PREDICTION OF DRY MATTER INTAKE BY CATTLE IN FEEDLOT

José Augusto Gomes Azevêdo[1]; Sebastião de Campos Valadares Filho[2]; Douglas dos Santos Pina[3]; Rilene Ferreira Diniz Valadares[4]; Edenio Detmann[5]

[1] Prof -UESC-B; [2]Prof DZO-UFV-Coordenador do INCT-Ciência Animal (scvfilho@ufv.br); [3]Prof da UFMT-MT; [4]Prof DVT-UFV-Membro do INCT-CA; [5]Prof DZO- UFV- Pesquisador do INCT-Ciência Animal (detmann@ufv.br);

INTRODUCTION

Dry matter intake (DMI) is the most important variable affecting animal performance (Waldo and Jorgensen, 1981). This is especially the case for beef cattle, considering their economic importance, their complex digestive systems and their particular metabolic functions (Forbes, 2007).

Feed intake restrictions can prevent the fulfillment of nutritional requirements. As most of the nutrients in beef cattle diets are used to meet their maintenance requirements, small alterations in feed intake may lead to limitations in the efficiency of the productive processes. Consequently, the growth rate will decrease, the genetic potential for weight gain will not be reached and the profitability of livestock activities will be jeopardized. In addition, problems associated with feeding stress, health and digestive disorders may arise.

The factors that control feed intake are complex and multi-factorial, and there is no consensus on how ruminants regulate this important activity (Forbes, 2007). Interactions between several factors, such as diet, animal, environment and management, are primarily responsible for the lack of accuracy in DMI prediction equations (McMenimam et al., 2009).

To plan an efficient feeding program capable of providing the best feed formulation to meet nutritional requirements, it is necessary to predict the level of voluntary intake of growing beef cattle under *ad libitum* feeding with great precision and accuracy.

DRY MATTER INTAKE (DMI) PREDICTION EQUATIONS

The DMI prediction equations suggested by the NRC (1984, 2000) were the most used in Brazil for many years. However, anabolic stimulants were used in animals utilizaded to develop DMI prediction model proposed by the NRC (1984, 2000). Since 1961, Brazil has prohibited the use of anabolic stimulants for any purpose. Currently, Ministerial Decree No. 51 (Brasil, 1991) is in force. This decree prohibits the production, import, commercialization, and use of anabolic stimulants for the growth and weight gain of animals for slaughter. For non-steroid compounds with anabolic activity, the ban even encompasses use for therapeutic purposes.

Moreover, the equations suggested by the NRC (1984, 2000) were especially developed for the *Bos taurus* species. According to Magnabosco (1997), 80% of the Brazilian beef cattle herd is composed of Zebu cattle. Due to its fertility, rusticity, adaptability to the tropical environment and suitability for the Brazilian meat production system, the Nellore breed is predominant. Fox et al. (1988) observed that genetic group is one of the factors that interfere with DMI. Based on this work, the NRC (1987) and AFRC (1993) proposed adjustment factors to DMI prediction for different beef cattle breeds because *Bos taurus* species had a greater DMI potential.

According to Neal et al. (1984), the DMI equations should be tested in conditions similar to those under which they will be used. This would mean there is no single equation that can be applied to all situations, and that is necessary to develop and validate DMI prediction equations for tropical conditions.

For this reason, Valadares Filho et al. (2006a,b) developed and validated a prediction equation of DMI for beef cattle under Brazilian conditions and with Zebu cattle (Nellore breed). This prediction, allied with the energy, protein and mineral requirements of the cattle, resulted in the BR-CORTE system. The suggested DMI equations indicated that the predicted values were equivalent to those observed in practical feeding conditions in tropical feedlots.

Ribeiro et al. (2008) evaluated the DMI of the Zebu genetic group and compared the observed values with those predicted by the NRC (2000), CNCPS 5.0 and BR-CORTE systems. These authors observed that BR-CORTE was more efficient in DMI prediction by breed, and for Zebu cattle as a whole.

Valadares Filho et al. (2006b) also observed a lack of adjustment for the equations suggested by the NRC (1984, 2000) in predicting DMI for beef cattle in tropical conditions. Therefore, the equations suggested by the NRC (1984, 2000) would be unable to explain the higher percentage of variation observed in the DMI when compared to the equations adopted by the BR-CORTE system.

DATA USED TO DEVELOP THE NEW EQUATIONS THROUGH META-ANALYSIS

Meta-analysis is a type of data analysis in which the results of several studies are grouped and evaluated as if they were the result of a single large study. According to St-Pierre (2001), it is possible to integrate the study effect (as a randon effect) with the fixed effects and their interactions as components of a mixed model by using meta-analysis. This method results in better prediction equations in biological systems and in a more accurate description of prediction errors. Meta-analysis was the main reason for recommending an alteration in DMI prediction equation proposed by Valadares Filho et al. (2006a).

The data used to estimate the parameters of the new equation were expanded in relation to those used by Valadares Filho et al. (2006a). These data were collected from performance experiments involving growing or finishing Nellore and crossbred (Nellore x *Bos taurus*) beef cattle. The data included information on all of the variables considered relevant for DMI prediction. The information collected for each observation included gender, initial body weight (BWi), final body weight (BWf),average body weight (ABW), DMI and daily average gain (ADG). All data were obtained from animals individually fed, and both Bull and Steers males were used.

The data included 561 observations from 27 theses and dissertations (studies), which were published in Federal University of Viçosa and University of São Paulo (Table 1).

In all of the studies, the diets were formulated using the current NRC recommendations. The beef cattle were housed in individual stalls and were fed twice daily with the total mixed ration *ad libitum*.

Following St-Pierre (2001) recommendations, the existence of the study effect was initially evaluated in the database. If the study effect was confirmed ($P<0.01$), it was considered in the subsequent analyses.

Table 1 - Description of database used in the development and validation of the Dry Matter Intake equation

Author	Year	N	DOF	Genetic Group	Forage	Gender
Teixeira	1984	47	242	Nellore and Crossbred	Molasses grass hay and corn silage	Bull
Lorezoni	1984	22	216	Nellore and Crossbred	Molasses grass hay and sorghum silage	Bull
Margon	1981	31	144	Nellore	Molasses grass hay	Steers
Galvão	1991	34	143	Crossbred	*Brachiaria decumbens* hay	Bull
Peron	1991	13	146	Crossbred	Napiergrass hay	Steers
Oliveira	1998	25	126	Nellore	Coast-cross hay	Bull
Gesualdi Júnior	1999	38	164	Crossbred	Coast-cross hay	Bull
Fernandes	2001	22	80	Nellore and Crossbred	Coast-cross silage	Bull
Silva	2001	19	112	Nellore	Tifton hay	Bull
Miranda	2005	3	117	Nellore and Crossbred	Corn silage	Bull
Véras	2000	25	125	Nellore	*Brachiaria* and coast-cross hay	Bull
Veloso	2001	28	171	Crossbred	Coast-cross hay	Bull
Albuquerque	1972	6	98	Crossbred	Sugar cane, and sorghum silage	Bull
Salvador	1980	30	144	Crossbred	Molasses grass hay	Bull
Backes	2003	8	129	Crossbred	Tifton hay	Steers
Resende	1999	23	123	Crossbred	Tanzania guinea grass hay	Bull
Jorge	1993	23	118	Crossbred	*Brachiaria decumbens* hay	Bull
Paulino	1996	10	114	Nellore	*Brachiaria decumbens* hay	Bull
Paulino	2002	14	100	Nellore	Tifton hay	Steers
Leonel	2003	8	156	Nellore	*Brachiaria decumbens* hay	Bull
Putrino	2002	21	246	Nellore	Corn silage	Bull
Paulino	2006	20	105	Nellore	Corn and napiergrass silage	Steers and Bull
Marcondes	2007	9	84	Nellore	Corn silage	Steers and Bull
Chizzotti	2007	12	111	Crossbred	Corn silage	Steers and Bull
Rigueira	2007	13	79	Crossbred	Soybean silage	Bull
Vieira	2007	20	84	Crossbred	Mombaça guinea grass silage	Bull
Marcondes	Unpublished data	37	74	Nellore and Crossbred	Corn silage	Steers and Bull

N = number of experimental units; DOF = days on feeding.

DEVELOPMENT OF THE DMI PREDICTION EQUATIONS

A significant effect of genetic group (GG) and its interactions was found using ANOVA (Table 2). The model used included average body weight (ABW and $ABW^{0.75}$), ADG and daily average gain squared (ADG^2) with all interactions. The equations that included ABW were considered independent equations in relation to those that included metabolic body weight ($ABW^{0.75}$) as the dependent variable for DMI effects in the complete statistical model. The effects of independent variables were considered significant for a probability level lower than 0.15.

Table 2 - Summary of analysis of variance: the effects of average body weight (ABW), metabolic average body weight ($ABW^{0.75}$), daily average weight gain (ADG) and ADG^2, in addition to the interaction with the genetic group (GG)

Variables	F	P Value	F	P value
	$ABW^{0.75}$		ABW	
$ABW^{0.75}$	377.53	<0.0001		
ABW			393.70	<0.0002
ADG	84.59	<0.0001	128.04	<0.0001
ADG^2	30.07	<0.0001	38.44	<0.0001
Interaction with GG				
$ABW^{0.75}$	4.76	0.0297		
ABW			4.95	0.0266
ADG	4.49	0.0347	4.78	0.0293
ADG^2	2.14	0.1443	2.43	0.1198

The ANOVA results indicate that GG is an important source of variation for all of the variables studied and that distinct equations should be proposed to predict DMI in Nellore and Crossbred (Zebu x *Bos taurus*) beef cattle. These results differ from those of Valadares Filho et al. (2006a,b), as these authors did not observe an effect for GG, and they suggested that a single equation could predict DMI for Nellore and Crossbred animals.

DEVELOPMENT OF NEW EQUATIONS FOR PREDICTING DMI

The descriptive statistics (minimum, maximum, mean, median, mode and standard error) for all variables in the development of DMI prediction equations for Nellore and Crossbred animals are listed in Table 3.

Table 3 - Descriptive statistics of dry matter intake (DMI), initial body weight (BWi), final body weight (BWf), average body weight (ABW), metabolic average body weight ($ABW^{0.75}$), daily average weight gain (ADG) and days on feeding (DOF) for Crossbred (n = 201) and Nellore (n = 360)

Variables	GG	Minimum	Maximum	Mean	Median	Mode	SE
DMI, kg d^{-1}	Crossbred	2.83	12.00	8.11	8.17	7.79	0.108
	Nellore	2.49	11.83	7.87	7.88	7.93	0.107
BWi, kg	Crossbred	151.05	45.00	324.58	328.70	360.00	4.294
	Nellore	139.00	497.00	308.56	321.35	270.00	3.748
BWf, kg	Crossbred	213.88	584.00	440.29	448.55	540.00	4.309
	Nellore	205.98	606.59	435.90	452.84	477.00	4.243
ABW, kg	Crossbred	196.94	504.50	382.44	387.40	453.00	3.939
	Nellore	172.88	538.33	372.23	391.98	330.00	3.699
$ABW^{0.75}$, kg	Crossbred	52.57	118.80	88.82	88.22	85.45	0.857
	Nellore	47.68	113.26	87.19	89.65	113.26	0.670
DMI, %ABW	Crossbred	1.28	2.75	2.12	2.16	2.23	0.018
	Nellore	1.03	2.85	2.10	2.09	2.44	0.019
ADG, kg d^{-1}	Crossbred	0.02	1.95	1.00	0.99	0.86	0.030
	Nellore	0.01	1.68	0.90	0.94	1.25	0.020
DOF, days	Crossbred	61.00	254.00	128.07	110.00	144.00	3.790
	Nellore	55.00	271.00	149.57	144.00	242.00	3.041

All data used came from experiments with a minimum duration of 50 days, in addition to a minimum adaptation period of 21 days to minimize the impact of compensatory growth on DMI. These factors were used because feedlot beef cattle in Brazilian conditions come into feddlot after long periods of feed restriction, which allows for compensatory growth at an accelerated rate. Fox et al. (1972) found that beef cattle undergoing compensatory gain consume 16% more feed than beef cattle in continuous growth.

Table 4 shows the solution of the fixed effects of the regression equations for predicting DMI with their regression coefficients (R^2). The negative coefficient for the variable ADG^2 (kg d^{-1}) for all adjusted equations indicates that the DMI reaches a plateau. The explanation for this may be related to the energy concentration of the diet. Based on the principle that the energy concentration of the diet should be high to get the maximum ADG, the DM intake will be inhibited; this is suggested by the energy intake regulation theory proposed by Mertens (1994).

Table 4 - Solution of fixed effects of the regression equations based on average body weight (ABW) or average metabolic body weight ($ABW^{0.75}$), daily average gain (ADG) and daily average gain squared (ADG^2) with their respective coefficients of determination (R^2) for Nellore and Crossbred beef cattle

Equations		Crossbred		Nellore	
		1.1	1.2	2.1	2.2
Intercept	Estimate	-2.6098	-1.0094	-2.7878	-1.3559
	SE	0.5289	0.4100	0.5029	0.3982
	P-value	0.0002	0.0274	<0.0001	0.0030
ABW	Estimate	---	0.0161	---	0.0160
	SE	---	0.0012	---	0.0011
	P-Value	---	<0.0001	---	<0.0001
$ABW^{0.75}$	Estimate	0.0884	---	0.0879	---
	SE	0.0067	---	0.0063	---
	P Value	<0.0001	---	<0.0001	---
ADG	Estimate	4.4672	4.4363	5.0487	5.6397
	SE	0.4987	0.4867	0.5927	0.5522
	P Value	<0.0001	<0.0001	<0.0001	<0.0001
ADG^2	Estimate	-1.3579	-1.2548	-1.6835	-1.8494
	SE	0.4987	0.2507	0.3384	0.3269
	P Value	<0.0001	0.0003	<0.0001	<0.0001
R^2		0.7374	0.7525	0.7579	0.7893

McMeniman et al. (2009) observed a positive relationship between energy intake and average daily gain (ADG), with a coefficient of determination (r^2) of 0.70. Considering the importance of this effect, the NRC (1984, 2000) proposed equations that included net energy (NE_m) with a quadratic effect. However, due to the practical difficulty in determining NE_m before knowing which feeds will make up the diet, Thornton et al. (1985) developed an equation to predict DMI that included both BWi and days on feeding (DOF). For Thornton et al.(1985), DMI is represented by a curve where the initial DMI gradually increases as a function of DOF until reaching a plateau. The curve then decreases in the last DOF due to the increased body fat content of the animals in confinement. The concentration of fat in the carcass is small at the beginning of the feeding period but accumulates at faster rates toward the end of the feeding period (Simpfendorfer, 1974).

To verify if the new DMI equations follow a standard curve with a plateau, a DMI prediction simulation was performed with animals of 200 or 400 kg of ABW (Figure 1). In this simulation, the DMI estimates expressed, in g/$ABW^{0.75}$, as a function of ADG display a curve with three distinct segments: the adaptation phase, plateau, and decline. These segments correspond to the adaptation to confinement or the environment, to the ABW increase and to the increase of body fat content. These three phases justify the idea that quadratic equations better represent biological adjustments for predicting DMI.

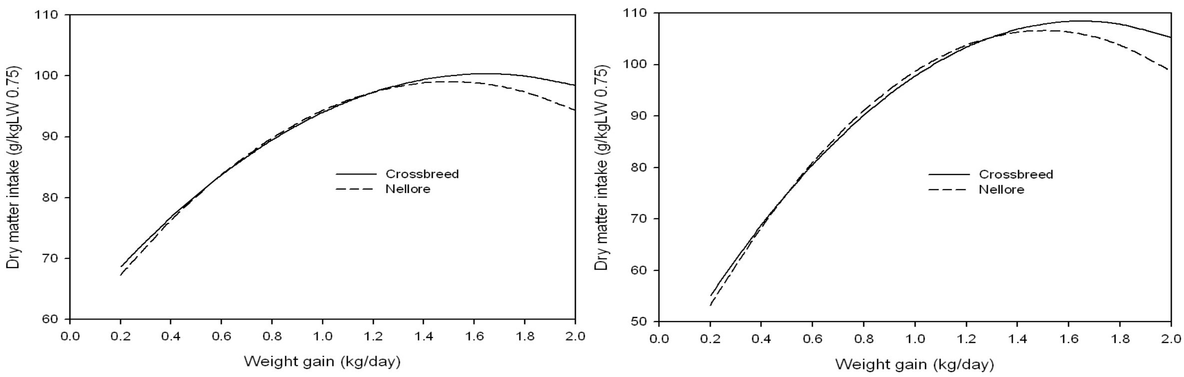

Figure 1 - DMI simulation prediction for young bulls with ABW of 400 kg (left) and 200 kg (right) and different ADG ($kg.d^{-1}$) values, using the adjusted equations for crossbred (eq 1.1) and Nellore (eq 2.1) cattle.

The plateau for the DMI of Nellore animals was lower than that estimated for crossbred cattle. This result indicates a good adjustment of the proposed equations, as can be seen in the simulation. The ADG values in equations 1.1. and 2.1 were 1.64 and 1.50 kg d^{-1}, which corresponds to 108.4 and 100.3 gDM / $ABW^{0.75}$ (equation 1.1 - Crossbred) and 106.64 and 99.04 gDM/ $ABW^{0.75}$ (equation 2.1 - Nellore) for animals with ABW of 400 and 200 kg, respectively.

Therefore, it is suggested that when the concentration of NE_m has not been accurately established, the NE_m variable should be replaced by ADG. With this simplification of the equation, the need to use variables that are not practical to obtain and the cumulative errors in determining the estimate are both avoided.

INDEPENDENT DATA FOR EVALUATING THE PRECISION AND ACCURACY OF THE NEW EQUATIONS

Eight articles (independent experiments) published between January 2005 and May 2008 in the Brazilian Journal of Animal Science were compiled for the validation of the DMI prediction equation for Nellore cattle. Twenty-one articles (independent experiments) were compiled from publications in the same period in the Brazilian Journal of Animal Science and Animal Industry Bulletin for the validation of the DMI prediction equation for the crossbred cattle. A summary of this information as descriptive statistics is shown in Table 5.

Table 5 - Descriptive statistics of dry matter intake (DMI), initial body weight (BWi), final body weight (BWf), average body weight (ABW), average metabolic body weight ($ABW^{0.75}$), daily average gain (ADG) and days on feeding (DOF) for crossbred (n = 90) and Nellore (n = 30) cattle

Variables	Genetic Group	Minimum	Maximum	Mean	Median	Mode	SE
DMI, kg d^{-1}	Crossbred	4.46	12.74	8.18	8.13	7.47	0.163
	Nellore	6.04	10.78	8.57	8.60	8.60	0.228
BWi, kg	Crossbred	181.20	422.91	312.78	314.30	219.30	5.982
	Nellore	296.00	438.00	377.55	384.75	339.80	6.057
BWf, kg	Crossbred	221.60	578.77	441.91	451.06	434.00	6.779
	Nellore	424.00	536.00	476.66	471.25	465.00	5.110
ABW, kg	Crossbred	202.26	474.46	377.39	391.21	ND	5.714
	Nellore	373.00	487.00	427.11	424.68	ND	5.062
$ABW^{0.75}$, kg	Crossbred	53.63	101.66	85.44	87.96	87.67	1.004
	Nellore	84.88	103.67	93.92	93.55	ND	0.833
DMI, %ABW	Crossbred	1.06	2.70	2.16	2.19	2.27	0.032
	Nellore	1.37	8.67	2.67	2.07	2.06	0.359
ADG, kg d^{-1}	Crossbred	0.14	2.15	1.20	1.23	0.94	0.037
	Nellore	0.75	1.53	1.11	1.10	1.10	0.047
DOF, day	Crossbred	63.00	149.00	102.64	105.00	84.00	2.016
	Nellore	70.00	133.00	91.93	86.00	86.00	3.519

ND – not determined.

Table 6 shows the results of the validation of DMI prediction equations proposed for crossbred and Nellore cattle in tropical conditions. It also shows the general quadratic equation, with the variable $ABW^{0.75}$ suggested in the BR-CORTE 2006 edition.

The slope and intercept calculated for the regression confirmed that the DMI prediction equations without $ABW^{0.75}$ (with the exception of the equation suggested by the BR-CORTE system [2006]) were significantly different from 1 and zero, respectively (P>0.10). This result indicates that these equations are not appropriate for predicting DMI, considering the database used for the validation. However, for the prediction equation that included $ABW^{0.75}$ in the meta-analysis, the intercept was not different from zero, and the slope was not different from 1. This result indicates that the estimates were accurate in predicting the DMI of beef cattle in tropical conditions.

Table 6 - Regression statistics between the DMI values observed and those predicted by the new equations and the equation recommended by the BR Corte (2006)

Item	Genetic Group					
	Crossbred			Nellore		
	Eq. 1.1	Eq. 1.2	BR-CORTE 2006	Eq. 2.1	Eq. 2.2	BR-CORTE 2006
Intercept (a)	0.568±0.587	0.671±0.569	1.157±0.756	-2.769±2.418	-2.11 ±2.177	-1.917±2.803
Slope (b)	0.930±0.077	0.891±0.073	0.821±0.087	1.276±0.269	1.145±0.231	1.109±0.296
P value (Ho:a=0 & b=1)	0.780	0.061	0.001	0.186	0.001	0.001
r^2	0.498	0.504	0.509	0.349	0.362	0.334
MSEP, kg^2	1.194	1.250	1.322	1.106	1.543	1.792
CCC	0.680	0.681	0.682	0.428	0.385	0.340

MSEP = mean squared error of prediction; CCC = concordance correlation coefficient .

Considering the mean squared error prediction (MSEP), we can conclude that the smallest errors were observed for the equations that included the average metabolic body weight ($ABW^{0.75}$). Furthermore, the concordance correlation coefficient (CCC), also known as the reproducibility index, which simultaneously considers accuracy and precision, showed few differences between the equations for Crossbred and better results for the equations that included $ABW^{0.75}$ for Nellore cattle.

FINAL CONSIDERATIONS

The equations proposed by the NRC might be inappropriate for predicting DMI for beef cattle in tropical conditions. The use of the following DMI predicting equations is suggested: **Nellore, $DMI = -2.7878 + 0.08789ABW^{0.75} + 5.0487ADG – 1.683ADG^2$; Crossbred, $DMI = -2.6098 + 0.08844ABW^{0.75} + 4.4672ADG – 1.3579ADG^2$**. These equations are more precise and accurate, and they generate lower prediction errors of the DMI of beef cattle in tropical conditions.

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