

Phenotypic ranges and relationships among carcass and meat palatability traits for fourteen cattle breeds, and heritabilities and expected progeny differences for Warner-Bratzler shear force in three beef cattle breeds^{1,2}

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ABSTRACT: Carcass and Warner-Bratzler shear force (WBSF) data from strip loin steaks were obtained from 7,179 progeny of Angus, Brahman, Brangus, Charolais, Gelbvieh, Hereford, Limousin, Maine-Anjou, Red Angus, Salers, Shorthorn, Simbrah, Simmental, and South Devon sires. Trained sensory panel (TSP) evaluations were obtained on 2,320 steaks sampled from contemporary groups of progeny from one to five sires of each breed. Expected progeny differences for marbling and WBSF were developed for 103 Simmental sires from 1,295 progeny, 23 Shorthorn sires from 310 progeny, and 69 Hereford sires from 1,457 progeny. Pooled phenotypic residual correlations, including all progeny, showed that marbling was lowly correlated with WBSF (−0.21) and with TSP overall tenderness (0.18). The residual correlation between WBSF and TSP tenderness was −0.68, whereas residual correlations for progeny sired by the three *Bos indicus* breeds were only

slightly different than for progeny sired by *Bos taurus* breeds. The phenotypic range of mean WBSF among sires across breeds was 6.27 kg, and the phenotypic range among breed means was 3.93 kg. Heritability estimates for fat thickness, marbling score, WBSF, and TSP tenderness, juiciness, and flavor were 0.19, 0.68, 0.40, 0.37, 0.46, and 0.07, respectively. Ranges in EPD for WBSF and marbling were −0.41 to +0.26 kg and +0.48 to −0.22, respectively, for Simmentals; −0.41 to +0.36 kg and 0.00 to −0.32, respectively, for Shorthorns; and −0.48 to +0.22 kg and +0.40 to −0.24, respectively, for Herefords. More than 20% of steaks were unacceptable in tenderness. Results of this study demonstrated that 1) selection for marbling would result in little improvement in meat tenderness; 2) heritability of marbling, tenderness, and juiciness are high; and 3) sufficient variation exists in WBSF EPD among widely used Simmental, Shorthorn, and Hereford sires to allow for genetic improvement in LM tenderness.

Key Words: Beef, Expected Progeny Differences, Genetics, Palatability, Tenderness

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Introduction

Consumers eat beef primarily for its great flavor; however, the National Beef Tenderness Study (Morgan et al., 1991) found that, except for the tenderloin, considerable variability occurred in tenderness, and a sig-

nificant proportion of LM steaks was unacceptable in tenderness. Tenderness generally is measured on the LM because it has the most total value and is expected to be acceptably tender, juicy, and flavorful. Market studies have shown that consumers were able to distinguish between varying levels of steak tenderness, and that they were willing to pay more for beef of known tenderness (Boleman et al., 1997). Lusk et al. (2001) reported that blind tests revealed that 72% of consumers preferred tender steak relative to tough steak, and, when information regarding tenderness was revealed together with a taste sample, 51% were willing to pay an average premium of \$4.06/kg for tender steaks.

Reviews of published literature on the genetic control of tenderness indicate that the heritability of Warner-Bratzler shear force (WBSF) is moderately high (29%), and the heritability of marbling is high (38%; Dikeman et al., 2000). Gregory et al. (1994) reported that the

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heritabilities of WBSF and trained sensory panel (TSP) tenderness were only 0.12 and 0.21, respectively, in a population of eight cattle breeds, but marbling and LM chemical fat were highly heritable (0.52 and 0.47, respectively). Splan et al. (2002) reported heritability estimates of 0.34 for WBSF and 0.35 for marbling. Shackelford et al. (1994) reported heritability estimates of 0.65 for calpastatin activity, 0.53 for WBSF, and 0.93 for i.m. fat content. Their genetic correlation of i.m. fat with WBSF was -0.57 , whereas the phenotypic correlation was only -0.27 (Shackelford et al., 1994).

Expected progeny differences are user-friendly tools for cattle producers in the selection for numerous traits, but until the current project, no breed association had EPD for WBSF. Therefore, our objectives in this study were to collect carcass information and measure LM WBSF on progeny of widely used sires in 14 breeds to allow breed associations to develop EPD for carcass traits and WBSF and to measure LM sensory attributes on a sample of progeny to evaluate the relationships among carcass and LM steak palatability traits.

Materials and Methods

Data were generated from the Carcass Merit Traits research project initiated in 1998 and coordinated by the National Cattlemen's Beef Association. Thirteen breed associations (14 breeds) provided 7,179 progeny from the most widely used sires within their respective breeds, primarily from commercial cow herds. One or more reference sires of each breed were used in each test herd to tie contemporary groups together for the breed being tested. Beef Improvement Federation guidelines for sire evaluation were followed (BIF, 1986). The number of progeny allowed in the project from each breed was determined by the number of registrations of the respective breeds, calculated as a proportion of the total number of cattle registered by the cooperating breed associations. Each breed association was responsible for conducting progeny testing, funding the costs of synchronizing and mating cows, blood sampling for DNA analyses, feeding and management of cattle, and determining slaughter endpoint. The selection of test herds, sires, feedlots and feedlot regimen, slaughter endpoint, and beef processing plants were at the discretion of each breed association. There were no test herds in which sires from multiple breeds were evaluated. The breed associations funded approximately 50% of the total costs of the research project, whereas the Cattlemen's Beef Board provided funds for carcass data collection, WBSF, TSP evaluations, and one-half of the DNA analysis. MetaMorphix, Inc. (Beltsville, MD) funded the other 50% of DNA analysis. The agreement with the breed associations was that the project would not be a breed comparison study; instead, the project was designed to compare and evaluate sires within breeds. Therefore, breed identity was coded to prevent associations or breeders from comparing breeds.

Each breed association was allocated a minimum of 10 sires plus additional sires based on the number of registrations for each breed. The number of allocated sires for the different breed associations ranged from 10 to 54. Carcass data and WBSF were obtained on all progeny from all sires. Yield and quality grade traits were obtained in cooperation with the USDA, AMS grading service. From progeny of one to five designated sires within each breed, TSP evaluations were conducted on LM steaks. Progeny data were accumulated over the 3.5-yr period of the project, as long as reference sires were repeated. Before, or at the time of entering the feedlot, blood samples were obtained and sent to Texas A & M (College Station) and to MetaMorphix, Inc. for DNA analysis. A small muscle tissue sample from all progeny also was obtained for DNA analysis at the time of slaughter. Analysis of DNA from sire semen, blood of progeny, and muscle tissue of progeny were used to verify animal and parent identity. Detailed carcass data were obtained after carcasses were chilled. An LM section (13th rib for WBSF and first lumbar vertebrae for TSP evaluations) was shipped overnight to Kansas State University. Steaks 2.54-cm thick were cut and vacuum-packaged. Steaks for both WBSF and TSP evaluations were aged at 1 to 2°C until 14 d post-mortem, at which time TSP steaks were frozen at -22°C and later thawed at 4°C for TSP evaluations. Steaks for WBSF determinations were cooked at 14 d post-mortem to an internal temperature of 71°C in a Blodgett forced-air, convection-gas oven (Model DFG-201; G. S. Blodgett Co., Inc., Burlington, VA) at 163°C. Internal temperatures were monitored by 30-ga., type-T copper and constantan wire thermocouple probes connected to a Doric temperature recorder (Model 205; Vas Engineering, San Francisco, CA). Steaks were turned over once at 35°C. After reaching the endpoint temperature, steaks were then cooled at 1 to 2°C for 24 h, and eight 1.27-cm diameter cores were removed parallel to the muscle fiber orientation and sheared with a Warner-Bratzler shear V-blade attached to an Instron Universal Testing Machine (Model 4201; Instron Corp., Canton, MA) with a 50-kg compression load cell and a cross-head speed of 250 mm/min. The WBSF values for eight cores were averaged and used in statistical analyses (AMSA, 1995). Steaks for descriptive attribute TSP evaluations were cooked by the same procedure as for WBSF.

After steaks for TSP evaluations reached the endpoint temperature, steaks were cut into 2.54-cm \times 1.27-cm \times 1.27-cm cubes that were placed in double boilers held at a stove-top setting of 93°C for up to 10 min before evaluations. The procedures for training and conducting the TSP were in accordance with AMSA (1995) guidelines. Duplicate samples from one steak (2.54 cm \times 1.27 cm \times 1.27 cm) were provided to panelists. Traits evaluated by the descriptive attribute TSP included myofibrillar tenderness, juiciness, beef flavor intensity, connective tissue amount, and overall tenderness (1 = extremely tough, extremely dry, extremely bland, abun-

Table 1. Mean, minimum, and maximum phenotypic values and SD for carcass and meat palatability traits

Trait	Mean	Minimum	Maximum	SD
Hot carcass weight, kg	349.9	201.8	471.7	45.32
Adjusted fat thickness, cm	1.23	0.47	3.56	0.41
LM area, cm ²	85.0	52.3	141.9	3.73
Yield grade	2.78	0.50	6.10	0.75
Marbling ^a	420	190	900	97.09
Shear force, kg	4.61	1.84	13.14	1.51
Juiciness ^b	5.6	3.3	6.8	0.45
Flavor intensity ^b	5.8	4.3	6.8	0.28
Overall tenderness ^b	5.6	1.4	7.4	1.00

^a400 = Small⁰⁰, 500 = Modest⁰⁰.

^b8 = Extremely tender, juicy, intense, or none; 7 = very tender, juicy, intense, or practically none; 6 = moderately tender, juicy, intense, or slight; 5 = slightly tender, juicy, intense, or slight; and 4 = slightly tough, dry, bland, or moderate.

dant, and extremely tough to 8 = extremely tender, extremely juicy, extremely intense, none, and extremely tender).

Analyses were performed for phenotypic and residual correlations among carcass and meat palatability traits using the GLM procedure of SAS (SAS Inst., Inc, Cary NC). The effect fitted in the model was contemporary group, which was defined by breed, gender, yearling contemporary group, pen contemporary group, and slaughter contemporary group. There were 175 contemporary groups for all traits in the study, with an average of 11.85 calves per group.

Genetic parameters were estimated in an animal model using REML procedures of MTDFREML (Boldman et al., 1995). The effects fitted in the model were the contemporary group as previously defined, the sire effect, and the additive genetic animal effect. The full relationship among the animals was included by incorporation of all available pedigree data, and 25 generations of pedigree information of the sires were used in the analyses. Six-trait analyses were conducted to estimate the heritabilities. To ensure that $-2 \log$ likelihood was the global and not a local maximum, multiple cold restarts of the MTDREML program were performed using different starting values. Convergence was assumed when the variance of $-2 \log$ likelihood value in the Simplex reached 10^{-9} for each analysis and the first four decimals of $-2 \log$ likelihood did not change.

Warner-Bratzler shear force EPD were computed using standard BLUP procedures (Henderson, 1972) under a mixed model that included a contemporary group effect (fixed) and a random sire effect plus residual. A sire-maternal grandsire pedigree was used (at least three generations if available). Contemporary groups were defined by ranch of origin, feedlot, and day of slaughter. Because cattle were the result of single synchronized AI matings, there was little variation in age within a contemporary group and none in days on feed.

Results and Discussion

The agreement among the cooperating breed associations, the Cattlemen's Beef Board, and the researchers

collaborating on this project was that the study was not to be a comparison among breeds. Breed effects are confounded with contemporary group effects because there were no multi-breed groups. Some breed associations used test herds in which the dams were of the same breeding as the sires being tested, whereas other breed associations used test herds in which the breed of dam was different than the sires being tested. Therefore, no comparisons of mean values will be made with breed name identified.

Table 1 contains mean, minimum, maximum, and SD values for carcass and meat palatability traits for all progeny in the study. The means for all carcass traits were quite acceptable for the beef industry and showed that 22.8% of the cattle had WBSF values >5.0 kg and 26.3% had TSP tenderness scores of slightly tough or tougher (<5.0). All steaks were aged to 14 d postmortem (not mechanically tenderized), cooked to a medium degree of doneness, and originated from relatively young cattle that had been managed optimally. Wulf et al. (1996) used WBSF values of >3.85 kg as unacceptable tenderness, whereas Tatum et al. (1999) used WBSF values of >4.54 kg as unacceptable tenderness based on the consensus established at the National Beef Tenderness Conference (NCBA, 1994). In our laboratory, >5.0 kg was equivalent to TSP tenderness scores of <5.0 (5 = slightly tender). Tatum et al. (1997) reported that 24% of strip loin steaks obtained in supermarkets throughout the United States and with an average post-fabrication aging interval of 20 d received panel tenderness ratings of "slightly tough" or "tougher." Our results agree closely with those of Tatum et al. (1997).

The ranking of breeds from least to greatest WBSF mean is presented in Table 2. The phenotypic range of WBSF means of progeny from sires within breeds ranged from 0.77 kg in the least variable breed to 3.0 kg in the most variable breed. In general, the ranges of sire means for WBSF were greater within the breeds ranking high and those ranking low for WBSF and were lower for those breeds ranking intermediate for WBSF. The breed ranking 14th had an especially large WBSF range and SD. The phenotypic range across breed means was quite large at 4.01 kg, whereas the range

Table 2. Mean Warner-Bratzler shear force (WBSF) and trained sensory panel scores for tenderness, flavor, and juiciness, as well as phenotypic ranges and breed SD for sires ranked from lowest to highest shear force values^a

Breed	WBSF			Overall tenderness ^{bc}			Flavor ^{bc}			Juiciness ^{bc}		
	Rank	Mean	Range, kg	SD, kg	Mean, kg	Range	SD	Mean	Range	SD	Mean	Range
1	3.75	2.47	0.81	6.21	0.76	0.46	5.88	0.77	0.25	5.71	0.71	0.43
2	3.81	1.61	0.90	—	—	—	—	—	—	—	—	—
3	3.87	2.07	0.96	—	—	—	—	—	—	—	—	—
4	3.89	1.29	0.78	5.97	1.19	0.59	5.91	0.17	0.25	5.65	0.64	0.43
5	4.17	1.02	0.82	5.84	0.96	0.83	5.93	0.26	0.23	5.81	0.29	0.37
6	4.25	0.77	0.72	—	—	—	—	—	—	—	—	—
7	4.36	1.53	0.90	5.77	0.81	0.83	5.81	0.55	0.25	5.63	0.53	0.35
8	4.40	0.96	0.75	4.78	0.51	0.62	5.94	0.54	0.25	5.70	0.59	0.44
9	4.45	1.06	1.06	5.65	0.47	0.91	5.92	0.25	0.26	5.71	0.92	0.40
10	4.51	0.88	0.09	5.87	0.78	0.65	5.86	0.48	0.26	5.72	0.57	0.39
11	4.59	1.24	0.78	—	—	—	—	—	—	—	—	—
12	4.74	3.00	0.96	5.62	0.80	0.77	5.84	0.19	0.23	5.79	0.28	0.30
13	4.75	1.90	1.05	5.43	1.24	0.94	5.84	0.22	0.22	5.55	0.34	0.33
14	7.76	2.88	1.81	3.78	1.05	1.07	5.49	0.48	0.28	5.13	0.70	0.53

^aFor sires with five or more progeny. Sire mean range across breeds for WBSF = 6.27 kg.

^bOnly breeds with ≥ 100 progeny. Sire mean ranges across breeds for tenderness, flavor, and juiciness were 3.22, 0.96, and 1.18, respectively.

^c6 = moderately tender, moderately intense flavor, or moderately juicy; 5 = slightly tender, slightly intense flavor, and slightly juicy; and 4 = slightly tough, slightly bland flavor, or slightly dry.

among sire means across breeds was a dramatic 6.27 kg. Gregory et al. (1994) reported a range of only 1.15 kg among breeds for WBSF means of LM steaks from progeny of nine purebred and three composite *Bos taurus* breeds in a controlled study in which management was the same for all breeds. Tatum et al. (1999) reported a range of 2.3 kg among 31 progeny groups when strip loin steaks were aged for 21 d. Our results indicate that there is considerable variation in WBSF of LM steaks from young cattle, even when sired by popular AI sires, managed optimally, and slaughtered at a young age.

On an eight-point scale (8 = extremely tender to 1 = extremely tough), the range in TSP overall tenderness means of steaks from progeny of sires within breeds ranged from 0.47 in the breed with the lowest sire range to 1.24 in the breed with the largest sire range (Table 2). Only breeds that had >100 progeny evaluated for TSP traits were included; therefore, TSP results are

not presented for those breeds ranking 2nd, 3rd, 6th, and 11th for WBSF. With the exception that the breed ranking 10th for WBSF ranked 3rd out of 10 for TSP tenderness, breeds ranked almost the same for WBSF as for TSP tenderness. The range for mean tenderness across breeds was 2.96, whereas the range among sires across breeds was 3.22. In contrast, Gregory et al. (1994) reported a range of only 0.92 for TSP tenderness means of LM steaks from progeny of nine purebred and three composite *Bos taurus* breeds in a controlled study.

The range for TSP flavor scores for sires within breeds was much smaller than the range for tenderness scores (Table 2). In addition, the range across breeds and the range among sires across all breeds were small compared with the range for tenderness scores, whereas the SD for all breeds were small and very similar.

The range for mean TSP juiciness scores (Table 2) for sires within breeds was larger than that for flavor,

Table 3. Residual correlations (means) among the traits of marbling, Warner-Bratzler shear force (WBSF), and trained sensory panel traits^a

Trait	Mean						
	WBSF, kg	Marbling	Myofibrillar tenderness	Juiciness	Flavor intensity	Connective tissue	Overall tenderness
WBSF, kg	—	-0.21**	-0.68**	-0.03	-0.13*	-0.65**	-0.70**
Marbling	0.15**	—	0.20**	0.21**	0.14*	0.13*	0.20**
Myofibrillar tenderness	-0.72**	0.18**	—	0.22**	0.20**	0.82**	0.98**
Juiciness	0.07	0.10*	0.12*	—	0.40**	0.09†	0.21**
Flavor	-0.14*	0.10*	0.23**	0.40**	—	0.18**	0.21**
Connective tissue	-0.73**	0.14**	0.87**	-0.02	0.22**	—	0.86**
Overall tenderness	-0.74**	0.19**	0.98**	0.09†	0.23**	0.90**	—

^aValues above the diagonal are for all progeny, whereas values below the diagonal are for only 443 *Bos indicus* progeny.

† $P < 0.10$, * $P < 0.05$, and ** $P < 0.01$.

Table 4. Heritability estimates for carcass and meat palatability traits for *Bos taurus*-sired progeny

Item	Shear force	Marbling	Fat thickness	Juiciness	Flavor intensity	Overall tenderness
Estimate	0.40	0.68	0.19	0.46	0.07	0.37

but not as large as for TSP tenderness. Rankings of breeds for TSP traits from most tender, most flavorful, and most juicy to least tender, least flavorful, and least juicy, respectively, were quite dissimilar, except that the two breeds ranking last for WBSF also ranked last for almost all traits. This result suggests that tenderness, flavor, and juiciness generally are independent traits and that breeds rank differently for them.

Table 3 contains pooled residual correlations among WBSF, marbling, and TSP evaluations. Residual correlations above the diagonal were for all progeny in the study for which there were both WBSF and sensory panel data, whereas those below the diagonal were for progeny of *Bos indicus* sires only. In general, the differences in residual correlations when all progeny were included and those when only *Bos indicus* progeny were included were minor. The only exception to this generalization was that, when all progeny were included, there was a slight negative correlation of WBSF with juiciness (-0.03) and flavor (-0.13); however, for *Bos indicus* progeny only, there was a slight positive correlation (0.10) of WBSF with these two traits.

Contemporary group was a fixed effect defined by breed, year, pen, slaughter contemporary group, and sex. Sire was random and assumed unrelated. The residual correlations can be interpreted as phenotypic correlations. The residual correlation between WBSF and TSP tenderness score when all progeny were included was -0.68 . The residual correlations of marbling with WBSF and TSP overall tenderness were significant ($P < 0.05$), but relatively low (-0.21 and $+0.20$, respectively). These correlations are somewhat lower than those in the literature and indicate that marbling is weakly related to tenderness. Shackelford et al. (1994) reported a relatively high genetic correlation between i.m. fat content and WBSF of -0.57 and a phenotypic correlation of -0.27 . Wulf et al. (1996) reported that sire means for marbling explained only 5% of the variation in sire means for WBSF within Charolais but explained 34% of the variation in sire means for WBSF within Limousin cattle. In our study, ranges of residual

correlations of marbling with tenderness within breeds ranged from -0.01 to -0.35 for WBSF and -0.03 to $+0.34$ for TSP tenderness (results not shown).

Residual correlations of marbling with flavor and juiciness were significant ($P < 0.05$), but low ($+0.14$ and $+0.21$, respectively), indicating that as marbling increases, flavor and juiciness tend to increase. Interestingly, the residual correlation between yield grade and WBSF was nearly as high as the correlation between marbling and WBSF (-0.13 vs. -0.19 ; results not shown). These results suggest that selection for increased marbling would be expected to result in only a small improvement in tenderness. Therefore, to improve both marbling and tenderness, there would need to be selection for each trait simultaneously.

Heritability estimates presented in Table 4 are for the *Bos taurus* cattle only. Information on the *Bos indicus* sired-progeny was more limited because they are a different cattle type and because previous analyses showed that heritability estimates were inflated when the *Bos indicus* cattle were included. The heritability for WBSF in our study (0.40) was similar to the values of 0.29 reported by Koots et al. (1994), 0.31 reported by Wulf et al. (1996), and 0.53 reported by Shackelford et al. (1994). Our estimate, however, is much greater than the values of 0.11 and 0.12 reported by Devitt et al. (2002) and Gregory et al. (1994). The heritability for marbling score in our study was high at 0.68 , which is lower than the value of 0.93 reported by Shackelford et al. (1994), similar to the value of 0.65 reported by Koots et al. (1994), and greater than the values of 0.43 and 0.46 reported by Devitt et al. (2002) and Nephawe et al. (2004), respectively. Heritability for fat thickness (0.19) was slightly lower than the previously reported values of 0.23 (Koots et al., 1994) and 0.26 (Wilson et al., 1993). Our heritability value for TSP juiciness of 0.46 was much greater than the value of 0.01 reported by Nephawe et al. (2004) and greater than the value of 0.24 reported by Gregory et al. (1994), whereas our low heritability value of 0.07 for TSP flavor is consistent with other reported values of 0.06 (Gregory et al., 1994).

Table 5. Examples of Warner-Bratzler shear force (WBSF) and marbling EPD for four Simmental sires from data generated in the Carcass Merit Traits project

Sire name	WBSF EPD, kg	Accuracy	Marbling EPD	Accuracy
GW Lucky Break 047G	-0.41	0.27	0.09	0.71
Circle S Leachman 600U	-0.36	0.50	0.16	0.91
GW Lucky Strike 147G	-0.06	0.14	0.48	0.80
Nichols Shannigan F5	0.26	0.38	-0.22	0.68

Table 6. Examples of Warner-Bratzler shear force (WBSF) and marbling EPD for four Shorthorn sires from data generated in the Carcass Merit Traits project

Sire name	WBSF EPD, kg	Accuracy	Marbling EPD	Accuracy
Deep Impact of Volga	-0.41	0.31	-0.32	0.47
SC Irish Mark	-0.14	0.37	-0.18	0.51
Byland Gold Spear	0.14	0.16	-0.42	0.47
HHFS Dream Weaver	0.36	0.27	0.00	0.59

and 0.05 (Nephawe et al., 2004). These results suggest that selection for improved tenderness and juiciness could result in significant progress, but selection for flavor would not result in much progress. Nonetheless, juiciness can only be measured by sensory panel evaluations of cooked steaks, and obtaining such phenotypic data is very difficult and costly.

Expected progeny differences for WBSF were calculated for 103 of the AI sires most widely used by breeders in the Simmental breed, 23 of the sires most widely used by Shorthorn breeders, and 69 of the sires most widely used by Hereford breeders. For each breed, the sires with the best and worst WBSF EPD, as well as two sires with intermediate values, were chosen for illustration purposes. Examples of the EPD for four Simmental sires are shown in Table 5. The tenderest Simmental sire had an EPD of -0.41 kg, whereas the sire that ranked lowest for tenderness had an EPD of +0.26 kg (SimTalk, 2004). If these two sires were mated randomly in a herd of cows of uniform breeding, it would be expected that WBSF values of LM steaks from progeny of GW Lucky Break would be approximately 0.67 kg less than those from Nichols Shannigan F5. It is interesting that the tenderest sire was only slightly above breed average for marbling (results not shown), and the sire ranking second in the breed for marbling was only average for WBSF EPD. These differences among sires in Tables 5, 6, and 7 for Simmental, Shorthorn, and Hereford sires, respectively, are genetic differences in contrast to the results presented in Table 2, which shows phenotypic ranges among sires within breeds. The range in EPD for the 23 Shorthorn sires was -0.41 to +0.36 (Table 6; American Shorthorn Association, 2003), which is a slightly larger range than that for Simmental sires. It is interesting that the Shorthorn sire with the most desirable WBSF EPD was considerably below average for marbling. The range in EPD for the Hereford sires was from -0.48 to +0.22 kg (Table 7). It is interesting that the Hereford sire ranking first

for WBSF (-0.48 kg) was only slightly above average in marbling (+0.12; Moser, 2004).

It must be emphasized that EPD cannot be compared across these three breeds. For example, the WBSF EPD for the most tender Simmental and Shorthorn sires were the same (-0.41), but may or may not result in the same phenotypic values when mated to similar cows in the same herd because the EPD values only indicate the deviation from breed average for WBSF. No EPD for WBSF or any measure of tenderness have been published previously in the scientific literature. Results from these three breeds demonstrate that considerable genetic difference exists among sires within breeds and that genetic progress could be made in selecting for tenderness. However, the sustainability of collecting additional tenderness data by retrieving muscle sections in commercial processing plants and the costs of conducting shear tests likely will limit further data collection for tenderness EPD development. Hopefully, DNA markers currently being marketed and/or specific genes can be identified in the future to provide a method for genetic improvement in tenderness and/or an accurate, practical method for predicting tenderness in carcasses at the time of grading can be developed to identify tenderness differences in progeny tests.

Implications

Results from this study clearly demonstrate that considerable variation exists in Warner-Bratzler shear force of longissimus muscle steaks from progeny of different breeds and from progeny among sires within breeds. It would be expected that 20 to 25% of longissimus muscle steaks from yearling finished cattle would be unacceptable in tenderness unless effective electrical stimulation, needle tenderization, and/or aging longer than 14 d are used. Selection for marbling to improve tenderness would be expected to result in only subtle improvements in tenderness in most breeds. Heritabil-

Table 7. Examples of Warner-Bratzler shear force (WBSF) and marbling EPD for four Hereford sires from data generated in the Carcass Merit Traits project

Sire name	WBSF EPD, kg	Accuracy	Marbling EPD	Accuracy
MC Ranger 9615	-0.48	0.37	0.12	0.45
Feltons Endurance 745	-0.26	0.43	0.40	0.73
XTD 6T RST TMP 9A ET	0.13	0.23	-0.24	0.50
WHR 10H Domino 512	0.22	0.29	-0.07	0.32

ity estimates and expected progeny differences for tenderness are sufficiently large in Simmental, Shorthorn, and Hereford breeds to allow breeders to begin to improve tenderness genetically.

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