IDENTIFYING DIFFERENCES IN EFFICIENCY IN BEEF CATTLE

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PREFACE

Over the past 10 years, we have been working with various groups in the beef cattle industry to find ways of applying the nutritional models we have developed at Cornell University over the last 25 years to identify differences in feed efficiency among individual beef cattle fed in groups. Applications they have been interested in include:

1. Accurate prediction of rate and cost of gain during growth so cattle can be marketed at their most profitable endpoint,
2. Allocation of feed among individual cattle fed in feedlot pens so they can be penned with mixed ownership by days to finish,
3. Identifying the optimum combination of beef cow mature size and level of milk for the land and feed resource available, and
4. Identifying differences in feed efficiency for use in evaluating breeding programs.

The Cornell Value Discovery System (CVDS) is a computer program that we have developed for applying our models to meet the above objectives. It is available on our web page: http://www.cncps.cornell.edu/cvds.

The intent of this bulletin is to provide three papers that have been presented at various regional, national, and international conferences that provide an overview of the research and science behind the models in the CVDS and to provide examples of how it is being used. The first paper, *"Identifying differences in feed efficiency in beef cattle during post weaning growth"*, summarizes the development of the model to be used in applications 1 and 2 above; we are presently exploring its potential use for application 4 also. The second paper, *"Increasing land and beef cow efficiency: matching cow type and milking ability to your land and forage"* summarizes the development of the COWHERD and CVDS computer programs for application 3. The third paper, "*Unveiling the production efficiency of the beef cow: a systematic approach using nutrition models*" summarizes the development for the CVDS computer program for application 4 for beef cows.

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IDENTIFYING DIFFERENCES IN FEED EFFICIENCY IN BEEF CATTLE DURING POST-WEANING GROWTH[1]

Danny G. Fox, Luís O. Tedeschi, Michael J. Baker and David P. Kirschten

Development of models to predict feed efficiency

Over 2/3 of the cost of producing beef is for feed. Thus, it is important to accurately predict feed efficiency and how to improve it with alternative management strategies. Much of the improvement in feed efficiency in beef cattle over the past 30 years has been through one of the following:

1. Feeding more grain to reduce the time required to reach market weight,
2. Implanting growth stimulants and feeding ionophores, or
3. More accurate ration balancing programs, based on research that has been conducted on animal requirements.

We have been developing models for the past 30 years for use in ration balancing and performance prediction programs to account for factors that affect feed efficiency in beef cattle in each unique production situation. Because of the wide variations in breed types and their crosses used for beef production in North America and environments in which they are raised prior to marketing as finished beef, these models have focused on accounting for differences in maintenance requirement, mature body size and composition of gain, implant program, feed composition and feeding system. The objective has been to apply these models to account for these variables in predicting feed requirements and cost of production from the information typically available on farms or ranches. These models have primarily been used in the following ways:

1. Use feed intake and composition, animal, and environment data to accurately predict nutrient requirements and supply of nutrients from the available feeds in balancing rations to optimize performance of pens of cattle in feedlots from the diet fed, and
2. Use feed intake and composition, animal, and environment data to predict cost of gain for individual cattle fed in groups for each day on feed, days on feed to optimum sale weight, break even sale price and profits.

Two models have evolved from our research over the past 30 years to accomplish the above applications; the Cornell Net Carbohydrate and Protein System (CNCPS) to accomplish objective 1 and the Cornell Value Discovery System (CVDS) to achieve objective 2. They both use the same base equations to predict energy requirements for each physiological function. The CVDS applies most of the CNCPS equations to predict feed requirements and performance for each day during the entire feeding period. A priority has been to publish the CNCPS and CVDS models in the scientific literature for several reasons:

1. To obtain rigorous review by our academic peers to insure that they are based on the best science available, and that the models are based on our best understanding of each of the

[1] A modification of invited papers presented at the Future Beef Organization workshop (February 2001), the Beef Improvement Federation (May 2001, 2002), the Bell Ranch, NM, Genetic Evaluation Workshop (August 2003) and at the Nebraska Sandhills Cattle Assn. Convention (May 2004).

physiological functions involved in determining nutrient requirements (maintenance, lactation, growth, pregnancy, energy reserves). The peer reviewed publications that describe our models are listed in the literature cited (Fox and Black, 1984; Fox et al., 1988, 1992a, 2004; Perry and Fox, 1997, Guiroy et al., 2001 and Tedeschi et al., 2004b). These publications include studies conducted to determine the accuracy of these models in predicting animal requirements and performance. About 50 additional papers have been published on the development and evaluation of various components of these models,

2. To establish scientific credibility for the models,
3. To make the models available for teaching and research. This has encouraged other scientists to conduct independent evaluations of these models and publishing improvements in model components, and
4. To make the models available for use on farms, feedlots and ranches by the feed industry, feeding consultants, and extension educators.

Components of the CNCPS model were used in developing the recent revisions of the standards most often used nationally and internationally to predict nutrient requirements of cattle (National Research Council Nutrient Requirements for Beef Cattle (NRC, 2000) and Dairy Cattle (NRC, 2001)). We have developed computer programs to apply these models, which are available on our website at http://www.cncps.cornell.edu.

These models have proven to be accurate in predicting nutrient requirements and performance in feedlot cattle. The question we are addressing now is, ***can we use these models to identify differences in feed efficiency in individual cattle fed in groups***?

Economic benefits of improved feed efficiency

Table 1 illustrates the impact of improved growth rate or feed efficiency on feed and total cost of gain. The average steer is approximately 1170 lb when marketed (NRC, 2000), with approximately 50% grading choice (Fox et al., 2001). Table 1 shows the effects of growth rate and feed efficiency for this steer on cost to gain 600 lb (570 lb initial weight to 1170 lb at low choice grade). This table shows that animals that grew faster to the same finished weight can be expected to have improved feed efficiency and profits. The reduction in feed cost was due to a reduction in feed required for maintenance due to fewer days required to gain 600 lb, which also reduced feed costs. When the intake remained the same but efficiency of energy use by the animal was improved by an amount that resulted in a 10% improvement in feed efficiency, profits were improved by 43%.

The observation that increased growth rate is associated with improved feed efficiency has led us to select for growth rate over the last 40 years since it is relatively easy to measure. Koch et al. (1963) concluded that "selecting for gain should be effective and lead to both increased feed efficiency and increased feed consumption".

However, studies have shown that mature size also increases if differences in composition of gain and finished weight are not accounted for. The research of Harpster et al. (1978) is representative of these studies. Four types of cattle were developed from a herd of

Hereford cows through the use of selection and crossbreeding to improve weaning and feedlot growth rate. The types included Unselected Herefords, Selected Herefords, Angus x Hereford x Charolais, and Angus x Hereford x Holstein. At weaning, steer calves were finished in the feedlot on all corn silage or high grain based rations to the low choice grade, and heifer calves not kept for herd replacements were fed all corn silage rations to the low choice grade.

Table 1. The effect of improvement in rate of gain and feed efficiency on profits

	Average steer	Effect of 10% higher ADG	Effect of 10% higher feed efficiency
Dry matter intake, lb/day	18.7	20.0	18.7
Daily gain, lb	3.21	3.53	3.61
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

Table 2 shows the results of that study. Differences in initial weights reflect differences in weaning weights, since the calves were placed on the feedlot trial within 30 days of weaning. The following were our conclusions from that study:

1. Selection for growth rate increased cow mature weights and steer and heifer weaning weights, and weights at a similar degree of body fat (low choice grade).
2. Selection and crossbreeding based on growth rate alone did not improve feed efficiency in the feedlot-finishing phase.
3. Crossbreeding with dairy to improve milk production increased weaning weights but reduced feed efficiency in the feedlot-finishing phase.
4. Heifers reach the same degree of body fat at about 80% of the weight of their steer mates.
5. Selection for growth rate was beneficial in that carcass weights across both steers and heifers were the most acceptable in weight in the selected and crossbred groups. Thus, selection for growth rate until the mature size is reached where carcass weights are of an optimum size is beneficial.
6. ***This study agrees with others that indicate most differences in feed efficiency are due to differences in stage of growth/composition of gain and level of intake above maintenance requirements. Thus, these factors must be accounted for in evaluating differences in feed efficiency.***

Therefore, a key factor in being able to predict feed efficiency with our models is the accuracy of our equations to predict energy and protein deposited in the gain by different cattle types. We evaluated these equations for their accuracy in predicting performance of pens of cattle with data computed from pen averages (NRC, 2000). Three data sets were used to test this system. Two of the data sets included 82 pen observations of *Bos taurus* implanted steers and heifers varying in breed type, body size and diet type and 142 serially harvested non-implanted steers, heifers and bulls varying in body size aggregated into “pens” by harvest groups. Our model accounted for 94% of the variation in energy deposited (retained) with only a 2% under-prediction bias However, it cannot be assumed that this accuracy in predicting pen averages will apply to individual animals at a particular point in time during growth. A model can be accurate in predicting performance of the pen average while inaccurately predicting performance of individual animals in the pen, because of averaging out of under-predicted and over-predicted values. So further work was needed to see if these equations could be applied to individual cattle to predict their performance and feed efficiency. Our involvement with the development of individual cattle management systems in feedlots in recent years has been the impetus to modify our model to accurately predict performance of individual cattle fed in group pens.

Table 2. The effect of selecting for growth rate[1]

Item	Unselected Hereford	Selected Hereford	Angus x Hereford x Charolais	Angus x Hereford x Holstein
		Steers fed high grain rations		
Initial weight, lb	379	438	537	563
Final weight, lb	1043	1136	1268	1241
Daily gain, lb	2.82	2.96	3.09	2.86
Daily DM intake, lb	15.7	16.8	18.8	19.3
Feed/gain ratio	5.58	5.66	6.08	6.76
		Carcass weight at 29% carcass fat (lb)		
Steers	588	665	733	768
Heifers	468	552	584	627

[1]Harpster et al. (1978). Cattle were harvested when estimated to be at low Choice grade.

Identifying differences in feed efficiency in individual cattle fed in groups

Systems for individual cattle management are being developed to minimize excess fat produced, increase consistency of product and to identify and reward individual owners for superior performance in the feedlot. Their objective is to market individual animals at their optimum economic endpoint, considering live and carcass cost of gain each day during growth and carcass prices for various grades in a grid pricing system. To accomplish this, cattle are marketed as individuals when at their optimum carcass composition, which typically requires sorting and penning cattle according to days to finish. This often results in having cattle with different owners in the same pen. Also individual cattle management systems require the ability to allocate and bill 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.

We developed and evaluated a model for use in the CVDS to predict requirements of individual animals in a pen, based on their observed performance, for use in allocating feed (Perry and Fox, 1997; Guiroy et al., 2001; Tedeschi et al., 2004b). Instead of using expected average pen intakes, this model uses the animals' body weight, daily gain, carcass measurements, and ration to predict their feed requirement for the observed performance. This information can be used to determine their proportional share of the feed fed to the pen to determine their feed cost of gain. Dividing this feed required for the observed performance by the daily gain gives the feed conversion ratio. Table 3 gives an example of how the feed requirement and feed conversion ratio was computed by the CVDS for an actual steer from the Cornell Herd that was fed in a mixed ownership pen in The New York Feedlot and Carcass Value Discovery Program.

Table 3. Example calculation with the feed allocation model[1]

Inputs	Results
Initial shrunk weight = 713 lb	Daily gain = 4.64 lb
Final shrunk weight = 1265 lb	28% fat weight = 1241 lb
Days on feed = 119	Net energy for gain = 10.82 Mcal/day
Hot carcass weight = 803 lb	Feed DM for gain = 17.64 lb/day
Quality grade = 5.0 (USDA low Choice)	Net energy for maintenance = 6.83 Mcal/day
Rib eye area = 12.3 in^2	Feed DM for maintenance = 7.49 lb/day
Backfat depth = 0.59 in	Total feed DM required = 25.16 lb/day
Diet NEm = 0.91 Mcal/lb	Feed conversion = 5.42
Diet NEg = 0.61 Mcal/lb	Feed efficiency = 184.5 g/kg

[1]Group inputs included pen dry matter intake for the entire feeding period, and ration NE_m and NE_g values.

We evaluated the ability of the CVDS to predict dry matter required by individuals for the observed performance with published data (Guiroy et al., 2001). This data base included 365 individually fed steers of diverse biological types in which chemical body composition was determined and carcass measurements were taken, and complete information on feeds fed were available to accurately predict diet net energy values in each experimental group.

Figure 1 shows the DM requirements predicted by the CVDS compared to the actual DM consumed. The CVDS accounted for 74% of the variation in actual DM consumed, with essentially no bias (0.34%) and a coefficient of variation of 8.18%. Figure 2 shows that the error in allocating feed to individual animals is small when the owner has at least 5 animals in the pen.

In common feedlot situations, each owner owns more than one animal in a pen. Therefore, they will be concerned with knowing the accuracy of predicting the total of all of their animals' share of the total feed consumed by the pen. A reduction in the error of prediction of DM required is expected when predicting groups of animals instead of individuals within a pen. To measure this reduction, the predicted and observed individual DM requirements of the 365 individually fed animals used to validate our feed allocation model were summarized by groups of 5, 10, 20, 40, or 80 animals; these groups were randomly created for this analysis. Figure 2 shows the result of this analysis. The coefficient of variation was reduced more than 50% (from 8.18 to 3.76%) when predicting DM required for groups of 5 animals instead of individuals, and was less than 2% in groups of more than 20 animals. This analysis shows that accuracy of allocating feed by individual owner is very high when owners have at least 5 animals in a pen.

Figure 1. Evaluation of prediction of feed requirements (DM) of individual animals. Data include 365 individually fed steers (Guiroy et al., 2001)

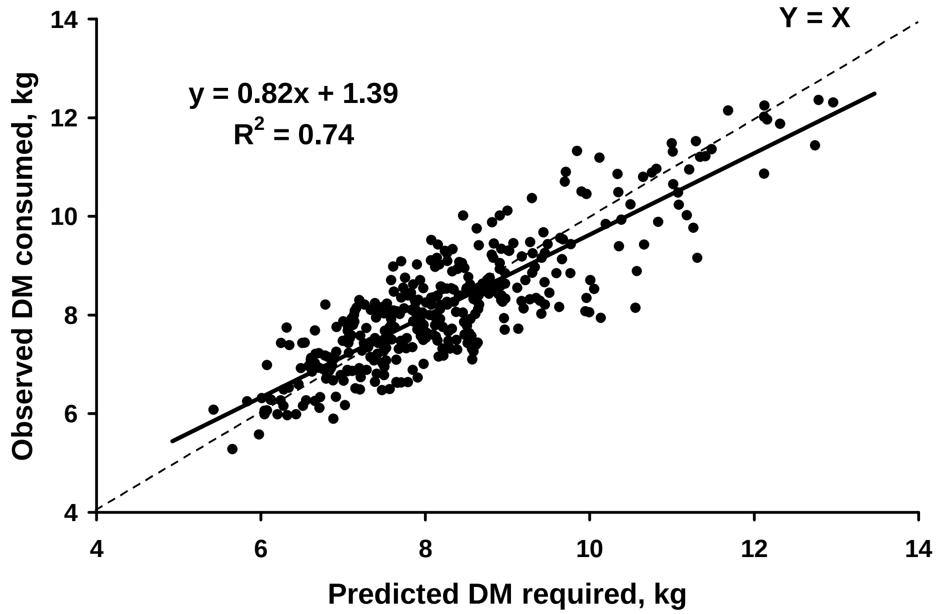
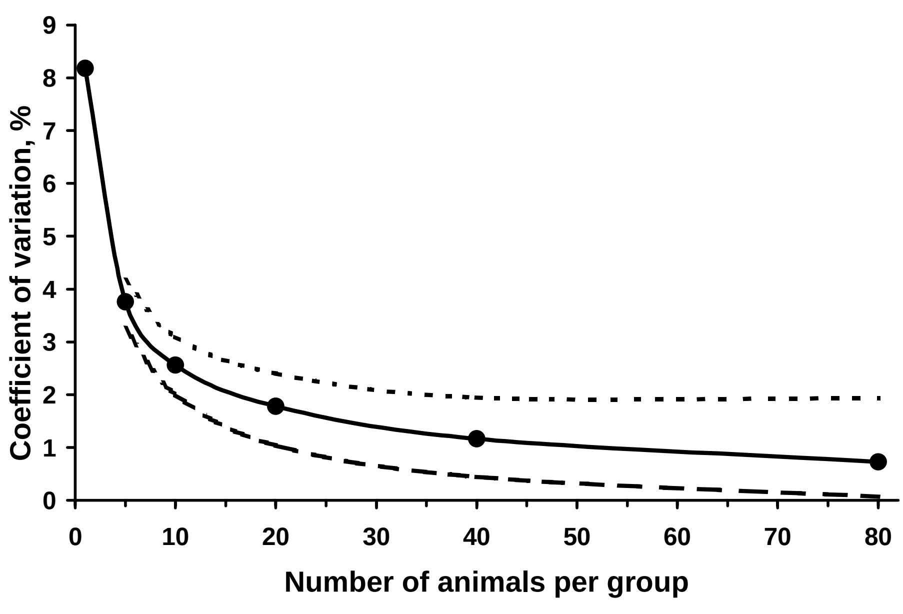
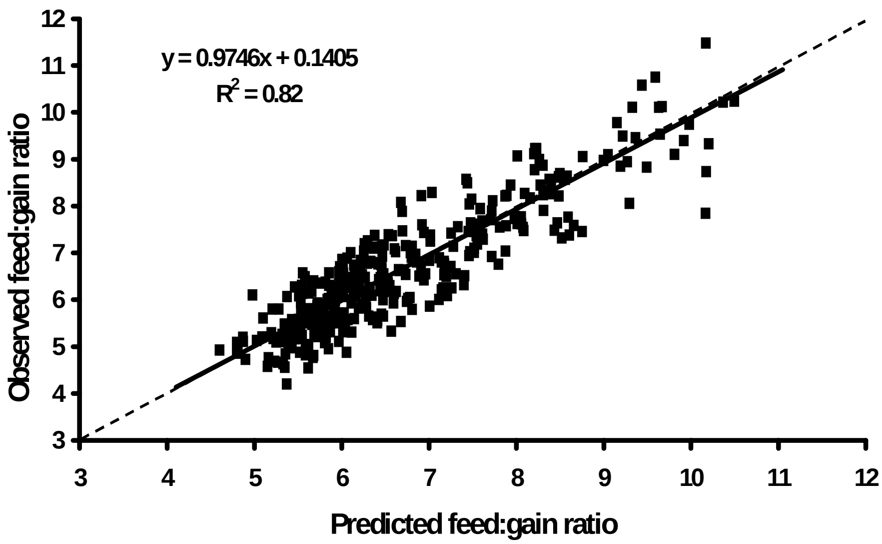


Figure 2. Reduction in the coefficient of variation of predicting DM required from an individual animal to groups of animals with increasing number of animals per group (Guiroy et al., 2001)



We used this data base to evaluate the accuracy of this model for determining the feed conversion ratio (Figure 3). The CVDS model accounted for 82% of the variation in individual animal feed efficiency. The variation not accounted for in this system is due to individual animal variations that the system cannot fully account for with the inputs available (body weights, carcass measurements, feed chemical composition, etc.) including differences in maintenance requirements, diet digestibility and metabolizability, initial body fat, and fat distribution at the same body fat. Predicted DM requirements also contain all of the accumulated errors in predicting each component. However, all of the feed is allocated by multiplying the ratio of the total actual pen DM consumed to the total pen DM required times each animal's DM required. Therefore, this system provides a fair method for allocating feed to individuals fed in a group on a biological basis, considering differences known to affect requirements (breed type, body size, stage and rate of growth).

Figure 3. Evaluation of prediction of feed efficiency of individual animals. Data include 365 individually fed steers (Guiroy et al., 2001)



But, ***does the system work in a commercial feedlot?*** To answer this question, a feedlot data set of 12,105 steers and heifers (Table 4) was developed to evaluate the system. The feedlot data was provided by Micro Beef Technologies, Inc. (Amarillo, TX), which was collected with their computerized electronic cattle-tracking system. Total feed DM delivered vs the sum of each individual animal predicted DM required was compared using the CVDS model. Results from this comparison (Table 4) shows DM required was predicted with very little bias by the model (underprediction of –0.91% for steers, and overprediction of 0.89% for heifers). The small bias for each sex indicates the model works equally well for steers and heifers. An underprediction bias of up to 2% in the total DM consumed by feedlot cattle can be expected due to feed fed that was lost and not consumed by cattle (bunk cleaning, wind, etc). A bias is also expected by using a fixed maintenance requirement of 0.077 Mcal/d/kg $SBW^{0.75}$, which likely varies within and between feedlots due to animal interactions with actual environmental conditions. However, in this data set, the effects of environment were accounted for in the diet NE_m and NE_g provided by the feedlot consultant. The feedlot consultant's values reflect diet NE values required to have predicted and observed ADG agree in the historical data base used for performance projection.

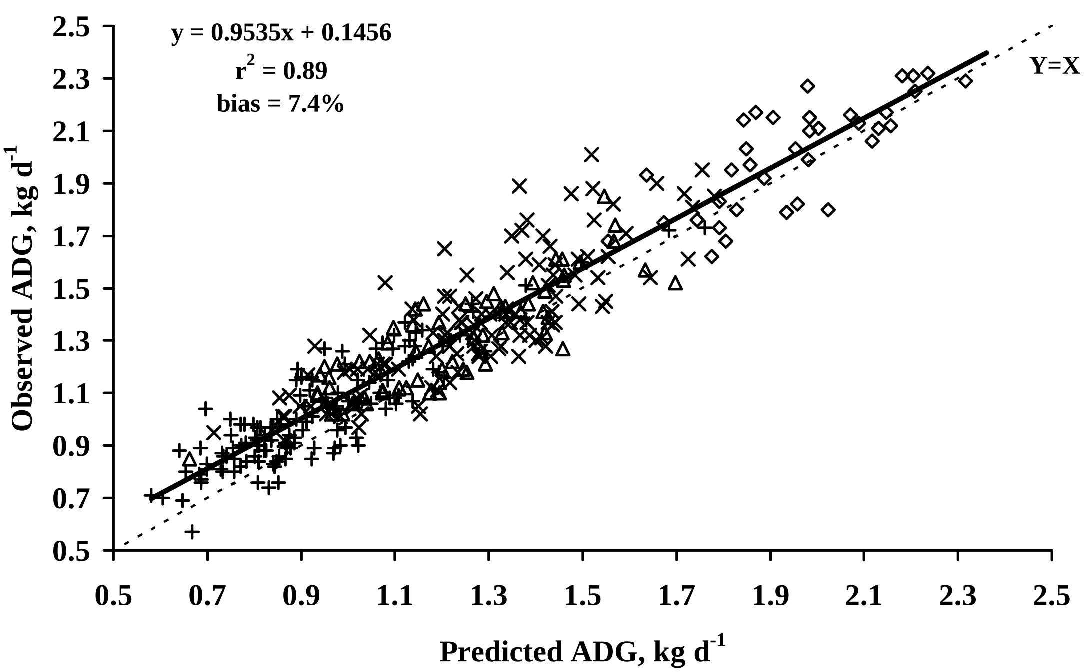
Table 4. Prediction of individual feed requirements with actual feedlot data[1,2]

Variable	Steers (n = 8,624)	Heifers (n = 3,481)	Total (n = 12,105)
Body fat %	28.22 ± 2.25	28.37 ± 2.26	28.26 ± 2.25
28% fat weight, lb	1166 ± 123	1085 ± 126	1144 ± 130
Observed feed DM consumed, lb	22.98	20.88	21.68
Predicted DM required, lb	21.79± 3.31	21.08 ± 3.33	21.59 ± 3.33
Bias, %	-0.91	0.89	-0.41

[1] Guiroy et al., 2001.
[2] Values are mean ± SD.

An important application of the model is to predict ADG from the ration fed during growth to predict days to finish. Figure 4 shows an evaluation of the CVDS model (Tedeschi et al., 2004b) with the same data base used to evaluate the prediction of feed conversion ratio (Fox et al., 2004). The CVDS accounted for 89% of the variation in ADG of individually fed steers when actual feed intake is known.

Figure 4. Prediction of average daily gain using the growth model simulation when dry matter intake is known (Fox et al., 2004)



Application of the CVDS in evaluating feed efficiency of individual animals in commercial feedlots and progeny evaluation programs

Any model developed to evaluate feed efficiency of progeny must be applicable in practical feeding systems if it is to be widely used. This section provides three example of applications being made of the CVDS model.

Large commercial feedlot application. A version of our model is being used in a computerized Electronic Cattle Management sorting and tracking system (Accu-Trac®; Micro Beef Technologies, Inc., Amarillo, TX) in several large commercial feedlots. The objective of the Accu-Trac® system is to predict incremental live and carcass cost of gain, quality and yield grade as cattle progress during the feeding period to determine optimum profitability sale weight and grade. The key components of the Accu-Trac® system are:

1. Cattle are processed on arrival through a series of low-stress stations in a processing snake where they are measured for frame size by video imaging to predict body size, are weighed, vaccinated, implanted and given an electronic ear tag, and ultrasound backfat depth between the 12th and 13th rib measurements are taken. This data is processed and stored in a computer database that automatically places them in one of seven pens according to their projected optimum finish date. The computer analyzes the animal, opens the gate to the destination pen, senses when the animal passes the gate and automatically closes it. Cattle are measured again at re-implanting and are re-sorted based on new predicted finished dates. Equations from a version of our model are used in this system to predict daily gain, feed efficiency, days to finish, cost of gain and profit margin, and to allocate feed to individual cattle in pens for billing owners during the feeding period.

2. Post harvest, equations from our model are used to more accurately determine each animal's share of pen feed consumption, based on predicted shrunk body weight at 28% empty body fat based on carcass measurements to determine composition of gain, and actual body weight and daily gain.

An evaluation of the Accu-Trac® system was conducted under commercial feedlot conditions with 735 steers (unpublished data supplied by Thomas Eck and Max Garrison; test sponsored by Allflex USA, Inc. and Micro Beef Technologies, Inc.). The cattle were allowed to continue on feed until the maximum carcass weight or the maximum back fat thickness reached 0.5 inches as predicted by the Accu-Trac® system. As a result, the cattle finished at an average predicted 29.4 (SD of 2.3) percent body fat, which was above the target of 28% body fat. Actual backfat depth averaged 0.47 (SD of 0.15) inches. Ninety three percent of the Cattle achieved the targeted yield grade of 3 or better, 73% of the cattle were YG 2 or better, and 99% of the cattle had a YG of less than 3.99. The cattle graded 73% Choice or better and 98.5% of the carcasses were within the targeted hot carcass range (550 to 950 lb). The carcass discounts ($/cwt) were $7 for select, $12 for yield grade 4, $10 for carcasses under 550 lb, $5 for carcasses 950 to 1000 lb and $25 for carcasses over 1000 lb The economic benefit was $23.69/head for using the Accu-Trac® system to avoid these discounts.

University or private steer and heifer progeny evaluation. This example application is our progeny test conducted at Cornell, in which we have used the CVDS for the past 8 years to provide feeder calf producers with information on individual animals from their herd for use in selection programs. The 1997 program demonstrates how it works, which included feeder steers (74) of seven sire breeds from different herds in New York. The steers were implanted with Synovex-S and were re-implanted 70 days later with Revalor, placed on a high-energy diet, and were weighed every 28 days. The research center manager estimated final shrunk body weights at low Choice grade for each steer; some of these estimates were corrected during the study. It was not possible to send each steer to harvest when they were at their optimum finished point, because of the cost of trucking and collecting the carcass data. For these reasons, we sent the steers to harvest at Taylor Packing Co. at Wyalusing, PA in two groups. Those chosen for the first group were expected to be at the fatness of low Choice grade. All remaining steers were sent in the second group. The NCBA carcass data service was utilized to obtain complete carcass data. The carcass data was entered into the computer program to compute adjusted final 28% fat weight and feed requirements.

Table 5 summarizes the performance of that year's program. The total feed DM consumed by all cattle was within 1% of the sum of individual predicted feed requirement. The summary in table 5 is based on computing the feed required by each individual, based on the averages (SBW, ADG, and expected final SBW) during the entire trial. The range (minimum and maximum) and standard deviation (SD) are provided to evaluate the variation within this group. The SD added and subtracted from the average gives the range in values that includes two thirds of the cattle.

Table 5. Performance of the 1997 Value Discovery steers

Variables (n = 71)	Average	Min	Max	SD
Days on feed	183	174	193	13.4
Initial SBW, lb	592	412	741	79
Final SBW, lb	1235	960	1536	108
ADG, lb/d	3.47	2.25	4.62	0.40
Individual feed requirement, lb	3815	2652	4616	411
Feed conversion ratio	5.97	4.77	7.19	0.45
Individual feed cost, $	191	133	231	20
Feed cost per lb ADG	0.3	0.24	0.36	0.02
Carcass weight, lb	803	596	1027	73
Marbling Score [a]	5.2	4	8	0.78
Quality Grade [b]	5.2	4	8	0.78
Yield Grade	3.4	1.9	4.7	0.61
Price, $/lb carcass weight	1.08	0.99	1.12	0.04
Initial Value, $/head	355	247	445	48
Profitability, $/head	251	59	411	48

[a]3 = traces; 4 = slight; 5 = small; 6 = modest; 7 = moderate; 8 = slightly abundant; 9 = abundant.

[b]3 = Standard; 4 = Select; 5.0 = Choice-; 6.0 = Choice0; 7.0 = Choice+; 8 = Prime-; 9 = Prime0; and 10 = Prime+.

The days on feed averaged 183 days, with an ADG of 3.47 lb/d The weight at harvest averaged 1235 lb; the average estimated weight at low choice was 1250 lb The cattle varied widely in finished weight, with the extremely large steers having carcass weights outside of the range desired by the industry. The individual feed requirement varied from 2652 to 4616 lb, depending on total weight gain, composition of gain, and feed efficiency. Feed required per lb of gain varied from 4.77 to 7.19; the most efficient required 20% less than the average and the least efficient required 20% more than the average. Part of this variation is due to differences in stage of growth when started on feed. However, much of it is due to differences in rate of gain relative to average body size. Those that gain faster relative to their body weight use a higher proportion of the feed consumed for growth.

The quality grade indicates on the average, the target of low choice grade was achieved; 86% graded choice or above. None were below select and some were prime grade. The yield grades, which indicate trimmable fat, varied greatly, with the average being above the target of three. Base choice carcass price was $1.12/lb for group 1 sold on May 14, 1997 and $1.09 for group 2 sold on June 2, 1997. Carcass discounts ($/lb) were $0.05 for carcass weight (over 929 lb or under 599 lb), $0.10 for grade (select), and $0.12 for yield grade (above 4). The prices paid for different weights and grades varied, reflecting the needs of the packer for different markets.

Average profits per head were high, because of the dramatic improvement in the market during the trial. However, individual profitability range ranged from $59 to $411, with a SD of $48. To identify factors most associated with profitability, prices paid for each category (base price adjusted for yield and quality grade and carcass weight) were averaged to allow the data to be pooled over both harvest groups to compute correlation coefficients. Correlations of various factors with profitability were: carcass weight, 0.57; total live weight gain, 0.54; average daily gain, 0.42; and feed efficiency, 0.41. Thus the most profitable steers in each group were characterized by maximum carcass weight without discounts that would grade choice at less than yield grade 4 and a high rate of gain and feed efficiency during feedlot finishing. The range in carcass weights without discounts is wider than industry standards, which are more typically 650 to 850 lb. We encourage producers to target that weight range to insure that their cattle size will be acceptable in various markets.

Use of the CVDS to identify differences in feed efficiency in bull tests. We have used the CVDS for three years in the New York State Bull test to predict differences in feed efficiency of individual bulls fed in group pens. The sum of the individual feed required has averaged within 2% of the actual feed fed, which agrees closely with our steer and heifer data. 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. Similar results have been observed by Dave Bittner (Paxton, NE) in his bull testing program. Jorgensen Angus provides a ratio for each bull relative to others in their contemporary group for CVDS predicted feed efficiency. Dave Bittner includes an adjustment for feed efficiency in his profit index that includes cost of gain and carcass value. In a study with individually fed bull calves from our Cornell herd, the CVDS identified 6 of the most efficient 10 bulls. However, the actual feed efficiency of the ninth highest in CVDS predicted feed efficiency was actually in the low third. The CVDS identified the lowest 35% in actual feed efficiency except it missed on two bulls that should have been in this group. This demonstrates the risk of being wrong does not appear to be high, and we conclude the CVDS can be used as a *decision support system* in identifying differences among individual bulls in feed efficiency.

Heritability of CVDS predicted feed efficiency

The next question is, ***can we select for feed efficiency, using the CVDS predicted dry matter required as an indicator trait?*** We are involved in two studies to address that question. David Kirschten from Cornell University is conducting a large study for his PhD thesis project to explore this possibility. Three breed Associations and several of their members are providing bull test performance data and pedigree information for this study. Included to date are performance data from 2500 to 3000 beef bulls from each of 3 breeds (Black Angus, Red Angus, and Charolais. Feed efficiency is the ADG per unit of feed fed. Since actual ADG is known but dry matter intake is not, predicted dry matter required must be used as the indicator trait to predict feed efficiency. Preliminary analyses of part of this data base indicate that predicted dry matter required has moderate heritability (0.34 to 0.36). One data set, from Circle A Angus (Iberia, MO), is unique in that it contains data from 6 tests with 567 individually fed steer progeny from 84 sires over 5 years with pedigree information on each animal. A preliminary analysis of the Circle A data indicated the genetic correlation for dry matter intake is high (0.78), indicating that progress can be made by selecting for that trait. Since CVDS predicted dry matter required was highly related to dry matter intake, it appears that it is a good indicator trait for actual feed intake. We are hopeful that data from a second study will provide additional information on this question. This study involves evaluation of data from a feed efficiency experiment being conducted by Dr. Gordon Carstens at Texas A & M University on cattle from the King Ranch.

Conclusions

The CVDS 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 (breed type, body size, stage and rate of growth). This model is being successfully used in commercial feedlots to market cattle on an individual basis at the optimum time, considering incremental cost of gain and carcass weight and composition discounts. 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 data suggest this model has potential use 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.

INCREASING LAND AND BEEF COW EFFICIENCY: MATCHING COW TYPE AND MILKING ABILITY TO YOUR LAND AND FORAGE[2]

Danny G. Fox, Michael J. Baker and Luís O. Tedeschi

Improving beef herd efficiency and profitability

Beef cattle producers are searching for ways to improve efficiency to increase profitability of beef production. In large studies at the USDA Agriculture Research Service Meat Animal Research Center (MARC), feed consumption during the cow calf component of the production cycle represented 72% of the metabolizable energy (ME) consumed from conception to harvest (Ferrell and Jenkins, 1982). Thus, economic viability of beef herds typically depends on maximizing weaning weight on the available forage.

Dickerson (1978) recommended that each biological type have to be evaluated under the production and marketing system for which it is best suited, due to genotype and environmental interactions. To evaluate biological efficiency, productivity must be expressed relative to some measure of input, and feed energy required per unit of output is logical (Jenkins and Ferrell, 2002). In studies at the MARC, Jenkins and Ferrell (1994) found that cattle types with the highest potential for growth and milk production were the most efficient where feed energy availability was sufficient for the genetic potentials to be expressed. Cows with moderate potential became fatter under these conditions. At low feed availability, breeds that were moderate in growth and milk were more efficient because of high conception rates and a relatively lower maintenance requirement. Animals with a greater productivity potential have less ability to lower their maintenance requirement when feed is limited (Jenkins and Ferrell, 2002). In evaluating alternative systems, the energy required for conception and conceptus growth must be accounted for to assure reproductive efficiency is not reduced. Milk yield is correlated with efficiency, due to increased weaning weight, but the higher energy cost for milk production and increased maintenance expressed during both lactation and the dry period must be accounted for (Jenkins and Ferrell, 2002). Studies have shown that differences between mature sizes in efficiency are small when calves are fed to same market grade (Klosterman and Parker, 1976; Morris and Wilton, 1976). Therefore cow size should be based on the expected weight at the target carcass composition, because of its effect on carcass discounts and energy content of the pre-weaning weight gain (Fox et al., 2001, 2002). Thus, identifying the most efficient cow type requires finding the best match of ME requirements with the feed energy available with alternate combinations of cattle types and forage management systems on a particular farm.

The most common way used to maximize weaning weight sold on a particular farm is to use sires with high EPD for milk or growth until problems with meeting herd feed requirements, reproductive performance or cow size become problems. However, research and experience show that using this trial and error approach to optimizing production can be expensive, with a long time required to recover when errors are made. If milk production gets too high relative to

[2] Modification of invited paper presented at the NY Beef Cattle Winter Management Meeting, Corning, NY January 24, 2004.

the forage energy available, reproductive rate is reduced (Jenkins and Ferrell, 1994). Selecting for calf growth alone can result in increased cow mature size and unacceptable harvest weight at a target fat content (Fox et al., 2001).

Given the availability and widespread use of computers on farm, we now have a way to avoid the costly trial and error process in improving production and economic efficiency of the beef herd. We can now use a computer to predict the herd requirements with alternative mature sizes, milk production and stocking rates to find the best fit with alternative forage management programs. We now use computers for all kinds of things in our daily lives; communication, searching for information, education, financial and tax records, travel planning, even running our vehicles and farm machinery. Also, we have a large amount of underutilized research data on beef cow requirements and forage management because of the difficulty in integrating and applying it. Why not use computers to apply this knowledge to optimize the beef herd management system for each farm to improve efficiency and profits with the cow herd???

We developed two models at Cornell for this purpose, using research conducted at Cornell University over a period of 12 years. The Cornell Net Carbohydrate and Protein System model (CNCPS; Russell et al., 1992; Sniffen et al., 1992; and Fox et al., 1992a) was developed to predict nutrient requirements and nutrients derived from any feedstuff for all classes of cattle under widely varying conditions. An updated version of the CNCPS was recently published (Fox et al., 2004). The beef cow model in the CNCPS (Fox et al., 1988, 2004) is used in two types of computer programs (COWHERD (Fox et al., 1999) and Cornell Value Discovery System) to account for dam mature weight and milk production, age at weaning, and calf forage intake and energy content of gain in identifying the optimum combination of cow mature weight and level of milk production with the forage available on a particular farm.

The objectives of this paper are to summarize the variables that must be accounted for in matching beef cow type to the land and forage base on each unique farm, and the biological basis of the Cornell Beef Cow model that accounts for these variables. The second objective is to discuss how the COWHERD and Cornell Value Discovery System computer programs can be applied on each farm to optimize the cattle type and forage management system.

The effect of cattle type on weaning weights and herd requirements

The first variables that must be accounted for in optimizing the beef herd are the differences between cattle types in energy requirements. The CNCPS model was developed to predict requirements for all cattle types for maintenance, pregnancy, lactation, growth and body reserves fluxes and nutrients derived from feedstuffs during digestion and metabolism in each unique production situation. Table 1 shows milk production predicted by the CNCPS model by month of lactation over the range that has been measured in beef cows (6, 12, 18, 24 and 30 lb/day). The lowest peak milk level (6 lb/day) would be that expected for breed types kept to utilize forage under limited rainfall and continuous grazing conditions. The highest peak milk (30 lb/day) is that expected from high milk breeds kept to utilize high quality forage under intensive grazing management where intake is not limited. Pregnancy requirements were based on days pregnant for the expected birth weight for each mature size.

Table 1. Monthly milk production for beef cows with 5 different levels of milk production [a]

Peak milk, lb	Month of lactation							
	1	2	3	4	5	6	7	8
	Milk production, lb/day							
6	6	6	5.5	4.9	4.2	3.6	3	2.6
12	11	12	11	9.7	8.3	6.9	5.7	4.6
18	17.6	18	16.6	14.6	12.4	10.4	8.6	7
24	23	24	22.3	19.7	16.8	14.1	11.6	9.5
30	28.6	30	28.2	25	21.4	18	14.8	12

[a] Fox et al. (1988).

To account for the effects of these variables on feed requirements in the COWHERD model (Fox et al., 1988), energy requirements of different cattle types were developed for the beef cow-calf unit. A major limitation in predicting requirements on a beef farm is the prediction of milk production. We developed a system of using the weaning weights of the calves to predict milk production. This was accomplished by using the CNCPS model to determine expected nursing calf weights at different ages for different combinations of mature sizes and milk production. These weights are entered into COWHERD to estimate milk production level of the cow. Table 2 shows expected weights for nursing calves with different cow sizes and levels of milk production that were predicted with the CNCPS model for use in COWHERD.

To develop Table 2, nursing calf ME requirements and body weight for each month were computed with the CNCPS for the 9 frame sizes of cows, using dam milk production computed from the lactation curve, forage ME intake (expected DMI – milk intake), accumulated body weight and expected composition of weight gain based on dam mature weight. Thus, calf weight for each month reflects milk + forage ME required for the composition of gain, which is a function of the proportion of mature weight and rate of gain. As expected, Table 2 shows that calf weights increase with cow size, milk production, and weaning age.

A study was conducted to evaluate the CNCPS model predictions of the effect of milk intake on calf growth (Fox et al., 1992b, Table 32). Calves were fed milk in buckets from birth to 200 days of age according to the five lactation curves shown in Table 1 and chopped alfalfa hay to appetite. At weaning, the calves were all fed the same high energy finishing ration to low choice grade. Table 3 shows the results of that study. The effects of milk production level on weaning weight are consistent with those in Table 2; as milk level increased, calf weaning weight increased. The impact of an increase in milk production was the greatest at the two lowest levels of milk production. Finished weights were about 100 lb lighter for those fed the lowest two levels of milk, and required more days to reach that lighter weight.

Table 2. Expected weights (lb) for nursing calves [a]

Peak Milk, lb	Month since birth 1	2	3	4	5	6	7	8
Frame size 3 (1030 lb cow; expected weight of nursing male calf)								
6	128	179	229	276	325	377	433	501
12	139	201	258	312	362	417	477	547
18	148	217	280	338	392	450	511	583
24	156	233	300	353	420	480	546	618
30	164	247	319	373	445	508	575	647
Frame size 5 (1170 lb cow; expected weight of nursing male calf)								
6	136	191	244	295	350	405	466	539
12	148	223	274	331	385	444	508	583
18	157	230	296	358	416	478	543	620
24	165	245	317	384	445	509	578	655
30	172	259	337	407	472	538	608	688
Frame size 7 (1320 lb cow; expected weight of nursing male calf)								
6	144	203	259	313	368	427	492	570
12	157	225	290	350	407	469	537	617
18	166	242	312	380	442	508	573	655
24	174	258	334	404	469	537	607	689
30	181	272	354	428	496	566	640	725
Frame size 9 (1470 lb cow; expected weight of nursing male calf)								
6	152	214	273	330	386	449	518	600
12	165	237	305	368	429	494	566	650
18	174	254	328	401	467	537	603	689
24	182	270	350	424	492	564	635	722
30	190	284	370	448	520	594	672	761

[a] Fox et al. (1988). Based on pasture at the vegetative stage (1.14 Mcal/lb of dry matter) consumed at 80 to 90% of maximum intake along with the monthly milk intake associated with the peak milk level.

Table 3. Effect of nursing calf milk intake on weaning weight and post-weaning performance [a]

Peak milk, lb	Weaning wt., lb	Avg. daily forage DM, lb	Post weaning daily gain, lb	Choice grade weight, lb	Age at harvest, days
6	337	4.0	2.93	1019	449
12	440	3.8	2.82	1054	429
18	510	3.6	3.12	1133	412
24	521	2.6	2.71	1078	419
30	550	2.3	2.99	1148	411

[a] Fox et al. (1992b), Table 32, based on Abdelsamei (1989). Calves were bucket fed milk from birth to 200 days according to 5 lactation curves, with chopped alfalfa hay (57.3% TDN in the dry matter) fed to appetite. Finished weights are weight at low choice marbling (4 to 5% fat) in the *Longissimus dorsi* muscle between the 12^{th} and 15^{th} rib.

Table 4 shows the energy requirements (expressed as lb of TDN) for the cow/calf unit that were developed with the CNCPS model for use in COWHERD. To develop this table, Expected nursing calf ME intake from immature pasture (70% TDN in the dry matter measured in grazing studies at Cornell University) was added to the beef cow ME requirement to predict the total ME intake of the beef cow-calf unit. The predicted forage intakes used for this model (Fox et al., 1988) are a function of calf weight and milk intake. This table shows that TDN requirements increase for the cow calf unit as cow size and milk production increase. Therefore, more feed is required as mature size and milk production increase, which requires improved forage management.

Table 4. TDN requirements of beef cows and their nursing calves (lb/day) [a]

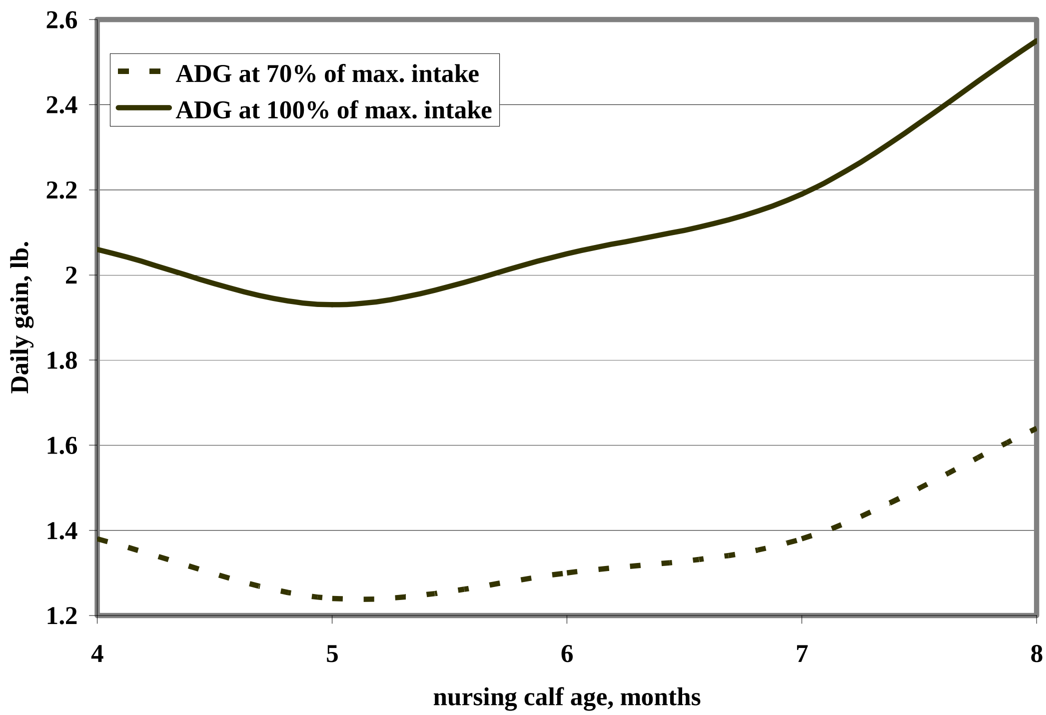
Peak	Month since birth							
Milk, lb	1	2	3	4	5	6	7	8
Frame size 3 (1030 lb cow; expected weight of nursing male calf)								
6	11.9	12.8	13.4	14.1	14.7	15.5	16.6	18.3
12	13	14.2	15.1	15.7	16.2	17	18	19.7
18	13.6	15.4	16.4	17	17.5	18.2	19.2	20.8
24	14.9	17	18.2	18.8	19.3	20	21	22
30	16	18.1	19.6	20.2	20.6	21.2	22	23
Frame size 5 (1170 lb cow; expected weight of nursing male calf)								
6	12.9	13.9	14.7	15.3	15.9	16.8	17.9	19.7
12	14.1	15.3	16.2	16.9	17.4	18.2	19.3	21.1
18	14.9	16.5	17.5	18.2	18.7	19.5	20.5	22.3
24	16.2	18.1	19.3	20	20.5	21.3	22.3	24.1
30	16.9	19.2	20.7	21.4	21.8	22.5	23.4	25.1
Frame size 7 (1320 lb cow; expected weight of nursing male calf)								
6	13.9	14.7	15.3	15.9	16.3	17	18.2	20
12	15.1	16.4	17.4	18.1	18.6	20	21	22.9
18	16	17.7	18.6	18.9	19.9	20.7	21.8	23.7
24	17.3	19.3	20.5	21.2	21.7	22.6	23.6	25.5
30	18	20.4	21.9	22.6	23.1	23.8	24.8	26.5
Frame size 9 (1470 lb cow; expected weight of nursing male calf)								
6	14.8	15.4	15.9	16.4	16.6	17.2	18.4	20.3
12	16.1	17.5	18.5	19.2	19.8	21.7	22.6	24.7
18	17	18.8	19.7	19.5	21	21.9	23	25
24	18.4	20.4	21.7	22.4	22.9	23.8	24.9	26.8
30	19.1	21.5	23	23.8	24.3	25.1	26.1	27.9

[a] Fox et al. (1988). Daily lb TDN needed for each month are by frame size and milk production level. The expected weaning weights in table 2 are used to determine the milk production level for the cow size.

The effect of forage management on TDN available to meet herd requirements

Forage intake is driven by the production potential of the cow and her calf. Thus, cows and calves with higher TDN requirements (Table 4) need more pasture each day. There are two components of forage management that affect the ability of a beef cow and her calf to meet their energy requirements: 1) having enough forage to allow the cattle to achieve voluntary intake, and 2) having the quality high enough so requirements can be met from the amount that can be consumed. Figure 1 shows the consequences of not meeting forage intake requirements (Fox et al., 1988). The 100% of maximum intake line is predicted performance with the CNCPS model of a male calf nursing a frame size 5 cow (1170 lb) with milk intakes shown for 18 lb/d peak milk in Table 1. The 70% of maximum intake line is predicted performance of a male nursing calf when intake of this cow is only adequate to support the milk intakes shown for the 12 lb/d peak milk and calf forage intake is 70% of maximum.

Figure 1. Effect of forage intake on nursing calf daily gain



There are two consequences of forage availability not being adequate for maximum voluntary intake; 1) weaning weights will be decreased, and 2) conception will be delayed until milk production drops low enough to allow ovulation. To maintain a 365 day calving interval, the average beef cow only has 85 days to conceive after calving, assuming a 280 day gestation. If we assume 21 days between ovulations and allow 2 ovulations before conception, the first ovulation must occur within 43 days after calving, which is close to the time when demands for milk production peak (Figure 2). Thus energy demands of the cow peak within the first two months of calving, and increase with level of milk production.

Figure 2. Effect of month of lactation on the metabolizable energy (ME) requirements of beef cows

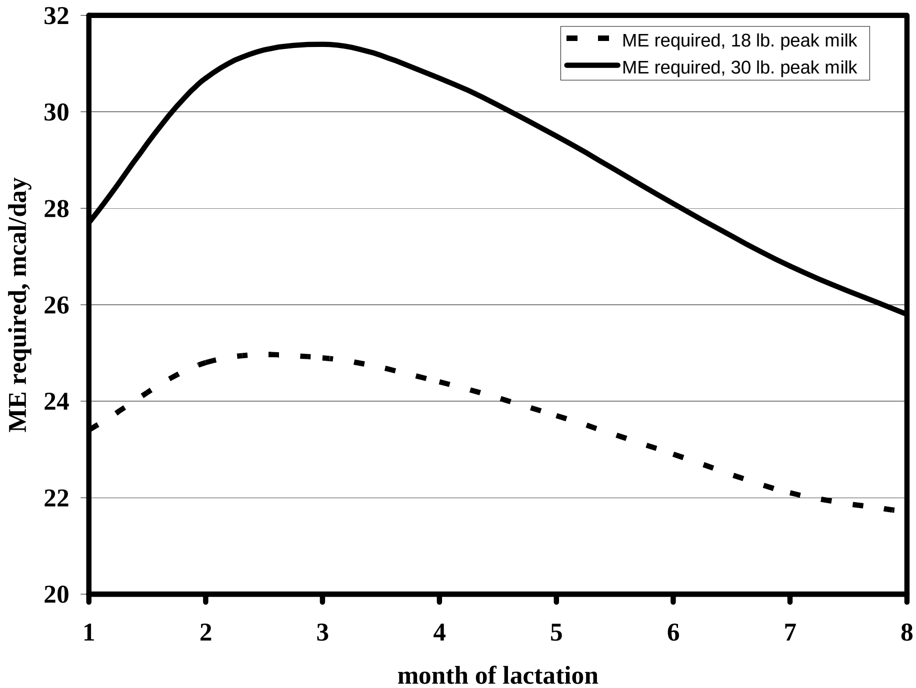


Table 5 shows the expected monthly growth of forage with different total seasonal yields that can be expected in New York, based on the studies summarized by Fox et al. (1992b). There are several conclusions about forage production that can be made from that table. First, about half of the growth occurs in the first two months of the growing season. Thus, we must harvest about half of the forage if the number of cattle stays constant across the entire grazing season, in order to keep the pasture in the vegetative stage of growth and to have the regrowth available for summer and fall grazing. Harvesting, whether by cattle defoliation or by machine, stimulates regrowth. The second observation is that part of the acreage must be deferred for summer and fall grazing to insure meeting the requirements during that time. A system of rotational grazing gives the forage time to regrow and accumulate between harvests by grazing, and has a built-in system for allowing regrowth to accumulate for grazing at a later time. The third observation is that improved species produce better in the summer and fall when species typical of unimproved pastures such as bluegrass and white clover are not very productive. Most farms in New York have areas where improvement is not possible or economical because of site and soil limitations. However, having a combination of forages with different growth patterns combined with a system of rotational grazing to allow harvest management with animal and machine will allow optimum use of different land areas while allowing the cattle to meet their requirements each month of the grazing season.

Table 5. Predicted forage growth, tons of 90% dry matter/month[a]

Forage Type	Season total tons/acre	Expected growth, tons/month MAY	JUNE	JULY	AUGUST	SEPT
Bluegrass and White Clover	1.00	0.40	0.30	0.15	0.10	0.05
Ladino, White Clover, and Timothy	2.70	0.86	0.86	0.35	0.22	0.40
	2.35	0.79	0.79	0.29	0.17	0.30
	2.00	0.72	0.72	0.23	0.12	0.20
	1.65	0.62	0.62	0.18	0.09	0.13
	1.30	0.52	0.52	0.13	0.06	0.06
Tall grasses	3.30	1.12	1.19	0.46	0.13	0.40
	3.00	1.07	1.11	0.39	0.12	0.32
	2.70	1.02	1.03	0.32	0.11	0.24
	2.00	0.77	0.78	0.23	0.09	0.16
	1.30	0.52	0.52	0.13	0.06	0.07
Trefoil and grass	4.10	0.94	1.11	0.94	0.70	0.41
	3.65	0.89	1.04	0.79	0.62	0.32
	3.20	0.83	0.96	0.64	0.54	0.22
	2.40	0.65	0.75	0.46	0.41	0.14
	1.60	0.46	0.53	0.27	0.27	0.06
Alfalfa rotational grazing	5.20	1.30	1.30	1.20	0.88	0.52
	4.35	1.14	1.18	0.92	0.69	0.42
	3.50	0.98	1.05	0.63	0.49	0.31
	2.70	0.80	0.87	0.45	0.35	0.22
	1.90	0.61	0.68	0.27	0.21	0.13

[a] Based on Fox et al. (1992b), Table 39.

Table 6 summarizes the effects of pasture maturity on energy value of the pasture, based on the studies summarized by Fox et al. (1992b) from rotational grazing studies with improved legume and grass, improved grass alone, or unimproved pasture.

Table 6. Pasture digestibility in rotationally grazed pastures[a]

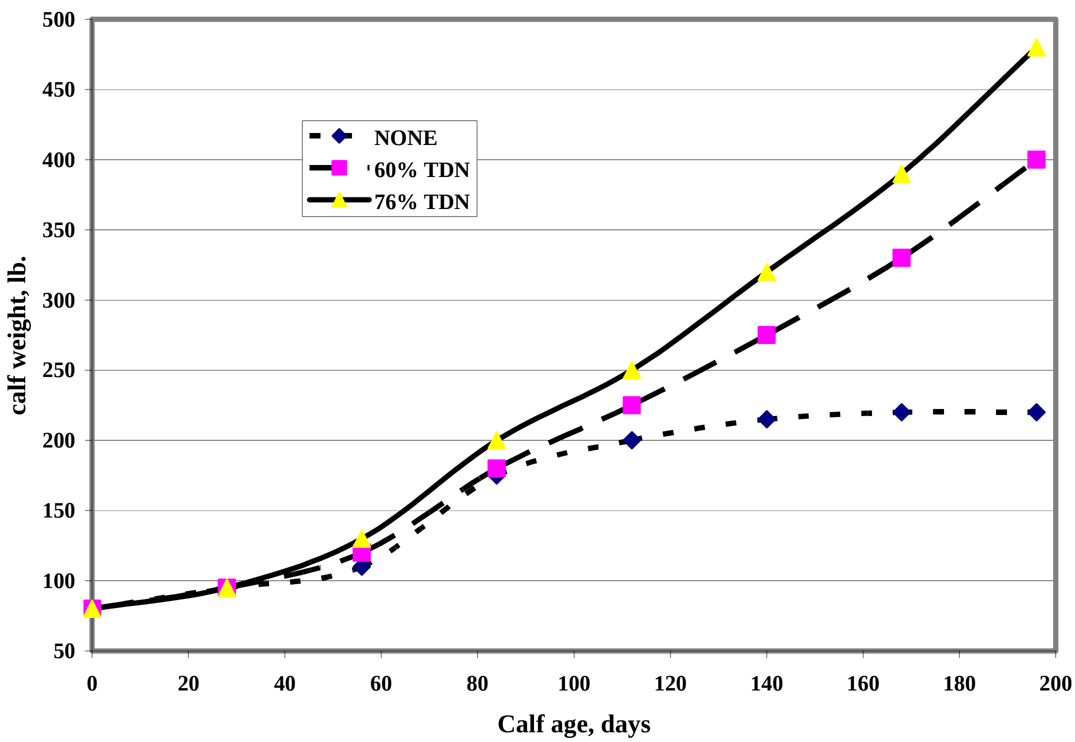
	June	July	August	September
Start of grazing	85.8	83.4	83.9	86.8
End of grazing	77.0	67.2	63.8	61.1

[ab] Fox et al. (1992b), Tables 24 and 25. The data represent an average across 3 pasture types (improved legume and grass, improved grass alone, or unimproved pasture), since there were no significant differences due to pasture type.

Pasture digestibility at the start of grazing was similarly high in all pasture types from the spring through the fall, indicating the potential for high quality forage for the entire forage growth and grazing season in New York. However, the quality of the forage left at the end of grazing declined as the summer progressed. Thus, if the pasture is not harvested or clipped, the forage quality will decline.

In a drylot study (Fox et al., 1992b), weights of calves taken at 28 day intervals indicate that even if forage available is adequate for nursing calves to maximize voluntary intake potential, forage quality has a large impact on calf growth (Figure 3).

Figure 3. The effect of supplemental feed on nursing calf weights



COWHERD accounts for all of the variables shown in this section for forage production and quality and those in the previous section on cow requirements. When both the monthly forage yields and quality are accounted for, COWHERD indicates the best chance to meet the herd requirements with the forage that can be grown on the farm is to have the nursing calves 30 to 60 days old (March and April calving) when pasture becomes available in the spring. Pasture yields are peaking when cow requirements are at a peak, and nursing calves are beginning to consume forage. Then using rotational grazing to keep yields and quality high as the season progresses will support the increased pasture needs of the calf as milk production of the cow declines.

Application of COWHERD to optimize the herd and forage management on actual farms

COWHERD was used to evaluate profits and herd size supported on 100 acres of hillside land on the Cornell Animal Science Farm with four forage management systems and two types of beef cows, using data from herd records and grazing studies summarized by Fox et al. (1992b) as inputs. The two cow types were Moderate (M; cows averaged 1212 lb and peak milk was estimated to be 18 lb/day from the male calf weaning weight of 560 lb) and high (H; cows averaged 1270 lb and peak milk was estimated to be 30 lb/d from the average male calf weaning weight of 650 lb). The four forage systems were rotational grazing with intensive or moderate management (RI and RM, respectively) and continuous grazing of improved or unimproved pastures (CI and CU, respectively). Grazed and harvested forage ME values (average of 1.13 and 0.93 Mcal ME/lb DM, respectively) were predicted with the CNCPS from measured chemical composition of feeds. The simulation assumed a 6 month grazing season, with harvested hay used for winter feed. The herd size was altered until the total forage production needs for the year were met. The only supplements fed were minerals for the herd and concentrates for weaned heifers during the non- grazing period. Cash costs for inputs (seed, fertilizer, labor, minerals, veterinary, feed supplements, repairs) and market prices for weaned calves and cull cows were used as inputs into COWHERD to compute net cash farm income for each of the systems.

Detailed results are available in Animal Science Mimeo 142 (Andersson et al., 1990). Table 7 summarizes the beef herd size supported, total forage produced and required, and tons 90% dry matter hay harvested for winter feed with each of the eight beef herd management systems.

Table 7. Forage production, herd size, and profits with eight different management systems [a]

Beef herd management system							
M-RI	M-RM	M-CI	M-CU	H-RI	H-RM	H-CI	H-CU
beef herd size supported (number of mature cows)							
70	43	30	29	62	38	27	26
total forage produced (tons, 90% dry matter basis)							
393	246	169	172	393	246	169	172
total forage required (tons, 90% dry matter basis)							
391	242	166	168	392	242	168	167
hay harvested for winter feed (tons, 90% dry matter basis)							
203	136	82	96	201	131	79	93
returns over cash costs ($)							
10,656	8,064	4,719	6,517	12,592	8,552	4,917	6,605

[a]Andersson et al. (1990). M-RI = moderate milk, intensive rotational grazing; M-RM = moderate milk, moderate rotational grazing; M-CI = moderate milk, continuous grazing of improved pasture; M-CU = moderate milk, continuous grazing of unimproved pasture; HRI = high milk, intensive rotational grazing; H-RM = high milk, moderate rotational grazing, H-CI= high milk, continuous grazing of improved pasture; and H-CU = high milk, continuous grazing of unimproved pasture.

This table shows how COWHERD can be used to integrate and apply a large amount of research data on beef cow requirements, forage management, and economics to optimize the combination of cattle type, herd size and forage management system. In this case study, table 7 shows that the best system for this combination of land resource, production costs and returns is the H-RI system. However, the differences between the M and H herds were much smaller when less intensive forage management was used.

Similar results were observed in an on-farm case study in central New York. This farm consisted initially of 70 acres of unimproved pasture, and started with 30 Angus cows (mature size of about 1100 lb); all winter feed was purchased. Weaning weights averaged 453 lb within a few years, an additional 90 acres of land was leased, increasing the land base to 160 acres. The results of the pasture research at Cornell were used to improve the productivity of the pastures (rotational grazing, addition of legumes, fertilization according to soil tests). Intensive rotational grazing was accomplished by dividing the farm into two areas; 1) the most productive land with improved grass-legume mixtures, and 2) the least productive land, which had lower productivity grasses and legumes. The first area was used to provide the winter feed with the first cutting harvested in mid to late June and to provide re-growth forage for summer and fall grazing. The second area was used for spring grazing, with the re-growth deferred for fall grazing. In each area, the fields were fenced with high tensile electric fence in paddock sizes that matched the needs of the herd for about 1 week, resulting in 17 paddocks for rotational grazing. The herd was expanded by keeping most of the heifers. Productivity of the herd was increased through selection for EPD for growth and milk. The first version of COWHERD became available during the development of this farm, and it became a powerful tool to identify the optimum management system. Once the herd, fields, equipment inventory and economic information was entered, it was easy to update and evaluate the impact of alternative management practices in herd size and costs and returns. The herd size reached a maximum of 75 beef cows with an average mature weight of about 1300 lb and weaning weights that averaged 550 to 600 lb, which COWHERD indicated was the herd size that could be supported on the land base, with no purchased forage. Annual feed balances predicted with COWHERD were within 5 to 10% of actual annual forage balances.

These studies and other on farm experiences indicate the land resources available to beef producers in New York will support the full range of options in beef cattle type and grazing management systems. Users have found COWHERD to be very simple to use and is fast and reasonably accurate in evaluating logical alternative beef herd and forage management alternatives. There are several trends that are apparent after using this program for several years. First, the most difficult time to balance the forage available vs. herd requirements for a spring calving herd is during the months when forage growth is slow, which usually is in late summer and fall. The cow-calf unit requirements are increasing while forage growth is declining. The problem is solved by changing combinations of forage and/or using rotational grazing in which some of the forage regrowth is saved for summer and fall grazing. Secondly, profits are maximized when all of existing resources are fully utilized. If there is excess forage, having more productive cows and/or more numbers of cows that will give increased weaning weights to sell for a similar cost structure will improve profits. If forage is deficient at certain times, the most economical first step is to have some type of rotational grazing system to control forage availability and to make easier harvesting of surpluses. If improvements in forage types are made, the cost must be more than offset by increased cattle productivity or reductions in supplemental feed. We have found that with some method of alternative budgeting as described here, along with records to evaluate actual performance and weak links, considerable progress can be made in improving the efficiency and profitability of individual beef herd operations.

Using the Cornell beef cow model to identify differences in efficiency among individual beef cows in the herd

The 2000 Beef NRC recommendations as implemented in the Cornell Net Carbohydrate and Protein System for energy requirements for maintenance, lactation, and pregnancy (Fox et al., 2004) were used to develop a beef cow model (Tedeschi et al., 2004a) for use in the Cornell Value discovery System (CVDS), which is discussed in the next paper. In summary, data from the study of Abdelsamei (1989) described earlier (Table 3) was used to develop a sub-model to estimate calf forage and peak milk intake, based on calf body weight and forage composition. This CVDS model was developed to use inputs readily available in each production situation to estimate for individual beef cows in the herd the ratio of cow metabolizable energy required to calf-weaning weight. This ratio is called the energy efficiency index (EEI). The CVDS beef cow model uses a statistical procedure to rank cows based on EEI estimates, and to identify cows that fall in least and most efficient categories. A database collected from the Bell Ranch, NM (N = 182) was used to evaluate the ranking from most to least efficient cows. The model-predicted least efficient cows were in agreement with culling decisions made prior to evaluating the EEI ranking. In this study, the model indicated that based on the distribution, mean, and variability of cow body weight, milk production and forage quality the cows having EEI lower than 14 or higher than 18 Mcal/lb are within the 10% more and less efficient cows, respectively.

Other simulations with the CVDS beef cow model indicated that efficiency was highly related to milk production, and was related to cow weight at a given level of milk production. It predicted smaller cows to be more efficient at a given milk production level, because they are producing more milk relative to their weight. However, milk production tends to be related to body weight. Over a period of 15 years, the average milk production in the Cornell dairy herd increased 25 lb/day/cow; during that time, average body weight of the cows increased about 100 lb (Wang, 2000). Numerous studies indicate that overall energetic efficiency tends to be independent of cow size. Cow size should be based primarily on market demands for finished weight of the feeder cattle produced. The level of milk production should be based on that allowed by forage quality and quantity without reducing % calves weaned. Once the target cow size is set, the CVDS cow model can be used to identify the most and least efficient cows for a given farm or ranch.

UNVEILING THE PRODUCTION EFFICIENCY OF THE BEEF COW: A SYSTEMATIC APPROACH USING NUTRITION MODELS [3]

Luis O. Tedeschi, Danny G. Fox, and Michael J. Baker

Introduction

The beef cattle seedstock industry is searching for ways to select for improved beef cow efficiency to improve their competitiveness and profitability. Increases in beef production have occurred due to enhancements in reproduction indexes (e.g. calving frequency, age at first calving, calving interval), nutrition concepts (e.g. strategic supplementation, type of forage as well as quantity and quality), genetic selection (e.g. bull selection, crossbreeding), and (or) ranch management (e.g. matching breeding and calving seasons with availability of forage). Nonetheless, beef production still is a relatively inefficient process from the standpoint of energy expenditure. Research has indicated that beef cows are responsible for 60 to 70% of the total of energy expenditure (Johnson, 1984) in beef production (Ferrell and Jenkins, 1985). Ideally, efficient beef cows use less resource to obtain the same outcome in a sustainable environment. There are several indexes used to identify efficient beef cows. Most are based on retaining beef cows that routinely produce a weaned calf with fewer inputs, with a high ratio of pounds of calf weaned per number of females exposed to a bull. Additionally, beef cow maturation rate has also been shown to be correlated with production efficiency and may be used to select for efficient cows (Parker et al., 1972; Tedeschi et al., 2000a, b).

Jenkins and Ferrell (2002) concluded that to evaluate biological efficiency, productivity must be expressed relative to some measure of input, and feed energy required per unit of output is logical. We have developed a beef cow model that uses this approach to identify differences in efficiency among beef cows. The principal objective of this paper is to present our model that estimates the Mcal of metabolizable energy (ME) required by a cow per kg or lb of weaned calf (energy efficiency index – EEI). A second objective is to demonstrate how the model compares the EEI computed for each beef cow to the range of expected EEI using Monte Carlo simulation to identify the upper and lower cutoff EEI. A third objective is to discuss the potential for identification and selection of mitochondrial DNA (mtDNA) mutants in beef cows that have higher energy efficiency.

A brief description of the beef cow model

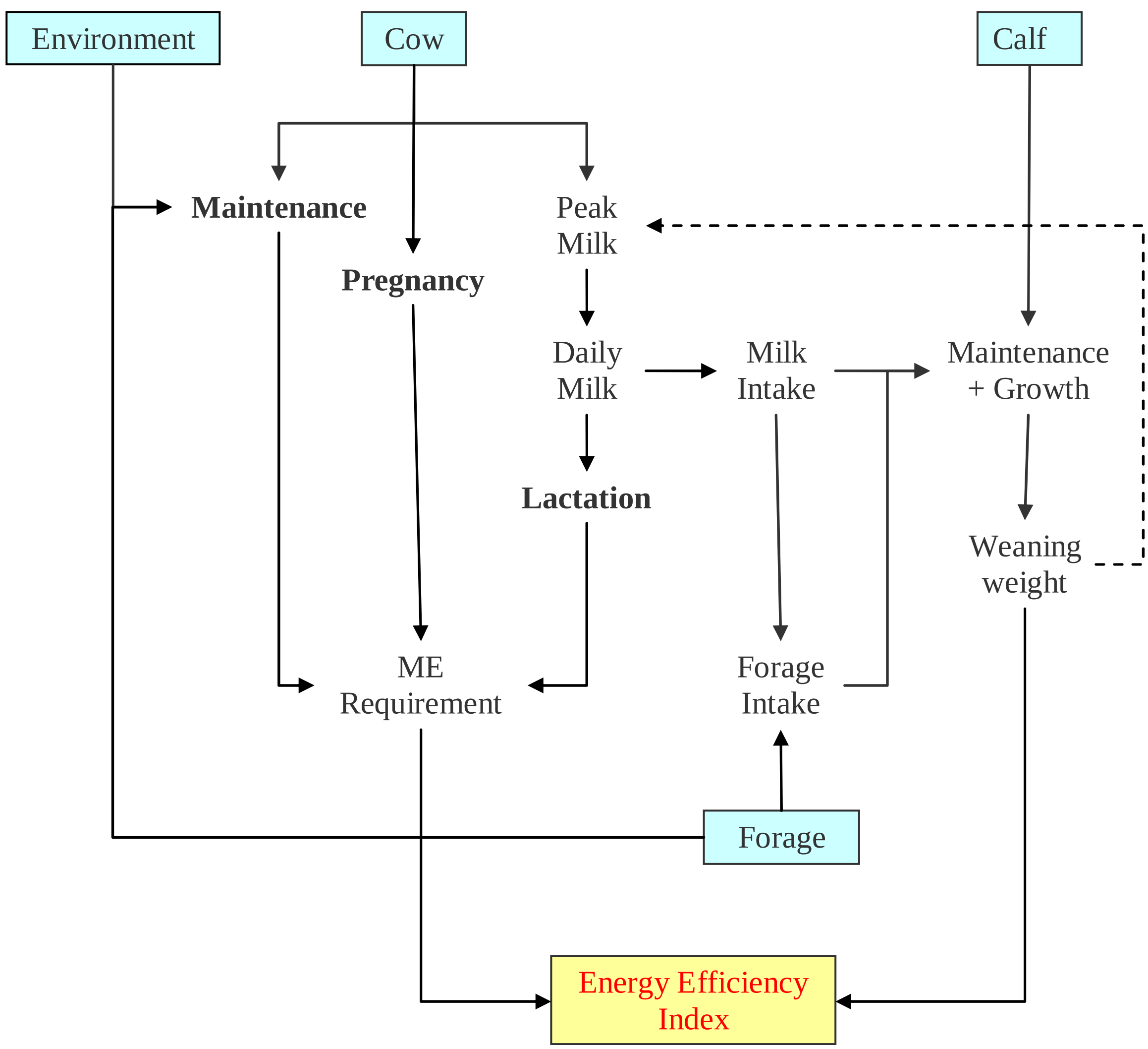
Several models have been developed to simulate cow/calf production systems (Boyd, 1977; Fox et al., 1988; Long, 1972; Miller et al., 1980; Naazie et al., 1997; Notter et al., 1979a, b, c). Fox et al. (1988) developed a nutritional model to evaluate the match of the energy requirements of a cow/calf herd with forage available each month to enhance profitability of the herd. Their model computes a balance between energy requirements for maintenance, pregnancy, lactation, and tissue mobilization and energy available from the forage; thus, allowing one to match availability of forage with periods of higher energy demand by the cow and calf.

[3] Modification of paper presented at the NY Beef Cattle Winter Management Meeting (Jan, 2004) and the International Modeling Conference (Sep, 2004).

Reynoso-Campos et al. (2004) published an application of the Cornell Net Carbohydrate and Protein System model for dual-purpose cattle that computes daily energy balances between the herd requirements and forage available. Our current model is based on those developed at Cornell as described by Fox et al. (1988) for beef cows and by Reynoso-Campos et al. (2004) developed for dual-purpose cows, with modifications as described in this paper.

Figure 1 summarizes the structure of our model developed to estimate daily energy requirements of the beef cow and the interactions between lactation and weaning weight (WW) of the calf. The objectives of this model include: (1) computing the energy requirements of individual beef cows each day of the year and simulating the growth of the nursing calf given the information available, (2) computing energy balances for the herd each day of the year to evaluate the balance between herd numbers and requirements with the forage available, and (3) identifying differences in efficiency among individual beef cows in a herd.

Figure 1. Flowchart of the mathematical model to predict energy efficiency index



Energy required for maintenance is based on body weight adjusted for conceptus weight, environment (climate effects), physical activities, and physiological stage (dry vs lactation) as recommended by the NRC (2000). Smooth curve adjustments using the cubic spline technique are used during transition phases since this is a time-dependent model. DiConstanzo et al. (1990) found that among non-pregnant non-lactating Angus cows of similar fat masses, those with larger protein masses had higher energy requirements for maintenance because the ME required to maintain 1 kg of protein was 9.3 times higher than fat (192.9 ± 24.8 vs 20.7 ± 21.5 kcal, respectively). We account for this effect in our growth model (Tedeschi et al., 2004b) and plan on including a component for body composition effects on maintenance requirement into our beef cow model.

Energy for pregnancy is based on the NRC (2000) recommendations that uses days pregnant to derive energy concentration of the conceptus. The model assumes a fixed calving interval of 365 d.

The model computes milk production by changing the peak milk until the WW predicted by the model matches the observed WW. The energy requirement for lactation is computed based on NRC (2000) and Fox et al. (2004). Milk composition is used to compute net energy of the milk, which drives the energy requirement for lactation. A fixed value of 5.29 Mcal of ME/kg of milk DM basis is assumed to compute intake of ME by the calf. The peak milk is used to plot the lactation curve, which predicts the daily amount of milk available for the nursing calf.

The data of Abdelsamei (1989) was used to develop equations for estimating forage intake of the calf. In his experiment, the *ad libitum* intake of chopped alfalfa of 40 Holstein calves fed 5 leves of milk production (peak milk at 59.5 DIM: 2.72, 5.44, 8.16, 10.88, and 13.6 kg) was measured for 200 d. We used this data to derive five multiple regression equations to estimate forage intake for the pre-peak milk phase as shown in Table 1.

Table 1. Regression coefficients for estimating forage intake by nursing calves for five milk levels before peak milk is reached

Variables	Peak Milk, kg				
	2.72	5.44	8.16	10.88	13.6
Calf BW, kg	-0.008	0.025	0.004	-0.004	-0.001
DIM, d	-0.019	0.221	0.108	-0.023	-0.002
Calf BW × DIM	0.000	-0.005	-0.002	0.000	0.000
Cow milk, kg	-1.272	0.496	-0.423	0.031	0.033
Calf BW × Cow milk	0.010	-0.008	0.007	0.001	0.000
DIM × Cow Milk	0.027	-0.226	-0.066	0.006	-0.002
Calf BW × DIM × Cow milk	0.000	0.005	0.001	0.000	0.000
Peak milk, kg	0.595	-1.147	-0.196	0.183	0.025

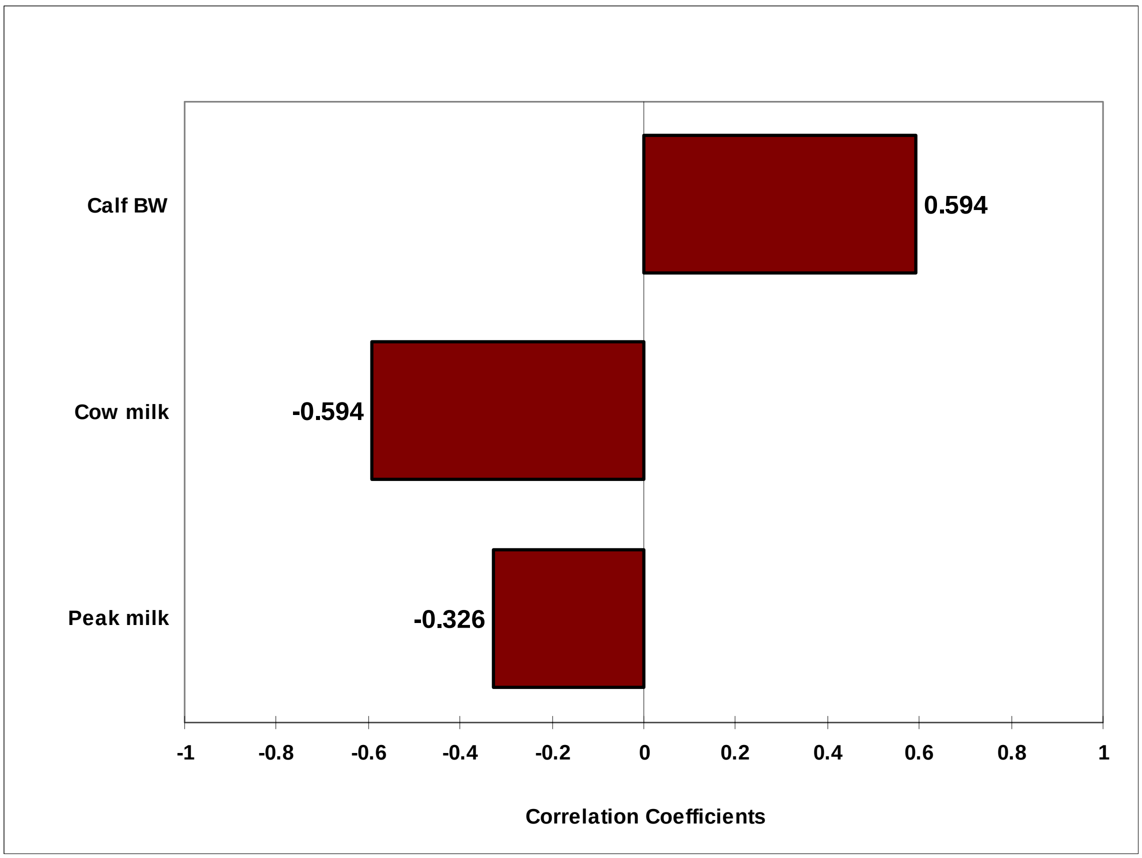
The intake of forage (kg/d) for the post-peak milk phase is computed using the multiple regression (R^2 = 98.6%, N = 394, RMSE = 281.24) listed below.

Forage intake = 30.313×Calf BW – 753.76×Cow Milk – 11.704×Calf BW×Cow Milk -190.316×Peak milk + 0.499 ×Calf BW×Peak milk + 112.106×Cow milk×Peak milk -0.085×Calf BW×Cow milk×Peak milk

Figure 2 shows the magnitude of the influence of the factors used to estimate forage intake by the nursing calf. Cow milk and peak milk have a negative correlation whereas calf BW has a positive correlation with forage intake.

It is well documented that BCS has an important role in beef production and (or) reproduction efficiency (Houghton et al., 1990; Mortimer et al., 1991). In our model, tissue mobilization will be used to compute energy available/required for body reserves based on BCS changes, similar to that described by Reynoso-Campos (2004).

Figure 2. Correlation of the most influential factors to predict forage intake



An evaluation of the model

Figure 3 shows the comparison of weaning weight and EEI of two cows (small and large) with five peak milk levels. Birth weight was assumed to be 6.5% of the mature weight of the cow. As peak milk increases, WW increases almost linearly (Figure 3A) and the energy efficiency index decreases exponentially (Figure 3B). Difference between the two cow sizes are due to differences in body weight at the same milk production. Published data indicates that cow mature weight does not influence the efficiency of energy use (Klosterman and Parker, 1976;

Morris and Wilton, 1976; Ferrell and Jenkins, 1984 a,b). Their studies indicate that as mature size increases, milk production, weaning weight and finished weight increase proportionally.

Figure 3. Comparison of weaning weight (A) and energy efficiency index (B) of two-cow sizes (990 lb – open bars and 1166 lb – dotted bars) at five peak milks

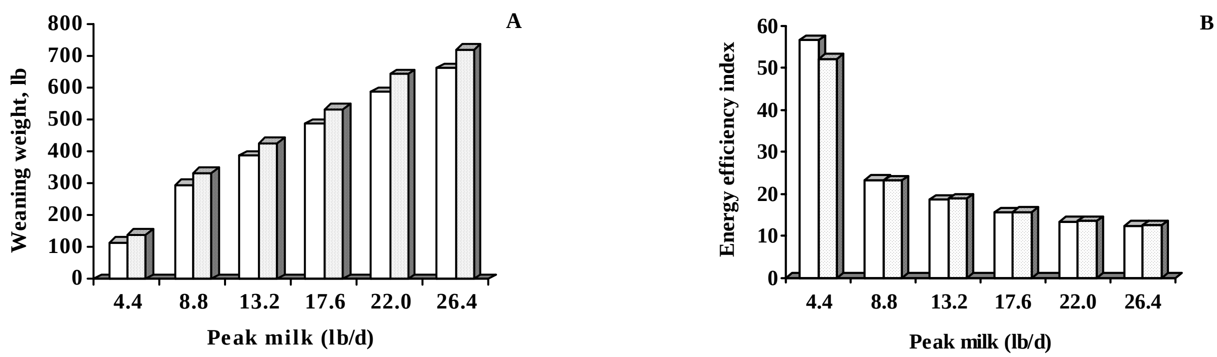


Figure 3B indicates that milk production is a determinant of calf WW and efficiency of the cow. Figure 3A indicates the higher the milk production, the greater the weaning weight (Abdelsamei, 1989; Clutter and Nielsen, 1987; Lewis et al., 1990). As milk production increases, cow maintenance requirement becomes increasingly diluted by the additional weaning weight produced. However, it is well known that high-milking cows have higher energy requirements for maintenance because the internal organs are larger and they have a faster metabolism compared to the low-milking cow (Ferrell and Jenkins, 1984a, b, 1985). This means that higher-milking cows require more feed for maintenance and energy per pound of BW than lower-milking cows (Montano-Bermudez and Nielsen, 1990). If feed available is adequate, this higher maintenance requirement will be offset by an increased weaning weight of the calf. Compensatory growth may also play a key role in the growth of calves from cows that produce less milk. In agreement with the study of Abdelsamei (1989), Lewis et al. (1990) found that post-weaning effects of increased WW on ADG due to higher milk intake pre-weaning were small. They reported that only calves from the low-milking group (5.6 kg/d) showed compensatory growth. Miller et al. (1999) reported no effect of milk yield on biological efficiency of Hereford, Charolais x Simmental x Maine-Anjou, and Tarentaise x Pinzgauer x Gelbvieh x Angus calves from calving to harvest.

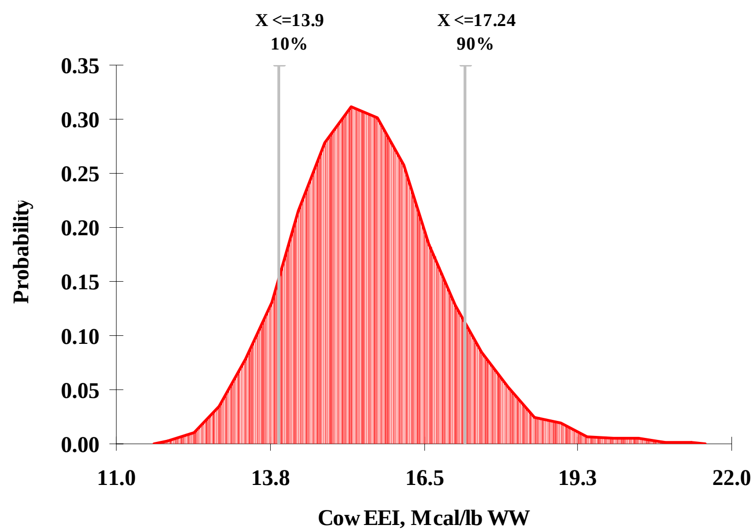
Cows selected for improved efficiency in a certain environment may not express their efficiency in another environment (Ferrell and Jenkins, 1985). When forage availability is not limiting, cattle with higher milk and growth potential can utilize the extra feed to wean heavier calves, therefore increasing weight sold for the forage available. However, when forage is limited, those with lower milk and growth potential can wean more calves for the same forage because there is a higher proportion of the energy intake above maintenance available for maintaining reproductive efficiency. ***We conclude the cow mature size should be determined by the optimum weight for the calves at the target carcass composition, and the milk production level should be based on the forage available.***

A practical application of the model

We are exploring the potential use of the EEI computed by the mathematical model described in Figure 1 in genetic selection programs. Using Monte Carlo simulation (Winston, 1993), one can simulate the expected outcomes of the EEI given the distribution, mean, and variability of the parameters used by the model.

Figure 4 shows a simulation with a model at a selected cow BW, peak milk, and forage quality. It indicated that for that scenario, cows that had EEI lower than 13.9 or higher than 17.24 Mcal/lb are within the 10% more and less efficient cows, respectively. Therefore, one could select for cows having less than 13.9 Mcal/lb to increase the efficiency of the herd, or conversely, one could cull those cows having EEI higher than 17.24 Mcal/lb

Figure 4. Monte Carlo simulation



A second application of the model is the simulation of availability and quality of forage throughout the year relative to forage requirements for different cattle types in the year to evaluate and improve the energy balance for the annual production cycle. This application is demonstrated in Figures 5 and 6. Figure 5 shows for this example the forage energy content for each month and Figure 6 shows the energy balance (requirement minus supply) for the same period. In this example, improved forage production, change in cattle type or numbers, or supplementation is needed during the months of July through December.

A third application is to determine the highest level of milk production for the target cow size that can be supported by the forage available.

Figure 5. Forage energy content throughout the production cycle

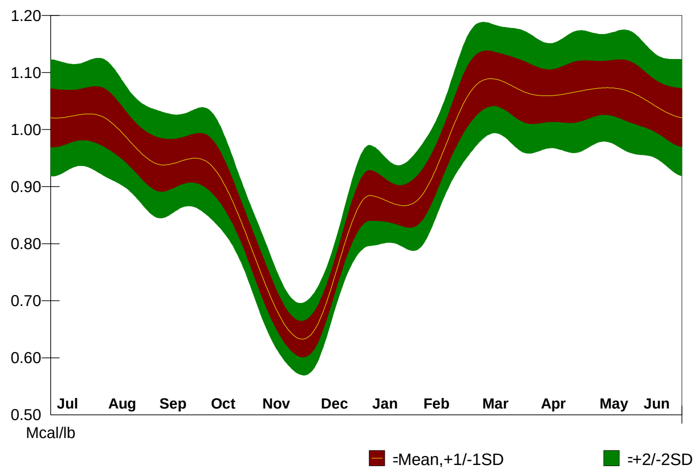
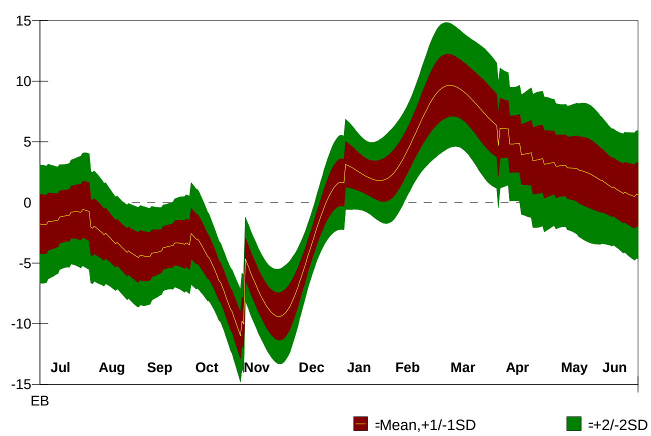


Figure 6. Energy balance throughout the production cycle



A glance of the future

The European Association on Animal Production published a report (Ostergaard et al., 1990) that provides definitions of efficiency for primary and secondary traits for dairy cow efficiency, which also applies to beef cow efficiency. 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*". However, the identification of differences among individual animals in these biological processes is difficult, particularly given the information typically available on farms and ranches. Australian scientists have used the residual feed intake (RFI) analysis of post-weaning growth of individually fed progeny to select efficient bulls (Archer and Bergh, 2000; Archer et al., 2001; Archer et al., 1999). The main problems with this technique are the need for measurement of individual intake and the tendency to select for leaner animals as an undesirable consequence. We are currently evaluating our mathematical model (Cornell Value Discovery System – CVDS; Tedeschi et al., 2004b) for ranking individual animals fed in groups on the basis of feed required for the observed growth and body weight. The CVDS estimates required intake given each animal's performance and adjusts gain and intake for body composition (degree of maturity). This model is currently available for growing/finishing animals and may be downloaded at http://www.cncps.cornell.edu. The beef cow model described in this paper is being incorporated into the CVDS. We are evaluating its potential for providing information that can be used to rank individual cows on the basis of their EEI. Our goal is to determine if the output of these biological models can be used to develop EPS's for feed efficiency for use in genetic selection programs.

We are also working on a genomic-modeling project that involves the mapping and identification of mitochondrial DNA mutants (mtDNA) that are more energetically efficient. The presence of maternal genetic effects has long been hypothesized to have an effect on traits of economic importance in beef cattle. However, little support has been found in the common statistical analysis of genetic breeders (Gibson et al., 1997). Mitochondria are a likely source of some of this "unexplained" variation since they contain their own DNA and are only maternally inherited. It is well known that mtDNA variation may cause bias in the estimation of variance components (Boettcher et al., 1996b). Therefore, a positive mitochondrial effect is desirable for dams of cows, but not for dams of sires, since they are not passed on to male progeny.

Mitochondrial DNA has been extensively used in phylogeny to identify cattle lineages using DNA displacement loop sequence variation (Bradley et al., 1996; Loftus et al., 1994). Additionally, mtDNA has also been used to characterize substitutions that could be responsible for several economically important traits, including meat quality (Mannen et al., 2003), milk production and animal health (Boettcher et al., 1996a; Boettcher et al., 1996c; Schutz et al., 1994).

The basic hypothesis is that a lineage of cattle that is more energetically efficient might exist due to certain arrangements in the mtDNA that permit the mitochondria to be more efficient. This energetic efficiency of the mitochondria is reflected in the bioenergetics of the whole animal and is responsible for some variation found among progeny of the same sire but different dams. External effects that might regulate mitochondria efficiency have also been reported, such as acetyl-L carnitine (Iossa et al., 2002) and fatty acids (Clarke et al., 2000; Jezek et al., 1998; Schrijver and Privett, 1984).

In broilers, low feed efficiency is related to defects in electron leak in muscle mitochondria (Bottje et al., 2002). In plants, ATP Synthase is a key enzyme in providing energy since it uses a transmembrane electrochemical proton gradient to drive synthesis of ATP. The enzyme complexes function as miniature rotary engines, ensuring energy coupling with very high efficiency (Bunney et al., 2001). In rats, a low mitochondrial proton leak rate may partially explain the abnormally lower heat production and bioenergetics efficiencies of the obese Zucker rat (21% lower than leaner animals) as reported by Ramsey et al. (1996).

Mitochondrial proton leak may be responsible for at least 20% of the resting oxygen consumption in mammals (Ramsey et al., 2001). It is also documented that uncoupling protein 1 homologue, UCP3, is responsible for a decrease in efficiency of energy metabolism because of the dissipation of energy as heat due to an uncoupling of adenosine triphosphate (ADP) production from mitochondrial respiration process (Schrauwen, 2002). Therefore; mutants that have a lower mitochondrial proton leak or have lower concentration of UCP3 will be more energetically efficient. We just have to identify them!

Conclusions

Mathematical models can be used to assist in the identification of efficient cows and simulation of different production scenarios to identify optimum management systems for beef cows to maximize profits on a given land base. In identifying the most efficient beef cow type, the cow mature weight should be determined by the optimum weight for the calves at the target carcass composition, and the milk production level should be based on the forage available. More work is needed to account for protein availability and quality to the current model. Once this is attained, this model can also be applied to select best strategy for forage management and supplementation to minimize costs and environment impacts of N.

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APPENDIX

DETERMINING FEED EFFICIENCY FOR INDIVIDUAL BULLS, STEERS, HEIFERS, OR FOR BEEF COWS

Danny G. Fox, Luís O. Tedeschi, and Michael J. Baker

This section describes the steps used by the Cornell Value Discovery System (CVDS) model and the data collection process to obtain the inputs needed by the CVDS model to predict feed required by individual animals fed in groups.

GROWING CATTLE

Steps we use for computing feed required for the observed performance

1. The net energy value of the ration for maintenance and gain must be determined. Feed analysis of the ration ingredients and the ration dry matter formula are used to predict the net energy value of the ration dry matter for maintenance and growth with the Cornell Net Carbohydrate and Protein System (CNCPS; Fox et al., 2004), or computer programs based on the Beef NRC (2000).
2. Beginning and ending weight and days on test are used to compute average weight and average daily gain during the test.
3. The animals' average body weight during test is used to predict their average daily maintenance requirement.
4. The average daily maintenance requirement is adjusted for the effect of environment on the energy required for maintenance.
5. This average daily maintenance requirement is divided by the net energy value of the ration for maintenance to compute the feed required for maintenance/day.
6. The animals' expected weight at 28% body fat (average fatness of low choice grade) is predicted from the animals' weight and backfat, rib eye area, and marbling score. Ultrasound measurements are used for bulls and replacement heifers to be kept for breeding purposes.
7. This 28% fat weight is divided into the weight of the animal used to develop the net energy requirement equations (standard reference weight) to get the ratio of the animal to this standard reference weight (standard reference weight ratio).
8. The standard reference weight ratio is multiplied by the average weight during the test to get the weight equivalent to the standard reference animal (Equivalent weight).
9. The average daily gain during the test and the equivalent weight are used to compute the daily net energy required for gain.
10. The net energy required for gain is divided by the ration net energy value for growth to obtain feed dry matter required for growth.
11. The feed required for maintenance and gain are added together to determine dry matter required/day.
12. Feed efficiency is then the dry matter required/day divided by the average daily gain.

The actual feed fed to the pen is allocated to the individual animals to determine the cost for each individual animal as follows.

1. The dry matter required/day required for each animal in a pen are summed to get the total required/day for the pen.
2. Each animals' dry matter required/day is divided by the total actually fed to the pen to compute the proportional share of the actual feed fed to the pen.
3. The proportional share for each animal is multiplied times the total feed fed to the pen to obtain the amount and cost of the feed for each individual animal.

The above calculations are used to compute the feed efficiency and cost for the actual weight gained during the test. However, the animals will be at different stages of growth at the end of the test, because of differences in initial age and weight, and rate of gain during the test. Therefore the data need to be adjusted to the same final endpoint to correctly evaluate them. To accomplish this, each animals' data is entered into the CVDS and performance is evaluated over a standard growth period, using the feed required to adjust dry matter intake to that observed during the test.

Collecting inputs required

1. Body weights.
    - Beginning of test
    - When ultrasound measurements are taken
    - End of test
2. Ultrasound measurements (taken as near the end of test as possible) or carcass measurements
    - Fat depth
    - Rib eye area
    - Marbling
3. age and hip height (taken at time of ultrasound measurements)
4. Ration
    - Dry matter formula (keep as constant as possible during the entire test)
    - Ration ingredient analysis (take as many samples as needed to represent each ration ingredient during the entire test).
        i. Dry matter, NDF, Lignin, CP, protein solubility, NDIP, ADIP.
        ii. Total feed fed to each pen during the test.
5. Environment description (average for each month during the test)
    - For the entire test
        i. Lot type (choose from the list)
        ii. Square feet/head
    - Average for each month during the test
        i. Wind speed and temperature the cattle are exposed to, lot conditions (choose from the list)

Example data input sheets

Pen Space: square feet per head: _____________

Animal Data-IN	Pen No.________			
Date	ID	Breed	Weight	BCS
Animal Data-OUT	Pen No.________			
Date	ID	Breed	Weight	

Date: ____________		
Animal ID	Hip Height	Birthdate

Ration		
Date	Ingredient	Lbs/batch
Date	Pen No.	Amount fed

Ultrasound Data					
Date					
	An ID	BF	Rump Fat	IMF	REA

Environmental data							
	Temp. (^oF)	RH (%)	Mud (in.)	Wind (MPH)	Hair Coat[1]	Hair Depth (in.)	Min. Temp. (^oF)
Month							

[1]1=No mud; 2=mud on lower body; 3=mud on lower body and sides; 4=heavily covered with mud.

BEEF COWS

Computational steps

1. Compute cow mature weight at BCS 5 adjusted for conceptus; assume energy balance of 0 over 12 month reproductive cycle
2. Compute daily cow NEm required daily (adjusted for activity, environment); convert to ME
3. Compute cow pregnancy requirement, and convert to ME
4. Predict cow peak milk from calf weaning weight and age
5. Compute cow lactation requirement (convert to ME)
6. Compute calf forage ME intake
7. Compute total ME required (MEm + MEpreg + MElact + MEcalf forage)
8. Compute ME efficiency
    a. ME required/actual weaning wt
    b. ME required/adjusted weaning wt
    c. ME required/(adjusted weaning wt + % of cull cow wt)
9. Compute total herd ME
10. Compute cow fractional share of herd ME
11. Compute cow cost (total costs × fractional share)

Data collection

The data collection involves obtaining the inputs necessary for the CVDS to compute metabolizable energy required per lb. of calf weaned.

Feed sampling and analysis

Send samples to a lab recommended by the Land Grant University for analysis for NDF, lignin, crude protein, protein solubility, ADF protein, fat, ash. Send to a university recommended.

1. <u>Pasture sampling (once/month during the grazing season).</u>
    a. Approximately once per month, observe plant parts cows are consuming, then pluck by hand forage parts being grazed, down to the level being grazed by the cattle. Take a bucket to collect 10-12 samples representative of the areas the cows are grazing in each pasture, mix in the bucket, then take what is needed of the mix to fill the forage sample bag. Then freeze and send immediately for analysis or store in a freezer until ready to send several samples.
    b. Estimate average forage availability (tons per acre if harvested as hay)
        i. Record stocking rate (acres/cow)

2. <u>Winter feed sample analysis.</u> Obtain analysis for the harvested feeds fed, including each type and quality of forage.

Animal data to collect at weaning

1. Cow: ID, body weight, body condition score, age in years (2, 3, 4, mature) and days pregnant.
2. Calf: dam, and sire ID; sire mature weight; calf sex, birth weight, weaning weight and age at weaning; hip height.

Environmental data

Monthly average temperature, wind, and humidity the cows exposed to.