DIVERGENT SELECTION FOR POSTWEANING FEED CONVERSION IN ANGUS BEEF CATTLE
V. PREDICTION OF FEED CONVERSION USING WEIGHTS AND LINEAR BODY MEASUREMENTS[1,2]

N. H. Park[3], M. D. Bishop[4] and M. E. Davis[5]

Animal Science Department, The Ohio State University
Columbus, OH U.S.A. 43210

Summary

Postweaning performance data were obtained on 187 group fed purebred Angus calves from 12 selected sires (six high and six low feed conversion sires) in 1985 and 1986. The objective of this portion of the study was to develop prediction equations for feed conversion from a stepwise regression analysis. Variables measured were on-test weight (ONTSTWT), on-test age (ONTSTAG), five weights by 28-d periods, seven linear body measurements: heart girth (HG), hip height (HH), head width (HDW), head length (HDL), muzzle circumference (MC), length between hooks and pins (HOPIN) and length between shoulder and hooks (SHHO), and backfat thickness (BF). Stepwise regressions for maintenance adjusted feed conversion (ADJFC) and unadjusted feed conversion (UNADFC) over the first 140 d of the test, and total feed conversion (FC) until progeny reached 8.89 mm of backfat were obtained separately by conversion groups and sexes and for combined feed conversion groups and sexes. In general, weights were more important than linear body measurements in prediction of feed utilization. To some extent this was expected as weight is related directly to gain which is a component of feed conversion. Weight at 112 d was the most important variable in prediction of feed conversion when data from both feed conversion groups and sexes were combined. Weights at 84 and 140 d were important variables in prediction of UNADFC and FC, respectively, of bulls. ONTSTWT and weight at 140 d had the highest standardized partial regression coefficients for UNADFC and ADJFC, respectively, of heifers. Results indicated that linear measurements, such as MC, HDL and HOPIN, are useful in prediction of feed conversion when feed intakes are unavailable.
(Key Words : Beef Cattle, Prediction, Linear Body Measurements, Feed Conversion)

Introduction

A primary goal of the beef cattle industry is to improve input/output efficiency of profitable production of quality meat for consumers. Differences in growth rate and efficiency of converting feed into body weight gains are important economic traits. However, determination of individual feed intake for purposes of estimating feed conversion is costly, labor intensive and impractical in many feeding situations. Therefore, equations involving easily measured body weights and linear measurements that could be used to accurately predict feed conversion would be useful. The objective of this study was to develop such prediction equations for postweaning feed conversion.

Materials and Methods

Source of data

Postweaning data were collected from 187 purebred Angus calves from 12 selected sires (six high and six low feed conversion sires) in 1985 and 1986. Until time of weaning, all calves were located at the Eastern Ohio Resource Development Center (EORDC), Belle Valley. Sires of these calves were selected from 35 individually fed bull calves each year based on feed conversion. The three most efficient (in terms of kilograms of feed required

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[3]Address reprint requests to Dr. N. H. Park, Korean Native Cattle Improvement Center, Seosan, Chungnam, Korea 352-830

[4]Present address: American Breeders Service, 6908 River Rd. P.O. Box 459 DeForest, WI 53532 U.S.A

[5]Anim. Sci. Dept., The Ohio State Univ., Columbus, OH U.S.A. 43210.

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per kilogram of gain) and the three least efficient bulls were randomly mated to approximately 20 cows each in a test herd of Angus cows located at EORDC. A different group of high and low feed conversion, Angus sires was used for breeding each year at 2 yr of age. A more detailed description of selection, management and feeding practices for the population from which the sires were selected was given by Davis et al. (1985). Since progeny were separated by sire group and sex and group fed during the postweaning period, feed conversions were measured on pens and not individuals. Thus, 24 experimental units were available. Detailed descriptions of ADJFC, UNADFC and FC were given by Park et al. (1994). Calves were weaned at approximately 7 mo of age and were then transported to the Northwestern Branch of the Ohio Agricultural Research and Development Center located at Hoytville. Calves were given approximately 2 wk to become accustomed to the feedlot and postweaning diet. After the adjustment period, all calves were placed on full feed. Composition of the postweaning diet was given by Park et al. (1994).

Weights were taken at the beginning of the postweaning test and at the end of each 28-d period until each calf reached 8.89 mm of backfat as measured via sonoray. Those calves with a fat measurement of 8.89 mm or greater after 140 d were removed from the test and slaughtered. At completion of the 140-d postweaning period, body measurements including height at hips (HH), depth of chest (CD), width of chest (CW), length of head (HDL), width of head (HDW), heart girth (HG), length between hooks and pins (HOPIN), length between shoulder and hooks (SHHO), circumference of muzzle (MC) and backfat thickness (BF) were obtained on both bull and heifer calves. Least squares means and standard errors for weights, feed conversions and body measurements by year-conversion group are presented in table 1. Volume (VOL = (HOPIN + SHHO) × CD × CW, cm^3) of body was calculated for calves born in 1985. Except BF, body measurements were obtained using a flexible steel or cloth measuring tape and metal calipers. Green and Carmon (1976) found these instruments to be accurate for such measurements. Points used in taking the measurements were described by Park et al. (1993, 1994).

Statistical analysis

Multiple regression prediction equations for ADJFC, UNADFC and FC were constructed in a stepwise manner using sire-six pen means according to a procedure that gave a maximum coefficient of multiple determination (R^2; SAS, 1982). Independent variables used were on-test weight (ONTSTWT), on-test age (ONTSTAG), five body weights by 28-d periods, BF and seven linear body measurements (HG, HH, HDW, HDL, MC, HOPIN and SHHO). Since depth of chest and width of chest were taken only in one year, VOL was used as an independent variable for calves born in 1985. Stepwise regressions for ADJFC, UNADFC and FC were run separately by conversion groups and sexes and also for combined feed conversion groups and sexes.

In our study, it is difficult to compare regression coefficients because of differences in the units to measure weights and linear traits. Therefore, standardized partial regression coefficients were employed to evaluate the relative importance of the independent variables.

Daniel and Wood (1971) recommended a measure of "total squared error" called the C(P) statistic when a large number of alternative equations are being considered. The C(P) statistic is a simple function of the residual sum of squares from fitting each model. To attain the most appropriate equations, the model where the value of C(P) first approached the number of the independent variable in the model was chosen.

Results and Discussion

Results of the analysis for feed conversion groups and sexes combined are shown in table 2. The ONTSTWT, WT112, HDL and MC were entered in all models. In addition, models for ADJFC and UNADFC contained WT56, HG, HDW and HOPIN. The BF was contained in the model for UNADFC and FC but not in the models for ADJFC. Regression coefficients of variables common to the model for ADJFC, UNADFC and FC were identical in sign and similar partial phenotypic relationships existed between these variables and each measure of feed conversion.

Positive regression coefficients for ONTSTWT (0.004, 0.004 and 0.005 kg feed × kg $gain^{-1}$ × kg body wt^{-1} for ADJFC, UNADFC and FC, respectively), WT28 (0.004 kg feed × kg $gain^{-1}$

TABLE 1. LEAST SQUARES MEANS AND STANDARD ERRORS FOR 28-D WEIGHTS, BODY MEASUREMENTS, 140-D FEED CONVERSION (FEED / GAIN) ADJUSTED FOR MAINTENANCE (ADJFC), 140-D FEED CONVERSION UNADJUSTED FOR MAINTENANCE (UNADFC) AND FEED CONVERSION MEASURED UNTIL CALVES REACHED 8.89 mm OF BACKFAT BY YEAR CONVERSION GROUP

Traits[b]	Year-conversion group[a]			
	1985		1986	
	High	Low	High	Low
ONTSTWT	207 ±4	195 ±4	211 ±4	204 ±4
WT28	246 ±2	244 ±4	247 ±2	243 ±2
WT56	278 ±3	274 ±3	283 ±3	275 ±2
WT84	316 ±3	307 ±3	320 ±3	309 ±2
WT112	351 ±4	340 ±5	354 ±4	342 ±4
WT140	387 ±6	374 ±6	391 ±5	377 ±5
Hip height	114.3 ±1.0	113.2 ±1.0	116.7 ±1.0	114.5 ±1.0
Heart girth	179.3 ±1.9	171.6 ±1.8	174.1 ±1.9	174.8 ±1.7
Width of chest			44.4 ±0.5	44.0 ±0.5
Depth of chest			58.8 ±0.6	57.4 ±0.6
Length of head	43.0 ±0.5	42.4 ±0.5	41.7 ±0.5	40.8 ±0.5
Width of head	20.6 ±0.3	20.6 ±0.3	21.7 ±0.3	21.5 ±0.3
Length between hooks and pins	44.2 ±0.8	43.5 ±0.8	49.1 ±0.8	48.9 ±0.8
Length between shoulder and hooks	94.0 ±1.6	93.2 ±1.6	95.7 ±1.7	93.1 ±1.5
Circumference of muzzle	41.3 ±0.6	41.4 ±0.6	40.7 ±0.7	41.8 ±0.6
Backfat thickness	0.98±0.05	0.86±0.05	0.85±0.05	0.84±0.05
UNADFC	5.32±0.16	5.74±0.17	5.62±0.16	6.02±0.15
ADJFC	5.21±0.19	5.62±0.18	5.65±0.18	6.10±0.18
FC	5.38±0.11	5.87±0.12	5.47±0.11	5.83±0.10

[a] High feed conversion calves were progeny of sires with low feed:gain ratios. Low feed conversion calves were progeny of sires with high feed:gain ratios.

[b] ONTSTWT = on-test weight (kg); WT28 = weight at 28 d (kg); WT56 = weight at 56 d (kg); WT84 = weight at 84 d (kg); WT112 = weight at 112 d (kg); WT140 = weight at 140 d (kg); cm for body measurements.

$\times$ kg body wt^{-1} for FC) and WT56 (0.005 and 0.007 kg feed $\times$ kg gain^{-1} $\times$ kg body wt^{-1} for ADJFC and UNADFC, respectively) indicated that animals that were lighter in weight during the first two 28-d periods had better feed conversion when other variables were held constant. Bishop et al. (1991) reported positive phenotypic correlations of on-test weight with postweaning feed conversion. Because young animals that are lighter in weight gain more rapidly than heavier animals, due to compensatory gain, this is somewhat expected. Also, lighter weight animals have lower maintenance requirements. Coefficients for regression of ADJFC, UNADFC and FC on WT112 were −0.008, −0.005 and −0.005 kg feed $\times$ kg gain^{-1} $\times$ kg wt^{-1}, respectively. Therefore, animals that were lighter in weight at the beginning of the postweaning test, gained rapidly during the postweaning period (Bishop et al., 1991) and were heavier by d 112 of the test were more efficient in feed utilization.

Brown et al. (1956) used weight and body measurements to obtain lifetime developmental patterns in Angus. According to their work, linear skeletal growth occurred more rapidly and matured earlier with less variation than weight. They also found that body weight was more variable than linear body measurements among animals at all ages. These results indicated that various parts of the body reach their maximal development at different times and at different rates.

Head measurements had negative regression coefficients, indicating that calves with larger muzzle circumferences (−0.048, −0.062 and −0.055 kg feed $\times$ kg gain^{-1} cm MC^{-1} for ADJFC, UNADFC and FC, respectively) and longer (−0.076, −0.068 and −0.091 kg feed $\times$ kg gain^{-1}

cm HDL^{-1} for ADJFC, UNADFC and FC, respectively) and wider heads (−0.044 and −0.063 kg feed × kg $gain^{-1}$ cm HDW^{-1} for ADJFC and UNADFC, respectively) were more efficient in feed utilization (feed/gain). These results are in agreement with those reported by Yao et al. (1953) who found that width of muzzle was negatively correlated with feed conversion (feed/gain) in beef and milking Shorthorns. Gilbert et al. (1993) found positive phenotypic correlations of ADG with head length and width, and with muzzle width measured at end of test. A possible explanation for this result is that calves with larger muzzle circumference tend to consume more feed than calves with smaller muzzle circumference, especially in group feeding situations, because of competition. Consequently, they have more energy available for weight gain.

A negative relationship was found between HG and feed conversion at d 140, whereas a positive relationship existed between HOPIN and feed conversion at that time, indicating that calves with larger HG and lower HOPIN had more acceptable feed:gain ratios. These results are in agreement with Khalil and Pirchner (1986), who found that feed conversion (feed:gain) had a negative correlation with heart girth of fattened yearling bulls of continental cattle breeds. Although body length (HOPIN and SHHO) obtained from calves born in 1985 and 1986 was entered in some models, volume, calculated as length (HOPIN + SHHO) × depth (CD) × width (CW) for progeny born in 1985, was not contained in the models for feed conversion groups and sexes combined.

Moulton et al. (1921) reported effects of plane of nutrition on growth and form of cattle. Plane of nutrition had little affect on hip height and wither height, whereas nutritional restrictions on growth involving body length, heart girth and hip width were reported. Results indicated that relationships between feed conversion and linear measurements may differ over time with differing diets. Therefore, caution must be exercised in interpreting relationships of feed conversion with linear measurements.

Standardized partial regression coefficients indicated that weight measurements were much more closely associated with feed conversion than were linear measurements. Among linear body measurements, head measurements, especially HDL (−0.255, −0.235 and −0.291 for ADJFC, UNADFC and FC, respectively) and MC (−0.224, −0.300 and −0.245 for ADJFC, UNADFC and FC, respectively) were most important.

Variation in feed conversion accounted for by the various equations approached significance significant ($p < 0.15$). Coefficients of multiple determination (R^2) indicated that more variation in ADJFC ($R^2 = 0.76$) and UNADFC ($R^2 = 0.75$) was accounted for than in FC ($R^2 = 0.55$). This result was to be expected because linear measurements were taken at the end of the period used to determine ADJFC and UNADFC (d 140), whereas FC was a measurement of feed conversion to a fat constant endpoint, which occurred after d 140 for many progeny.

In separate analyses of bull and heifer data, 12 pens each of bulls (86 bulls) and heifers (101 heifers) were used to examine relationship of various traits with feed conversion. Coefficients of multiple determination for the bull and heifer regression equations were substantially smaller than those for the earlier equations involving both sexes combined except for FC of bulls (table 2). Length of head and ONTSTWT for bulls and HOPIN for heifers were included in all models. Variables common to the models for ADJFC and UNADFC were ONTSTWT, HDL, MC and HOPIN for bulls and HDL and HOPIN for heifers. The HG and HH were included only in the model used to predict UNADFC for heifers. Standardized partial regression coefficients (0.694 and ·0.381 for bulls and heifers, respectively) indicated that BF was the variable most closely associated with FC of both sexes and that fatter bulls and heifers were more efficient. A possible explanation of this result is that more efficient calves have higher weight gains. Thus, they begin depositing fat earlier and become fatter. This result is in agreement with that reported by DiConstanzo et al. (1990) who used 14 mature, nonpregnant, nonlactating Angus cows to examine within-herd variation in energy utilization for maintenance. They reported that metabolizable energy required to maintain 1 kg of fat was lower than that required to maintain 1 kg of protein (20.7 vs 192.9 Kcal/kg). Bulls having lesser ONTSTWT and greater WT84 (standardized partial regression coefficients = 0.583 and −1.713, respectively) and heifers having greater WT140 (standardized partial regression coefficient 22 = 0.860) were more efficient in terms of UNADFC and ADJFC, respectively. Length of head was of

TABLE 2. REGRESSION EQUATIONS FOR MAINTENANCE ADJUSTED FEED CONVERSION (ADJFC) AND UNADJUSTED FEED CONVERSION (UNADFC) OVER THE FIRST 140 D OF THE TEST AND FOR TOTAL FEED CONVERSION (FC) UNTIL PROGENY REACHED 8.89 mm OF BACKFAT (PARTIAL REGRESSION COEFFICIENTS ARE GIVEN AND STANDARDIZED PARTIAL COEFFICIENTS IN BOLD)

Data set	Dependent variable	Intercept	Independent variables[a]						
			ONTSTWT	WT28	WT56	WT84	WT112	WT140	HG
Feed conversion groups and sexes combined	ADJFC	11.155	0.004		0.005		−0.008		−0.007
			0.309		**0.553**		**1.151**		**−0.106**
	UNADFC	10.684	0.004		0.007		−0.005		−0.011
			0.332		**0.812**		**−0.740**		**−0.161**
	FC	12.343	0.005	0.004			0.005		
			0.353	**0.319**			**−0.732**		
Bulls	ADJFC	5.334	0.004						
			0.687						
	UNADFC	4.701	0.002			−0.005			
			0.583			**−1.713**			
	FC	6.640	0.006					0.003	
			0.181					**0.684**	
Heifers	ADJFC	5.534				0.003		−0.004	
						0.532		**−0.860**	
	UNADFC	5.556	0.003						−0.009
			0.400						**−0.289**
	FC	4.006							
High feed conversion group	ADJFC	10.803	−0.004		0.010		−0.007		−0.009
			−0.413		**1.197**		**−1.210**		**−0.143**
	UNADFC	10.684			0.010		−0.008		0.009
					1.144		**−1.266**		**−0.140**
	FC	12.533							
Low feed conversion group	ADJFC	11.827			0.008			−0.007	
					0.867			**−1.125**	
	UNADFC	13.130	0.003		0.011			−0.003	0.013
			0.225		**1.110**			**−0.518**	**−0.179**
	FC	14.673	0.007			−0.003			
			0.543			**−0.368**			

TABLE 2. CONTINUED

Data set	Dependent variable	Intercept	Independent variables[a]							R^2
			HH	HDW	HDL	MC	BF	HOPIN	SHHO	
Feed conversion groups and sexes combined	ADJFC	11.155		−0.044	−0.076	−0.048		0.022		0.76
				−0.110	−0.255	−0.224		0.126		
	UNADFC	10.684	0.052	−0.063	−0.068	−0.062	0.970	0.022		0.75
			0.143	−0.160	−0.235	−0.300	0.119	0.130		
	FC	12.343			0.091	−0.055	−2.24			0.55
					−0.291	−0.245	−0.261			
Bulls	ADJFC	5.334			−0.047	0.023		0.017		0.44
					−0.312	0.144		0.210		
	UNADFC	4.701			−0.026	−0.025		0.014		0.49
					−0.260	−0.226		0.250		
	FC	6.640			−0.047		−4.30			0.60
					−0.205		−6.94			
Heifers	ADJFC	5.534			−0.038	0.039		0.056		0.31
					−0.159	0.161		0.501		
	UNADFC	5.556	0.069		-0.036			0.052		0.38
			0.204		0.157			0.459		
	FC	4.006				0.066	−0.246	0.032		0.23
						0.222	−0.381	0.182		
High feed conversion group	ADJFC	10.803				−0.088				0.82
						−0.470				
	UNADFC	10.684				−0.090				0.78
						−0.477				
	FC	12.533			−0.136		−0.380			0.62
					−0.675		−0.464			
Low feed conversion group	ADJFC	11.827			−0.097	−0.065	0.948	0.029		0.78
					−0.309	−0.322	0.120	0.173		
	UNADFC	13.130				−0.108	−0.007	0.133		0.78
						−0.329	−0.364	0.160		
	FC	14.673				−0.132	−0.046	−1.432	−0.025	0.52
						−0.369	−0.205	−0.141	−0.189	

[a] ONTSTWT = on-test weight (kg); WT28 = weight at 28 d (kg); WT56 = weight at 56 d (kg); WT84 = weight at 84 d (kg); WT112 = weight at 112 d (kg); WT140 = weight at 140 d (kg); HG = heart girth (cm); HH = hip height (cm); HDW = head width (cm); HDL = head length (cm); MC = muzzle circumference (cm); BF = backfat thickness (mm); HOPIN = length between hooks and pins (cm); SHHO = length between shoulder and hooks (cm).

greater importance in determining feed conversion in bulls than in heifers. A bigger muzzle was undesirable for heifers. In addition, bulls and heifers with shorter rumps (lower HOPIN) were more efficient.

Separate regression equations also were developed for the 12 pens of high (91 calves) and 12 pens of low (96 calves) feed conversion calves (table 2). Muzzle circumference entered into all models for both high and low feed conversion groups. In all cases, a larger muzzle was desirable with standardized partial regression coefficients ranging from −0.322 to −0.477. In addition to MC, WT56, WT112 and HG, for feed conversion through d 140, and BF, for feed conversion over the entire test, increased the reduction in sum of squares and explained a large portion of the variation in feed conversion in the high feed conversion group. Calves having lesser WT56 (standardized partial regression coefficients = 1.197 and 1.144 for ADJFC and UNADFC, respectively), but greater WT112 (standardized partial regression coefficients = −1.210 and −1.266 for ADJFC and UNADFC, respectively), HG (standardized partial regression coefficients = −0.143 and −0.140 for ADJFC and UNADFC, respectively) and BF (standardized partial regression coefficient = −0.464 for FC) were more efficient. Standardized partial regression coefficients indicated that HOPIN, MC and BF were closely associated with feed conversion in the low feed conversion group. Regression coefficients of the variables common to the equations for feed conversion in the high and low efficiency groups were identical in sign (except BF for ADJFC in the low feed conversion group) and similar in magnitude (except BF for FC in the high feed conversion group). Coefficients of multiple determination for these equations were similar to those for equations which involved all data.

Volume was entered only in the UNADFC equation of 1985 high (43 calves) feed conversion calves (table 3). This model also contained WT28 and HDL. Negative regression coefficients for HDL (−0.169 kg feed × kg gain^{-1} cm HDL^{-1}) and VOL (−0.00000791 kg feed × gain^{-1} × cm^{3} VOL^{-1}) indicated that 1985 high feed conversion animals that were longer headed and larger in volume had better feed conversion when other variables were held constant.

TABLE 3. REGRESSION EQUATIONS FOR UNADJUSTED FEED CONVERSION (UNADFC) OF PROGENY BORN IN 1985 (PARTIAL REGRESSION COEFFICIENTS ARE GIVEN AND STANDARDIZED PARTIAL REGRESSION COEFFICIENTS IN BOLD)

Data set	Dependent variable	Intercept	Independent variables[a]						
			ONTSTWT	WT28	WT56	WT84	WT112	WT140	HG
1985 High feed conversion group	UNADFC	13.134		0.005					
				0.397					

Data set	Dependent variable	Intercept	Independent variables[a]						R^2
			HH	HDW	HDL	MC	BF	VOL	
1985 High feed conversion group	UNADFC	13.134			−0.169			−0.00000791	0.60
					−0.581			**−0.539**	

[a] ONTSTWT = on-test weight (kg); WT28 = weight at 28 d (kg); WT56 = weight at 56 d (kg); WT84 = weight at 84 d (kg); WT112 = weight at 112 d (kg); WT140 = weight at 140 d (kg); HG = heart girth (cm); HH = hip height (cm); HDW = head width (cm); HDL = head length (cm); MC = muzzle circumference (cm); BF = backfat thickness (mm); VOL = volume (cm^3).

Conclusions

Efficiency of feed use is not a directly measurable trait. It is a ratio between direct measurements of gain and feed consumption. Therefore, it might be expected that weights would be more closely associated than linear body measurements with feed utilization, because gains contribute to weights and gain is one component of the feed:gain ratio. Weight at 112 d was the variable most closely related to feed conversion when data from both feed conversion groups and sexes were combined. In the prediction of feed conversion of bulls, weight at 84 and 140 d were important variables for UNADFC and FC, respectively, whereas in heifers on-test weight and weight at 140 d had the highest standardized partial regression coefficients for UNADFC and ADJFC, respectively. BF had the highest standardized partial regression coefficients for FC of both sexes. Among linear measurements, head length and muzzle circumference were the variables most closely associated with feed conversion in combined analysis of all data. Even though progeny of high and low feed conversion sires will not vary greatly in body type and conformation (Park et al., 1993), results of this study indicate that linear body measurements are useful in prediction of postweaning feed conversion when feed intake data are unavailable.

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