. B. and C. Herejk. 2001. Differences in yields of microbial crude protein from *in vitro* fermentation of carbohydrates. J. Dairy Sci. 84:2486-2493.

Kolver, E. S., M. C. Barry, J. W. Penno and L. D. Muller. 1996. Evaluation of the Cornell net carbohydrate and protein system for dairy cows fed pasture-based diets. Proc. NZ Soc. Anim. Prod. 56:251-254.

Lanzas, C., C. J. Sniffen, S. Seo, L. O. Tedeschi and D. G. Fox. 2007. A revised CNCPS feed carbohydrate fractionation scheme for formulating rations for ruminants. Anim. Feed Sci. Technol. 136:167-190.

Mayer, D. G. and D. G. Butler. 1993. Statistical validation. Ecol. Model. 68:21-32.

Mitchell, P. L. 1997. Misuse of regression for empirical validation of model. Agric. Syst. 54:313-326.

Mitchell, P. L. and J. E. Sheehy. 1997. Comparison of predictions and observations to assess model performance: a method of empirical validation. In: Applications of Systems Approaches at the Field Level (Ed. M. J. Kropff, P. S. Teng, P. K. Aggarwal, J. Bouma, B. A. M. Bouman, J. W. Jones, H. H. Van Laar). Volume 2. Kluwer Academic Publishers, Boston, USA. pp. 437-451.

Molina, D. O., I. Matamoros, Z. Almeida, L. Tedeschi and A. N. Pell. 2004. Evaluation of the dry matter intake predictions of the Cornell Net carbohydrate and protein system with Holstein and dual-purpose lactating cattle in the tropics. Anim. Feed Sci. Technol. 114:261-278.

National Research Council. 2000. Nutrient requirements of beef cattle, Seventh revised Ed. Updated. National Academy Press, Washington, DC, USA.

Offner, A. and D. Sauvant. 2004. Comparative evaluation of the MOLLY, CNCPS, and LES rumen models. Anim. Feed Sci. Technol. 112:107-130.

Sniffen, C. J., J. D. O'Connor, P. J. Van Soest, D. G. Fox and J. B. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J. Anim. Sci. 70:3562-3577.

Tedeschi, L. O. 2006. Assessment of the adequacy of mathematical models. Agrc. Syst. 89:225-247.

Tedeschi, L. O. and D. G. Fox. 2001. Application of the net Cornell carbohydrate and protein system for tropical conditions. Revista Corpoica. 3(2):1-10.

Tedeschi, L. O., D. G. Fox, A. N. Pell, D. P. D. Lanna and C. Boin. 2002. Development and evaluation of a tropic feed library for the Cornell net carbohydrate and protein system model. Sci. Agric. 59(1):1-18.

Tedeschi, L. O., D. G. Fox and J. B. Russell. 2000. Accounting for the effects of a ruminal nitrogen deficiency within the structure of the Cornell net carbohydrate and protein system. J. Anim. Sci. 78:1648-1658.

Zhao, J. S., Z. M. Zhou, L. P. Ren, Y. Q. Xiong, J. P. Du and Q. X. Meng. 2008. Evaluation of dry matter intake and daily weight gain predictions of the Cornell net carbohydrate and protein system with local breeds of beef cattle in China. Anim. Feed Sci. Technol. 142:231-246.