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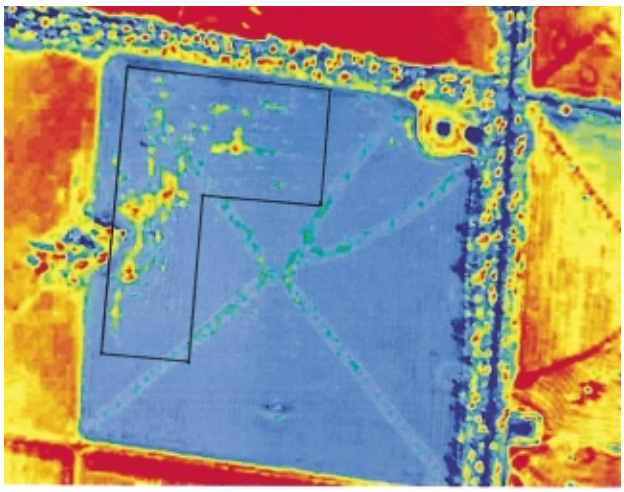

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Sources of variation in mechanical shear force measures of tenderness in beef from tropically adapted genotypes, effects of data editing and their implications for genetic parameter estimation

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Abstract. Warner-Bratzler shear force measures of tenderness were taken on 2 muscles from 2661 carcasses from 3 tropically adapted breeds: Belmont Red, Brahman and Santa Gertrudis. The data were used to determine suitable methods of editing the raw data and to partition sources of variation for meat tenderness measured in 2 different muscles. The effect of different methods of electrical stimulation was examined: non-stimulated, extra low voltage or high voltage. The results showed stimulation method had a large effect on the mean and variance of the shear force. Non-stimulated slaughter groups were more variable than high voltage treated groups, which were more variable than low voltage treated groups. The effect of stimulation method was greater for shear force measured in *M. longissimus dorsi* than in *M. semitendinosus*. The variability in tenderness associated with different methods of electrical stimulation and the larger effect seen for the *M. longissimus* muscle suggest cold shortening, a processing effect, may have occurred in some of the slaughter groups. Several methods of editing outlier records were used and the effects of removing these records on the partitioning of variances among the independent variables of tenderness were examined. Removal of non-stimulated slaughter groups and other outliers resulted in a large reduction in slaughter group variance and residual variance, with the estimate of heritability for shear force of the *M. longissimus* increasing from 19 to 39%. Beef tenderness, as measured mechanically, could be improved by selection. However, the fluctuating heritability estimates reflect differences in handling pre- and post-slaughter and thus highlight difficulties in measuring tenderness consistently. The low genetic correlation between the 2 muscles (r_g = 0.34) suggests improving overall tenderness of the carcass may be difficult. The large variance of the slaughter date effect within an abattoir (15% of the total variance) presents a problem in achieving consistently tender meat.

Introduction

Increasing the overall consistency and eating quality of beef is a goal of the Australian beef industry. Tenderness has been identified as the major contributing factor to the inconsistency of eating quality of beef (Egan *et al.* 2001). To provide tender beef consistently, an understanding of the factors that affect tenderness and how these factors can be manipulated is required. To improve tenderness by selection will require the trait to be accurately defined and consistently measured, to exhibit genetic variation and, importantly, to be highly correlated with consumer perception of tenderness. Beef tenderness can be measured objectively using mechanical shear force, which is a measure mainly of myofibrillar toughness (Bouton and Harris 1972). The *M. longissimus dorsi* (LD) is a high-value muscle but it is prone to cold shortening post mortem, a phenomenon that produces myofibrillar toughness (Shorthose 1996). Electrical stimulation decreases the potential for muscle shortening on cooling (Carse 1973). Conversely, the *M. semitendinosus* (ST) is a lower value muscle which is usually restrained from shortening when the carcass is hung by the Achilles tendon (Bouton *et al.* 1973). For genetic parameter estimation and ultimately the development of a genetic evaluation program for tenderness, the environmental influences both pre- and post-slaughter must be controlled or quantified. Robinson *et al.* (2001) reported results on the genetics of mechanically measured tenderness of the LD and ST muscles. Notable features of their analysis were the presence of considerable genetic variance for tenderness in the 3 tropically adapted breeds, and the existence of 2 highly variable slaughter groups that differed significantly from all remaining slaughter groups for mechanical measures of tenderness. The 2 groups had a mean (± s.d.) LD shear force measurement of 8.4 (± 3.0) and 7.4 (± 2.4) kg, compared with the mean of 4.3 (± 0.87) kg for the remaining slaughter groups. Inclusion of the 2 extreme groups in the analysis had little effect on the genetic variance but doubled the phenotypic variance. The reason given for the variability of the groups was ineffective electrical stimulation. Preliminary examination of additional data from

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the same project examined by Robinson *et al.* (2001) found further increased variability and greater numbers of outliers. The objectives of this study were to determine suitable methods of editing the raw data and to partition sources of variation for meat tenderness measured in 2 different muscles in tropically adapted genotypes. Implications are discussed in terms of genetic parameter estimation and strategies for controlling variation in tenderness.

Materials and methods

Mechanical measures of tenderness were obtained from cattle produced by the Cooperative Research Centre (CRC) for Cattle and Beef Quality. The experimental design and breeding program are described by Upton *et al.* (2001). In brief, the CRC project ran for 7 years (1993–99), with steer and heifer progeny being supplied from cooperating commercial herds across eastern Australia. Four temperate (Angus, Hereford, Murray Grey and Shorthorn) and 3 tropically adapted (Brahman, Belmont Red and Santa Gertrudis) breeds were represented. Results from the tropically adapted cattle are reported here. The animals were produced by artificial insemination or single sire mating in several cooperator herds. Calves were purchased from the cooperating breeders at weaning and divided into several treatment groups. Common sires were used across herds and years to create genetic linkage (for full description see Upton *et al.* 2001). Steers and heifers were backgrounded on pasture before being finished either on pasture or in a feedlot. One-third of the animals were relocated at weaning from their properties of origin in subtropical Central Queensland to the temperate region of northern New South Wales. The remainder were grown together postweaning in the Central Queensland environment. Slaughter occurred when the mean liveweight of an intake group reached the market liveweights [400 kg, Domestic; 520 kg, Korean or 600 kg, Japanese (steers only)]. Every effort was made to control and describe the slaughter procedure to enable detailed analyses of carcass and meat quality traits. Except on occasions when problems occurred with the electrical stimulation equipment, each carcass was electrically stimulated, either with low voltage (45 V for 40 s) within 5 min post slaughter (LVES), or high voltage (800 V) 30–60 min post slaughter (HVES). However, due to abattoir closures and operational difficulties, 6 different commercial abattoirs were used to process the cattle. As a result, handling, slaughter procedures (including electrical stimulation method) and chilling were not standard across abattoirs or slaughter groups.

Mechanical tenderness measures

Twenty to 24 hours post mortem, the *M. semitendinosus* and a 15 cm section of the *M. longissimus dorsi* caudal from the 12th/13th rib, were taken from the left side of the carcass and frozen immediately at –20°C for later analyses. Samples were thawed, cooked and measured for Warner-Bratzler shear force using the procedures outlined in Perry *et al.* (2001). The mean shear force for the 6 subsamples of LD (LDSF) and ST (STSF), respectively were used in all statistical analyses.

Statistical analyses

An initial series of analyses was performed to identify outliers and sources of variation for the dependant variable LDSF. Analyses included several procedures for removing data for entire slaughter groups, animals within groups and a combination of both. The effect of the editing procedure was then determined; first by examining the number of records removed and its effect on the trait mean and standard deviation, and second the effect on variance component estimates.

Variances were partitioned in univariate and bivariate REML analyses using VCE4.0 (Groeneveld and García-Cortéz 1998). The genetic component was modelled using a full animal model with a numerator relationship matrix constructed using up to 5 generations of pedigree. Environmental effects were partitioned into the random components of herd of origin and sex (HS) subclasses, slaughter group (SG) and residual. Slaughter group was defined as all animals run together from intake to slaughter and comprised intake, market, finish, abattoir and slaughter date subgroups. Intake represents a cohort of animals in the same year, season and sex. Market defined the 3 different market weight groups. Finish defined the 4 different finishing regimes of pasture and feedlot for both northern and southern finishing (see Upton *et al.* 2001). Data were pooled across the 3 breeds. Breed effects were confounded with herd of origin and, therefore, were accounted for by inclusion of the HS term in all models. Stimulation method was confounded with abattoir and slaughter date.

To further investigate the source of slaughter group variance on LDSF, 2 additional analyses were carried out. First, muscle pH at 24 h post slaughter was included in the model as a covariate, and second, the slaughter group effect was separated into its components (market, finish, stimulation method, slaughter date, and all first-order interactions) and fitted as random effects.

Bivariate analyses were performed where LVES and HVES stimulation methods were defined as a separate trait (for both LDSF and STSF). Independent variables included were the same as for the univariate analyses, with the exception that stimulation method was not required in the slaughter group definition. Finally, a bivariate analysis of LDSF and STSF was performed using the same model definition as used in the univariate analyses.

Table 1. Summary statistics for slaughter group means and standard deviations for shear force of the *M. longissimus dorsi* (LDSF) and *M. semitendinosus* (STSF) for slaughter groups with different methods of electrical stimulation

Variables[A]	No. of slaughter gps	No. of records	Mean ± s.d.	Range
All slaughter groups (Dataset 1)				
Mean LDSF	76	2661	4.60 ± 0.76	3.52–8.50
Mean STSF	75	2647	4.66 ± 0.34	3.81–5.36
s.d. LDSF	76	2661	0.94 ± 0.42	0.40–2.91
s.d. STSF	75	2647	0.53 ± 0.10	0.34–0.89
Low voltage electrical stimulation slaughter groups				
Mean LDSF	58	1834	4.41 ± 0.44	3.52–5.57
Mean STSF	57	1809	4.59 ± 0.34	3.81–5.36
s.d. LDSF	58	1834	0.80 ± 0.22	0.40–1.70
s.d. STSF	57	1809	0.52 ± 0.09	0.34–0.77
High voltage electrical stimulation slaughter groups				
Mean LDSF	15	654	4.82 ± 0.63	3.65–5.68
Mean STSF	15	664	4.84 ± 0.22	4.52–5.12
s.d. LDSF	15	654	1.14 ± 0.36	0.66–1.85
s.d. STSF	15	664	0.51 ± 0.08	0.37–0.64
Non-stimulated slaughter groups				
Mean LDSF	3	153	6.93 ± 1.79	4.97–8.50
Mean STSF	3	154	5.11 ± 0.15	4.94–5.23
s.d. LDSF	3	153	2.22 ± 0.68	1.55–2.91
s.d. STSF	3	154	0.65 ± 0.20	0.53–0.89
Low and high voltage electrical stimulation slaughter groups				
Mean LDSF	73	2488	4.49 ± 0.51	3.52–5.68
Mean STSF	72	2473	4.64 ± 0.33	3.81–5.36
s.d. LDSF	73	2488	0.87 ± 0.29	0.40–1.85
s.d. STSF	72	2473	0.52 ± 0.09	0.34–0.77

[A]Variables are within slaughter group means and standard deviations.

Results and discussion

Slaughter group statistics

Descriptive statistics for the slaughter group means and standard deviations are presented in Table 1. Results are presented for all data and for subsets of the data according to the electrical stimulation method used for each slaughter group. The complete data set (Dataset 1) comprised 76 slaughter groups with a mean slaughter group mean for LDSF of 4.60 kg, and a mean within-slaughter group standard deviation of 0.94 kg. Slaughter group means ranged from 3.52 to 8.50 kg and the within-slaughter group standard deviation ranged from 0.40 to 2.91 kg. Separating slaughter groups according to electrical stimulation methods showed HVES groups had a slightly higher mean and an increased standard deviation for LDSF compared to LVES groups. There were only 3 non-stimulated (NS) slaughter groups. They had a greater mean shear force and standard deviation compared with the stimulated groups. The STSF showed less variation across slaughter groups, with little differences evident across LVES and HVES groups for this muscle.

Removing the 3 non-stimulated slaughter groups ($n = 153$ records) reduced the LDSF within-group standard deviation from 0.94 to 0.87 kg (Table 1). An additional 15 animals were excluded that were *a priori* recorded as not being electrically stimulated (e.g. known equipment failure), these being from stimulated groups. The mean for the remaining 73 slaughter groups was 4.49 kg (range 3.52–5.68 kg), with a mean within-slaughter group standard deviation of 0.87 kg (range 0.40–1.85 kg; Table 1). Within the remaining data, large differences in means and standard deviations consequently still existed between slaughter groups. Shear force of the ST was less variable across slaughter groups and removal of the non-stimulated slaughter groups had little effect on STSF.

Effect of removing outliers by different methods

Different methods of removing LDSF records and the effect of removing these records on the variance structure of this trait were examined. In particular, the reduction of the residual variance and the maintenance of additive variance were used as key parameters in assessing the different editing strategies.

Results from this series of analyses are presented in Table 2. Partitioning of variances for Dataset 1, before any removal of outliers, revealed an additive genetic variance of 0.22 kg^2, slaughter group variance of 0.52 kg^2, HS variance of 0.038 kg^2, residual of 0.97 kg^2 and a heritability of 0.19.

Removing non-stimulated slaughter groups (Dataset 2). Removal of the 3 non-stimulated slaughter groups from Dataset 1 reduced the number of records to 2488. The mean LDSF in Dataset 2 was 4.55 kg with a standard deviation of 1.07 kg (Table 2). The reduction in total variance compared with Dataset 1 was mainly due to a large reduction in the between-slaughter group variance from 0.52 to 0.17 kg^2. The heritability estimate increased from 0.19 to 0.31. However, even with the removal of the 3 non-stimulated slaughter groups, large differences in means and standard deviations still existed between and within slaughter groups.

Removing outlier records within slaughter groups from Dataset 2 (Datasets 3 and 4). Removing the slaughter groups identified as non-stimulated illustrated the effect of these outlier groups on the variance structure. The next set of edits attempted to identify individual carcasses where electrical stimulation may have been ineffective. Dataset 2 was further edited to remove LDSF records greater than 7.5 kg (about 3 standard deviations above the mean). This resulted in the removal of 45 records, with 2443 records remaining (Dataset 3). The overall mean and standard deviation reduced slightly. The additive genetic variance and

Table 2. Means and variance components for datasets removing outlier records of shear force measures of *M. longissimus dorsi* (LDSF)

Dataset 1, all records; Dataset 2, non-stimulated records removed from Dataset 1; Dataset 3, records >7.5 kg LDSF shear force removed from Dataset 2; Dataset 4, records removed using SAS Univariate procedure from Dataset 2; Dataset 5, slaughter groups with a mean LDSF >5.0 kg removed; Dataset 6, slaughter groups with a mean LDSF >5.5 kg removed from Dataset 2; Dataset 7, slaughter groups with a s.d. >1.1 removed from Dataset 2; Dataset 8, records removed using the difference between STSF and LDSF from Dataset 2; Dataset 9, records removed from Dataset 2 using the methods used to create Datasets 4 and 6

n, number of records; n_{SG}, number of slaughter groups; V_E, residual variance; V_A, additive genetic variance; V_{SG}, slaughter group variance; V_{HS}, herd||sex variance; h^2, heritability

Dataset	n	n_{SG}	Mean ± s.d.	Range	V_E	V_A	V_{SG}	V_{HS}	h^{2A}
1	2661	76	4.70 ± 1.37	3.9–18.1	0.969	0.221	0.520	0.038	0.19
2	2488	73	4.55 ± 1.07	2.3–13.4	0.628	0.280	0.169	0.031	0.31
3	2443	73	4.47 ± 0.88	2.3–7.5	0.390	0.196	0.132	0.043	0.33
4	2424	73	4.46 ± 0.88	2.3–9.3	0.361	0.211	0.150	0.034	0.37
5	2108	62	4.39 ± 0.94	2.3–11.8	0.481	0.255	0.086	0.049	0.35
6	2335	68	4.48 ± 1.00	2.3–11.8	0.514	0.298	0.126	0.035	0.37
7	2065	63	4.41 ± 0.90	2.3–9.3	0.438	0.201	0.105	0.052	0.31
8	2341	73	4.39 ± 0.83	2.3–9.7	0.322	0.176	0.125	0.033	0.35
9	2279	68	4.40 ± 0.85	2.3–8.5	0.331	0.215	0.122	0.036	0.39

[A]Heritability was calculated as $V_A/(V_A+V_E)$.

residual variances were reduced although little change in the heritability was observed. Removal of these outlier records resulted in a large reduction in the residual variance from 0.63 to 0.39 kg^2, but still did not account for differences between slaughter group means.

The PROC Univariate procedure in SAS (SAS Institute Inc. 1988) was also used to identify potential outlier records within slaughter groups. This procedure tests for normality of the records within each slaughter group. Only records from slaughter groups that deviated significantly from normality ($P<0.10$) were removed. Box plots were used to identify outlier records (records greater than 2 interquartile ranges above the box plot). These records were then removed from Dataset 2 to produce Dataset 4. For example, one of the slaughter groups that deviated significantly from normality had 49 LDSF records with a mean (± s.d.) of 4.9 (± 1.3) kg. Two of those records were identified as outliers with LDSF values of 11.8 and 9.2 kg.

Using this procedure, 64 records were removed for Dataset 2 and the resulting residual variance was 0.36 kg^2, with a slight reduction in the additive genetic variance and a heritability of 0.37. Although this method reduced the residual variance, examination of the remaining data showed extreme records were not removed when the slaughter group mean and standard deviations were high.

Removal of outlier slaughter groups from Dataset 2 (Datasets 5, 6 and 7). Three editing procedures were used to investigate the effect of removing whole slaughter groups that were obvious outliers for LDSF. These could represent slaughter groups, for example, where electrical stimulation was applied but was ineffective. Alternatively, they may be slaughter groups that had effective stimulation but where the carcasses cooled too slowly, giving rise to rigor shortening (Devine *et al*. 1999). Dataset 2 was used as the basis for further editing. First, the 11 most extreme slaughter groups (those with a mean LDSF >5.0 kg) were removed (Dataset 5). These included 4 LVES and 7 HVES slaughter groups and accounted for 380 records. Compared with Dataset 2 this strategy reduced the additive genetic variance slightly, reduced the residual variance to 0.48 kg^2 and reduced the slaughter group variance to 0.086 kg^2. Second, only the 5 most extreme slaughter groups (those with a mean LDSF >5.5 kg) were removed (Dataset 6). This resulted in the removal of only 153 records but yielded similar variances to the previous edit. Lastly, slaughter groups with a standard deviation >1.1 kg were removed (Dataset 7). This produced results similar to the previous edits. Although all 3 methods reduced the residual variance, extremely large LDSF records still existed within some of the remaining slaughter groups.

Removal based on LD and ST shear force difference (Dataset 8). The effect of either cold shortening (ineffective ES) or rigor shortening (ES and rapid pH decline with slow cooling) is likely to be much greater in the LD compared with the ST when carcasses are hung by the Achilles tendon (Bouton *et al*. 1973). Therefore, on a within-animal basis, the difference between the shear force of the LD and the ST may identify animals whose LDSF has been affected by cold or rigor shortening. For each record in Dataset 2, the difference between the LDSF and the STSF was calculated. LDSF records were removed if this difference was significantly ($P<0.05$) larger than the mean difference of similar slaughter groups (i.e. same market, finish, sex subgroup) (Dataset 8). Removing these records (n = 147) resulted in a large reduction of both the additive genetic (from 0.28 to 0.176 kg^2) and residual (from 0.628 to 0.322 kg^2) variances. The reduction in additive genetic variance indicated this editing procedure was affecting the LDSF trait. An additional analysis showed the LD – ST difference, when considered as a trait, was heritable ($h^2 = 0.18$), and, therefore any editing done on the basis of this trait had a genetic component.

Removing outlier groups and records within groups (Dataset 9). The previous edits showed there were benefits from editing both outlier slaughter groups and individual records within slaughter groups. This last method is a combination of both methods. First, the 5 slaughter groups with means above 5.5 kg in Dataset 2 were removed and then individual records within the remaining slaughter groups were rejected using the SAS univariate procedure (Dataset 9). This resulted in the removal of 209 records, an additive variance of 0.22 kg^2, and a residual variance of 0.33 kg^2. The resultant heritability was 39%. This method resulted in the second lowest residual variance estimate, and largest heritability estimate compared with all other editing methods and, thus, formed the data set for subsequent analyses, including bivariate analyses.

Explaining between-slaughter group variance

Previous analyses identified between-slaughter group variance as the second largest source of explained variance for LDSF. Inclusion of ultimate pH (24 h post mortem) had little effect on the magnitude of slaughter group or residual variances. This is probably because both the initial pH and rate of temperature decline, as well as the ultimate pH, affects the tenderness of beef (Devine *et al.* 1999).

Variances of the known factors that contributed to the definition of slaughter group were estimated (Table 3). Market, finish and stimulation effects had only a small effect on the slaughter group and total variance of LDSF. Slaughter date effect, that includes both abattoir and day of slaughter effects, explained about 86% of slaughter group variance and 15% of the total variance of LDSF. This shows that other pre- and post-slaughter effects contributed to the variation in tenderness. One source of variation, which was not measured, that may give rise to variation in quality is the rate of cooling (Marsh *et al.* 1987).

Table 3. Factors contributing to the slaughter group variance (kg^2) of shear force measures in *M. longissimus dorsi*

n_{levels}, number of levels of each variable; % of TSG, percentage of total slaughter group variance; TV, total variance (0.71 kg^2)

Slaughter group variables	n_{levels}	Variance	% of TSG	% of TV
Market finish (MF)	12	0.010	8	1.4
Electrical stimulation (ES)	2	0.008	6	1.1
MF × ES	18	0	0	0
Slaughter date[A]	68	0.109	86	15.3
Total slaughter (TSG)		0.127		17.8

[A]Slaughter date includes the effect of intake group and abattoir nested within MF × ES.

Electrical stimulation method

Results in Table 4 show the difference between low voltage and high voltage stimulation methods. Records from LVES slaughter groups had a lower additive genetic and residual variance (0.196 and 0.296 kg^2, respectively) compared with HVES (0.368 and 0.363 kg^2). The heritability of LDSF from HVES was higher ($h^2 = 0.50$) than for LVES ($h^2 = 0.40$). Notwithstanding the low numbers for the HVES groups (n = 519), a preliminary estimate of the genetic correlation between LDSF from the 2 stimulation methods was 0.97. Variation between HVES slaughter groups was higher relative to variation between LVES groups (23 *v.* 15% of the total variance). Therefore, HVES produced more variable LDSF records. However, from the high correlation between the 2 methods, it appears that similar genes are involved in determining tenderness under the different electrical stimulation procedures.

Tenderness of the ST muscle

The data showed less variation between and within slaughter groups for STSF and therefore changing slaughter protocols and conditions may have less influence on this trait. This was evident when STSF was considered as a separate trait for records from LVES and HVES slaughter groups. Results in Table 4 show variances of similar magnitude for STSF from LVES and HVES slaughter groups, with the exception of the between-slaughter group variance for LVES. The slaughter group variance from HVES slaughter groups was more than double the variance for the LVES groups. The genetic correlation between STSF from the 2 methods of electrical stimulation was very high (0.92). STSF appears to be a more suitable measure of tenderness for genetic evaluation of mechanical tenderness as it is less influenced by the post-slaughter environment (requiring less data scrutiny) but conversely it has a much smaller additive genetic variance than LDSF. Its suitability will also depend on the genetic relationship between tenderness in this muscle and other muscles in the carcass.

Relationship between shear force of the two muscles

The genetic correlation between shear force (pooled across electrical stimulation method) in the LD and ST was 0.34. This estimate is very similar to that reported by Robinson *et al.* (2001) on a subset of this data. This low to moderate correlation can be explained by differences in connective tissue between the 2 muscles and the fact that shear force is a measure of myofibrillar rather than connective tissue toughness (Bouton and Harris 1972). This suggests that the genes contributing to tenderness in the 2 muscles may be substantially different. Therefore, to improve tenderness in both muscles, they will need to be measured and issues regarding analysis of LD data remain.

Strategies for improving tenderness

Genetics offers a means to improve beef tenderness. However, to increase consistency of tenderness, a better understanding of processing effects is required. The variance

Table 4. Summary statistics and variance components for bivariate analyses of shear force measures of *M. longissimus dorsi* (LDSF) and *M. semitendinosus* (STSF) for both low voltage (LVES) and high voltage (HVES) electrical stimulation

n, number of records; n_{SG}, number of slaughter groups; V_E, residual variance; V_A, additive genetic variance; V_{SG}, slaughter group variance; V_{HS}, herd and sex variance; h^2, heritability; r_g, genetic correlation

	n	n_{SG}	Mean ± s.d.	Range	V_E	V_A	V_{SG}	V_{HS}	h^{2A}	r_g
LDSF										
LVES	1760	56	4.34 ± 0.78	2.3–7.7	0.296	0.196	0.091	0.015	0.40	
HVES	519	12	4.59 ± 1.03	2.5–8.5	0.363	0.368	0.228	0.052	0.50	0.97
STSF										
LVES	1795	57	4.60 ± 0.62	2.8–7.2	0.194	0.093	0.097	0.002	0.32	
HVES	653	15	4.84 ± 0.56	3.5–7.0	0.172	0.110	0.036	0.004	0.39	0.92
Total[B]										
LDSF	2279	68	4.40 ± 0.85	2.3–8.5	0.330	0.216	0.122	0.036	0.40	
STSF	2448	72	4.66 ± 0.62	2.8–7.2	0.192	0.093	0.092	0.003	0.33	0.34

[A]Heritability calculated as $V_A/(V_A+V_E)$. [B]Pooled over electrical stimulation methods.

due to slaughter conditions identified in this study illustrates a problem with control of the slaughter process. Outliers identified in this study not only affect the ability to undertake genetic evaluation for beef tenderness, but also impact on consumer satisfaction. It is essential that any trait being used in a genetic evaluation system is well defined. It is therefore imperative that pre- and post-slaughter conditions are tightly controlled as it is unlikely that the data scrutiny and editing as practiced in this study would be viable in a genetic evaluation scheme. Alternative processing strategies, such as Tenderstretch, that make muscles such as the LD less prone to cold-shortening (J. M. Thompson, A. F. Egan, J. O'Halloran unpublished data) need to be evaluated to determine their influence on LDSF heritability and product uniformity. The CRC pre- and post-slaughter protocols used to generate these data from tropically adapted genotypes have yielded heritability estimates and phenotypic variances that would make genetic improvement in these mechanical measures of tenderness possible. The review of Koots *et al.* (1994) reported a mean heritability of 0.43 for Warner-Batzler shear force. Robinson *et al.* (2001), using a subset of these data, reported a heritability of 0.38. However, the additive variance and heritability for shear force in the temperate breeds in that study were only 0.06 kg^2 and 0.11, respectively. In recent studies, using genotypes with Brahman influence, Elzo *et al.* (1998) reported heritabilities ranging from 0.17 to 0.43 and Crews *et al.* (1998) reported an increase in additive variance for shear force with increasing Brahman percentage.

Before a genetic evaluation program for improving beef tenderness can be justified though, several additional steps are required. First, the cost of the measures and data collection relative to the benefits from selection will need to be quantified. Second, the relationship between mechanical measures of beef tenderness and the economically important trait of consumer-determined tenderness will need to be quantified. Finally, for a trait to be improved by selection in the absence of genetic markers or physiological characteristics that can be measured on the live animal, the seedstock sector of the beef industry will need to develop a structure to allow ongoing progeny testing of a sufficiently large number of animals that are candidates for selection.

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