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Using simulation models to predict feed intake: Phenotypic and genetic relationships between observed and predicted values in cattle

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ABSTRACT: The objectives of this study were to evaluate the accuracy of the Decision Evaluator for the Cattle Industry (DECI) and the Cornell Value Discovery System (CVDS) in predicting individual DMI and to assess the feasibility of using predicted DMI data in genetic evaluations of cattle. Observed individual animal data on the average daily DMI (OFI), ADG, and carcass measurements were obtained from postweaning records of 504 steers from 52 sires (502 with complete data). The experimental data and daily temperature and wind speed data were used as inputs to predict average daily feed DMI (kg) required (feed required; FR) for maintenance, cold stress, and ADG; maintenance and cold stress; ADG; maintenance and ADG; and maintenance alone, with CVDS (CFR_{mcg}, CFR_{mc}, CFR_g, CFR_{mg}, and CFR_m, respectively) and DECI (DFR_{mcg}, DFR_{mc}, DFR_g, DFR_{mg}, and DFR_m, respectively). Genetic parameters were estimated by REML using an animal model with age on test as a covariate and with genotype, age of dam, and year as fixed effects. Regression equations for observed on predicted DMI were OFI = 1.27 (SE = 0.27) + 0.83 (SE = 0.04) × CFR_{mcg} [R^2 = 0.44, residual SD ($s_{y.x}$) = 0.669 kg/d] and OFI = 1.32 (SE = 0.22) + 0.8 (SE = 0.03) × DFR_{mcg} (R^2 = 0.53, $s_{y.x}$ = 0.612 kg/d). Heritability of OFI was 0.27 ± 0.12, and heritabilities ranged from 0.33 ± 0.12 to 0.41 ± 0.13 for predicted measures of DMI. Phenotypic and genetic correlations between OFI and CFR_{mcg}, CFR_{mc}, CFR_g, CFR_{mg}, CFR_m, DFR_{mcg}, DFR_{mc}, DFR_g, DFR_{mg}, and DFR_m were 0.67, 0.73, 0.41, 0.63, 0.78, 0.73, 0.82, 0.45, 0.77, and 0.86 ($P < 0.001$ for all phenotypic correlations); and 0.95 ± 0.07, 0.82 ± 0.13, 0.89 ± 0.09, 0.95 ± 0.07, 0.91 ± 0.09, 0.96 ± 0.07, 0.89 ± 0.09, 0.88 ± 0.09, 0.96 ± 0.06, and 0.96 ± 0.07, respectively. Phenotypic and genetic correlations between CFR_{mcg} and DFR_{mcg}, CFR_{mc} and DFR_{mc}, CFR_g and DFR_g, CFR_{mg} and DFR_{mg}, and CFR_m and DFR_m were 0.98, 0.94, 0.99, 0.98, and 0.95 ($P < 0.001$ for all phenotypic correlations), and 0.99 ± 0.004, 0.98 ± 0.017, 0.99 ± 0.004, 0.99 ± 0.005, and 0.97 ± 0.021, respectively. The strong genetic relationships between OFI and CFR_{mcg}, CFR_{mg}, DFR_{mcg}, and DFR_{mg} indicate that these predicted measures of DMI may be used in genetic evaluations and that DM requirements for cold stress may not be needed, thus reducing model complexity. However, high genetic correlations for final weight with OFI, CFR_{mcg}, and DFR_{mcg} suggest that the technology needs to be further evaluated in populations with genetic variance in feed efficiency.

Key words: cattle, feed intake, mathematical model, nutrient requirement

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INTRODUCTION

Feed costs were found to represent about 66 and 77% of the total cost of gain in calf and yearling beef cattle finishing systems (Anderson et al., 2005); hence, any improvement in gain or feed efficiency has the potential to result in increased profits. Fox et al. (2001) simulated the impact of a 10% improvement in rate of gain or a 10% improvement in feed efficiency on profits for an average steer that gained 272 kg of BW to finish at 532 kg of BW at low choice grade. Simulated results showed that the improvement in rate of gain increased profits by 18%, whereas the improvement in feed efficiency increased profits by 43%.

Cattle finished in commercial feedlots represent a potential population that can be used to progeny test beef sires for feed efficiency. These cattle are fed high concentrate diets in large group pens and may have individual growth performance and carcass data. Selection for feed efficiency requires a measurement of individual DMI, and it is possible that biological models may be programmed to predict the individual DMI required for cattle to achieve their individual feedlot performance data.

The Decision Evaluator for the Cattle Industry (**DECI**; Williams and Jenkins, 2003a,b) and the Cornell Net Carbohydrate and Protein System (Fox et al., 2004)

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Table 1. Experimental design and distribution of individually fed steers (1961 to 1963) in phase 1 of Fort Robinson heterosis experiment

Breed of sire	No. of sires	Breed of dam		
		Hereford	Angus	Shorthorn
Hereford	12	47	16	26
Angus	14	28	46	28
Shorthorn	12	26	18	51

are 2 publicly available biological models that can predict animal performance when DMI and nutrient supply are known. The DECI model is capable of working in a reverse manner to predict the DMI and nutrient supply required for an animal to achieve a known level of performance, and the Cornell Value Discovery System (**CVDS**; Tedeschi et al., 2004) was developed as a separate model from the Cornell Net Carbohydrate and Protein System framework for this purpose.

The objectives of this study are to evaluate the accuracy of DECI and CVDS in predicting individual DMI and to evaluate the feasibility of using these predicted individual DMI data in animal genetic evaluations.

MATERIALS AND METHODS

Experimental Data

Individual postweaning records of feed consumption, growth, and carcass traits were obtained for 504 steers produced in phase 1 and phase 2 of a comprehensive heterosis experiment with Hereford, Angus, and Shorthorn cattle. This experiment was initiated in 1957 at the Fort Robinson Beef Cattle Research Station, Crawford, NE, and was described by Gregory et al. (1965). The experimental design and distribution of the 286 crossbred and straightbred steers from straightbred dams and numbers of sires used in phase 1 are given in Table 1. The experimental design and distribution of the 218 2-breed and 3-breed cross steers, and the numbers of sires used in phase 2, are given in Table 2. Phase 1 calves were born in 1961, 1962, and 1963, and phase 2 calves were born in 1963, 1964, and 1965. The calving season was from February 10 to May 1; most of the calves were born between February 20 and the end of March.

Calves were weaned in early October each year at an average age of 200 to 210 d and after a 28-d adjustment period were individually fed for an average of 224 d in phase 1 and 235 d in phase 2. The average ME density of the diet fed in phases 1 and 2 was 2.61 Mcal/kg of DM (Olson et al., 1978a,b). All steers were slaughtered at the end of the postweaning feeding period. Data for intact carcasses were obtained at a commercial slaughter plant each year. The right side of each carcass was transported to the University of Illinois, where complete cutout data were obtained. Carcass cutout procedures were described by Gregory et al. (1966), and more information on management, nutrition, and data collection was published by Olson et al. (1978a) for phase 1 and Olson et al. (1978b) for phase 2. There were 502 steers from 52 sires that had complete data on feed intake, growth, and carcass composition.

Simulated Data

The DECI and CVDS models were parameterized using individual steer growth and carcass information to predict the average daily feed DMI required by individual steers to achieve the body composition and growth performance in the observed data. This individual feed requirement is the sum of feed required for maintenance and the observed BW gain over the experimental period. In both models, the maintenance requirement was adjusted for cold stress with equations published by Fox et al. (2004). The only climatic data that were available were average monthly temperatures for Fort Robinson, NE, and hourly wind speed data from Scottsbluff, NE, for 1961 to 1965. These data were used in calculating the cold stress maintenance adjustments. Experimental data serving as inputs for both models were dietary ME density, beginning BW, ending BW, and ADG for the experimental period. Inputs that were not in the experimental data were beginning body composition and ending body composition.

Body composition at the end of the experimental period in terms of ether-extractable lipid (**FAT**) and fat-free matter (**FFM**) was calculated from the individual animal experimental data for fat trim, HCW, cold carcass weight, and bone weight, as discussed by Williams

Table 2. Experimental design and distribution of individually fed steers (1963 to 1965) in phase 2 of Fort Robinson heterosis experiment

Breed of sire	No. of sires	Breed of dam[1]								
		HH	AA	SS	HA	AH	HS	SH	AS	SA
Hereford	12	—	12	10	—	—	—	—	22	25
Angus	12	16	—	14	—	—	17	20	—	—
Shorthorn	11	15	17	—	26	24	—	—	—	—

[1]HH, AA, SS = purebred Hereford, Angus, and Shorthorn dams, respectively. HA and AH = dams from reciprocal crosses of Hereford and Angus breeds. HS and SH = dams from reciprocal crosses of Hereford and Shorthorn breeds. AS and SA = dams from reciprocal crosses of Angus and Shorthorn breeds.

et al. (1995). Growth and body composition of individual animals from birth to the beginning of the experiment were simulated with the CVDS and DECI models to obtain estimates of individual animal body composition at the beginning of the experiment. In these simulations, the body composition at birth was assumed to be 3% FAT and 97% FFM, and the experimental individual animal data on birth weight, weaning weight, weight at the beginning of the experiment, ADG from birth to weaning, and ADG from weaning to the beginning of the experiment were used as inputs.

The Cornell Value Discovery System. At the beginning of the simulation, the ending BW and composition of each steer was used to calculate the ending empty BW (**EBW**) and ending empty body fat percent (**EBFP**). Each steer's ending EBW was adjusted to a target EBFP of 28%, and this adjusted EBW was divided by 0.891 to convert it to an adjusted final shrunk BW at 28% FAT (**AFBW**), as follows:

$$\text{AFBW} = (\text{EBW} + [\{28 - \text{EBFP}\} \times 14.26])/0.891.$$

Animal differences in mature BW affect the composition of gain at a particular weight, and to account for this effect, a size-scaling procedure was used to adjust the daily shrunk BW of each steer to an equivalent shrunk BW (**EQSBW**). This procedure calculated the EQSBW by multiplying the daily shrunk BW by a ratio of the standard reference animal BW (478 kg) to AFBW. The EQSBW was used to predict energy requirements for growth on a daily basis.

Simulation of each animal was begun with an initial estimate of DMI, and equations from Tedeschi et al. (2004) were used to calculate feed for maintenance, feed for gain, energy for gain, and ADG. The DMI was iterated each day until the predicted daily ADG was the same as the observed ADG. In calculating energy for gain, an initial estimate for NE_g that was based on the ME density of the diet was first used, and this estimate was updated each round of iteration using information on protein retention. At the end of the simulation, the final BW was the same as the observed BW, but the fat weight may have been different because convergence was based on ADG and not on body composition.

The predicted value for DMI, when the observed and predicted ADG converged, was the DMI required for maintenance, cold stress, and ADG. Daily DMI requirements were summed and divided by the days on feed, and this average daily feed DMI was referred to as the CVDS feed intake required for maintenance, cold stress, and ADG (**CFR_{mcg}**). Average daily feed DMI were also predicted for maintenance and ADG (**CFR_{mg}**), maintenance and cold stress (**CFR_{mc}**), maintenance (**CFR_m**), and ADG (**CFR_g**).

The Decision Evaluator for the Cattle Industry. The CVDS model is based on empirical equations for which analytical solutions are easily obtained; in contrast, the DECI model is based on 13 differential equations that are numerically integrated on a daily basis to obtain solutions. Compared with the CVDS model, a different approach was used in simulating each steer with the DECI model. In this case, the observed ADG was used as the main input, and 2 parameters that determined body composition were iterated until the predicted ending BW and composition were the same as that observed. The 2 parameters were a fattening parameter (**THETA**) and FFM at maturity (**FFM_{mat}**), and breed averages (Williams et al., 1995) were used as initial values for these 2 parameters. Both THETA and FFM_{mat} were negatively correlated with fatness, and in making adjustments, FFM_{mat} was changed at twice the percentage change as that of THETA.

Daily individual animal feed requirements for maintenance and gain were obtained according to Williams and Jenkins (2003a,b), and these requirements, together with feed requirements for cold stress, were summed for the entire experimental period. The total DMI for the experimental period was divided by the number of days fed, and this average daily required DMI was referred to as the DECI feed intake requirement for maintenance, cold stress, and gain (**DFR_{mcg}**). Average daily feed DMI were also predicted for maintenance and ADG (**DFR_{mg}**), maintenance and cold stress (**DFR_{mc}**), maintenance (**DFR_m**), and ADG (**DFR_g**).

Statistical Analysis

Descriptive statistics for observed average daily DMI (**OFI**), and predicted measures of average daily required DMI were computed with the Means procedure of SAS (SAS Inst. Inc., Cary, NC). The accuracy of CVDS and DECI in predicting average daily DMI was evaluated by comparing CFR_{mcg} and DFR_{mcg} with OFI. Linear regressions were calculated between OFI and CFR_{mcg}, and between OFI and DFR_{mcg}, allowing the intercepts to be calculated; then in a second analysis the intercepts were forced through the origin. The second regression model tested how closely the predictions followed the observed animal response (i.e., the line where predicted equals observed). When the regression is forced through the origin, the SE of the dependent variable estimate (**$s_{y.x}$**) is an estimate of the precision of the predicted values over the range of observations, and the regression coefficient is an estimate of the bias.

Heritability and Genetic Correlations Estimates

Estimates of (co)variance components, heritabilities, and genetic correlations were made for the traits in Table 3, yearling weight (**YWT**), final weight (**FWT**), and ADG using the MTDFREML programs (Boldman et al., 1995). Fixed effects were genotype defined by the combination of sire breed and dam breed or dam crossbreed (15 combinations), year of birth (1961 to 1965), age of dam (2 to 6 yr of age), and a covariate defined by age at the beginning of the test period (mean = 239 d; range = 170 to 275 d). Random sources

Table 3. Simple statistics for observed average daily DMI (OFI) of steers, and measures for average daily required DMI predicted with the Cornell Value Discovery System (CVDS) and the Decision Evaluator for the Cattle Industry (DECI)

Variable[1]	Mean, kg	CV, %	Minimum, kg	Maximum, kg
OFI	6.614	13.55	3.519	9.381
CFR_{mcg}	6.382	11.16	3.737	8.518
CFR_{mc}	3.594	10.08	2.643	4.721
CFR_{g}	2.789	18.57	0.968	4.438
CFR_{mg}	6.186	12.16	3.362	8.477
CFR_{m}	3.397	11.72	2.371	4.592
DFR_{mcg}	6.622	12.35	3.685	9.238
DFR_{mc}	3.859	11.82	2.674	5.272
DFR_{g}	2.762	18.05	0.898	4.276
DFR_{mg}	6.468	13.45	3.303	9.156
DFR_{m}	3.706	14.04	2.204	5.221

[1]CFR_{mcg}, CFR_{mc}, CFR_{g}, CFR_{mg}, and CFR_{m} = average daily required DMI predicted with CVDS for maintenance, cold stress, and gain; maintenance and cold stress; gain; maintenance and gain; and maintenance, respectively. DFR_{mcg}, DFR_{mc}, DFR_{g}, DFR_{mg}, and DFR_{m} = average daily required DMI predicted with DECI for maintenance, cold stress, and gain; maintenance and cold stress; gain; maintenance and gain; and maintenance, respectively.

of variation were direct genetic and residual effects. An animal model was used for direct genetic effects. There were 947 animals in the pedigree. All animals with data had sire and dam identified. Maternal sire and dam also were known for animals born in phase 2 of the experiment.

Single-trait analyses were used to estimate heritabilities. Two-trait analyses were used to estimate genetic and phenotypic correlations.

RESULTS AND DISCUSSION

Summary of Observed and Predicted Data

The mean, CV, minimum and maximum values for OFI of steers, and predicted measures of average daily required DMI are shown in Table 3. Compared with the OFI mean, the DFR_{mcg} mean was very similar, but the CFR_{mcg} mean was about 3.5% lower. Mean values and CV for DFR_{g} and CFR_{g} were about the same, suggesting that the CVDS and DECI performed about the same in predicting the average daily required DMI for gain. The difference in means between DFR_{mcg} and CFR_{mcg} is mainly due to the difference in means for DFR_{m} and CFR_{m} because the difference in requirements for cold stress ($DFR_{mc} - DFR_{m}$; $CFR_{mc} - CFR_{m}$) were small. These results suggest that the CVDS model may be underpredicting maintenance requirements compared with the DECI model. Predicted average daily required DMI variables showed a similar variability compared with OFI, except for average daily required DMI for gain, and this agrees with a CV of 17% for ADG in the observed data.

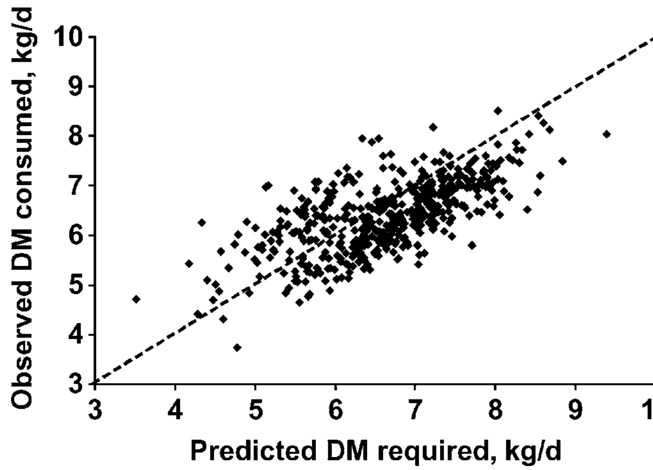

Figure 1. Relationship between observed average daily DMI (OFI) and average daily required DMI for maintenance, cold stress, and ADG of steers predicted using the Cornell Value Discovery System. Dashed line y = x indicates the position of the perfect fit between observed and model predicted values. The data used were from 502 individually fed steers produced in a heterosis experiment (Olson et al., 1978a,b).

Prediction of Individual DM Required

The relationship between OFI and CFR_{mcg} is illustrated in Figure 1, and the relationship between OFI and DFR_{mcg} is illustrated in Figure 2. Results of regressions of OFI on CFR_{mcg} and OFI on DFR_{mcg} are reported in Table 4. The intercept and slope for the regression

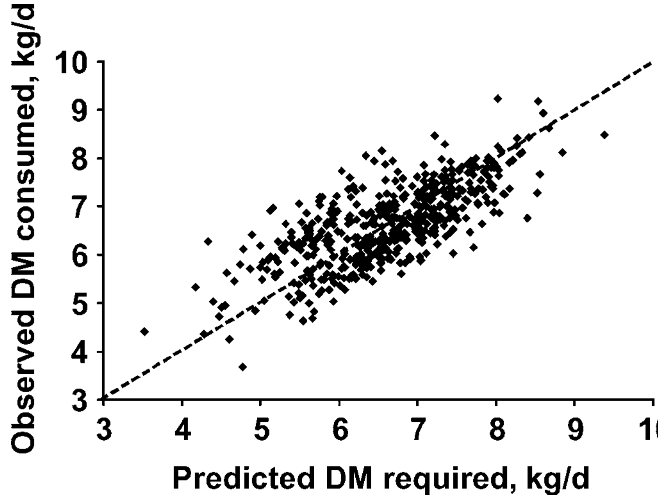

Figure 2. Relationship between observed average daily DMI (OFI) and average daily required DMI for maintenance, cold stress, and ADG of steers predicted using the Decision Evaluator for the Cattle Industry. Dashed line y = x indicates the position of the perfect fit between observed and model predicted values. The data used were from 502 individually fed steers produced in a heterosis experiment (Olson et al., 1978a,b).

Table 4. Regression analysis of observed average daily DMI (OFI) vs. average daily required DMI for maintenance, cold stress, and ADG predicted with the Cornell Value Discovery System (CVDS) and the Decision Evaluator for the Cattle Industry (DECI)

	CVDS		DECI	
Item	Unrestricted[1]	Origin[2]	Unrestricted[1]	Origin[2]
Intercept	1.271 ± 0.269	0.00	1.316 ± 0.223	0.00
Slope	0.837 ± 0.042	1.034 ± 0.005	0.801 ± 0.033	0.996 ± 0.004
$s_{y.x}$[3]	0.669	0.683	0.612	0.633
R^2	0.44	0.99	0.53	0.99

[1]Least squares regression.
[2]Least squares regression forced through the origin.
[3]Residual SD.

of OFI on CFR_{mcg} were very similar to the values obtained by Guiroy et al. (2001) for the regression of OFI on daily DM required predicted with the CVDS model, except that the R^2 was smaller in this study. The CVDS and DECI models accounted for 44.3 and 53.4% of the variation in OFI, respectively. The $s_{y.x}$ summarizes all the deviations of predicted from observed values into one statistic and is useful in comparing the precision of different models of the same dependent variable. In this case low $s_{y.x}$ values would indicate greater precision. For the regressions of OFI on CFR_{mcg} and OFI on DFR_{mcg} that were forced through the origin, the $s_{y.x}$ of the predicted values about OFI values were 0.683 and 0.633 kg, respectively. These results are similar to a $s_{y.x}$ value of 0.58 kg obtained by Rayburn and Fox (1990) for a regression of observed on predicted DMI that was forced through the origin. The CVDS model underpredicted OFI with an average bias of 3.4%, and the DECI model overpredicted OFI with an average bias of 0.4%. These results suggest that both models were not very accurate phenotypically in predicting the individual average daily required DMI.

Heritability and Phenotypic and Genetic Correlations

Heritability estimates for OFI and predicted measures of average daily required DMI, and phenotypic and genetic correlations between OFI and predicted measures of average daily required DMI are shown in Table 5. Heritability values were very similar for each measure of average daily required DMI predicted with the CVDS model and the DECI model. The heritability for OFI (0.27 ± 0.12) was similar to values reported for beef cattle by Koots et al. (1994a), Arthur et al. (2001b), and Robinson and Oddy (2004). Phenotypic correlations between OFI and each of the predicted measures of average daily required DMI were greater for the DECI model compared with the CVDS model. The lowest phenotypic and genetic correlations were obtained with CFR_{mc} and DFR_{mc} for both models, which suggest that the predicted feed required for maintenance and cold stress may not be good indicators of overall feed requirements.

Genetic correlations between OFI and predicted measures of average daily required DMI were much greater than the respective phenotypic correlations, and the greatest correlations were obtained with CFR_{mcg}, CFR_{mg}, DFR_{mcg}, DFR_{mg}, and DFR_{m}. These results suggest that for these data, the estimation of a feed requirement for cold stress did not increase the genetic relationship between OFI and the average daily feed required DMI for maintenance and gain predicted with both models. It appears that the inclusion of a fixed effect for year in the statistical model accounted for the variation in climatic conditions between years; hence, it is possible that, at a single location, feed requirements for cold stress may not be needed when predicting required DMI for use in genetic evaluations, and this would reduce the complexity of the simulation models. The high genetic correlation between OFI and DFR_{m} is

Table 5. Heritabilities for observed average daily DMI (OFI) and measures for average daily required DMI predicted with the Cornell Value Discovery System (CVDS) and the Decision Evaluator for the Cattle Industry (DECI), and phenotypic (r_p) and genotypic (r_g) correlations between OFI and measures for average daily required DMI predicted with CVDS and DECI

Variable[1]	Heritability	r_p	r_g
OFI	0.27 ± 0.12	—	—
CFR_{mcg}	0.34 ± 0.12	0.785[a]	0.95 ± 0.07
CFR_{mc}	0.41 ± 0.13	0.662[a]	0.82 ± 0.13
CFR_{g}	0.32 ± 0.12	0.736[a]	0.89 ± 0.09
CFR_{mg}	0.34 ± 0.12	0.784[a]	0.95 ± 0.07
CFR_{m}	0.35 ± 0.13	0.716[a]	0.91 ± 0.09
DFR_{mcg}	0.34 ± 0.12	0.798[a]	0.96 ± 0.07
DFR_{mc}	0.41 ± 0.13	0.742[a]	0.89 ± 0.09
DFR_{g}	0.33 ± 0.12	0.759[a]	0.88 ± 0.09
DFR_{mg}	0.33 ± 0.12	0.801[a]	0.96 ± 0.06
DFR_{m}	0.36 ± 0.13	0.781[a]	0.96 ± 0.07

[a]Correlation differs from zero, $P < 0.001$.
[1]CFR_{mcg}, CFR_{mc}, CFR_{g}, CFR_{mg}, and CFR_{m} = average daily required DMI predicted with CVDS for maintenance, cold stress, and gain; maintenance and cold stress; gain; maintenance and gain; and maintenance, respectively. DFR_{mcg}, DFR_{mc}, DFR_{g}, DFR_{mg}, and DFR_{m} = average daily required DMI predicted with DECI for maintenance, cold stress, and gain; maintenance and cold stress; gain; maintenance and gain; and maintenance, respectively.

Table 6. Phenotypic (r_p) and genotypic (r_g) correlations between measures for average daily required DMI predicted with the Cornell Value Discovery System (CVDS) and the Decision Evaluator for the Cattle Industry (DECI)

CVDS[1]	DECI[a]	r_p	r_g
CFR_{mcg}	DFR_{mcg}	0.993[a]	0.99 ± 0.004
CFR_{mc}	DFR_{mc}	0.947[a]	0.98 ± 0.017
CFR_g	DFR_g	0.992[a]	0.99 ± 0.004
CFR_{mg}	DFR_{mg}	0.991[a]	0.99 ± 0.005
CFR_m	DFR_m	0.951[a]	0.97 ± 0.021

[a]Correlation differs from zero, $P < 0.001$.
[1]CFR_{mcg}, CFR_{mc}, CFR_g, CFR_{mg}, and CFR_m = average daily required DMI predicted with CVDS for maintenance, cold stress, and gain; maintenance and cold stress; gain; maintenance and gain; and maintenance, respectively. DFR_{mcg}, DFR_{mc}, DFR_g, DFR_{mg}, and DFR_m = average daily required DMI predicted with DECI for maintenance, cold stress, and gain; maintenance and cold stress; gain; maintenance and gain; and maintenance, respectively.

probably due to the fact that in the DECI model the maintenance requirement includes a requirement that is positively related to production; hence, in this case, maintenance would vary positively with ADG.

Genetic and phenotypic correlations between each measure for average daily required DMI predicted with the CVDS and DECI models are reported in Table 6. Except for correlations between CFR_{mc} and DFR_{mc} and between CFR_m and DFR_m, all other phenotypic and genetic correlations were high. The lower phenotypic and genetic correlations between CFR_{mc} and DFR_{mc} and between CFR_m and DFR_m are a result of differences in calculating maintenance requirements between the 2 models. The high phenotypic and genetic correlation between CFR_g and DFR_g suggest that both models perform about the same in predicting requirements for ADG. The high phenotypic and genetic correlation between CFR_{mcg} and DFR_{mcg} suggest there may be very little difference between CVDS and DECI in predicting the average daily required DMI.

Heritability estimates for YWT, FWT, and ADG, and phenotypic and genetic correlations for YWT, FWT, and ADG with OFI, CFR_{mcg}, and DFR_{mcg} are shown in Table 7. Heritability estimates for YWT, FWT, and ADG agree with mean values of 0.35 ± 0.11, 0.45 ± 0.12, and 0.40 ± 0.12, respectively, reported by Koots et al. (1994a) for 154 heritability estimates for YWT, 19 heritability estimates for carcass weight at a constant age, and 184 heritability estimates for postweaning ADG. Phenotypic correlations for YWT, FWT, and ADG with CFR_{mcg} and DFR_{mcg} were greater than those with OFI. This is due to the fact that daily DMI requirements predicted with CVDS and DECI are influenced to a great extent by ADG and weight.

Genetic correlations for YWT, FWT, and ADG with CFR_{mcg} and DFR_{mcg} were very similar, suggesting little difference between CVDS and DECI, and these correlations were also similar to those with OFI. Phenotypic and genetic correlations for ADG with OFI, CFR_{mcg}, and DFR_{mcg} were smaller than those for YWT, indicating that maintenance requirement is an important component of OFI, CFR_{mcg}, and DFR_{mcg}. Final weight had the greatest genetic correlations with OFI (0.96 ± 0.07), CFR_{mcg} (0.98 ± 0.01), and DFR_{mcg} (0.96 ± 0.02). Genetic correlations of 0.94 ± 0.04 and 0.89 between FWT and OFI have been reported by MacNeil et al. (1991) and Bishop (1992), respectively. Final weight is a combination of initial BW and ADG and as such it represents DMI requirements for both ADG and maintenance; this suggests that in these data, feed requirements for maintenance and gain account for most of the genetic variation in OFI.

The differences between lower phenotypic and greater genetic correlations for OFI and FWT are similar to those between phenotypic and genetic correlations for OFI and predicted DMI in Table 5. Lower phenotypic and greater genetic correlations were also observed by Koots et al. (1994b) and Arthur et al. (2001b) for DMI and growth traits. Reasons for the differences between phenotypic and genetic correlations could be errors in measurement of OFI from using an individual feeder system or in the input measurements used for prediction. Measurement error is expected to contribute to phenotypic variance but not to the covariance between traits.

The high genetic correlations for FWT with OFI, CFR_{mcg}, and DFR_{mcg} indicate that there may be little opportunity for genetic variance in feed efficiency, both in the experimental and predicted data. Several re-

Table 7. Heritability estimates for yearling weight (YWT), final weight (FWT), and ADG, and phenotypic (r_p) and genetic (r_g) correlations for YWT, FWT, and ADG with observed average daily DMI (OFI) and average daily required DMI for maintenance, cold stress, and ADG predicted with the Cornell Value Discovery System (CFR_{mcg}) and the Decision Evaluator for the Cattle Industry (DFR_{mcg})

		OFI		CFR_{mcg}		DFR_{mcg}	
Item	Heritability	r_p	r_g	r_p	r_g	r_p	r_g
YWT	0.45 ± 0.13	0.74[a]	0.87 ± 0.09	0.87[a]	0.93 ± 0.04	0.86[a]	0.91 ± 0.05
FWT	0.41 ± 0.13	0.77[a]	0.96 ± 0.07	0.98[a]	0.98 ± 0.01	0.97[a]	0.96 ± 0.02
ADG	0.35 ± 0.13	0.71[a]	0.91 ± 0.1	0.9[a]	0.9 ± 0.06	0.92[a]	0.92 ± 0.05

[a]Correlation differs from zero, $P < 0.001$.

searchers (Herd and Bishop, 2000; Arthur et al., 2001a,b) have found genetic variance in feed efficiency (residual feed intake and feed conversion ratio) in different sets of experimental data, and Arthur et al. (2001a,b) reported lower genetic correlations of 0.83 ± 0.04 and 0.56 ± 0.09 for OFI with 400-d BW and 15-mo BW, respectively, in their experimental data. This suggests that the approach of using predicted required DMI in genetic evaluations needs to be further evaluated in populations where genetic variance in feed efficiency exists.

IMPLICATIONS

Use of biological models to predict feed intake could provide the beef cattle industry with a cost effective approach to genetically improve feed efficiency using data frequently collected by the industry. The high genetic correlations between observed and predicted feed intakes obtained in this study indicate that this technology would be potentially useful to estimate breeding values for feed efficiency with nearly the same accuracy but at a considerably lower cost than breeding values based entirely on individual feeding records. The technology would also facilitate evaluation of a much larger number of animals, and this could potentially have a greater impact on response to selection for feed efficiency than selection based only on individual feeding records. However, high genetic correlations for final weight with observed and predicted feed intakes suggests that the technology needs to be further evaluated in populations with genetic variance in feed efficiency.

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