Effects of Different Age End Points on the Accuracy of Predicting Percentage Retail Product, Retail Product Weight, and Hot Carcass Weight

A.S Leaflet R1531

A. Hassen, graduate student,
D. E. Wilson, professor of animal science, and
G. H. Rouse, professor of animal science

Summary

Data from 970 feedlot steers and bulls were used to evaluate effects of different age end points on the accuracy of prediction models for percentage of retail product, retail product weight, and hot carcass weight. Cattle were ultrasonically scanned three or four times for fat thickness, longissimus muscle area, and percentage of intramuscular fat. Live animal measures of body weight and hip height were also taken during some of the scan sessions. Before development of prediction equations, live and ultrasound data were adjusted to four age end points using individual animal regressions. Age end points represented mean age at slaughter (448 d), mean age at the second last scan before slaughter (414 d), mean age at the third last scan before slaughter (382 d), and an age end point of 365 d. Ultrasound and live animal measures accounted for a large proportion of the variation in the dependent variables regardless of the age end point considered. For all three traits, final models based on independent variables adjusted to earlier ages of 365 d and 382 d showed better or at least similar model R^2 and root mean square errors than those based on independent variables adjusted to a mean slaughter age of 448 d. Validation of the models using independent data from 282 steers resulted in a mean across-age rank correlation coefficient of .78, .88, and .83 between actual and predicted values of percentage retail product, hot carcass weight, and retail product weight, respectively. Mean across-age rank correlation of breeding values for the corresponding traits were .92, .89, and .82. The results of this study suggest that live and ultrasound traits measured as early as 365 d could be used to predict end product traits as accurately as similar measures made prior to slaughter at age 448 d.

Introduction

Several workers have evaluated the efficacy of using real-time ultrasound (RTU) technology in predicting the amount and percentage of retail product. Most of these authors have concluded that live- and RTU-based prediction models are as accurate as those based on postmortem carcass measures.

Further attempts to improve accuracy of prediction have thus far involved a search for alternative measurement sites. The next logical step in the design of an efficient data collection strategy should be determining the most appropriate age of measurement that maximizes the correlation with final carcass measures. The objective of this study was to evaluate the efficiency of prediction models for percentage of retail product, retail product weight, and hot carcass weight when live and RTU measures are adjusted to four age end points.

Materials and Methods

Description of Data

Model development. Data for model development included RTU, live and carcass information from 970 feedlot steers and bulls fed at the Rhodes and McNay beef research farms of Iowa State University (ISU). These cattle were part of a serial scan and serial slaughter project designed to evaluate sex, age, and frame size differences in carcass composition. A detailed description of data is given elsewhere (Hassen et al.,1997).

Cattle were ultrasonically scanned between the 12th and 13th ribs three to five times for external fat thickness (UFAT) and longissimus muscle area (ULMA). Ultrasound measurements were made by a Beef Improvement Federation (BIF)-certified technician using an Aloka 500-V unit (Corometrics Medical Systems, Inc., Wallingford, CT) equipped with a 3.5-MHz, 17.2-cm linear array transducer. With the exception of the first 2 yr, weight (WT) measurements were taken during each scan session. Hip height (HT) and RTU-predicted percentage intramuscular fat (UPIMF) were measured on about 200 progeny.

Live and RTU data were adjusted to four different age end points. These age end points represented mean age at slaughter (448 d), mean age at the second last scan before slaughter (414 d), and mean age at the third last scan before slaughter (382 d). For a more practical evaluation, data were also adjusted to an average age end point of 365 d. Data were adjusted based on individual animal regression resulting from previous work (Hassen et al., 1997).

Model validation. Data for model validation came from 282 cross-bred steers from cycle V of the Germ Plasm Evaluation Study at the U.S. Meat Animal Research Center (Greiner et al., 1995). Steers were scanned by a BIF-certified technician for UFAT, ULMA, and UPIMF 4 to 5 d prior to slaughter using an Aloka 500-V unit (Corometrics Medical Systems, Inc., Wallingford, CT), equipped with a 3.5-MHZ, 17.2-cm linear array transducer. Cattle were slaughtered at a commercial facility, and carcasses were chilled for 24 h before routine measurements were taken. One side of each carcass was fabricated into boneless retail cuts trimmed to 0 cm of fat thickness to calculate percentage retail product (PRP) and retail product weight (RPW).

Statistical Analysis

Model development. Development of prediction models was initiated through evaluation of correlations between dependent variables of PRP, hot carcass weight (HCW), and RPW with adjusted live and RTU variables of UFAT, ULMA, WT, HT, and UPIMF. In further evaluation, data were subjected to multiple regression techniques using the stepwise procedure of SAS (1989). In all cases, a 10% level of significance was used as a criterion for variables to be included and to remain in a model.

Model validation. Steers used for model validation were slaughtered at a mean age of 441.6 d. In order to evaluate age-specific equations for PRP, HCW and RPW, RTU and live measures were adjusted to four different age end points; 448 d, 414 d, 382 d, and 365 d. Linear adjustment factors were developed by regressing each trait on age. Accuracy of prediction was assessed by calculating the mean bias (predicted minus actual) and rank correlation of phenotypic and breeding values (BV). Breed effect and animal solutions were generated using a computer package (Boldman et al., 1993) based on Multiple Traits Derivative Free Maximum Likelihood (MTDFREML).

Results and Discussion

Model Development

UFAT showed a strong ($P < .01$) and negative linear association with PRP ranging from -.57 to -.64 (Table 1). UPIMF is the other variable with a strong negative correlation with PRP. This strong and consistent association of UFAT and UPIMF with PRP suggests that these two variables may be the most valuable predictors of PRP regardless of the age end point. Although small, the correlation of WT with PRP was negative and different from zero ($P < .01$). Other variables such as HT and early measures of ULMA showed poor or no correlation. Although the correlations of ULMA with PRP at later ages were different from zero ($P < .01$), these values were quite small, indicating the limited role of ULMA in modeling PRP.

WT, HT, and ULMA were positively correlated ($P < .01$) with HCW and RPW. With the exception of marginal changes, the degree of this linear association across ages was consistent. However, UFAT and UPIMF were poorly associated with HCW and RPW.

There is unanimous agreement among researchers that measures of fat, especially of UFAT, is the single most important independent variable in its linear association with PRP. On the other hand, measures of weight and muscle including ULMA, WT, and HT do generally correlate well with kilograms of retail product. However, in this study the relative consistency of correlation coefficients across varying age end points is the main interest. The nearly uniform linear association of live and RTU variables with carcass measures across ages provides evidence for a possible use of early live and RTU measures in cattle and development of expected progeny difference. However, results of correlation analysis in the present study are not in complete agreement with our previous report on the same data, where correlations increased as scan sessions approach slaughter (Hassen et al., 1997). These differences could be attributed to the fact that data in the present study were adjusted to constant age end points, whereas in previous study correlations were computed by scan session, with major overlap of ages across sessions. Furthermore, data in this study did not include heifer.

Results of stepwise procedures for PRP are shown in Table 2. UFAT accounted for the largest proportion of the variation in PRP (42% to 48%) and was the first variable to be included in the model across all age end points. UPIMF was the second variable included in the model but accounted for only 3% of the variation across all ages. The low partial R^2 for UPIMF was expected and is not in contradiction with the results shown in Table 1. When PRP is regressed using a single variable model across all four age end points, on the average, UPIMF, WT, ULMA, and HT accounted for 30%, 20%, 1%, and .9% of the variation in PRP, respectively. However, once UFAT is in the model, the marginal contribution of UPIMF in terms of reducing the sum of squares becomes quite small. This means that UPIMF provides limited information beyond what is already explained by UFAT.

Although stepwise procedures for earlier ages of 365 d and 382 d required one additional step to complete model selection, final equations for all age end points involved the same number and kind of variables. However, except for UPIMF the partial R^2 of variables was not the same across all ages. One notable trend in this case is the slight increase in the amount of variation accounted for by UFAT and WT at earlier ages. Indeed, the increase in partial R^2 of these two variables seems to have resulted in a better model R^2 for the final models at earlier ages of 365 d (MP-365) and 382 d (MP-382) than at age 448 d (MP-448).

Live weight accounted for a larger proportion of the variation in HCW (66% to 73%), with a slight increase in partial R^2 as age at scans further away from slaughter (Table 3). In contrast to its strong linear association with HCW, HT did not provide a sufficient reduction in the partial sum of squares to warrant its inclusion in all HCW final models. The regression of HCW in a single variable model showed a mean across-age partial R^2 of .30, .38, .05, and .02 for HT, ULMA, UFAT, and UPIMF, respectively. However, in the presence of WT, HT did not provide any significant additional information, leading to its exclusion from HCW equations. ULMA had the second largest partial R^2 in equations at two of the age end points (MC-448 and MC-414 d), but was not included in model MC-365. Generally, the increase in final model R^2 at measurement dates further from slaughter seems to be due to an increase in partial R^2 for WT at earlier ages.

The output of the stepwise procedure for RPW (Table 4) is generally similar to the results for HCW. For all age end points, WT showed the largest partial R^2 (.59 to .63) and was the first variable to be included in the model. For ages 448 d and 414 d, ULMA was the second variable included in the model, accounting for an additional 7% and 8% of the variation in RPW for the respective ages. However, at earlier ages of 365 and 382 d, UFAT accounted for the second largest (9% to 10%) variation in RPW. Similarly, the model R^2 for MW-365 and MW-382 were larger than MW-448.

The Cp statistics is a criterion often used in regression model evaluation. Draper and Smith (1981) have shown that for adequate equations with *P* parameters, including the intercept, E(Cp) = *P*. That is, models with Cp values smaller than or equal to the number of parameters could be considered for further evaluation (Gorman and Toman, 1966). For each trait and age end point subclass, most final models satisfy this condition or at least have closer Cp values.

All final models at earlier ages have made a better or at least a similar R^2 and root mean square error (RMSE) as those at mean slaughter age. This could be due to several reasons. For those individuals slaughtered at earlier ages, there could be a problem of extrapolation when data are adjusted to a mean slaughter age of 448 d, likely reducing the variance of measurements. Based on their work on Brangus cattle, Waldner et al. (1992) related accuracy of RTU-measured UFAT and ULMA with age at scan. They recommended that animals be scanned for external fat thickness at an age of 12 mo and for ULMA at 12 to 14 mo. Hence a relatively low accuracy of measurement in the latter stages of feeding also might have affected accuracy of age adjustment.

The relative importance of some of the live and RTU measures is another concern. In the prediction of any particular end product trait, often there seem to be changes in the importance of independent variables when adjusted to different age end points, ranging from re ranking in the partial R^2 to deletion of some of the variables from a model. This may be due to the difference in the (co)variances of traits at different age end points. Therefore, this may suggest that if equations are to be developed for prediction of PRP, RPW, and HCW from earlier measurements, selection of independent variables and development of regression equations need to be done based on measurements made or adjusted to the corresponding age ranges.

Model Validation

Descriptive statistics for the unadjusted carcass, live, and RTU data used for validation testing is given in Table 5. Mean age of steers at slaughter was 441.6 d, and slaughter data were adjusted to a mean age of 448 d.

Table 6 shows the mean PRP, HCW, and RPW predicted by the four final equations. Mean predicted PRP values were closer to the adjusted actual value of 65.03%. While MP-365 often tended to overpredict ($P < .01$), MP-382 often underpredicted ($P < .01$) steer PRP. Model MP-448 overpredicted steer PRP, but the bias in this case was not different from zero ($P > .05$). However, the difference in the magnitude of bias between the four PRP prediction equations was not significant (P > .05).

Models for prediction of HCW have all underpredicted mean HCW of steers. Although biases in prediction of HCW are all different from zero ($P < .01$), differences in the magnitude of bias between equations were not important ($P > .05$). On the other hand, RPW prediction equations showed a relatively accurate prediction with mean bias not different from zero ($P > .05$).

The overall across-age mean rank correlations between actual predicted values of PRP, HCW, and RPW were .78, .88, and .83, respectively (Table 6). For all traits, except for the relatively low correlation coefficients for MC-365, differences between models were small. The mean across-age rank correlation coefficients of breeding values were higher than correlation of phenotypic measures showing overall mean values of .92, .89, and .82 for PRP, HCW, and RPW, respectively.

In this study, data for model development came from bulls and steers with varying proportions of Angus, Simmental, and other breeding, and validation was done on steers with even more diverse genetics. Hence, a more accurate model could be developed for a given age end point using a less variable group of cattle within a breed. However, this study has clearly addressed its purpose in terms of assessing effects of age of measurements on the components of prediction models and their accuracy. Therefore, observations made thus far suggest that earlier measured UFAT, ULMA, and UPIMF by a certified technician, together with other live measures, could be used to predict end products as well as similar measures made just before slaughter.

Implications

Live and RTU measures made as early as 365 d could be used to rank sires for respective end products and to manage feedlot operations. However, further research on weight and compositional end points is needed in order to decide on the best data adjustment strategy.

References

Boldman, K. G., Kriese, L. A., Van Vleck, D. L., and Kachman, S. D. 1993. A manual for use of MTDFREML- a set of programs to obtain estimates of variance covariances. ARS, USDA, Washington, DC.

Draper, N., and Smith, H. 1981. Applied Regression Analysis (2nd Ed). John Wiley and Sons, New York.

Epley, R. J., Hedrick, H. B., Stringer, W. C., and Hutcheson, D. P. 1970. Prediction of weight and percent retail cuts of beef using five carcass measurements. J. Anim. Sci. 30:872.

Gorman, J. W., and Toman, R. J. 1966. Selection of variables for fitting equations to data. Technimetrics. 8:27.

Greiner, S. P, Rouse, G. H., Wilson, D. E., and Cundiff, L. V. 1995. Predicting beef carcass retail product using real-time ultrasound and live measures. Progress report. In: Proceedings of the 5th Genetic Prediction Workshop, p 63. Kansas City, MO.

Hassen, A., Wilson, D. E., Rouse, G. H., and Willham, R. L.. 1997. Prediction of percent retail product, retail product weight and hot carcass weight from serially measured live animal traits. Beef Research Report, AS-637, Leaflet R1431, p 8. Iowa State University, Ames.

SAS. 1989. SAS/STAT® User's Guide (Version 6). SAS Inst. Inc., Cary, NC.

Waldner, D. N., Dikeman, M. E., Schalles, R. R., Olson, W. G., Houghton, P. L., Unruh, J. A., and Corah, L. R. 1992. Validation of real-time ultrasound technology for predicting fat thickness, longissimus muscle area and composition of Brangus bulls from 4 months to 2 years of age. J. Anim. Sci. 70:3044.

Table 1. Correlation between dependent variables and serially measured traits adjusted to constant age end points[a].

	Age end point, d			
	365	382	414	448
	--PRP--			
UFAT	-.57*	-.62**	-.64**	-.63**
ULMA	.01	.05*	.11**	.15**
WT	-.31**	-.29**	-.24**	-.18**
HT	-.06	-.04	-.02	-.00
UPIMF	-.45**	-.50**	-.52**	-.48**
	--HCW--			
UFAT	-.06	-.06*	-.06*	-.05*
ULMA	.35**	.38**	.38**	.31**
WT	.75**	.77**	.78**	.75**
HT	.65**	.65**	.64**	.60**
UPIMF	.01	-.02	-.06	-.08
	--RPW--			
UFAT	-.05	-.06	.07*	.07*
ULMA	.35**	.40**	.42**	.35**
WT	.71**	.74**	.75**	.73**
HT	.66**	.66**	.65**	.62**
UPIMF	-.04	-.08	-.13	-.15*

[a]UFAT = ultrasound fat thickness; ULMA = ultrasound longissimus muscle area; WT = live weight; HT = hip height; UPIMF = ultrasound predicted percentage intramusclar fat; PRP = percentage retail product; HCW = hot carcass weight; RPW = retail product weight.

* $P < .05$; ** $P < .01$.

Table 2. Regression equations for predicting percentage of retail product from variables adjusted to a constant age end point.[a]

Age end point	Equation number[b]	Step	R^2	Cp	RMSE	Intercept	Partial regression coefficients				
							UFAT	ULMA	WT	HT	UPIMF
448		1	.42	32.20	2.12	69.68	-4.6617	-	-	-	-
		2	.45	24.32	2.07	70.15	-3.7259	-	-	-	-.3201
		3	.48	16.64	1.97	74.07	-3.255	-	-.0073	-	-.3219
	MP-448	4	.53	4.00	1.94	70.64	-3.2242	.0679	-.0113	-	-.2571
414		1	.46	40.65	2.05	70.26	-5.9961	-	-	-	-
		2	.49	31.51	2.00	71.01	-4.7027	-	-	-	-.4367
		3	.51	23.65	1.87	74.56	-4.1194	-	-.0077	-	-.4151
	MP-414	4	.57	4.00	1.84	70.09	-4.0637	.1054	-.0149	-	-.3268
382											
		1	.48	51.06	2.01	70.76	-7.5039	-	-	-	-
		2	.51	41.10	1.96	71.80	-6.1269	-	-	-	-.4927
		3	.52	34.01	1.92	81.20	-6.2950	-	-	-.0742	-.4729
		4	.56	23.61	1.87	79.41	-6.9194	.0765	-	-.0992	-4595
	MP-382	5	.61	4.06	1.76	68.95	-5.4936	.1600	-.0197	-	-.3152
365		1	.46	52.13	2.04	70.84	-8.1534	-	-	-	-
		2	.49	42.42	1.99	71.95	-6.9788	-	-	-	-.4640
		3	.51	35.55	1.95	81.25	-7.1280	-	-	-.0745	-.4443
		4	.54	24.95	1.90	79.68	-7.9939	.0786	-	-.0993	-.4485
	MP-365	5	.60	4.11	1.78	68.82	-6.4233	.1757	-.0217	-	.2646

[a]UFAT = ultrasound fat thickness; ULMA = ultrasound longissimus muscle area; WT = live weight; HT = hip height; UPIMF = ultrasound-predicted percentage intramuscular fat.
[b]Only final models are given equation number.

Table 3. Regression equations for predicting hot carcass weight from variables adjusted to a constant age end point.[a]

Age End point	Equation number[b]	Step	R^2	Cp	RMSE	Intercept	Partial regression coefficients				
							UFAT	ULMA	WT	HT	UPIMF
448		1	.66	25.64	25.23	20.41	-	-	.5149	-	-
	MC-448	2	.70	4.15	23.71	21.02	-	.378	.4911	-	-
414		1	.71	37.68	23.19	21.00	-	-	.5698	-	-
		2	.75	11.66	21.60	-34.49	-	1.3245	.4849	-	-
	MC-414	3	.77	3.90	21.06	8.509	-6.5750	.4578	.5622	-	-
382		1	.73	37.76	22.69	40.35	-	-	.5933	-	-
		2	.76	13.08	21.23	31.26	-36.42	-	.6629	-	-
	MC-382	3	.77	5.28	20.69	57.25	-24.18	-.0570	.6181	-	-
365		1	.71	36.01	23.20	58.58	-	-	.5906	-	-
	MC-365	2	.76	6.18	21.37	80.73	-35.78	-	.6054	-	-

[a]UFAT = ultrasound fat thickness; ULMA = ultrasound longissimus muscle area; WT = live weight; HT = hip height; UPIMF = ultrasound-predicted percentage intramuscular fat.
[b]Only final models are given equation number.

Table 4. Regression equations for predicting retail product weight from variables adjusted to a constant age end point.[a]

Age End point	Equation number[b]	Step	R^2	Cp	RMSE	Intercept	Partial regression coefficients UFAT	ULMA	WT	HT	UPIMF
448		1	.59	53.04	14.86	57.87	-	-	.2599	-	-
		2	.66	16.79	13.53	21.94	-	.7163	.2229	-	-
	MW-448	3	.68	4.75	13.03	45.86	-5.8476	.3246	.2586	-	-
414		1	.63	79.60	14.05	58.44	-	-	.2870	-	-
		2	.71	33.41	12.62	17.42	-	.9714	.2273	-	-
	MW-414	3	.75	5.66	11.65	39.08	-13.1504	.4241	.2946	-	-
382		1	.64	83.33	13.91	68.63	-	-	.2982	-	-
		2	.73	26.08	12.16	60.57	-30.20	-	.3571	-	-
	MW-382	3	.76	6.26	11.47	65.07	-24.75	.1692	.3244	-	-
365		1	.63	74.96	14.16	77.97	-	-	.2965	-	-
		2	.73	13.35	12.16	69.57	-36.5383	-	.3658	-	-
	MW-365	3	.74	6.14	11.87	82.45	-30.66	.0496	.3277	-	-

[a]UFAT = ultrasound fat thickness; ULMA = ultrasound longissimus muscle area; WT = live weight; HT = hip height; UPIMF = ultrasound-predicted percentage intramuscular fat.
[b] Only final models are given equation number.

Table 5. Descriptive statistics for carcass, ultrasound, and live animal measures used for validation (not adjusted).

Trait[a]	Mean[b]	SD	Minimum	Maximum
Carcass				
PRP, %	65.18	4.31	54.99	75.83
RPW, kg	205.40	25.65	144.55	276.65
HCW, kg	333.89	40.47	214.55	450.45
Ultrasound and live				
UFAT, cm	1.00	.35	.23	2.0
ULMA, cm^2	77.05	7.49	59.26	102.20
HT, cm	132.57	4.78	113.03	144.78
WT, kg	548.27	63.77	354.55	731.82
UPIMF	3.83	1.05	1.34	7.34
Age, d	441.62	24.69	383.00	494.00

[a]UFAT = ultrasound fat thickness; ULMA = ultrasound longissimus muscle area; WT = live weight; HT = hip height; UPIMF = ultrasound-predicted percentage intramuscular fat; PRP = percentage retail product; RPW = retail product weight; HCW = hot carcass weight.
[b]Number of observations = 282.

Table 6. Mean predicted values and accuracy of models.

Trait-equation number[a]	Means ± SE		Rank correlation	
	Predicted value	Bias	Phenotypic values	Breeding values
PRP				
MP-448	65.40 ± .10	.36 ± .19	.79**	.92**
MP-414	65.07 ± .13	.03 ± .17	.78**	.92**
MP-382	64.48 ± .17	-.55 ± .16**	.78**	.91**
MP-365	65.72 ± .18	.68 ± .17**	.75**	.92**
HCW				
MC-448	323.71 ± 1.56	-15.86 ± .7**	.92**	.94**
MC-414	324.36 ± 1.77	-15.20 ± .69**	.92**	.93**
MC-382	325.65 ± 1.88	-13.92 ± .88**	.87**	.88**
MC-365	325.47 ± 1.88	-14.10 ± 1.04**	.82**	.81**
RPW				
MW-448	209.14 ± .70	.84 ± .80	.79**	.67**
MW-414	208.81 ± .97	.52 ± .71	.84**	.85**
MW-382	208.79 ± 1.06	.49 ± .71	.85**	.90**
MW-365	208.76 ± 1.09	.47 ± .72	.84**	.87**

[a]PRP = percentage retail product; RPW = retail product weight; HCW = hot carcass weight

** $P < .01$