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Genetic and environmental parameters for steer ultrasound and carcass traits[1]

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ABSTRACT: Carcass measurements for weight, longissimus muscle area, 12–13th-rib fat thickness, and marbling score, as well as for live animal measurements of weight at the time of ultrasound, ultrasound longissimus muscle area, ultrasound 12–13th-rib fat thickness, and ultrasound-predicted percentage ether extract were taken on 2,855 Angus steers. The average ages for steers at the time of ultrasound and at slaughter were 391 and 443 d, respectively. Genetic and environmental parameters were estimated for all eight traits in a multivariate animal model. In addition to a random animal effect, the model included a fixed effect for contemporary group and a covariate for measurement age. Heritabilities for carcass weight, carcass longissimus muscle area, carcass fat thickness, carcass marbling score, ultrasound weight, ultrasound longissimus muscle area, ultrasound fat thickness, and ultrasound-predicted percentage ether extract were 0.48, 0.45, 0.35, 0.42, 0.55, 0.29, 0.39, and 0.51, respectively. Genetic correlations between carcass and ultrasound longissimus muscle area, carcass and ultrasound fat thickness, carcass marbling score and ultrasound-predicted percentage ether extract, and carcass and ultrasound weight were 0.69, 0.82, 0.90, and 0.96, respectively. Additional estimates were derived from a six-trait multivariate animal model, which included all traits except those pertaining to weight. This model included a random animal effect, a fixed effect for contemporary group, as well as covariates for both measurement age and weight. Heritabilities for carcass longissimus muscle area, carcass fat thickness, carcass marbling score, ultrasound longissimus muscle area, ultrasound fat thickness, and ultrasound-predicted percentage ether extract were 0.36, 0.39, 0.40, 0.17, 0.38, and 0.49, respectively. Genetic correlations between carcass and ultrasound longissimus muscle area, carcass and ultrasound fat thickness, and carcass marbling and ultrasound-predicted percentage ether extract were 0.58, 0.86, and 0.94, respectively. The high, positive genetic correlations between carcass and the corresponding real-time ultrasound traits indicate that real-time ultrasound imaging is an alternative to carcass data collection in carcass progeny testing programs.

Key Words: Beef Cattle, Genetic Correlation, Ultrasound

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Introduction

The potential of real-time ultrasound (**RTU**) has been well reported by many authors (Herring et al., 1998; Moser et al., 1998; Reverter et al., 2000). In fact, several breed associations are using EPD derived from RTU to supplement or coincide with EPD derived from actual carcass measurements (IBBA, 2000; AAA, 2001). Actual carcass data from designed progeny-testing programs are used to calculate carcass EPD by many breed associations (AAA, 2001; AICA, 2001; NALF, 2001). However, implementation of these programs is costly, in part, due to harvesting whole contemporary groups simultaneously, disallowing the sorting of market animals into the most profitable harvest groups. If animals within designed progeny-testing programs could be scanned during the finishing phase and those data subsequently used for EPD calculation, then those animals could potentially be sorted into varying harvest groups. However, to proceed with such a genetic evaluation, an understanding of the genetic relationships among steer ultrasound and the same carcass traits must be determined. Thus, the objective of this study was to estimate the genetic and environmental relationships between live animal RTU and subsequent carcass traits within steers.

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Materials and Methods

Data

Data to develop the resulting models included pedigree, RTU, and carcass information from 2,855 Angus steers and were gathered over 5 yr (1996–2000). The steers were part of a sire progeny-testing program, consisting of 101 sires, conducted by Circle A Angus Ranches in Huntsville, Iberia, and Stockton, Missouri, in conjunction with the University of Missouri. The protocol used to create steer progeny was the one that is recommended by the AAA (2001) for evaluation of carcass traits via a designed progeny-testing program. Commercial Angus females were randomly allocated to one of 101 Angus sires for artificial insemination or natural service. Subsequent progeny information was collected beginning at birth and continuing through slaughter. All calves were spring-born, and those that were born in a given pasture were maintained together as a contemporary group through weaning and ultimately slaughter. Upon weaning, all steers went through a backgrounding period of approximately 124 d. The backgrounding diet was composed of corn silage (43%), whole or cracked corn (44%), protein-mineral supplement (8%), and ground alfalfa hay (5%) on an as-fed basis. The initial feedlot diet consisted predominantly of, on an as-fed basis, corn (67%), soybean hulls (12%), and alfalfa hay (8%). As the rations were modified throughout the feedlot period, these percentages were adjusted to 76, 5, and 6%, respectively. The 265 steers born in 1996 and the 675 steers born in 1997 were fed at Supreme Cattle Feeders, Inc., in Liberal, KS. The 983 steers born in 1998 and the 932 steers born in 1999 were fed at Platte Valley Feeders, Inc., in Kearney, NE. All animals within a contemporary group were then slaughtered on the same day under uniform conditions.

A single ultrasound technician, certified by both the Animal Ultrasound Practitioners Association (AUPA, 2000) and the Centralized Ultrasound Processing center (CUPC, 2000) affiliated with Iowa State University, performed all ultrasonic scanning approximately 53 d prior to slaughter. The average age of the steers at the time of RTU imaging was approximately 391 d. An Aloka 500-V unit (Corometrics Medical Systems, Wallingford, CT) equipped with a 3.5-MHz, 17.2-cm linear array transducer was used to capture RTU images. Before scanning, the appropriate area was made free of dirt and debris and clipped, and vegetable oil was then applied to ensure proper transducer-guide-animal contact. Approximately 80 steers were scanned per hour. Measurements were taken for fat thickness at the 12–13 ribs, longissimus muscle area, and RTU-predicted percentage ether extract. In addition, a weight, which will be referred to as yearling weight because it represents an average age of slightly over 1 yr, was taken. To measure RTU fat thickness and longissimus muscle area, the transducer was positioned laterally between the 12th and 13th ribs on the right side of the steer. To capture the necessary images for RTU-predicted percentage ether extract, the transducer was positioned longitudinally across the 11th to 13th ribs approximately three-fourths of the distance from the medial end of the longissimus muscle to the lateral end. All images were identified with a unique animal identification code, digitized via a video capture card (CX-100, Imagenation Corp., Beaverton, OR), saved to the hard drive of a personal computer, and later interpreted with software from Critical Vision, Inc., Atlanta, GA (developed by Iowa State University).

All steers within a contemporary group were slaughtered together. Steers were slaughtered at two commercial facilities. The approximate chain speed, within both facilities, was 300 animals per hour. There were one, three, two, and three slaughter dates for those steers born in 1996, 1997, 1998, and 1999, respectively. Carcass data were gathered, at chain speed, by experienced personnel from both the USDA and the University of Missouri. The carcass data were collected approximately 36 h postmortem and traits recorded included carcass weight, marbling score, fat thickness at the 12–13th ribs, and longissimus muscle area.

Variance Component Estimation

Genetic parameters were estimated for eight traits: RTU fat thickness, RTU longissimus muscle area, RTU-predicted percentage ether extract, yearling weight, carcass weight, carcass marbling score, carcass fat thickness, and carcass longissimus muscle area. Data were analyzed with a multivariate animal model using software that uses an EM-REML algorithm (REMLF90; Misztal, 1999) to obtain the variance component estimates. Starting values for the full model were obtained from multiple simpler models. Two models were used for final variance component estimation. The initial model (Model 1) possessed all eight traits of interest with fixed effects for contemporary group, covariates for the measurement age, and a random direct additive genetic effect due to animal. A contemporary group was defined as those steers that had been together from birth through measurement time and had been given an equal opportunity to perform. The second model (Model 2) included six of the eight traits, excluding carcass and yearling weight. This model maintained the fixed effects of contemporary group and the direct additive genetic effect but used both age and weight as covariates. This was an effort to view potential changes in either heritabilities or genetic correlations for any trait that may be highly weight dependent. There were 5,603 animals represented in the resulting relationship matrix, consisting of 2,855 slaughter progeny and 2,748 parents and ancestors without records. Maternal grandparents of steers were unknown. The models were expressed as

$$\mathbf{y}_i = \mathbf{X}_i\beta_i + \mathbf{Z}_i\mathbf{u}_i + \mathbf{e}_i$$

Table 1. Summary statistics for carcass and real-time ultrasound data

Item	Mean	SD	Minimum	Maximum
Carcass measurements[a]				
HCW	334	32	216	436
LMA	75	9	40	117
FAT	1.41	0.45	0.03	3.56
MARB	5.4	1.1	0.5	9.5
Age at time of slaughter, d	443	22	364	501
RTU measurements[b]				
YWT	462	48	302	609
ULMA	74	8	50	105
UFAT	0.81	0.22	0.18	1.73
UEE	4.6	1.1	1.8	8.8
Age at time of RTU, d	391	21	329	445

[a]HCW = carcass weight, kg; LMA = carcass longissimus muscle area, cm^2; FAT = 12–13th-rib carcass fat thickness, cm; MARB = marbling score, 4.0 = Slight[00], 5.0 = Small[00], etc.
[b]RTU = real-time ultrasound; YWT = weight at the time of real-time ultrasound, kg; ULMA = ultrasonically scanned longissimus muscle area, cm^2; UFAT = ultrasonically scanned 12–13th-rib fat thickness, cm; UEE = ultrasonically predicted percentage ether extract.

where

$\mathbf{y}_i$ = vector of observations for trait i
$\mathbf{X}_i$ = matrix that relates fixed effects to measures for trait i
β_i = vector of unknown fixed effects for measures of trait i
$\mathbf{Z}_i$ = matrix that relates animal of record to measures for trait i
$\mathbf{u}_i$ = vector of random animal effects for measures of trait i
$\mathbf{e}_i$ = vector of residual effects for measurements of trait i

and where for Model 1

i = 1 for carcass weight, 2 for carcass longissimus muscle area, 3 for carcass fat thickness, 4 for carcass marbling score, 5 for yearling weight, 6 for RTU longissimus muscle area, 7 for RTU fat thickness, and 8 for RTU-predicted percentage ether extract

and where for Model 2

i = 1 for carcass longissimus muscle area, 2 for carcass fat thickness, 3 for carcass marbling score, 4 for RTU longissimus muscle area, 5 for RTU fat thickness, and 6 for RTU-predicted percentage ether extract.

Results and Discussion

Summary Statistics

Table 1 shows the mean, SD, minimum, and maximum for each trait. The average ages of steers at the time of RTU and harvest were 391 and 443 d, respectively. The average live weight at the time of RTU imaging was 462 kg, whereas the average carcass weight at the time of harvest was 334 kg. Levels of additional fat deposition, as expressed by increases in both marbling and 12–13th-rib fat depth from the time of RTU scanning to harvest, are as expected. There is little change in the average ribeye area between RTU scans and carcass measurements.

Table 2 reports the number of sires represented within varying progeny class sizes. It is important to note that, of the 101 sires represented, 58 sires had at least 25 steer progeny and 30 sires were represented by at least 50 steer offspring each. Also, each dam averaged 1.33 steers in its progeny among the edited data.

Heritabilities

Table 3 summarizes the variance and covariance estimates for the various traits in Model 1. Heritability, genetic correlation, and environmental correlation estimates for the same traits are listed in Table 4.

Our heritability estimate for carcass longissimus muscle area of 0.45 is in line with those of Moser et al. (1998), Koots et al. (1994), and Arnold et al. (1991), who reported estimates of 0.39, 0.42, and 0.46, respectively, but much higher than the estimate of 0.07 obtained by Hassen et al. (1999).

The heritability for carcass fat thickness estimated at 0.35 is comparable to other reports. Hassen et al.

Table 2. Frequency of progeny per sire

Progeny per sire (n)	Sires (n)
All sires	101
Sires with < 10	21
Sires with ≥ 10	80
Sires with ≥ 25	58
Sires with ≥ 50	30

Table 3. Age-adjusted genetic and environmental variance and covariance estimates for carcass and real-time ultrasound traits[a]

Trait[b]	HCW	LMA	FAT	MARB	YWT	ULMA	UFAT	UEE
HCW	472.73 (497.27)	45.07	3.89	0.13	501.50	49.77	1.39	0.30
LMA	71.70	31.74 (38.84)	0.21	–0.07	47.60	9.63	0.16	0.06
FAT	0.96	–0.30	0.07 (0.12)	0.002	4.55	0.50	0.03	0.008
MARB	4.02	–0.38	0.07	0.47 (0.65)	–0.77	–0.18	–0.004	0.03
YWT	634.47	77.73	0.77	6.28	933.41 (764.17)	70.99	1.83	–0.23
ULMA	61.12	13.97	0.14	0.72	77.25	12.83 (31.63)	0.22	–0.07
UFAT	0.95	–0.18	0.03	0.04	1.37	0.11	0.02 (0.03)	0.002
UEE	2.25	–0.80	0.06	0.46	4.41	0.42	0.04	0.55 (0.53)

[a]Genetic estimates are below the diagonal, and environmental estimates above the diagonal. On the diagonal, both are presented. The environmental estimates are in parentheses.
[b]HCW = carcass weight, kg; LMA = carcass longissimus muscle area, cm^2; FAT = 12–13th-rib carcass fat thickness, cm; MARB = marbling score, 4.0 = Slight[00], 5.0 = Small[00], etc.; YWT = weight at the time of real-time ultrasound, kg; ULMA = ultrasonically scanned longissimus muscle area, cm^2; UFAT = ultrasonically scanned 12–13th-rib fat thickness, cm; UEE = ultrasonically predicted percentage ether extract.

(1999) and Arnold et al. (1991) cited heritability estimates for carcass fat thickness of 0.42 and 0.49, respectively. Additionally, Wilson et al. (1999) reported a heritability estimate for carcass fat thickness of 0.44. Koots et al. (1994) summarized 26 studies and reported a weighted average of heritability estimates for carcass fat thickness to be 0.44. Moser et al. (1998) used Brangus field data to estimate a heritability of 0.27 for carcass fat thickness, whereas an estimate, derived from Angus field data, of 0.26 was reported by Wilson et al. (1993).

A heritability estimate of 0.42 for carcass marbling score is also reported in Table 4. It appears that the reported estimate seems to be in the range of previous reports. Reverter et al. (2000) reported a heritability estimate for percentage intramuscular fat in Angus bulls and heifers of 0.43. In addition, they also reported a combined heritability estimate for Hereford cattle of 0.36. Marshall (1994) cited an unweighted average heritability estimate, compiled from nine sources, of 0.35. In a study conducted at the USDA Meat Animal Research Center, using numerous composite breeds, Gregory et al. (1994) found a heritability estimate of 0.52 for carcass marbling score, whereas an even higher estimate of 0.88 in Shorthorn steers was reported by Pariacote et al. (1998).

The heritability estimate reported for RTU longissimus muscle area (0.29) is also similar to estimates previously reported despite the present data being derived from a steer population, whereas most estimates have

Table 4. Age-adjusted estimates of heritability, genetic, and environmental correlations among carcass and real-time ultrasound traits[a]

Trait[b]	HCW	LMA	FAT	MARB	YWT	ULMA	UFAT	UEE
HCW	**0.48**	0.32	0.49	0.01	0.81	0.40	0.37	0.02
LMA	0.58	**0.45**	0.09	–0.01	0.28	0.27	0.15	0.01
FAT	0.17	–0.20	**0.35**	0.01	0.47	0.03	0.55	0.03
MARB	0.27	–0.10	0.38	**0.42**	–0.03	–0.04	–0.03	0.06
YWT	0.96	0.45	0.10	0.30	**0.55**	0.46	0.40	–0.01
ULMA	0.78	0.69	0.15	0.30	0.71	**0.29**	0.23	–0.02
UFAT	0.33	–0.24	0.82	0.45	0.33	0.23	**0.39**	0.02
UEE	0.14	–0.19	0.33	0.90	0.19	0.16	0.38	**0.51**

[a]Heritability estimates are on the diagonal, genetic correlations below the diagonal, and environmental correlations above the diagonal.
[b]HCW = carcass weight, kg; LMA = carcass longissimus muscle area, cm^2; FAT = 12–13th-rib carcass fat thickness, cm; MARB = marbling score, 4.0 = Slight[00], 5.0 = Small[00], etc.; YWT = weight at the time of real-time ultrasound, kg; ULMA = ultrasonically scanned longissimus muscle area, cm^2; UFAT = ultrasonically scanned 12–13th-rib fat thickness, cm; UIMF = ultrasonically predicted percentage ether extract.

resulted from breeding stock. Additionally, it is important to note that the measurements taken for all three RTU traits have heritability estimates that are similar to those estimates cited in the literature for the corresponding carcass traits. Reverter et al. (2000) reported heritability estimates for RTU longissimus muscle area in both Angus and Hereford bulls of 0.37 and 0.41, respectively. Moser et al. (1998), in Brangus data (bulls and heifers), reported a heritability estimate for RTU longissimus muscle area of 0.29. Additionally, Johnson et al. (1993) estimated heritability in Brangus cattle for RTU longissimus muscle area at 0.40. Shephard et al. (1996) conducted a study with serial ultrasonic scanning of Angus bulls and heifers and subsequently reported a heritability estimate for RTU longissimus muscle area of 0.11. Robinson et al. (1993) reported heritability estimates for both Angus and Hereford breeding stock ranging from 0.18 to 0.25.

Whereas Shephard et al. (1996) reported a heritability estimate in Angus cattle for RTU fat thickness of 0.56, the estimate of heritability for RTU fat thickness reported in Table 4 (0.39) more closely represents the estimates found in other studies. On a weight-constant basis, Izquierdo et al. (1997) reported a heritability of 0.34, whereas Arnold et al. (1991) reported an estimate of heritability for RTU fat thickness in Hereford cattle of 0.26. Johnson et al. (1993) and Moser et al. (1998) both reported lower estimates in Brangus data of 0.14 and 0.11, respectively. The range of estimates reported by Robinson et al. (1993) represents how variable the literature is with regards to this trait, with a range in estimates from 0.15 to 0.42.

The heritability estimate for RTU-predicted percentage ether extract (0.51) reported in the present study is similar to an estimate reported in Angus heifers of 0.47 by Reverter et al. (2000). Reverter et al. (2000) used the same model of hardware as that used in the present study to determine the percentage of intramuscular fat present. However, Izquierdo et al. (1997) reported heritability estimates on both an age and a weight-constant basis of 0.81 and 0.84, respectively.

The heritability estimates for yearling weight and carcass weight (0.48 and 0.55, respectively) are similar to other reports. Johnson et al. (1993) reported a heritability estimate for yearling weight of 0.44. Moser et al. (1998) produced a similar estimate for yearling weight of 0.40. Additionally, they reported an estimate for carcass weight at 0.59. Likewise, Reverter et al. (2000) produced estimates for carcass weight in Angus and Hereford cattle of 0.31 and 0.54, respectively.

The variance and covariance estimates for Model 2 are listed in Table 5. The corresponding heritability and genetic correlation estimates are listed in Table 6. Minimal differences were recognized for most estimates derived from this model with the exception of those relating to either carcass or RTU longissimus muscle area. The heritability estimates for carcass longissimus muscle area dropped from 0.45 in Model 1 to 0.36 in Model 2. Likewise, RTU longissimus muscle area went from 0.29 to 0.17. This is not surprising given that it is well documented that carcass weight and longissimus muscle area are highly correlated genetically (Gregory et al., 1995; Pariacote et al., 1998), and thus using weight as an additional covariate in Model 2 would tend to reduce the carcass and RTU longissimus muscle area genetic variance estimates. Furthermore, without exception, the genetic correlations between carcass longissimus muscle area and the other remaining traits in Model 2 were more negative (or less positive) than the corresponding genetic correlations from Model 1 (Table 4). The same held true for the relationship between RTU longissimus muscle area and the remaining traits. In addition, as the genetic correlations between the weight measurements and the traits pertaining to longissimus muscle area from Model 1 are evaluated, there appears throughout a moderately strong, positive relationship. The estimates for the genetic correlations between carcass longissimus muscle area and carcass weight, carcass longissimus muscle area and yearling weight, RTU longissimus muscle area and carcass weight, and RTU longissimus muscle area and yearling weight are 0.58, 0.45, 0.78, and 0.71, respectively.

Genetic Correlations

Given the nature and the overall objective of this project, certain genetic correlations were of great interest, particularly those between the actual carcass measurements and the measures captured via RTU that preceded them. The genetic correlations between carcass and RTU longissimus muscle area, derived from Models 1 and 2, of 0.69 and 0.58, respectively are comparable with Moser et al. (1998), who cited a genetic correlation between carcass and RTU longissimus muscle area of 0.66. However, the estimate from Moser et al. (1998) is representative of most reported, in that it is derived from field data with no animals actually having both ultrasound and carcass data. These two estimates (0.69 and 0.58) were the weakest of the genetic correlations between the RTU measures and their corresponding carcass measurements reported in the present study. This could be, in part, due to RTU longissimus muscle area being the most difficult of the ultrasound measurements to accurately obtain. Perkins et al. (1992) and Smith et al. (1992) conducted studies to examine the accuracy of ultrasonic measurements of composition. Both reported simple correlations between the ultrasonically determined trait and the corresponding carcass trait. Perkins et al. (1992) and Smith et al. (1992) reported correlations between carcass and RTU fat thickness of 0.75 and 0.81, respectively. However, both authors reported lower correlations between carcass and RTU longissimus muscle area of 0.60 and 0.20, respectively. Both studies suggest that longissimus muscle area estimates were less consistent than would be desirable.

The genetic correlations between carcass and RTU fat thickness were highly favorable, with estimates from

Table 5. Age and weight-adjusted genetic and environmental variance and covariance estimates for carcass and real-time ultrasound traits[a]

Trait[b]	LMA	FAT	MARB	ULMA	UFAT	UEE
LMA	20.40 (36.47)	–0.17	–0.12	5.33	0.02	–0.03
FAT	–0.48	0.07 (0.10)	0.0008	0.15	0.02	0.004
MARB	–0.80	0.05	0.44 (0.66)	–0.14	–0.002	0.03
ULMA	6.48	–0.006	0.26	6.12 (29.32)	0.13	0.05
UFAT	–0.29	0.03	0.03	0.009	0.02 (0.03)	0.006
UEE	–0.96	0.06	0.46	0.11	0.03	0.53 (0.55)

[a]Genetic estimates are below the diagonal and environmental estimates above the diagonal. On the diagonal, both are presented. The environmental estimates arenin parentheses.
[b]LMA = carcass longissimus muscle area, cm^2; FAT = 12–13th-rib carcass fat thickness, cm; MARB = marbling score, 4.0 = $Slight^{00}$, 5.0 = $Small^{00}$, etc.; ULMA = ultrasonically scanned longissimus muscle area, cm^2; UFAT = ultrasonically scanned 12–13th-rib fat thickness, cm; UIMF = ultrasonically predicted percentage ether extract.

Model 1 and Model 2 of 0.82 and 0.86, respectively. Reverter et al. (2000) reported genetic correlations between Angus and Hereford seedstock herds and carcass data from Angus and Hereford slaughter cattle. They cited an estimate, averaged across sexes, between carcass and RTU fat thickness in Angus cattle of 0.88. Additionally, they cited an estimate of 0.87 for Hereford bulls. Likewise, Izquierdo et al. (1997) reported estimates that were approaching 1.

A major point of interest within this study was the application of RTU for determining intramuscular fat. The estimates reported from Model 1 and Model 2 for estimates between carcass marbling score and RTU-predicted percentage ether extract are 0.90 and 0.94, respectively. Both indicated a very strong, positive genetic relationship between the marbling score assigned by trained personnel in the packing plant and the information derived by an experienced technician using RTU technology. There is a very limited amount of information on this topic to be found in the literature. To our knowledge this is the only study that has evaluated this trait as extensively using steers that have both live animal RTU measurements and subsequent carcass data.

Because carcass weight is the most important factor determining carcass value, the relationship between weight at the time of RTU imaging and carcass weight is crucial if RTU is to be used as an acceptable predictor of carcass merit. Yearling and carcass weight were only included in Model 1 and resulted in a subsequent genetic correlation between them of 0.96.

Due to the unique nature of valuing beef carcasses, relative to other livestock species, the balance between acceptable levels of intramuscular fat and subcutaneous fat is a persistent question. Several authors have found that selection against external fat does not negatively impact intramuscular fat deposition (Benyshek et al., 1988; Bertrand et al., 1993; Vieselmeyer et al., 1996). However, the majority of authors have cited genetic correlations more reflective of the genetic correla-

Table 6. Age and weight-adjusted estimates of heritability, genetic, and environmental correlations among carcass and real-time ultrasound traits[a]

Trait[b]	LMA	FAT	MARB	ULMA	UFAT	UEE
LMA	**0.36**	–0.09	–0.02	0.16	0.02	–0.01
FAT	–0.41	**0.39**	0.00	0.09	0.45	0.02
MARB	–0.26	0.29	**0.40**	–0.03	–0.02	0.05
ULMA	0.58	0.00	0.16	**0.17**	0.15	0.01
UFAT	–0.51	0.86	0.37	0.03	**0.38**	0.05
UEE	–0.29	0.31	0.94	0.06	0.33	**0.49**

[a]Heritability estimates are on the diagonal, genetic correlations below the diagonal, and environmental correlations above diagonal.
[b]LMA = carcass longissimus muscle area, cm^2; FAT = 12–13th-rib carcass fat thickness, cm; MARB = marbling score, 4.0 = $Slight^{00}$, 5.0 = $Small^{00}$, etc.; ULMA = ultrasonically scanned longissimus muscle area, cm^2; UFAT = ultrasonically scanned 12–13th-rib fat thickness, cm; UIMF = ultrasonically predicted percentage ether extract.

tion estimates we obtained of both 0.38 between carcass fat thickness and marbling score and between RTU fat thickness and RTU-predicted percentage ether extract for Model 1, and 0.29 and 0.33 respectively for Model 2. In fact, in a review of the literature regarding carcass traits, Marshall (1994) cites four authors reporting ranges for the genetic correlation between carcass fat thickness and marbling score from –0.13 to 0.73. Of the four reports, the only negative genetic correlation is derived from Angus field data. The other three genetic correlations of 0.73, 0.73, and 0.16 all result from experimental conditions.

The genetic correlations between carcass longissimus muscle area and carcass fat thickness (–0.20 and –0.41 for Models 1 and 2, respectively) tend to agree with those estimates found in the literature. Within steers, Hassen et al. (1999) estimated a genetic correlation of –0.25. Likewise, Moser et al. (1998) cited an estimate for the relationship between longissimus muscle area and fat depth, in Brangus seedstock, of –0.05.

Conversely, the genetic correlations between RTU longissimus muscle area and RTU fat thickness (0.23 and 0.03 for Models 1 and 2, respectively) are lowly positive. This sign difference between carcass data and ultrasonic imaging between fat thickness and longissimus muscle area is not uncommon in the literature (Arnold et al., 1991; Johnson et al., 1993; Moser et al., 1998). It has been suggested that this may be a result of most studies using compiled data sets with RTU measurements from seedstock exclusively and carcass data from slaughter cattle. Arnold et al. (1991) suggests that the sign difference may indicate different relationships between growth patterns between bulls and slaughter cattle, and subsequent selection based on RTU measures in seedstock may negatively impact the cutability of slaughter progeny. Whereas Moser et al. (1998) also reported a sign difference between the two genetic correlations, both estimates had confidence intervals, which included zero. Since the RTU and carcass data used within this study were all collected from the same set of steers, the findings would disagree with the argument that the sign differences widely reported within the literature are attributable to gender differences. They may, however, still be a result of differences in measurement age. Ultrasound scans were taken an average of 53 d before the corresponding carcass traits were gathered. It is certainly reasonable to postulate that differences in growth and deposition curves within animals could result in the sign changes of the genetic correlation. Moser et al. (1998) goes on to disagree with the hypothesis of Arnold et al. (1991), suggesting that RTU measurements in seedstock could have a deleterious effect on the cutability of subsequent slaughter progeny. Moser et al. (1998) cites the moderately strong genetic correlations they reported between both carcass and RTU fat thickness (0.69) and carcass and RTU longissimus muscle area (0.66) as justification for selection of seedstock based on RTU. The genetic correlations reported earlier, from both models, between carcass and RTU longissimus muscle area (0.69 and 0.58) and carcass and RTU fat thickness (0.82 and 0.86), support this claim.

The strong, positive genetic correlations resulting from this study exhibit the ability of RTU technology to accurately reflect subsequent carcass merit. Additionally, the described format allows RTU measurements to be captured in a manner that will assimilate into current industry practices. Thus, RTU presents an opportunity to reduce the amount of time required to collect pertinent data. Real-time ultrasound may not only allow for more timely data collection, but also encourage some producers to participate in designed progeny-testing programs aimed at attaining information that accurately reflects steer body composition.

Implications

The results presented here indicate that real-time ultrasonic imaging, gathered in a high-speed, commercial setting, can be a substitute for carcass data in genetic evaluation programs. The realities and difficulties associated with maintenance of contemporary groups at the time of slaughter are evident. It is most often not cost effective to slaughter all members of a contemporary group on the same day. This approach allows data from all animals to be collected in a narrow time span, and animals can then be merchandised in the most profitable fashion. Thus, real-time ultrasound technology may encourage greater participation in later stage data collection by seedstock and commercial beef producers alike.

Literature Cited

AAA. 2001. American Angus Association home page. Available at: http://www.angus.org/sireeval/. Accessed April 19, 2001.

AICA. 2001. American-International Charolais Association home page. Available at: http://www.charolaisusa.com/AICA/Carcass_EPD/carcass_epd.htm. Accessed April 19, 2001.

AUPA. 2000. Animal Ultrasound Practitioners Association home page. Available at: http://www.asft.ttu.edu/aup/. Accessed April 19, 2001.

Arnold, J. W., J. K. Bertrand, L. L. Benyshek, and C. Ludwig. 1991. Estimates of genetic parameters for live animal ultrasound, actual carcass data, and growth traits in beef cattle. J. Anim. Sci. 69:985–992.

Benyshek, L. L., J. W. Comerford, D. E. Little, and C. Ludwig. 1988. Estimates of carcass trait genetic parameters from Hereford field data. J. Anim. Sci. 66(Suppl. 1):10 (Abstr.).

Bertrand, J. K., W. O. Herring, S. E. Williams, and L. L. Benyshek. 1993. Selection for increased marbling and decreased backfat in Angus cattle using expected progeny differences. J. Anim. Sci. 71(Suppl. 1):93 (Abstr.).

CUPC. 2000. Centralized Ultrasound Processing Center home page. Available at: http://www.exnet.iastate.edu/Pages/ansci/ultrasound/CUPbrochure.p df. Accessed April 19, 2001.

Gregory, K. E., L. V. Cundiff, and R. M. Koch. 1995. Genetic and phenotypic (co)variances for growth and carcass traits of purebred and composite populations of beef cattle. J. Anim. Sci. 73:1920–1926.

Gregory, K. E., L. V. Cundiff, R. M. Koch, M. E. Dikeman, and M. Koohmaraie. 1994. Breed effects, retained heterosis, and estimates of genetic and phenotypic parameters for carcass and meat traits of beef cattle. J. Anim. Sci. 72:1174–1183.

Hassen, A., D. E. Wilson, and G. H. Rouse. 1999. Evaluation of carcass, live, and real-time ultrasound measures in feedlot cattle: I. Assessment of sex and breed effects. J. Anim. Sci. 77:273–282.

Herring, W. O., L. A. Kriese, J. K. Bertrand, and J. Crouch. 1998. Comparison of four real-time ultrasound systems that predict intramuscular fat in beef cattle. J. Anim. Sci. 76:364–370.

IBBA. 2000. International Brangus Breeders Association home page. Available at: http://www.int-brangus.org/whatrepds.asp. Accessed April 19, 2001.

Izquierdo, M. M., D. E. Wilson, and G. H. Rouse. 1997. Estimation of genetic parameters for fat composition traits measured in live beef animals. In: Proc. BIF Research Symposium, Dickinson, ND. pp 99–101.

Johnson, M. Z., R. R. Schalles, M. E. Dikeman, and B. L. Golden. 1993. Genetic parameter estimates of ultrasound-measured longissimus muscle area and 12th rib fat thickness in Brangus cattle. J. Anim. Sci. 71:2623–2630.

Koots, K. R., J. R. Gibson, C. Smith, and J. W. Wilton. 1994. Analyses of published genetic parameter estimates for beef production traits. 1. Heritability. Anim. Breed. Abstr. 62:309–338.

Marshall, D. M. 1994. Breed differences and genetic parameters for body composition traits in beef cattle. J. Anim. Sci. 72:2745–2755.

Misztal, I. 1999. Complex models, more data: simpler programming. In: Proc. Inter. Workshop Comput. Cattle Breed. Tuusala, Finland. Interbull Bul. 20:33–42.

Moser, D. W., J. K. Bertrand, I. Misztal, L. A. Kriese, and L. L. Benyshek. 1998. Genetic parameter estimates for carcass and yearling ultrasound measurements in Brangus cattle. J. Anim. Sci. 76:2542–2548.

NALF. 2001. North American Limousin Foundation home page. Available at: http://www.nalf.org/perform/. Accessed April 19, 2001.

Pariacote, F., L. D. Van Vleck, and R. E. Hunsley. 1998. Genetic and phenotypic parameters for carcass traits of American Shorthorn beef cattle. J. Anim. Sci. 76:2584–2588.

Perkins, T. L., R. D. Green, and K. E. Hamlin. 1992. Evaluation of ultrasonic estimates of carcass fat thickness and longissimus muscle area in beef cattle. J. Anim. Sci. 70:1002–1010.

Reverter, A., D. J. Johnston, H.-U. Graser, M. L. Wolcott, and W. H. Upton. 2000. Genetic analyses of live-animal ultrasound and abattoir carcass traits in Australian Angus and Hereford cattle. J. Anim. Sci. 78:1786–1795.

Robinson, D. L., K. Hammond, and C. A. McDonald. 1993. Live animal measurement of carcass traits: estimation of genetic parameters for beef cattle. J. Anim. Sci. 71:1128–1135.

Shepard, H. H., R. D. Green, B. L. Golden, K. E. Hamlin, T. L. Perkins, and J. B. Diles. 1996. Genetic parameter estimates of live animal ultrasonic measures of retail yield indicators in yearling breeding cattle. J. Anim. Sci. 74:761–768.

Smith, M. T., J. W. Oltjen, H. G. Dolezal, D. R. Gill, and B. D. Behrens. 1992. Evaluation of ultrasound for prediction of carcass fat thickness and longissimus muscle area in feedlot steers. J. Anim. Sci. 70:29–37.

Vieselmeyer, B. A., R. J. Rasby, B. L. Gwartney, C. R. Calkins, R. A. Stock, and J. A. Gosey. 1996. Use of expected progeny differences for marbling in beef: I. Production traits. J. Anim. Sci. 74:1009–1013.

Wilson, D. E., G. H. Rouse, C. L. Hays, V. R. Amin, and A. Hassen. 1999. Carcass expected progeny differences using real-time ultrasound measures from yearling Angus bulls. J. Anim. Sci. 77(Suppl. 1):143 (Abstr.).

Wilson, D. E., R. L. Willham, S. L. Northcutt, and G. H. Rouse. 1993. Genetic parameters for carcass traits estimated from Angus field records. J. Anim. Sci. 71:2365–2370.