

# A DECISION SUPPORT SYSTEM FOR INDIVIDUAL CATTLE MANAGEMENT<sup>1</sup>

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## INTRODUCTION

Individual cattle management systems are being developed in the beef industry to improve profitability, minimize excess fat produced, increase consistency of product and to identify and reward individual owners for superior performance in the feedlot. To accomplish this, cattle are marketed as individuals when at their optimum carcass composition, which typically requires having cattle with different owners in the same pen. This requires allocating and billing feed fed to a pen to the individual animals in the pen. To make individual animal management work, the method used to allocate the feed consumed by animals from different owners that share the same pen must accurately determine cost of gain of each animal in a pen.

There are three critical control points in launching a successful individual cattle management system (ICMS) for growing beef cattle: (1.) Predicting optimum finished weight, incremental cost of gain and days to finish to optimize profits and marketing decisions while marketing within the window of acceptable carcass weights and composition, (2.) Predicting carcass composition and backfat deposition rate during growth to avoid discounts for under or over weight carcasses and excess backfat, and (3.) Allocating feed fed to pens to individual animals for the purpose of sorting of individuals into pens by days to reach target body composition and maximum individual profitability, requiring mixed ownership of individuals in pens, determination of individual animal cost of gain for the purposes of billing feed and predicting incremental cost of gain, and providing information that can be used to select for feed efficiency and profitability. We have developed two models to address the critical control points; the DAYSTEP model (1, 2, 3) addresses control points 1 and 2 and the FEED ALLOCATION model (4) addresses control point 3. Both of these models are being used in feedlots, and have been incorporated into a decision support system (Cornell Value Discovery System) (5). The objective of this paper is to describe these models as applied in our Cornell Value Discovery System for individual cattle management.

## PREDICTING ANIMAL REQUIREMENTS AND FEED ENERGY VALUES IN THE CORNELL VALUE DISCOVERY SYSTEM

Because of the wide variations in breed types and their crosses used for beef production in North America and environments in which they are fed prior to marketing as finished beef, modeling systems to predict feed requirements and cost of gain must be able to account for differences in basal maintenance requirement, the effect of environment on maintenance requirement, the effect of in body size, implant program

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and feeding system on finished weight and growth requirements, feed energy values, and dry matter consumption.

### Accounting for Body Composition at the Marketing Target

The critical first step for predicting feed required for the observed growth and incremental cost of gain and body composition as cattle grow is to identify the body composition at the marketing target. Carcass value in most markets and cost of gain can be related to proportion of protein and fat in the carcass. Body fat in finished cattle when marketed typically varies from 16 to 21% empty body fat (EBF) in the French (6) and Brazilian (7) markets to over 30% EBF in segments of the Japanese and Korean Markets. Most other markets range between these two. The single most recognizable quality grade in the world is USDA choice. Premium brand name products typically utilize the prime and upper 2/3 of the Choice grades and are increasing the value of U.S. beef products. Table 1 shows a summary of data from our experiments (4) that support the value of the Choice and prime grades level of fatness to minimize the percent of the beef that is unacceptable to consumers in the U.S.

Table 1. Relationship of carcass and empty body fat to quality grade (total of 1,355 animals; 4). Values in a row are means for that grade.

Number of animals	USDA Quality Grade <sup>a</sup>	Mean carcass fat, %	Mean EBF, % <sup>b</sup>	EBF SEM	Taste panel score <sup>c</sup>	Percent unacceptable <sup>c</sup>
45	3.5	23.55	21.13 <sup>u</sup>	0.63	5.3	40
470	4.5	28.98	26.15 <sup>v</sup>	0.19	5.6	13
461	5.5	31.64	28.61 <sup>w</sup>	0.20	5.8	8
206	6.5	33.02	29.88 <sup>x</sup>	0.29	6.2	0
90	7.5	34.23	31.00 <sup>xy</sup>	0.44	-	-
51	8.5	35.24	31.94 <sup>y</sup>	0.59	-	-
32	9.5	35.80	32.45 <sup>z</sup>	0.74	-	-

<sup>a</sup>Standard = 3 to 4; Select = 4 to 5; low Choice = 5 to 6; mid Choice = 6 to 7; high Choice = 7 to 8; low Prime = 8 to 9; mid Prime = 9 to 10.

<sup>b</sup>Column means with different superscripts are significantly different at  $P < 0.05$ .

<sup>c</sup>Taste panel scores (from 1 to 8) and percent unacceptable values are from a subset of this data base.

These data show that EBF was significantly ( $P < 0.05$ ) higher with each incremental increase in grade up to the mid Choice grade. Taste panel scores and percent unacceptable followed the same trend. This data also indicate we can correlate grade to changes in body composition as cattle grow. The most critical factor in this table for our model is the percent EBF at Standard (21.1%), Select (26.2%), and low Choice grade (28.6%) grade since these are the body composition endpoints for different marketing targets used to identify feed requirements during growth.

The National Beef Quality Audit (8) reported the percent of steaks with low eating quality for the USDA Prime, Choice, Select, and Standard grades were 5.6, 10.8, 26.4, and 59.1 percent, respectively in data collected from typical feedlot cattle. The percent unacceptable values were lower for the Cornell data, likely because they were uniform

calves fed a 90% concentrate diet beginning at approximately 7 months of age. The 1995 National Beef Quality Audit also reported that up to 20% of all beef does not pass U.S. consumer satisfaction in eating quality and recommends that the percentage of cattle grading low Choice and above be increased. Based on a survey of retailers, purveyors, and exporters, the ideal mix would be 62% low Choice or better and 38% Select, with no Standard grade beef. This compares to the current 51% low Choice or better, 42% Select and 7% Standard grade and lower (9). The 10% of U.S. beef that is exported would have none below low Choice. The strong message from our consumers is that the external fat must be removed from beef, but intramuscular (marbling) fat is required in the edible product. This is likely due at least in part to the method of cookery commonly used compared to what is common in most other countries (10).

### Accounting for Differences in Requirements for Growth

We determined that cattle of different mature sizes had different fat and protein content of the weight gain at the same weight during growth (11). Therefore we developed a size scaling procedure to account for differences in energy and protein requirements for growth among cattle of different frame sizes and sexes (11, 12, 13, 14, 15) which was adapted by the National Research Council Nutrient Requirements of Beef Cattle (16). This growth model was found to be accurate for predicting requirements for dairy heifers (14), and was adapted for use in the Nutrient Requirements of Dairy Cattle (17). In this model, the animal's weight at 28% fat (or mature weight if replacement heifers) is divided into the weight of the standard reference animal at that composition. This ratio is then multiplied by the animal's actual weight to adjust it to the standard reference animal for use in the energy requirement equation. The standard reference animal represents the cattle body size used to develop the equations to predict the net energy content of weight gain. Table 2 shows an example of requirements for growth computed with this model for two mature sizes of cattle. This table shows that as mature size increases, weight at the same energy content of gain increases, because larger size animals are at an earlier stage of growth at the same weight and therefore have more protein and less fat in the gain. It also shows that energy requirements increase with increasing stage of growth and rate of gain.

Table 2. Relationship of stage of growth and rate of gain to body composition

28% fat weight, lb	Weight during growth, lb		
1100 lb	600	800	1000
1300 lb	708	944	1180
% of 28% fat wt.	55	73	91
ADG, lb/day	Net energy required, Mcal/day		
2.0	3.23	4.01	4.74
3.0	5.04	6.26	7.40
4.0	6.92	8.58	10.14

Three data sets were used to test this system (16). With two of the data sets (82 pen observations of *Bos taurus* implanted steers and heifers varying in breed type, body

size and diet type and 142 serially slaughtered nonimplanted steers, heifers and bulls varying in body size aggregated into “pens” by slaughter groups), this system accounted for 94% of the variation in energy retained with only a 2% underprediction bias. Similar results were observed for Holstein heifers (14). However, it cannot be assumed that this accuracy will apply to individual animals at a particular point in time during growth, since these results were obtained from pen averages and total energy retained. Many factors can alter estimates of finished weight of individuals, such as previous nutrition, implant programs, level of intake and energy derived from the diet, limits in daily protein and fat synthesis, and daily energy retained. The problem is to be able to predict those effects in individual animals based on information that will be available in feedlots and is practical to apply.

### Accounting for Differences in Requirements for Maintenance

The model used for this purpose is described by Fox and Tylutki (18). The effects of breed type are accounted for by adjusting the base  $NE_m$  requirement of 77 kcal/kg MBW (metabolic body weight) for *Bos indicus* and dairy types (-10 and +20% compared to *Bos taurus*). The effects of previous nutrition are accounted for by relating body condition score to  $NE_m$  requirement. On a 1 to 9 scale, maintenance requirement is reduced 5% for each condition score below 5 and is increased 5% for each score above 5. The effects of acclimatization are accounted for by adjusting for previous month's average temperature (ranges from 70 kcal/kg MBW at 30 °C to 105 kcal/kg MBW at -20 °C). This adjustment is continuous, with no effect at 20 °C. Current environmental effects are accounted for by computing heat lost vs heat produced, based on current temperature, internal and external insulation, wind, and hair coat depth and condition. This becomes important when the animal is below the computed lower critical temperature, and can range from no effect at 20 °C to twice as high (thin, dirty hide at -12 °C and 1 mph wind).

### DETERMINING RATION ENERGY VALUES FOR USE IN PREDICTING DMI, DAYS TO FINISH, AND FEED REQUIRED

Accurate predictions of DMI and  $NE_g$  are highly dependent on having feed net energy values that accurately represent the feeds being fed. Further, energy allowable performance must be supported by dietary protein allowable growth. Tedeschi et al. (3) evaluated the accuracy of alternative methods for determining feed energy and protein values (NRC levels 1, which uses tabular values, NRC level 2, which uses the CNCPS model, and a summative equation commonly used by feed analysis laboratories to predict feed energy values from chemical composition (19, 20, 21). The regression analyses of observed and predicted ADG are shown in Table 3. Metabolizable energy was predicted by the CNCPS to be first limiting in 19 treatment groups. Across these groups, the observed ADG varied from 0.8 to 1.44 kg/d. When ME was first limiting, the ADG predicted by the CNCPS model accounted for more of the variation (80%) than did the summative equation or tabular (73 and 61%, respectively). Metabolizable energy allowable ADG predicted with the tabular system gave an overprediction bias of 11%, but the bias was less than 2% when predicted with the CNCPS or summative equation. The MSE were similar in all predictions, but the CNCPS model had the highest accuracy (lowest RMSPE). Metabolizable protein was predicted by the CNCPS to be first limiting

in 28 treatment groups (Table 3). Across these groups, the observed ADG ranged from 0.12 to 1.36 kg/d. The ADG predicted by the CNCPS model accounted for more of the variation (92%) than did the summative equation or tabular (79 and 80%, respectively). Metabolizable protein-allowable ADG predicted with the tabular gave an overprediction bias of 4%, whereas the bias was less than 2% when predicted with the CNCPS or summative equation. Similar to the ME first limiting analysis, the CNCPS model had the highest accuracy (lowest RMSPE: 0.11).

Table 3. Evaluation of the tabular TDN and TDN predicted by a summative equation and by the Cornell Net Carbohydrate and Protein System (CNCPS) to estimate ADG (kg/d) when ME or MP are first limiting <sup>a</sup>

	ADG, kg/d			Regression statistics <sup>b</sup>			RMSPE
	Min.	Mean ± SE	Max.	r <sup>2</sup>	MSE	bias, %	
ME first limiting (n = 19)							
Observed	0.80	1.11 ± 0.04	1.44	-	-	-	-
Tabular (16)	0.73	1.25 ± 0.06	1.78	0.61	0.01	-11.4*	0.23
Summative (21)	0.74	1.13 ± 0.06	1.62	0.73	0.01	-2.2	0.14
CNCPS v. 4.0	0.79	1.10 ± 0.05	1.48	0.80	0.01	0.4	0.10
MP first limiting (n = 28)							
Observed	0.12	0.78 ± 0.07	1.36	-	-	-	-
Tabular (16)	0.11	0.81 ± 0.09	1.78	0.80	0.03	-4.3	0.21
Summative (21)	0.13	0.78 ± 0.09	1.73	0.79	0.03	-0.5	0.22
CNCPS v. 4.0	0.12	0.77 ± 0.07	1.45	0.92	0.01	1.9	0.11

<sup>a</sup> Data were obtained from Boin and Moura (22), Fox and Cook (23), Danner et al. (24), Lomas et al. (25), Abdalla et al. (26), and Ainslie et al. (27), and Wilkerson et al. (28) (only in the MP sub-dataset evaluation).

<sup>b</sup> Observed values (Y) were regressed on predicted ADG (X) using tabular TDN (NRC, 2000) or predicted TDN by the Weiss et al. (1992) equation or CNCPS v. 4.0. A positive bias means that Y values (observed) are greater than X values. MSE is the mean square error from the regular regression, SE is the standard error, and RMSPE is the root of the mean square prediction error. Asterisks indicate statistical difference from zero using the t-test (unequal variance) at  $\alpha=0.01$  (\*\*),  $\alpha=0.05$  (\*), or no difference (no asterisk).

#### MODEL TO PREDICT DAYS TO FINISH, CARCASS WEIGHT, BODY FAT, QUALITY AND YIELD GRADE

We utilize the maintenance and growth models described previously to predict daily gain, feed required, body fat, and quality and yield grade on a daily basis as an animal grows (1, 2, 3, 5). Equations to predict carcass weight and composition, and the above prediction of DM required in live cattle during growth must rely on estimates of finished weight, and data that can be obtained on individuals during growth, such as current weight, ADG and ultrasound estimates of fat depth, marbling and rib eye area. Perry and Fox (29) developed equations for utilizing ultrasound measurements for this purpose, and the reader is referred to that paper for details of those equations. An additional component needed for this model is the prediction of dry matter intake. The NRC (16) provided equations that can be used to account for the effects of variables

that influence individual animal performance in each production situation; diet energy density, degree of maturity, and environment (temperature and mud effects). Therefore, we chose to use the DMI equation adopted by NRC (16) in our DAYSTEP model. In applying the NRC (16) equation to predict DMI, we converted the adjustments for EBF into an equation to allow continuous adjustment for this effect if equivalent shrunk BW (EQSBW) is greater than 350 kg. Table 4 summarizes the sequence of calculations in the DAYSTEP model used to predict days required to reach a target composition.

Table 4. Sequence of calculations in the DAYSTEP model

Step	Description
1	Determine NEm and NEg concentration of the diet using the CNCPS model
2	Determine the expected shrunk body weight (SBW) at 28% body fat (Choice AFSBW)
3	Determine the expected SBW at USDA Select grade using the following relationship: Select AFSBW = Choice AFSBW – (14.26 × (28.6 - 26.15))
4	Determine the expected SBW at YG 4
5	Predict daily DMI based on current SBW, diet energy, environmental conditions, and Choice AFSBW
6	Predict feed required for maintenance (FFM, kg) based on current SBW and environmental conditions as follows: FFM = NEm required / diet NEm
7	Predict NE available for gain (NEFG, Mcal) from DMI and diet NEg ; NEFG = (DMI – FFM) × diet NEg
8	Predict daily Shrunk Weight Gain (SWG) from NEFG and the current SBW equivalent to the standard reference animal (EQSBW)
9	Compute the new SBW of the animal by adding SWG in step 6 to the initial SBW
10	Repeat steps 5 to 9 for each additional day until animal reaches expected finished SBW
11	Compute daily carcass weight (CW) from equivalent Carcass Weight (EQCW)
12	Compute carcass daily gain
13	Adjust predicted DMI of individuals with ratio of pen actual/predicted as appropriate
14	Allocate feed to individual animals in pens when sorted by days to finish at re-implant time with the feed allocation model (4)

#### Evaluation of the DAYSTEP Model for Growth Predictions

A validation of this model was conducted with 365 individually fed steers with measured body composition and feed energy values predicted with the CNCPS version 4.0. The model accounted for 90% of the variation in individual animal ADG with no bias and deviation tendency. As a result, the observed weight at the actual total days on feed was accurately predicted ( $r^2 = 0.86$ ) with no bias and no deviation tendency. When ADG was predicted using the mean body weight and actual DMI, the variation accounted for was reduced to 80%, compared to the model daily DMI adjusted for the overall ratio of actual/predicted DMI. This approach results in a higher DMI early and lower DMI later in the feeding period, in agreement with the data of Thornton et al. (30).

In the above data, weight at 28% EBF could be accurately determined because final body fat of each individual animal was known. A small data set was available to evaluate the ability of model equations that use hip height and age to predict AFSBW. The data set consisted of 29 bulls of five different breeds fed to finished weights. When only SBW, hip height and age were available to predict AFSBW, the regression accounted for 58% of actual AFSBW variation. However; when carcass measurements from ultrasound were used to generate inputs for the equation of Guiroy et al. (4) to predict AFSBW, the regression between observed and predicted AFSBW had an  $r^2$  of 0.75. Feed required for the observed ADG with AFSBW computed with hip height and age or with ultrasound used to predict carcass fat depth, rib eye area and quality grade accounted for 93 and 96%, respectively of the variation in feed required with AFSBW computed from actual carcass measures. These results suggest the use of ultrasound can improve the prediction of AFSBW.

## Prediction of Carcass Weight and Composition in the DAYSTEP Model

Because carcass weight as a proportion of live weight increases as body fat increases, profit potential predictions would be more accurate on a carcass weight basis if it can be accurately predicted. We developed equations to predict carcass weight (CW) during growth for this purpose, which use a size scaling procedure to account for stage of growth. Three published equations (31, 32, 33) were compared to predict CW from EBW with or without size scaling. The equation of Garrett et al. (33) with size scaling had the lowest mean bias. Therefore, we selected the equation of Garrett et al. (33) to predict CW from EBW.

Carcass quality grade can be predicted from predicted empty body fat with the relationships shown in Table 1. Therefore we developed a sub-model to predict EBF to be used with the DAYSTEP model for use in predicting carcass quality and yield grades during growth. This sub-model was based on published equations in which SWG is converted to empty weight gain (EWG) using the NRC (16) relationship and proportion of fat in gain is computed using the equation developed by Garrett (34), which uses RE. Fat is accumulated over time and EBF is calculated by dividing the amount of accumulated fat by EBW. An equation to predict initial body fat from EQEBW ( $r^2 = 0.84$ ) was developed from a database containing 143 initial body compositions in 5 studies. These equations explained 81% of the variation in actual body fat but had a bias of -14.4%. In a second evaluation with pen average data ( $n = 63$  pens containing 590 animals), these equations accounted for 70% of the variation with an overprediction bias of 10%. These results suggest a bias of 10 to 14% needs to be subtracted from the predicted body fat until more data are developed to improve this prediction.

The equation developed to predict YG from EBF had an  $r^2 = 0.57$ ,  $MSE = 0.38$ , and used 389 animals. When validated on an independent data set containing 915 animals, the equation developed explained 49% of the variation in YG, using EBF as the only predictor. A significant bias ( $P < 0.01$ ) was observed in the prediction. However, within the range 2.5 to 3.5, 77% of the predicted YG values were  $\pm 0.5$  units. Table 5 shows the risk associated with predicting YG at three YG thresholds. As the YG threshold increases, the ratio of error 1 (observed YG is greater than the threshold and predicted YG is lower than the threshold) to error 2 (observed YG is lower than the threshold and predicted YG is greater than the threshold) increases more than 8 times, indicating the

risk of an overprediction is greater than an underprediction of YG of the carcass at higher YG values.

Table 5. Comparative risk of prediction of yield grade (YG) given the observed YG for three thresholds <sup>a</sup>

Error	Yield Grade		YG Threshold		
	Observed (YGo)	Predicted (YGp)	3.0	3.5	4.0
--	≤ Threshold	≤ Threshold	46.4	77.3	94.4
--	≥ Threshold	≥ Threshold	29.1	7.8	1.3
1	≥ Threshold	≤ Threshold	9.6	9.2	3.6
2	≤ Threshold	≥ Threshold	14.9	5.7	0.7

<sup>a</sup> Values are percentage of 915 animals.

#### MODEL TO PREDICT INDIVIDUAL ANIMAL FEED REQUIREMENTS WHEN FED IN GROUPS

The system of equations we developed (4) to predict individual animal feed requirements is summarized in Table 6, which is implemented in the Cornell Value Discovery System (5).

Table 6. Equations to predict individual dry matter requirements

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- (1)  $EBW = 1.316 HCW + 32.29$ ; from Garrett et al. (34)
  - (2)  $EBF\% = 17.76207 + 4.68142 FT + 0.01945 HCW + 0.81855 QG - 0.06754 LMA$
  - (3)  $AFBW = (EBW + ((28 - EBF\%) \times 14.26)) / 0.891$
  - (4)  $EQSW = SBW (478/AFBW)$ ; from NRC (16)
  - (5)  $RE = 0.0635EQEBW0.75 EBG1.097$ ;  $EQEBW$  is  $0.891EQSW$ ; from NRC (16)
  - (6)  $FFG = RE/diet\ NEg$
  - (7)  $FFM = NEm\ required/diet\ NEm$ ;  $NEm\ required$  can be calculated as described by Fox et al. (13) and NRC (16)
  - (8) Individual DM required is  $FFM + FFG$
  - (9) Adjusted individual DM required = individual DM required x (total actual pen DM consumed/ total pen DM required)
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Individual feed required is the sum of the feed required for maintenance (FFM), and the feed required for growth (FFG). Feed for maintenance is a function of the NE required for maintenance and the NEm concentration of the diet. Similarly, FFG is a function of the energy retained in the weight gain and the NEg concentration of the diet. Animal differences in mature body size are accounted for as described previously. Perry and Fox (29) and Guiroy et al. (4) presented a detailed description of the development of these equations. Table 7 shows a summary of the calculations for an actual Angus steer fed in a group pen.

Table 7. Example calculation with the feed allocation model <sup>a</sup>

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	Net energy for maintenance = 6.83 lb/day
Rib eye area = 79.4 cm <sup>2</sup>	Feed DM for maintenance = 7.49 lb/day
Backfat depth = 1.5 cm	Total feed DM required = 25.16 lb/day
Diet NEm = 0.91 Mcal/lb	Feed efficiency = 5.42
Diet NEg = 0.61 Mcal/lb	

<sup>a</sup> Group inputs included pen dry matter intake for the entire feeding period, and ration NE<sub>m</sub> and NE<sub>g</sub> values.

### Evaluation of the Cornell Value Discovery System Feed Allocation Model

The set of equations to predict dry matter consumed by individuals (Table 8) was evaluated with data from the studies of Nour (35), Perry et al. (36), Perry and Fox (29) and Guiroy et al. (37). This data used 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. Guiroy et al. (4) presented a complete description of this data base.

We evaluated DM requirements predicted by the Cornell Value Discovery System against actual DM consumed. The equations presented in Table 4 accounted for 74% of the variation in actual DM consumed, with essentially no bias (0.34%) and a coefficient of variation of 8.18%.

To compute EBF under feedlot conditions, we developed a new equation to predict EBF percentage from carcass measurements commonly taken in U.S. packing plants with a large database (4). This equation accounted for 61% of the variation in EBF with a coefficient of variation of 11.9% and no bias since the intercept and the slope of the regression equation were not different ( $P > 0.10$ ) from zero and one, respectively. This equation was validated with 951 animals including steers and heifers from a variety of breeds and diets fed and explained 51% of the variation in EBF%, with a coefficient of variation of 10.7% and no bias. The 39% of the variation in EBF in the development data base and 49% of the variation not explained by this equation in the evaluation data base can be explained by the variation in the carcass measurements used by the equation at a similar empty body fat (4).

When the same analysis to predict individual feed requirements evaluated using this predicted rather than the observed EBF (%), the variation accounted for by the model was not reduced. This result indicates that we can accurately predict individual feed requirements using a prediction of EBF from carcass measurements available from U.S. packing plants.

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. 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 even though we can account for 74% of the variation in individual animal feed requirements with a coefficient of variation of 8.18, the error in our prediction is greatly reduced when predicting groups of animals, which is an important concept for producers using this system to allocate feed consumed among groups of cattle within a pen.

We also evaluated predicted vs measured feed efficiency in this data set. The model accounted for 82% of the variation in actual feed efficiency. We conclude the use of Cornell Net Carbohydrate and Protein System model (38) predicted energy values for the diet and pen feed intakes along with individual measurements that can be obtained (individual body weight and ADG, and carcass measurements) accounted for 82% of the differences in feed efficiency. The variation not accounted for in this system is due to individual animal variations that the system cannot fully account for, including differences in maintenance requirements, diet digestibility and metabolizability, and body composition. 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 (Equation 9 in Table 6). 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).

A feedlot data set of 12,105 steers and heifers 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 individual cattle-tracking system. Total feed DM delivered vs the sum of each individual animal predicted DM required was compared using our model. Results from this evaluation shows DM required was predicted with very little bias with our modified 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 theoretical maintenance requirement of  $0.077 \text{ Mcal/d/kg SBW}^{0.75}$ , which likely varies within and between feedlots due to animal interactions with actual environmental conditions. However, in this data set evaluated, the effects of environment are accounted for in the diet NEm and NEg provided by the feedlot consultant, since those values reflect diet NE values required to have predicted and observed ADG agree in the historical data base used to develop their performance projection program.

## SUMMARY

A modeling system is presented that provides a 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). Post harvest, feed can be accurately allocated based on prediction of final EBF from carcass measures. This modeling system along with additional equations developed by Perry and Fox (29) to predict carcass weight and compositional changes during growth can be used to market cattle on an individual basis at the optimum time, considering incremental cost of gain and carcass weight and composition discounts. The data can also be used in selecting for feed efficiency that accounts for differences in body size and rate and composition of gain. However, when allocating feed to animals fed in groups, it does not account for differences in efficiency of use of metabolizable energy; to make this calculation, actual individual intake must be known.

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