Using ultrasound to predict body composition changes in steers at 100 and 65 days before harvest

P. B. Wall[1], G. H. Rouse, D. E. Wilson, R. G. Tait, Jr., and W. D. Busby
Department of Animal Science, Iowa State University, Ames 50011

ABSTRACT: Steers from research crossbreeding projects (n=406) were serially scanned using Real-Time Ultrasound at 35-day intervals from re-implant time until slaughter. Cattle were evaluated for rump fat depth (URFAT), longissimus muscle area (UREA), 12th rib fat thickness (UFAT), and percent intramuscular fat (PFAT) to determine the ability of ultrasound to predict carcass composition at extended periods before harvest. Additional background information on the cattle, such as weight, gain, breed of sire, breed of dam, implant and frame score was also utilized. Carcass data was collected by trained personnel at ?chain speed,? and samples of the 12th rib longissimus muscle were taken for ether extract analysis. Simple correlation coefficients showed positive relationship between ultrasound measures taken less than 7 days before harvest and carcass measures: UREA and CREA(r = .66); UFAT and CFAT(r = .74); and PFAT and MARB(r = .61). The same correlation coefficients for ultrasound measures taken 96-105 days before harvest and carcass values were: (r = .52), (r = .58), and (r = .63). Steers were divided into Source Verified and Non-Source Verified groups based on the level of background information for each individual. Regression equations were developed for the carcass measurements; 46% of the variation could be explained for CREA and 44% of CFAT at re-implant time. 46% of the variation in MARB or USDA Quality grade could be explained, and 42% of the variation in CALCYG. Regressions using ultrasound data taken 61-69 days before harvest showed increasing R-squared values. Live ultrasound measure at re-implant time is a viable tool for making decisions regarding future carcass composition.

Keywords: steers, ultrasound, carcass quality, carcass yield

Introduction

Ultrasound has been utilized extensively in beef cattle enterprises over the past decade, and is continuing to gain in popularity. However, ultrasound technology is not used extensively in the feedlot. Feedlot managers are reluctant to subject animals to added stress, and scanning takes considerably more chute time than a typical 90 animal per hour rate in most commercial feedlots. Nevertheless, ultrasound in the feedlot is not a new application.

Brethour (1994; 2000a, b) assessed marbling and backfat deposition in beef cattle at several stages of growth. It was established that carcass composition could be accurately predicted pre-harvest, but its usefulness for animals that were already USDA Yield Grade 4 was questionable. Predicting carcass composition from animals entering the feedlot as calves proved inaccurate, due to differences in pre-weaning environment (Brethour, 2000a). Rouse et al. (1998; 2000) used similar technology to predict carcass composition at various pre-harvest points, finding that a chute-side application just prior to harvest was feasible, but predicting carcass composition for extended periods before harvest would require a more appropriate model.

The first objective of this study was to develop ultrasound derived prediction equations for quality and yield grade at extended periods prior to harvest. A second objective was to investigate whether 100 days, 65 days, or another interval prior to harvest was the best time to scan feedlot animals. The final objective was to validate the prediction models in a commercial setting, testing their accuracy.

Materials and Methods

Data for this study were obtained from four hundred six crossbred feedlot steers in 2000, 2001, and 2002. Angus, Simmental, Red Angus, and Charolais breeds were represented in both sires and dams of these cattle. Crossbred females were mated to purebred bulls from the previously mentioned breeds. All steers were fed as calves, double-implanted, and harvested at approximately 12-15 months of age based on marketability to a grid paying premiums for quality grade. Ultrasound information was utilized to make marketing decisions. Steers that experienced continued illness, chronic bloating, or average daily gains below 0.25 kilograms per day were removed from the dataset.

The steers were serially scanned by a centralized ultrasound processing (CUP) certified field technician in 2000 and 2001 and an annual proficiency testing and certification (APTC) qualified technician in 2002. All images were interpreted by a CUP or APTC certified lab technician at the Iowa State University Image Lab. These images were collected using the Classic Scanner 200 (Classic Medical Co., Tequesta, FL) equipped with a 3.5 Mhz 18cm linear array transducer. Steers with missing ultrasound data were deleted from the dataset.

Abbreviations for the measurements collected in this study are listed in Table 1. Live animal ultrasound measurements recorded were: 1) live weight (held off feed overnight until after the scan session had taken place) (SCANWT), 2) a cross-sectional image was taken between the 12th and 13th ribs to obtain subcutaneous fat thickness measured at ? the distance from the medial end of the longissimus dorsi muscle (UFAT) and 3) longissimus dorsi muscle area (UREA), 4) a longitudinal image taken between the hooks and pins perpendicular to the shaft of the ileum to measure subcutaneous fat depth over the termination point of the biceps femoris in the rump (reference point) (URFAT), and 5) four independent images collected laterally across the 12th and 13thribs to estimate percentage intramuscular fat within the longissimus dorsi (PFAT). Four independent images are necessary to follow APTC standard format for data submission. Analysis of PFAT was based on the average of the four images collected.

In 2000, steers were only scanned once in February and once in May (one week prior to slaughter), and all cattle were harvested within 7 days. The cattle from the next two years were serially scanned every 30-35 days from February to May in 2001 or from January to May in 2002. Steers harvested in 2001 and 2002 were marketed at two scheduled dates. Steers that scanned Choice (over 4.0% PFAT) or with excessive subcutaneous fat were harvested on the first date. The remaining steers were fed an additional 30-35 days before harvest.

Data was analyzed separately within each year. Carcass traits most likely did not differ across years due to similarities in genetic base and management. All of the steers came from three calf crops of the same breeding project. Additionally, the steers were all fed as calves in a confinement facility, fed a typical, high-energy corn-based diet, double-implanted, and marketed on a grid emphasizing quality grade. Selection for a grid environment may have helped make the averages more uniform.

Data were grouped together based on the number of days from the scan date to the corresponding harvest date of each individual. Cattle from all three years were classified into a period of days from slaughter. The first group was steers scanned 96-105 days prior to harvest (n=228). The second group was steers ultrasonically measured 61-69 days prior to harvest (n=254).

Cattle were transported to a commercial harvesting facility, where routine carcass data was collected by trained individuals. Carcass measurements collected approximately 24 hours post mortem were: 1) hot carcass weight (HCW), 2) subcutaneous fat thickness collected at the ? position between the 12th and 13th ribs (CFAT), 3) area of the longissimus dorsi between the 12th and 13th ribs (CREA), 4) percent kidney, pelvic, and heart fat (KPH), and 5) numeric marbling scores were given by a USDA grader (MARB). Fat thickness was only adjusted if an obvious deviation in fat thickness was noticeable at the measurement location due to excess fat removal from the hydraulic hide puller. In these situations, the opposite side of the carcass was measured, or the fat depth was adjusted based on a visual estimate of overall fat distribution of the carcass. USDA yield grade (CALCYG) was then calculated using the carcass measurements.

Additional cattle background information was also included as possible sources of variation in statistical analysis. Breed of sire, breed of dam, percentage Black Angus in the individual?s pedigree (PCTANGUS), age of the animal from birth in days (AGE), hip height (HIPHT), then converted to a frame score using the 2002 BIF Guidelines equation (FRSCR) (Beef Improvement Federation, 2002), brand of implant administered, and average daily gain (ADG) was known for each steer. All data were analyzed using CORR, STEPWISE, GLM, and MEANS procedures from version 8.1 of SAS (SAS Institute, Cary, NC). Simple correlation coefficients were calculated between carcass measurements and the corresponding ultrasound measure. All regression equations allowed SCANWT, UFAT, URFAT, UREA, PFAT, and all of the above mentioned background information as potential sources of variation for the final prediction model.

Regression analysis with stepwise procedures was used to develop prediction equations for CALCYG, MARB, CREA, and CFAT from live animal measures. Significance levels for variables to enter a model and to stay in a model were set at $P<0.10$. A separate model for each of the scan periods was developed, starting with a model simulating ?Source Verified? (SV) cattle, where AGE and breed composition (PCTANGUS) was known. Other variables eligible for inclusion into stepwise regression equations included: SCANWT, UREA, UFAT, LFTK, URFAT, PFAT, ADG, HIPHT, FRSCR, breed of sire, and breed of dam.

Brethour (2000a) reported exponential models best fit serial scans of backfat thickness, reporting a strong final R^2 value (0.89). In this study, model R^2 values for predicting carcass backfat 100 days prior to harvest that included the natural log of backfat thickness were also higher. Thus, the natural log of 12th-13th rib fat thickness (LFTK) was used as a possible source of variation in all of the regression analysis with stepwise procedures. A HIPHT measurement was not taken on all of the steers, therefore, FRSCR information was also not available on all of the cattle. As a result, a separate model was developed without using those variables. Finally, a model, which mirrors cattle purchased at an auction, was developed. These regressions, also known as ?Non-source verified? (NSV) cattle, do not utilize AGE, HIPHT, FRSCR, or PCTANGUS as possible variables. When none of the above mentioned variables were utilized by the regression using stepwise procedures, only one model was printed in the table. Environmental factors were intentionally not included in the regressions to obtain a more robust model.

Results and Discussion

Simple statistics for the live animal measurements and the carcass data collected across all three years are listed in Table 2.

Simple correlation coefficients were calculated for ultrasound vs. carcass traits at the 96-105 day period, the 61-69 day period, and a pre-harvest measurement taken within one week of harvest. UFAT showed moderate to high positive relationship with CFAT and CALCYG 100 days before harvest (r=0.58 and r=0.51, respectively), and a stronger relationship within one week of harvest (r=0.74 and r=0.60, respectively). These results are consistent with Tait (2002), who reported pre-harvest correlations of UFAT vs. CFAT and CALCYG (r=0.68 and r=0.61, respectively).

Collecting a rump fat measurement to help predict CFAT at extended periods before harvest seems useful. The correlation of URFAT to CFAT rose only slightly from the 96-105 day scan period to the pre-harvest scan session (r=0.49 to r=0.53, respectively). According to Tait (2002), from a growth and development standpoint, rump fat is deposited much earlier than rib fat, but then levels off in the latter stages of the feeding period. Based on the results of this study, it appears that cattle with more rump fat upon feedlot entry often end up with more subcutaneous rib fat at slaughter. The predictive value of rump fat at extended periods before harvest needs to be further explored. This result is consistent with Tait (2002), who reported a similar pre-harvest correlation between URFAT and CFAT (r=0.54). Realini et al. (2001) found URFAT to be a significant predictor ($P<0.05$) of percentage and amount of fat in a carcass.

The correlation between PFAT and MARB remained somewhat constant from 100 days before harvest to just one week (r=0.63 to 0.61). The pre-harvest correlation is very similar to that published by Tait (2002) (r=0.63). Results from the 61-69 day scanning period were consistent with all other scan sessions (r=0.62). The deposition of marbling appears to be linear over days of age, suggesting that a PFAT measurement taken 100 days before harvest may as helpful as one taken much closer to the harvest date. Brethour (2000b) also used a linear model to predict marbling scores of beef calves. High quality ultrasound images are easier to obtain on leaner, younger cattle. As a result, it may prove helpful to scan steers at re-implant time, while management changes in feeding and implanting can still be made.

When HIPHT is regressed with AGE to predict a FRSCR, the correlation of FRSCR to other measures seems to stay fairly constant, regardless of the scan session. In this data set, larger framed, Continental-based steers were consistently heavier muscled, leaner, and later-maturing with lower marbling scores. In Table 2, the relationships between FRSCR and CREA, CFAT, and MARB illustrate these trends (r=0.29, -0.26, and ?0.14, respectively).

Tables 3 and 4 are the stepwise regression to predict CREA at 96-105 and 61-69 days prior to harvest, respectively. UREA was the first variable to enter all SV models accounting for 27.7% (Table 3) and 30.0% (Table 4) of the variation. HIPHT entered next in all of the regressions, accounting for an additional 9.0% and 7.4% of the variation, respectively. FRSCR was also included in the SV models, though not in the same order each time, with a partial regression coefficient of 0.060 (Table 3) and 0.025 (Table 4). Marketing decisions may possibly explain other variables inclusion in the models. For instance, PFAT entered several regressions with a negative coefficient. Therefore, animals that scanned with more PFAT often had smaller CREA. However, animals that scanned into the Choice grade (PFAT >4.0%) were sent to market earlier. Thus, these steers were usually lighter weight animals with logically smaller CREA. In the NSV regressions, UREA was still important, accounting for 27.5% (Table 3) and 31.9% (Table 4) of the variation. When FRSCR or HIPHT was not available, SCANWT surfaced in all three models, yielding an additional 3.8% and 1.9% of the variation, respectively. Hamlin et al. (1995) also found weight to be a good predictor of muscling when performing regression of UREA on SCANWT in four different biological types of cattle (R^2 from 0.65 to 0.78).

Numerous studies have tested the usefulness of CREA in the USDA yield grade equation (Crouse et al., 1975 and Abraham et al., 1980). At extended periods before harvest, the accuracy of projecting CREA is somewhat low. The root mean squared error (RMSE) for the SV 96-105 day prediction model is 6.00cm^2. At 65 days prior to harvest, the RMSE drops to 5.52cm^2. Since USDA yield grade is not heavily influenced by ribeye area, taking extra time chute-side to trace for UREA may not significantly help the final projection of USDA yield grade.

Tables 5 and 6 list the stepwise regression to predict CFAT at 96-105 and 61-69 days before harvest, respectively. LFTK was the first variable to enter the SV model at 100 days pre-harvest (R^2=0.347). However, UFAT was most important in the 65-day projection (R^2=0.508). As the number of days before harvest decreases, the change in fat depth becomes less, making a log transformation unnecessary. Models excluding LFTK were also computed to be sure log transformation was necessary. Model R-squared values were all lower compared to those produced in Table 5 (R^2=0.431, 0.419, and 0.405, respectively). URFAT was a significant predictor of CFAT in the SV models, especially at extended periods before harvest, accounting for an additional 4.8% (Table 5), 2.8% (Table 6) of the variation as animals near harvest. HIPHT was also significant in SV cattle accounting for 1.1% additional variation in the 100-day projection and 2.8% in the 65-day projection.

Since AGE and PCTANGUS were not significant predictors when HIPHT and FRSCR were excluded, the results for the model excluding HIPHT and FRSCR are identical to the NSV model, making it the only one necessary in Table 6. AGE and PCTANGUS accounted for a small amount of variation in the 100-day projection of rib fat thickness so the model was included in Table 5. In comparison, Hamlin et al. (1995) found AGE as a source of variation ($P<0.05$) for UREA and UFAT in five measurements in a serial scanning study. PFAT was significant in both NSV models accounting for 1.9% (Table 5) and 0.8% (Table 6) of the additional variation. The genetic relationship reported by the American Angus Association (2002) between subcutaneous fat and marbling was only 0.04, with the phenotypic relationship only slightly higher at 0.16.

Accuracy of predicting CFAT is very important with its influence on the USDA yield grade equation. At 96-105 days prior to harvest, the RMSE of the SV model is 0.20cm, dropping to 0.17cm 61-69 days pre-harvest. Brethour (2000a) found that accuracy improved if cattle were given time on feed when projecting number of days to reach 10mm of CFAT. Evaluation 90 days before harvest to predict days to 10mm backfat produced a model accounting for 65% of the variation, with an average error of 33 days. At 43 days before slaughter, the R^2 value rose slightly to 0.70, but the average error was 25 days.

When predicting USDA Yield Grade(CALCYG), LFTK was the first variable entered in each SV model accounting for 26.3% and 36.3% of the variation 100 and 65 days before harvest, respectively. Just one week before harvest, Tait (2002) found UFAT to account for 30% of the variation in percent retail product from the four primal cuts. In this study, the addition of UREA, SCANWT, HIPHT, and FRSCR added an additional 15.3% of the variation in the 100-day projection.

A measure of carcass muscling, UREA, entered NSV models, accounting for 4.5% (Table 7) and 2.5% (Table 8) additional variation as cattle progressed towards harvest. SCANWT also entered both projections, reporting a partial regression coefficient of 0.052 in the two-month projection of NSV cattle. Comparatively, Tait (2002) reported a prediction of percent retail product from the four primals, which included UFAT, UREA, SCANWT, and PFAT as sources of variation (R^2=0.49). Also within one week of harvest, Greiner et al. (2003) included UFAT, URFAT, UREA, SCANWT and ultrasound of body wall thickness to achieve R^2values of 0.61 and 0.67.

Testing accuracy of USDA yield grade can be extremely difficult. This study tried to project yield grade calculated from carcass measurements taken at the time the USDA grader stamps the cattle (CALCYG). Prediction of CALCYG 100 days before harvest had a RMSE of 0.36, with error decreasing to 0.33 for the 65-day projection model.

Stepwise regressions to predict MARB at 96-105 and 61-69 days before harvest are listed in Tables 9 and 10. Since only a few variables entered the projection of MARB at any extended period before harvest, the results for the SV and NSV groups were identical, and only one result is reported. PFAT was most important, accounting for 39.3% and 42.7% of the variation in the 100 and 65-day projections, respectively. LFTK was included next accounting for an additional 4.9% and 3.9% of the variation, respectively. With few significant sources of variation, accurately projecting marbling scores in a commercial feedlot facility seems very possible. A similar model by Brethour (2000b) projects marbling using AGE, PCTANGUS, and the initial ultrasound marbling estimate.

The RMSE for a 100-day projection of MARB is 0.66 marbling score degrees. At two months pre-harvest, the RMSE falls to 0.56 marbling score units. Brethour (2000b) reported a relative accuracy of 76 to 78% in predicting carcass marbling within one-third of the USDA quality grade. When a power function model was used, cattle that entered with low traces of marbling (Standard^{00}) usually failed to become Choice within feeding periods of up to 200 days (Brethour, 2000a). A linear model, like the one used in this study, may tend to regress animals closer to the data set mean. Extensive field testing needs to be performed to assess the error and bias of a commercial model.

In order to validate the prediction models in this study for accuracy, a group of 63 genetically similar British x Continental crossbred steers were scanned at the Iowa State University Allee Research Farm and harvested 95 days later. The correlation between CFAT and predicted subcutaneous fat was r=0.81, and Standard Error of Prediction (SEP) was 0.166. The correlation between CREA and predicted ribeye area was r=0.41, and SEP was 7.807. USDA Yield Grade was calculated from carcass data and compared with the prediction model for yield grade. The raw mean for yield grade across all 63 steers from the carcass data was 2.66; the prediction model produced an average value of 2.60. The correlation between CALCYG and predicted yield grade was r=0.83, and SEP was 0.339. The average USDA marbling score was 5.70 (Small 70); the mean value from the prediction model for marbling was 5.77 (Small 77). The correlation between MARB and predicted marbling score was r=0.75, and SEP was 0.663.

The prediction models were also validated on an individual basis. Seven of the sixty-three steers were stamped USDA Select (4.00-4.99). Using the prediction model for marbling, six of those seven steers projected marbling scores below 5.10, or on the border between Low Choice and High Select (5.0). The USDA yield grade prediction model was also tested on an individual level. Three steers calculated USDA yield grades greater than 3.90 from the carcass measures collected. Those same three individuals were projected to have USDA yield grades greater than 3.90 when the prediction model for yield grade was used. If the ?average? steer in this data set is scanned at re-implant time and fed an additional 100 days, a producer could expect a .35cm increase in subcutaneous fat, a 17.2cm^2 increase in ribeye area, and a 1.06% increase in percent intramuscular fat, while gaining 1.54kg per day.

Implications

Value-based markets pay premiums to those producers who can deliver a specific, consistent product, but discounts those who cannot. Ultrasound in the feedlot may offer a unique opportunity; it can help the producer recognize which grid environment offers the most profit potential. More importantly, scanning feedlot cattle at extended periods before harvest still allows sufficient time to make crucial management decisions and reduce carcass discounts. Developing prediction models that are sensitive to differences in genetics and management will be much more difficult. Individual feedlots could refine a robust model to best fit their operation, or help them decide how to manage and market a pen of cattle.

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Table 1. Abbreviations of traits used

Trait	Definition
Live animal measurements	
UFAT, cm	Ultrasound of rib fat thickness between the 12th and 13th ribs
UREA, cm^2	Ultrasound of ribeye area between the 12th and 13th ribs
URFAT, cm	Ultrasound of rump fat depth taken at the reference point
PFAT, %	Ultrasound of predicted percent intramuscular fat
SCANWT, kg	Live weight of the animal (held off feed overnight until after scan session)
ADG, kg/day	Average daily gain (taken from feedlot entry weight to scanning weight)
FRSCR	Frame score of the animal on scanning date (using the BIF bull equation)
AGE, days	Age of the animal from birth date to scanning date
HIPHT, cm	Height of the animal at the hip on the scanning date
PCTANGUS, %	Percentage of Black Angus in the animal's pedigree
LFTK	Natural log of 12th-13th rib fat thickness
Carcass Measurements	
CFAT, cm	Carcass 12th-13th rib fat thickness
CREA, cm^2	Carcass 12th-13th ribeye area
KPH, %	Percent kidney, pelvic, and heart fat
HCW, kg	Hot carcass weight
MARB	Numeric marbling score as given by USDA grader
CALCYG	Calculated USDA yield grade based on carcass measurements

Table 2. Simple statistics for live animal and carcass data collected from the population[a]

Trait	N	Mean	SD	Minimum	Maximum
Live animal measurements					
SCANWT, kg	405	548	45.51	416	688
UFAT, cm	405	1.08	0.29	0.38	1.98
UREA, cm^2	405	82.5	8.08	60.0	108.4
PFAT, %	405	4.98	1.16	2.27	9.05
URFAT, cm	406	0.88	0.25	0.30	2.16
ADG, kg/day	404	1.57	0.48	0.33	5.23

FRSCR	327	6.13	0.81	3.73	7.98
AGE, days	406	384	20.66	321	430
HIPHT, cm	327	131.21	4.33	119.05	141.61
PCTANGUS, %	406	43.23	20.15	0	75
Carcass measurements					
HCW, kg	406	342	29	264	436
CFAT, cm	406	1.08	0.28	0.25	2.03
CREA, cm^2	406	81.6	7.88	58.7	105.2
MARB[b]	406	5.67	0.91	3.80	9.50
KPH, %	406	2.2	0.4	1.0	3.5
CALCYG	406	2.83	0.48	1.48	4.38

[a] See Table 1 for description of acronyms.

[b] Traces^{00}=3.00, Slight^{00}=4.00, Small^{00}=5.00, Modest^{00}=6.00, Moderate^{00}=7.00

Table 3. Stepwise regression to predict REA at 96-105 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
Source Verified (n=224)					
	Intercept	-148.985			
1	UREA	0.557	<0.0001	0.277	0.277
2	HIPHT	2.129	<0.0001	0.090	0.367
3	FRSCR	-9.406	<0.0001	0.060	0.427
4	AGE	-0.097	0.0020	0.024	0.451
5	LFTK	-2.580	0.0966	0.007	0.458
Without Hip Height and Frame Score (n=226)					
	Intercept	30.746			
1	UREA	0.431	<0.0001	0.275	0.275
2	SCANWT	0.088	0.0006	0.038	0.313
3	LFTK	-5.013	0.0046	0.025	0.337
4	ADG	-6.409	0.0257	0.015	0.352
Non-Source Verified (n=226)					
	Intercept	36.009			
1	UREA	0.441	<0.0001	0.275	0.275
2	SCANWT	0.075	0.0006	0.038	0.313
3	ADG	-5.959	0.0411	0.013	0.325

[a] See Table 1 for description of acronyms.

Table 4. Stepwise regression to predict REA at 61-69 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
Source Verified (n=176)					
	Intercept	-55.813			
1	UREA	0.449	<0.0001	0.300	0.300
2	HIPHT	1.004	<0.0001	0.074	0.374
3	PFAT	-1.097	0.0022	0.033	0.407
4	FRSCR	-3.900	0.0071	0.025	0.432
5	LFTK	-3.272	0.0477	0.013	0.445
Without Hip Height and Frame Score (n=253)					
	Intercept	18.626			
1	UREA	0.502	<0.0001	0.319	0.319
2	AGE	0.074	0.0003	0.035	0.354
3	PFAT	-1.035	0.0104	0.017	0.371
4	ADG	3.916	0.0306	0.012	0.383
Non-Source Verified (n=253)					
	Intercept	28.450			
1	UREA	0.527	<0.0001	0.319	0.319
2	SCANWT	0.036	0.0086	0.019	0.337
3	LFTK	-2.763	0.0416	0.011	0.348

[a] See Table 1 for description of acronyms.

Table 5. Stepwise regression to predict 12th rib fat at 96-105 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
Source Verified (n=224)					
	Intercept	1.860			
1	LFTK	0.404	<0.0001	0.347	0.347
2	URFAT	0.275	<0.0001	0.048	0.395
3	PFAT	0.037	0.0078	0.019	0.414
4	HIPHT	-0.009	0.0403	0.011	0.425
5	ADG	0.145	0.0425	0.011	0.436
6	PCTANGUS	-0.001	0.0897	0.007	0.444
Without Hip Height and Frame Score (n=226)					
	Intercept	1.455			
1	LFTK	0.450	<0.0001	0.347	0.347

2	URFAT	0.295	<0.0001	0.049	0.397
3	PFAT	0.044	0.0079	0.019	0.416
4	AGE	-0.002	0.0620	0.009	0.425
5	PCTANGUS	-0.001	0.0666	0.009	0.433
Non-Source Verified (n=226)					
	Intercept	0.863			
1	LFTK	0.413	<0.0001	0.347	0.347
2	URFAT	0.324	<0.0001	0.049	0.397
3	PFAT	0.041	0.0079	0.019	0.416

[a] See Table 1 for description of acronyms.

Table 6. Stepwise regression to predict 12th rib fat at 61-69 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
Source Verified (n=176)					
	Intercept	1.841			
1	UFAT	0.706	<0.0001	0.508	0.508
2	HIPHT	-0.013	0.0014	0.028	0.537
3	URFAT	0.267	0.0015	0.026	0.563
4	ADG	0.131	0.0805	0.008	0.571
Non-Source Verified (n=253)					
	Intercept	0.863			
1	LFTK	0.413	<0.0001	0.399	0.399
2	URFAT	0.324	<0.0001	0.028	0.427
3	PFAT	0.041	0.0079	0.008	0.435

[a] See Table 1 for description of acronyms.

Table 7. Stepwise regression to predict USDA yield grade at 96-105 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
Source Verified (n=224)					

	Intercept	10.686			
1	LFTK	0.742	<0.0001	0.263	0.263
2	UREA	-0.022	0.0089	0.023	0.286
3	SCANWT	0.006	<0.0001	0.048	0.334
4	HIPHT	-0.078	0.0005	0.036	0.370
5	FRSCR	0.314	<0.0001	0.046	0.416
Non-Source Verified (n=226)					
	Intercept	3.199			
1	LFTK	0.831	<0.0001	0.264	0.264
2	ADG	0.359	0.0021	0.031	0.294
3	UREA	-0.020	0.0001	0.045	0.339
4	SCANWT	0.002	0.0547	0.011	0.350

[a] See Table 1 for description of acronyms.

Table 8. Stepwise regression to predict USDA yield grade at 61-69 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
Source Verified (n=176)					
	Intercept	10.672			
1	LFTK	0.866	<0.0001	0.363	0.363
2	UREA	-0.017	0.0810	0.011	0.374
3	SCANWT	0.007	0.0017	0.035	0.409
4	HIPHT	-0.083	<0.0001	0.054	0.463
5	FRSCR	0.289	0.0010	0.033	0.496
Without Hip Height and Frame Score (n=253)					
	Intercept	4.075			
1	LFTK	0.758	<0.0001	0.205	0.205
2	UREA	-0.019	0.0046	0.025	0.230
3	SCANWT	0.007	<0.0001	0.052	0.282
4	AGE	-0.005	0.0796	0.009	0.291
5	ADG	-0.472	0.0103	0.019	0.309
Non-Source Verified (n=253)					
	Intercept	2.891			
1	LFTK	0.747	<0.0001	0.205	0.205
2	UREA	-0.019	0.0046	0.025	0.230
3	SCANWT	0.004	<0.0001	0.052	0.282

[a] See Table 1 for description of acronyms.

Table 9. Stepwise regression to predict marbling at 96-105 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
n=224					
	Intercept	2.873			
1	PFAT	0.542	<0.0001	0.393	0.393
2	LFTK	0.683	<0.0001	0.049	0.443
3	ADG	0.601	0.0060	0.019	0.461

[a] See Table 1 for description of acronyms.

Table 10. Stepwise regression to predict marbling at 61-69 days prior to harvest[a]

Order	Trait	Coefficient	P-Value	Partial R^2	Model R^2
n=176					
	Intercept	3.718			
1	PFAT	0.477	<0.0001	0.427	0.427
2	LFTK	0.583	0.0005	0.039	0.466

[a] See Table 1 for description of acronyms.