Using Mathematical Nutrition Models to Improve Beef Cattle Efficiency[1]

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Introduction

Mathematical models integrate the scientific knowledge of energy and nutrients supply by the feedstuffs and requirements by the animals that have been accumulated over time and allow us to apply it in different production scenarios. Models have an important role in assisting the improvement of feeding systems and helping to understand the feedback structure that dictates the behavior of production systems. Thus, they can provide essential information to be used in the decision-making process of policy makers, producers, and consultants to maximize production while minimizing the environmental impacts through reduced nutrient excretion in an economically feasible fashion. Several mathematical nutrition models have been developed to account for more of the variation in ruminant production (Tedeschi et al., 2005c).

The Cornell Net Carbohydrate and Protein System (**CNCPS**) model has been developed for more than 30 years (Fox et al., 2004b) for use in ration balancing and performance prediction programs to account for factors that affect performance, feed efficiency and nutrient excretion in beef and dairy cattle in each unique production situation. Because of the wide variations in breed types and their crosses used for beef production around the world and environments in which they are fed prior to marketing as finished beef, the CNCPS model has focused on accounting for differences in maintenance requirement, mature body size and composition of gain, implant program, feed composition and feeding system. Evaluations of the CNCPS model have demonstrated the impact nutrition models can have on improving performance and reducing feed cost of production and nutrient excretion (Fox et al., 2004b;Tedeschi et al., 2005a).

The equations developed for the CNCPS to predict beef cow requirements in each unique production situation are being utilized in a beef cow/calf model to identify differences in feed requirements and feed efficiency among beef cows (Tedeschi et al., 2006b).The search for ways to select for improved beef cow efficiency has become a high priority for the beef cattle seedstock industry. Beef production is perceived as a relatively inefficient process from the standpoint of energy expenditure. Research has indicated that 70 to 75% of dietary energy expenditure is used for maintenance (Ferrell and Jenkins, 1985), the remaining is used for pregnancy and lactation requirements, and that beef cows are responsible for 60 to 70% of the total of energy expenditure (Johnson, 1984); at least 50% of this energy is expended to maintain the cow. Efficient beef cows

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use less resource to obtain the same outcome in a sustainable environment. Jenkins and Ferrell (2002) concluded that productivity must be expressed relative to some measure of input, and feed energy required per unit of output is logical.

An insightful report that outlined definitions of efficiency for primary and secondary traits for dairy cow efficiency, which also applies to beef cow efficiency, has been produced by the European Association on Animal Production (Ostergaard et al., 1990). They summarized as follows: "*The improvement in biological efficiency is important, and research has to be focused on the underlying processes such as rumen function, utilization of digested and metabolized energy, and the partitioning of feed energy between milk and body tissue. Knowledge about genetic variation between animals for these different biological processes is very limited, and should be studied in relation to the composition of feed ration, the feeding strategy and the physiological state of the animal*".

Growth models are being used in individual cattle management systems (**ICMS**) that are being developed for the beef industry to improve profitability, to minimize excess fat produced, to increase consistency of products, and to identify and reward individual owners for superior performance in the feedlot. To accomplish this, cattle are marketed as individuals when at their optimum carcass composition, which typically requires having cattle with different owners in the same pen (co-mingle). This requires allocating and billing feed fed to a pen to the individual animals in the pen. To make individual animal management work, the method used to allocate the feed consumed by animals from different owners that share the same pen must accurately determine cost of gain of each animal in a pen. There are three critical control points in launching a successful ICMS:

- Predicting optimum finished weight, incremental cost of gain and days to finish to optimize profits and marketing decisions while marketing within the window of acceptable carcass weights and composition,
- Predicting carcass composition and backfat deposition rate during growth to avoid discounts for under- or over-weight carcasses and excess backfat, and
- Allocating feed fed to pens to individual animals for the purpose of sorting of individuals into pens by days to reach a target body composition and maximum individual profitability.

A mathematical growth model (Cornell Value Discovery System, **CVDS**) was developed (Guiroy et al., 2001; Perry and Fox, 1997; Tedeschi et al., 2004, , 2005b) to address these critical control points for growing animals.

The objective of this paper is to describe the CVDS, to evaluate its accuracy in prediction of dry matter required (**DMR**), and to discuss practical applications of the CVDS for identifying differences in feed efficiency among growing animals fed high-forage diets. The models can be downloaded at http://nutritionmodels.tamu.edu.

Description of the CVDS Model to Predict Energy and Protein Requirements

Modeling systems used to predict feed requirements and cost of gain must be able to account for differences in basal maintenance requirement, the effect of environment on maintenance requirement, the effect of body size, implant program and feeding system on finished weight and growth requirements, feed energy values, and dry matter consumption.

Accounting for body composition at the marketing target end point. The first step for predicting feed required for the observed growth and incremental cost of gain and body composition as cattle grow is to identify the body composition at the marketing target end point. Carcass value in most markets and cost of gain can be related to proportion of protein and fat in the carcass. Body fat in finished cattle when marketed typically varies from 16 to 21% empty body fat (**EBF**) in the French (INRA, 1989) and Brazilian (Leme et al., 2000) markets to over 30% EBF in segments of the Japanese and Korean Markets. Most other markets range between these two.

The single most recognizable quality grade in the world is USDA choice. Premium brand name products typically utilize the prime and upper 2/3 of the Choice grades and are increasing the value of U.S. beef products. Table 1 shows a summary of several experiments (Guiroy et al., 2001) that support the value of the Choice and prime grades level of fatness to minimize the percent of the beef that is unacceptable to consumers in the U.S.

Table 1. Relationship of carcass and empty body fat (EBF) to quality grade

N	USDA Quality Grade [a]	Carcass fat %	Mean EBF [b] %	EBF Std Error	Taste panel score [c]	Not acceptable [c] %
45	3.5	23.6	21.1 [u]	0.63	5.3	40
470	4.5	29.0	26.2 [v]	0.19	5.6	13
461	5.5	31.6	28.6 [w]	0.20	5.8	8
206	6.5	33.0	29.9 [x]	0.29	6.2	0
90	7.5	34.2	31.0 [xy]	0.44	-	-
51	8.5	35.2	31.9 [y]	0.59	-	-
32	9.5	35.8	32.5 [z]	0.74	-	-

[a] Standard = 3 to 4; Select = 4 to 5; low Choice = 5 to 6; mid Choice = 6 to 7; high Choice = 7 to 8; low Prime = 8 to 9; mid Prime = 9 to 10.
[b] Column means with different superscripts are significantly different at $P < 0.05$.
[c] Taste panel scores (1 to 8) and percent unacceptable values are from a subset of this data base.
Adapted from Guiroy et al. (2001).

These data show that EBF was significantly ($P < 0.05$) higher with each incremental increase in grade up to the mid Choice USDA grade. Taste panel scores and percent unacceptable followed the same trend. This data also indicate the correlation between USDA quality grades to changes in EBF as cattle grow. The most critical factor in this table for our model is the EBF at Standard (21.1%), Select (26.2%), and low

Choice (28.6%) grades because these are the body composition endpoints for different marketing targets used to identify feed requirements during growth.

Table 2 lists the inter conversion between USDA quality grade, marbling score, and intramuscular values obtained from ultrasound measurements. The CVDS model (Tedeschi et al., 2004, , 2005b) utilizes the values listed in Tables 1 and 2 to compute EBF.

The National Beef Quality Audit (Smith et al., 1995) reported the percent of steaks with low eating quality for the USDA Prime, Choice, Select, and Standard grades were 5.6, 10.8, 26.4, and 59.1 %, respectively, in data collected from typical feedlot cattle. The % unacceptable values were lower for the data analyzed by Guiroy et al. (2001) likely because they were uniform calves fed a 90% concentrate diet beginning at approximately 7 mo of age. The National Beef Quality Audit conducted by Smith et al. (1995) also reported that up to 20% of all beef does not meet North America consumer satisfaction in eating quality and recommends that the % of cattle grading low Choice and above be increased.

Table 2. Interconversion between marbling score, quality grade, and intramuscular fat measured using ultrasound [a]

Marbling Score	USDA Quality Grade	IMF (BIF) [b]	IMF from Iowa [c]	Marbling Score from Iowa [c]
2	Standard	---	0.28	700
3	Standard	2.76	1.37	800
4	Select	3.83	2.58	900
5	Low Choice	5.04	3.9	1000
6	Choice	6.72	5.33	1100
7	High Choice	7.25	6.88	1200
8	Low Prime	10.13	8.55	1300
9	Prime	---	10.32	1400
10	High Prime	---	---	---

[a] More information at http://meat.tamu.edu/beefgrading.html.
[b] Intramuscular fat based on BIF (http://www.beefimprovement.org).
[c] Standards of the Iowa State University (http://www.ans.iastate.edu).

Based on a survey of retailers, purveyors, and exporters, the ideal mix would be 62% low Choice or better and 38% Select, with no Standard grade beef. This compares to the current 51% low Choice or better, 42% Select and 7% Standard grade and lower (McKenna et al., 2001). The 10% of the United States beef that is exported would have none below low Choice. The strong message from North America consumers is that the external fat must be removed from beef, but intramuscular fat (marbling) is required in the edible portion. This is likely due at least in part to the method of cookery commonly used compared to what is common in most other countries (Dikeman, 1987).

Even though other countries around the world do not utilize the North American standards for beef quality, techniques have to be developed (or adapted) to measure the intramuscular fat (marbling) because this is an important factor affecting not only consumer preferences but also the energy required for growth across different breeds; some breeds tend to deposit more intramuscular fat than others (e.g. Angus vs. Nellore).

Accounting for differences in requirements for growth. It has been determined that cattle of different mature sizes have different fat and protein content of the weight gain at the same weight during growth (Fox and Black, 1984). Therefore, a size scaling procedure to account for differences in energy and protein requirements for growth among cattle of different frame sizes and genders has been developed (Fox and Black, 1984; Fox et al., 1988; Fox et al., 1992; Fox et al., 1999; Tylutki et al., 1994) and was adopted by the National Research Council Nutrient Requirements of Beef Cattle (NRC, 2000).

In this model, the animal BW at the target empty body fat % (**AFBW**) is divided into the weight of the standard reference weight (**SRW**) of an animal at that composition. This ratio is then multiplied by the animal's actual BW to adjust it to the standard reference animal for use in the energy requirement equation; this value is called the equivalent BW (Eq. [1]).

$$\text{Equivalent SBW} = \text{Current SBW} \times \frac{\text{SRW}}{\text{SBW at Target \%EBF}} \qquad [1]$$

The standard reference animal represents the cattle body size used to develop the equations to predict the net energy content of weight gain. Table 3 provides an example of the calculation of net energy required for growth (retained energy) computed with this model for three mature sizes (500, 550, and 600 kg) of cattle.

Table 3. Relationship of stage of growth or maturity (u), body weight at 28% EBF (AFBW), and rate of gain (ADG) in computing retained energy

AFBW, kg	Stage of maturity (u), %				
	50	60	70	80	90
500	250	300	350	400	450
550	275	330	385	440	495
600	300	360	420	480	540
Equivalent SBW, kg	239	287	335	382	430
ADG, kg/d	Retained energy, Mcal/d				
1.0	3.37	3.86	4.34	4.79	5.24
1.2	4.12	4.72	5.30	5.85	6.40
1.5	5.26	6.03	6.77	7.48	8.17

Tables 3 shows that as mature size increases, weight at the same energy content of gain increases, because larger size animals are at an earlier stage of growth at the same weight and therefore have more protein and less fat in the gain. It also shows that energy requirements increase with increasing stage of growth and rate of gain because of more fat in the composition of the gain.

The following equations (Equations [2] to [7]) from the NRC (2000) were used to compute the retained energy (Mcal/d) values shown in Table 3. Note that equivalent SBW (**EqSBW**) value is the same within the same stage of maturity regardless of the AFBW. This is because the equivalent BW is the degree of maturity (or stage of growth) multiplied by the SRW (478 kg).

$$RE = 0.0635 \times EqEBW^{0.75} \times EWG^{1.097} \tag{2}$$

$$EqEBW = 0.891 \times EqSBW \tag{3}$$

$$EqSBW = SBW \times \frac{478}{AFSBW} \tag{4}$$

$$SBW = 0.96 \times BW \tag{5}$$

$$AFSBW = 0.96 \times AFBW \tag{6}$$

$$EWG = 0.956 \times ADG \tag{7}$$

Three data sets were used to test this system (NRC, 2000). With two of the data sets (82 pen observations of *Bos taurus* implanted steers and heifers varying in breed type, body size and diet type and 142 serially slaughtered nonimplanted steers, heifers and bulls varying in body size aggregated into "pens" by slaughter groups), this system accounted for 94% of the variation in energy retained with only a 2% underprediction bias. Similar results were observed for Angus and Holstein heifers (Fox et al., 1999). However, it cannot be assumed that this accuracy will apply to individual animals at a particular point in time during growth, since these results were obtained from pen averages and total energy retained. Many factors can alter estimates of finished weight of individuals, such as previous nutrition, implant programs, level of intake and energy derived from the diet, limits in daily protein and fat synthesis, and daily energy retained. The problem is to be able to predict those effects in individual animals based on information that will be available in feedlots and is practical to apply.

Accounting for differences in requirements for maintenance. The model used for this purpose is described by Fox and Tylutki (1998). The effects of breed type are accounted for by adjusting the base NE_m requirement of 77 kcal/kg metabolic body weight (**MBW**) for *Bos indicus* and dairy types (-10 and +20% compared to *Bos taurus*).

The effects of previous nutrition are accounted for by relating body condition score (**BCS**) to NE_m requirement. On a 1 to 9 scale, maintenance requirement is reduced by 5% for each BCS below 5 and is increased by 5% for each BCS above 5. The effects of acclimatization are accounted for by adjusting for previous month's average temperature (ranges from 70 kcal/kg MBW at 30 ^{o}C to 105 kcal/kg MBW at -20 ^{o}C). This adjustment is continuous, with no effect at 20 ^{o}C (Fox and Tylutki, 1998). Current environmental effects are accounted for by computing heat lost vs heat produced, based on current temperature, internal and external insulation, wind, and hair coat depth and condition. This becomes important when the animal is below the computed lower critical temperature, and can range from no effect at 20 °C to twice as high (thin, dirty hide at -12 °C and 1 mph wind).

These adjustments were developed based on the data reported by the NRC (1981). Further examinations have to be conducted for different levels of production, animal type, environment (climate), and modeling approaches. The above adjustment should be used for static models, which are valuable for the mean of a period of growth but cannot be used consecutively in a dynamic model because of double accounting the previous climate effect over and over (Kebreab et al., 2004; Tedeschi et al., 2004). The effects of environment (climate) have an important effect on animal production and have to be accurately accounted for. Berman (2003; 2005) provided some information regarding heat stress for producing animals and such information could be adapted to current models.

Determining ration energy values. Accurate predictions of dry matter intake (**DMI**) and net energy for growth (**NEg**) and maintenance (**NEm**) are highly dependent on having feed net energy values that accurately represent the feeds being fed. Tedeschi et al. (2005a) evaluated the accuracy of alternative methods for determining feed energy and protein values: the level 1 of the NRC (2000), which uses tabular values for feed composition and energy; the level 2 of the NRC (2000), which uses the CNCPS (Fox et al., 2004b); and a summative equation commonly used by feed analysis laboratories to predict feed energy values from chemical composition (Weiss, 1993, , 1999; Weiss et al., 1992).

Metabolizable energy (**ME**) was predicted by the CNCPS to be first limiting in 19 treatment groups (Tedeschi et al., 2005a). Across these groups, the observed ADG varied from 0.8 to 1.44 kg/d. When ME was first limiting, the ADG predicted by the CNCPS model accounted for more of the variation (80%) than did the summative equation or tabular (73 and 61%, respectively). Metabolizable energy allowable ADG predicted with the tabular system gave an overprediction bias of 11%, but the bias was less than 2% when predicted with the CNCPS or summative equation. The MSE were similar in all predictions, but the CNCPS model had the highest accuracy (lowest RMSPE).

Metabolizable protein (**MP**) was predicted by the CNCPS to be first limiting in 28 treatment groups (Tedeschi et al., 2005a). Across these groups, the observed ADG ranged from 0.12 to 1.36 kg/d. The ADG predicted by the CNCPS model accounted for more of the variation (92%) than did the summative equation or tabular (79 and 80%, respectively). Metabolizable protein-allowable ADG predicted with the tabular gave an overprediction bias of 4%, whereas the bias was less than 2% when predicted with the CNCPS or the summative equation. Similar to the ME first limiting analysis, the CNCPS model had the highest accuracy (lowest RMSPE: 0.11).

Predicting days to finish, carcass weight, body composition, quality and yield grade. Fox et al. (2002; 2001a) listed and exemplified the sequence of calculations of the growth model (Guiroy et al., 2001; Perry and Fox, 1997; Tedeschi et al., 2004, , 2005b) developed to account for individual animals when fed in groups. Previous evaluations of this model have indicated the CVDS model predicted DMR with an r^2 of 74% and mean bias of 2% (Tedeschi et al., 2004, , 2005b) and feed conversion ration (**FCR**) with and r^2 of 84% and a mean bias of 1.94% (Tedeschi et al., 2006a) using the data of 362 individually fed steers. Guiroy et al. (2001) reported that the CVDS accurately allocated the feed fed to 12,105 steers and heifers in a commercial feedlot, with a bias of less than 1%. Recent evaluations with pen-fed Santa Gertrudis steers and heifers indicated the model was able to accurately predict the feed that was allocated to the pens with a bias of 2.43% (Bourg et al., 2006a).

Practical Applications of the CVDS Model in Identifying Differences in Efficiency

Selecting for Efficient Animals. Fox et al. (2001b) utilized an early version of the CVDS (Cornell Cattle Systems v. 5) to simulate the effect of growth rate and feed efficiency on cost to gain 270 kg (initial BW of 260 kg and final BW of 530 kg). Based on their simulation (Table 4), an increase of 10% in ADG alone was predicted to increase DMI 7% and improve profits by 18%, probably due to fewer days on feed and thus less non-feed costs. The reduction in feed cost was due to a reduction in feed required for maintenance due to fewer days required to gain 270 kg. On the other hand, when intake was kept the same but efficiency of ME use by the animal was improved by an amount that resulted in a 10% improvement in feed efficiency, profits increased by 43%. The simulations of Fox et al. (2001b) clearly suggested that improving feed efficiency or feed conversion ratio may result in a higher benefit to the producer.

Table 4. The effect of improvement in rate of gain and feed efficiency on profits [a]

Variables	Average steer	Effect of 10% higher ADG	Effect of 10% higher feed efficiency
DMI, kg/d	8.48	9.01	8.48
ADG, kg/d	1.46	1.60	1.64
Feed:gain ratio	5.82	5.67	5.18
Feed cost, $	176	172	157
Non feed cost, $	98	91	89
Total cost of gain, $	274	263	246
Profit, $	65	77	93

[a] Adapted from Fox et al. (2001b). Values were computed using the CCS v. 5.0 model.

Okine et al. (2004) compared the profitability of animals with different efficiency traits. Animals started at 250 kg and were slaughtered at 560 kg. Those with 5% increase in ADG saved US$ 2 per head versus US$ 18 per head for steers with a calculated increase of 5% in feed efficiency (Table 5).

Similar to Fox et al. (2001b), Okine et al (2004) also concluded that an increase in feed efficiency (or a decrease in feed conversion ratio) leads to a higher profit. In part, this is because the same percentage change in DMI is numerically greater than that for ADG, which leads to a greater impact on the outcome; less days on feed. Thus, comparison should be made on a *ceteris paribus* condition in which all variables are kept constant and only one variable is varied at a time. Animals with higher ADG will always be more efficient as long as the maintenance requirement is constant. This happens because of the dilution of the amount of feed required for maintenance compared to the total amount of feed consumed, leading to a more efficient animal per unit of gain. Nonetheless, in practice this may not happen and maintenance requirement increases as ADG increases. Therefore, the most efficient animal will be that one that has a lower increase in maintenance per unit of ADG.

Table 5. Simulated cost and saving of steers with calculated 5% increase in feed efficiency or average daily gain compared to actual performance [a]

Variables	Actual data (200 d)	Calculated 5% increase in FER (200 d)	Calculated 5% increase in ADG (200 d)
DMI, kg/d	9.45	8.98	9.91
ADG, kg/d	1.55	1.55	1.63
Feed:gain ratio	6.08	5.78	6.08
Total cost of gain, $	424	406	422
Savings for 200 d, $/hd	---	18	2

[a] Adapted from Okine et al. (2004).

We performed a simulation slightly different than that shown by Fox et al. (2001b) and Okine et al (2004). In our simulation, the ADG (1.62 kg/d) was identical across the first three scenarios; therefore, we assumed that animals would change either DMI or maintenance requirements to obtain the same performance. In a fourth scenario, ADG was increased 10% for the same DMI. A 250-kg steer with AFBW of 560 kg was fed a diet containing 2.9 Mcal/kg of ME and costing US$ 0.19/kg to set the conditions for the scenarios (Table 6). A purchase cost of US$ 1.95/kg BW and sale price of US$ 1.9/kg of BW were assumed.

When ADG was held constant, 185 days on feed were required to reach the low Choice USDA grade; a 10% increase in ADG reduced days on feed to 168 days. A decrease in efficiency by 10% (increased DMI by 10%) reduced profits by 42% and an increase in efficiency by 10% (decreased DMI by 10%) increased profits by 37%. The increase in efficiency is smaller than that reported by Fox et al. (2001b). Likely, because they changed ADG rather than DMI; increasing ADG by 10% and keeping DMI similar to the standard scenario, would have increased the profit by 44%, identical to the Fox et al. (2001b) finding. Selecting for animals with an increased ADG can improve feed efficiency so long as it does not change the mature size. If mature size is increased, the apparent increase in profit could be offset by the longer days on the feedyard to reach the USDA low Choice grade.

Table 6. The impact of changing feed efficiency, DMI, or ADG by 10% on profits [a]

Variables	Standard	Increased DMI 10%	Decreased DMI 10%	Increased ADG 10%
DMI, kg/day	9.35	10.29	8.40	9.35
ADG, kg/d	1.62	1.61	1.61	1.77
Feed:gain ratio	5.78	6.40	5.22	5.27
Feed cost, US$	326.98	361.86	295.43	298.37
Total cost, US$	935.71	971.92	903.96	898.10
Profit, US$	86.27	49.91	117.85	124.39
Total cost/gain, US$/kg/d	1.57	1.69	1.46	1.44
Purchase breakeven, $/kg BW	2.30	2.15	2.44	2.47
Annual margin for all costs, %	18.29	10.13	25.72	30.09

[a] Values were computed using the CVDS model version 1.0.18.

We performed risk analysis simulations using the CVDS model to evaluate the impact of initial BW (300 ± 20 kg), diet ME (2.8 ± 0.2 Mcal/kg), and a fixed feed cost of (US$ 0.05/kg) of a finishing steer fed for 120 days. The risk analysis was conducted with @Risk using 5,000 iterations and normal distribution was assumed for initial BW and diet ME (Figure 1). Our simulation indicated an expected ADG skewed to the right and was expected to be between 1.2 and 1.7 kg/d (90% confidence interval), the DMR was expected to be between 8.3 and 9.4 kg/d (90% confidence interval), and the FCR was predicted as 5.03 to 7.89 kg/kg (90% confidence interval).

The analysis of the FCR indicated a higher correlation between ADG and FCR (-0.971) than DMR and FCR (0.703). Figure 1 also indicated that variation in the standard deviation of mean SBW and initial SBW had the highest impact on the standard variation of the profit (0.524 and -0.512, respectively). Similarly, for each increase in the standard deviation of the mean ADG, profit would increase by 0.233 standard deviation units. A unitary change in the DMR standard deviation would decrease the profit by 0.048 standard deviation units. Therefore, for practical applications, the BW and consequently the cost associated with the purchase of each animal has the highest effect on profitability during the feedlot finishing period. The ADG would have a higher impact on the profit than the DMR, and because these two variables had inverse effects on profit, changing feed efficiency would have a higher impact on profit than a change in ADG or DMR alone. This result is in agreement with that shown in Tables 4, 5, and 6; ADG has a stronger impact on profit than intake, therefore, selecting for higher ADG than lower intake might be more profitable.

Tedeschi et al. (2006a) reported a phenotypic correlation between DMR and DMI, ADG, and Kleiber ratio of 0.75, 0.65, and 0.55, respectively. The DMR is the expected intake predicted by the model given the information on animal, diet and environment. This is similar to the expected intake predicted by the RFI using mean BW and ADG. Tedeschi et al. (2006a) reported the correlation of the residual (observed minus expected intake) between these two approaches was 0.84. Similarly, Bourg et al. (2006b) reported a correlation of 0.80.

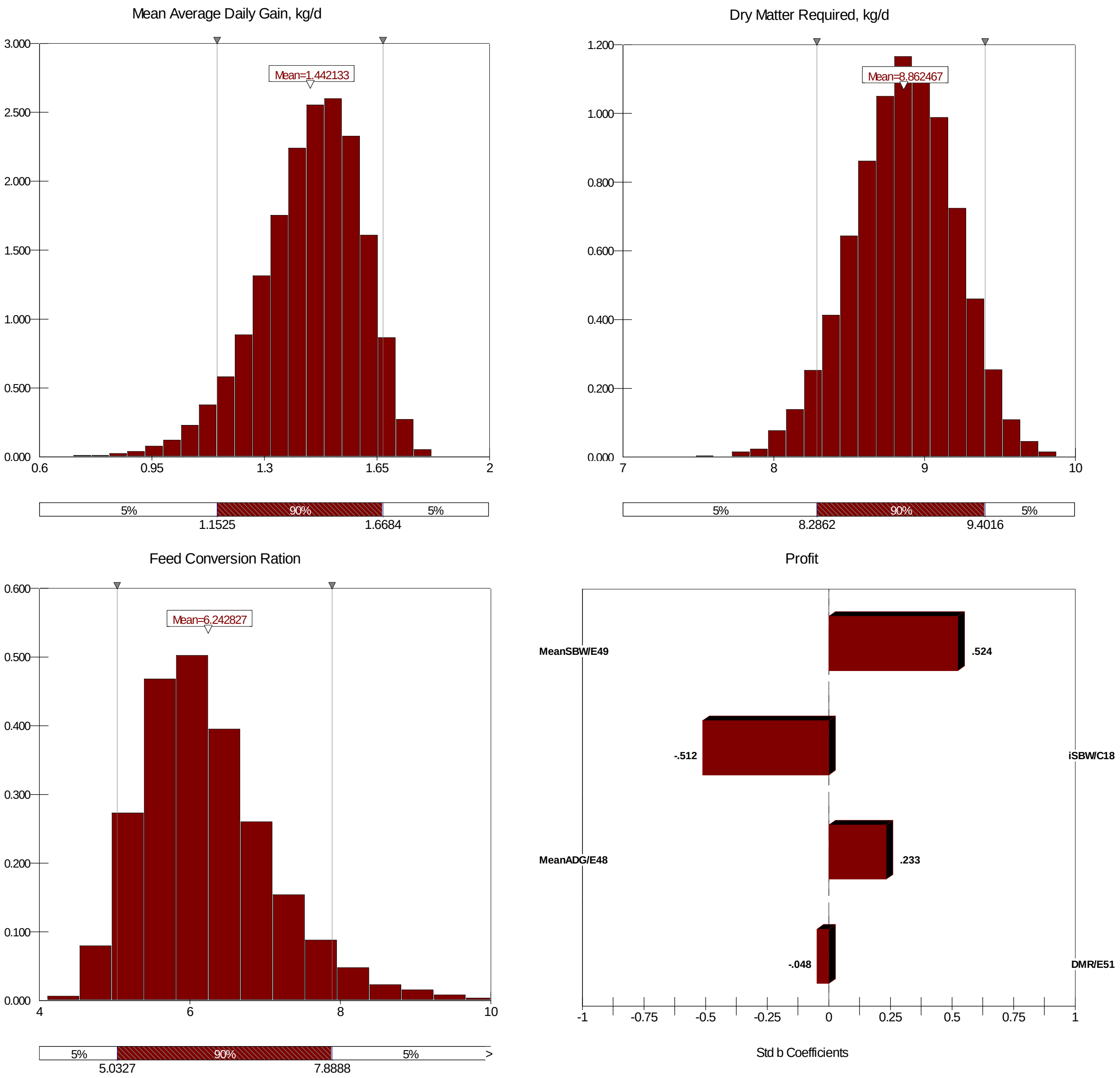

Figure 1. Simulation results of average daily gain, dry matter required, feed conversion ratio, and profit predicted by the CVDS model varying initial body weight and dietary metabolizable energy for an steer fed for 120 days.

<u>*Using Mathematical Models for Genetic Selection*</u>. Additional evaluations of mathematical models have been conducted to assess heritability and genetic correlations. Williams et al. (2005) compared the Decision Evaluator for the Cattle Industry (**DECI**) and the CVDS models to predict DMR, using 504 steers and 52 sires. Heritability for DMR was around 0.33 for both models and genetic correlations between actual DMI and predicted DMR was greater than 0.95. Similarly, Kirschten et al. (2006) evaluated the genetic merits of the CVDS predictions and reported heritability of 0.35 and genetic correlations between DMI and DMR of 0.98, with low re-ranking of sires. These authors suggested that predicted DMR may be used in genetic evaluations with minimal genetic differences between DECI and CVDS models.

Evaluation of the CVDS Predictions of DMR for Animals Fed High-Forage Diets

We developed a database to evaluate the CVDS model with animals fed high-forage diets under tropical conditions. The database consisted of six studies containing steers, heifers, and bulls (N = 148) as shown in Table 7. The diet ME varied from 1.85 to 2.96 Mcal/kg with animals varying from 230 to 360 kg initial BW and 350 to 500 kg final BW.

Table 7. Description of animals and diets used in the evaluation database [a]

Ref[b]	Breed [c]	Sex [d]	DMI	ME	iBW	fBW	iEBF	fEBF	ADG	N
1	F1 Si x Ne	B	9.7±0.7	2.28 to 2.72	354±19	501±6	8.0	17.3±1.4	1.2±0.3	24
2	Ne	B	8.3±0.5	2.11 to 2.51	325±23	451±8	14.9	22.9±1.8	1.1±0.3	25
3	F1 Li × Ne	B	7.4±0.5	1.85 to 2.76	321±20	491±14	10.4	20.3±1.5	1.1±0.2	40
4	Ne	B	7.0±1.5 7.3±0.9	2.64 to 2.96	231±61 360±0	352±21 434±15	14.7 15.9	21.1±2.2 21.2±2.1	1.2±0.3	30
5	Ne	S	7.5±1.0	2.31 to 2.61	267±30	358±58	5.5	13.8±2.6	1.1±0.2	12
6	F1 RA × Ne	B S H	9.1±0.9 8.5±0.6 7.7±1.5	1.94 to 2.34	290±20 293±27 249±32	448±43 426±36 377±59	6.6 5.5 10.2	18.7±3.7 17.4±3.4 21.6±4.0	1.5±0.4 1.2±0.3 1.2±0.3	17

[a] Values are mean ± SD for dry matter intake (DMI, kg/d), initial and final shrunk body weight (iBW and fBW, kg), initial and final fat in the empty body (iEBF and fEBF, % of empty body weight) and average daily gain (ADG, kg/d). ME is the range of ME of the diets, Mcal/kg.

[b] References: 1 – Ferreira (1998), 2 – Véras (2000), 3 – Veloso (2001), 4 – Silva (2001), 5 – Paulino (2002), and 6 – Chizzotti et al. (2006).

[c] Breeds: Si – Simmental, Ne – Nellore, Li – Limousin, and RA – Red Angus.

[d] Sex: B – bulls, S – steers, H - heifers.

The CVDS model was used to predict DMR under two scenarios: (1) without adjustment for composition of gain (Figure 2A) and (2) with adjustment for composition of gain (Figure 2B). After predictions of DMR by the CVDS model, we adjusted the DMI and DMR to account for study effects using a mixed model (Littell et al., 1999) assuming studies as random effects and unstructured variance-(co)variance matrix (Eq. [8]).

$$DMI_{ij} = a_i + b_i DMR_{ij} + e_{ij}$$

$$where$$

$$\begin{pmatrix} a_i \\ b_i \end{pmatrix} \sim iid\ \mathbb{N}\left(\begin{pmatrix} \beta_0 \\ \beta_1 \end{pmatrix}, \psi\right); \psi = \begin{pmatrix} \sigma_a^2 & \sigma_{ab} \\ \sigma_{ab} & \sigma_b^2 \end{pmatrix}; e_{ij} \sim iid\ \mathbb{N}(0, \sigma^2) \qquad [8]$$

As shown in Figure 2, the adjustment for composition of gain resulted in a better prediction of DMI mainly because of low fat content of the gain of the studies of Silva (2001) and Chizzotti et al. (2006). When adjustment for composition of gain was used, the model mean bias was 0.68%, accuracy measured by the concordance correlation coefficient (Tedeschi, 2006) was 0.93, and precision measured by the r^2 was 0.75 compared to -11.1%, 0.67, and 0.77, respectively, when no adjustment was used.

Fox et al. (2004a) provided a summary of the evaluations of the CVDS used to compute feed required of group-fed animals. The result of a three-year Bull test conducted at New York indicated the CVDS predicted sum of the individual feed required averaged within 2% of the actual feed fed to pens. Jorgensen Angus (Ideal, SD) has used the CVDS to predict feed efficiency in 867 bulls from 56 sires over the past 5 years. The sum of predicted feed required has been within 3 to 5% of actual feed fed. Recently, Bourg et al. (2006a) evaluated the predictions of the CVDS for Santa Gertrudis steers and heifers (N = 457) fed in pens and reported an overall bias between actual feed fed and model-predicted DMR of 2.43%.

Conclusions

The CVDS model provides a method for predicting energy requirements, performance and feed required by individual cattle fed in a group with good accuracy by accounting for factors known to affect cattle requirements (e.g. breed type, body size, stage and rate of growth). Feed can be accurately allocated to individual steers, heifers or bulls fed in group pens, based on prediction of final EBF from carcass measures. This allows cattle from different owners to be fed in the same pen, allowing for more efficient marketing of feedlot cattle and collection of data in progeny test programs.

Our preliminary analysis suggests this model also has the potential to be used in identifying differences in feed efficiency between individual animals fed in group pens. The predicted feed required for the observed performance appears to be strongly related to actual feed intake, and is moderately heritable. We are hopeful that research underway will provide additional information on the use of the CVDS in selection programs to improve feed efficiency of beef cattle.

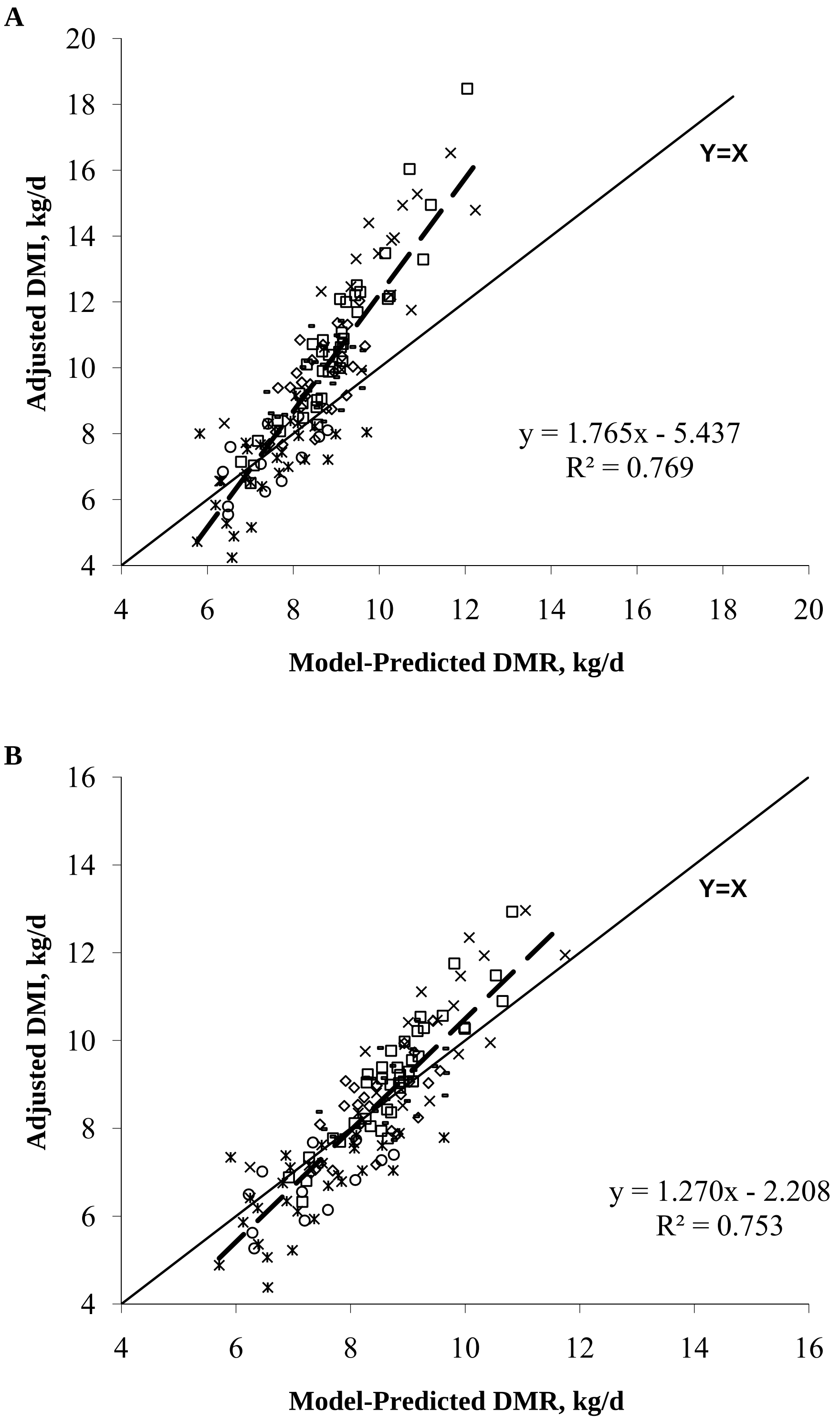

Figure 2. Relationship between dry matter intake (DMI, kg/d) adjusted for study effect and model predicted dry matter required (DMR, kg/d) (A) without and (B) with adjustment for composition of gain. Symbols are studies: ○, Paulino (2002); *, Véras (2000); ◊, Veloso (2001); ×, Silva (2001); −, Ferreira (1998); □, Chizzotti et al. (2006).

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