Effect of Biological Type of Cattle on the Incidence of the Dark, Firm, and Dry Condition in the Longissimus Muscle[1]

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ABSTRACT: The objectives of this experiment were to characterize longissimus muscle color, texture, and firmness for beef carcasses of diverse biological types and to determine the genetic parameters of lean color, texture, and firmness. The carcasses (n = 3,641) used in this experiment were from steers produced by mating Angus, Brahman, Braunvieh, Charolais, Chianina, Galloway, Gelbvieh, Hereford, Jersey, Limousin, Longhorn, Maine Anjou, Nellore, Piedmontese, Pinzgauer, Red Poll, Sahiwal, Salers, Shorthorn, Simmental, South Devon, and Tarentaise sires to Hereford and Angus dams. Steers were fed a corn-corn silage diet from weaning until slaughter at 356 to 575 d of age. Steers were slaughtered at commercial packing plants and longissimus muscle color, texture, and firmness were scored by trained carcass evaluators. Sire line least squares means for lean color, texture, and firmness ranged approximately one unit on a 7-point scale. Chianina crosses had darker-colored lean than all breed groups except Tarentaise and Simmental crosses ($P < .05$). Moreover, a higher percentage ($P < .05$) of Chianina crosses than of all other breed groups had unacceptably dark-colored ("dark red" or darker) lean. *Bos indicus* sire lines were not different from *Bos taurus* sire lines in frequency of carcasses with unacceptably dark-colored lean. However, *Bos indicus* crosses were more likely to be scored "very light cherry-red." Lean color and texture were lowly heritable, whereas lean firmness was moderately heritable. Thus, this experiment demonstrated that there is genetic variation in the incidence of the DFD condition; however, genetic variation was small relative to environmental variation.

Key Words: Beef Breeds, Color, Firmness, Heritability, Longissimus, Texture

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Introduction

The National Beef Quality Audit revealed that 5% of federally inspected steer and heifer carcasses had the DFD condition in the longissimus muscle (Lorenzen et al., 1992). Moreover, the frequency and severity of DFD was dependent on breed type; 9.7% of dairy carcasses were DFD. Dark-cutting meat results in reduced product value because of 1) reduced quality grade (USDA, 1989), 2) decreased consumer appeal due to abnormal color (Tarrant, 1980), and 3) decreased shelf-life (Vanderzant et al., 1983). Little is known about the effect of biological type on the propensity of cattle to exhibit the DFD condition. Because the incidence of DFD fluctuates seasonally and peaks during the fall (Tarrant and Sherington, 1980), tropically-adapted (*Bos indicus*) breeds have been suspected to be more susceptible to DFD. Tyler et al. (1982) reported that Brahman crosses were less stress-susceptible than Hereford and Shorthorn steers when reared under typical Australian production systems. Lorenzen et al. (1992) reported a slightly lower incidence of DFD in *Bos indicus* than in *Bos taurus* carcasses. The present experiment investigates the effect of biological type on the incidence of the DFD condition in the longissimus muscle for carcasses from matings of 28 sire lines to Hereford and Angus dams. Additionally, genetic parameters of lean color, texture, and firmness are presented.

[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of other products that may also be suitable. The authors are grateful to Darryl Light and Patty Beska for their assistance in the execution of this experiment and to Carol Grummert for her secretarial assistance.

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Materials and Methods

Animals. The carcasses (n = 3,641) used in this experiment were from Cycles I, II, III, and IV of the Germplasm Evaluation project at the Roman L. Hruska U.S. Meat Animal Research Center (MARC). Experimental design and carcass handling procedures have been reported previously (Koch et al., 1976, 1979, 1982b; Cundiff et al., 1993). Briefly, each cycle has involved the mating of Hereford and Angus cows to sires of diverse breeds by artificial insemination. Cycle I included Hereford, Angus, Charolais, Jersey, South Devon, Simmental, and Limousin sires. Cycle II included Hereford, Angus, Red Poll, Braunvieh, Gelbvieh, Maine Anjou, and Chianina sires. Cycle III included Hereford, Angus, Brahman, Sahiwal, Pinzgauer, and Tarentaise sires. Cycle IV included Hereford, Angus, Charolais, Gelbvieh, Pinzgauer, Shorthorn, Galloway, Longhorn, Nellore, Piedmontese, and Salers sires. The same Hereford and Angus sires (sires born in 1968–70; referred to as Old Hereford and Old Angus, respectively) have been used throughout the experiment to provide control Hereford × Angus and Angus × Hereford in each cycle. Additional Hereford and Angus sires (sires born in 1982 to 1984; referred to as New Hereford and New Angus, respectively) were included in Cycle IV to evaluate genetic trends within these breeds. Charolais, Gelbvieh, and Pinzgauer were repeated in Cycle IV to facilitate comparison of breeds across the various cycles of this experiment. The Charolais sires used in Cycle IV were representative of those available in the U.S. in 1985 through 1987, whereas those used in Cycle I were representative of those available in 1969 through 1971. In Cycle IV, Angus, Hereford, and Charolais sires were used for natural service cleanup following the AI breeding season. These sires were from lines available at MARC that should not be considered to be the same as those sampled from the commercial population. Thus, there were three lines (Old, New, and MARC) of Angus, Hereford, and Charolais used in the entire experiment.

Steers were weaned at approximately 200 d of age, preconditioned for 30 d, and then fed a corn-corn silage diet until slaughter. Experimental procedures varied slightly from year-to-year to adjust for climatic conditions (e.g., in 1974 steers were weaned at 167 d of age due to drought conditions). During Cycles I and II, steers received three 12-mg diethylstilbestrol implants at the beginning of the feeding trial. During Cycles III and IV, steers were implanted with zeranol. Steers were slaughtered serially at commercial packing plants (different packing plants were used over the course of this experiment) after 169 to 329 d on feed.

Carcasses were processed according to the standard operating procedures of the commercial packing plants. Although the standard operating procedures varied from year to year, they were held constant throughout a given year. For instance, Cycle IV occurred after the adoption of electrical stimulation by the U.S. beef processing industry. Thus, all carcasses in Cycle IV were electrically-stimulated (68 V, 3 s on, 3 s off; 70 V, 2 s on, 3 s off; 70 V, 2 s on, 3 s off; 70 V, 2 s on, 3 s off) and spray-chilled (carcasses were sprayed with a fine mist of 2°C water for 30 s every 5 min until 12 h postmortem). The effects of variation in the parameters of electrical stimulation, spray-chilling, and chilling time (24 vs 48 h) before ribbing were accounted for by having year included in the statistical model. However, any interaction of year effects with genotype could not be accounted for. Following chilling, carcasses were ribbed and longissimus muscle lean color (1 = very light cherry-red, 2 = cherry-red, 3 = slightly dark, 4 = moderately dark, 5 = dark red, 6 = very dark red, 7 = black), texture (1 = very fine, 2 = fine, 3 = moderately fine, 4 = slightly fine, 5 = slightly coarse, 6 = coarse, 7 = very coarse), and firmness (1 = very firm, 2 = firm, 3 = moderately firm, 4 = slightly soft, 5 = soft, 6 = very soft, 7 = extremely soft) were scored by trained carcass evaluators. Those carcasses with lean color scores of 5 or greater were considered to be unacceptably dark.

The protocol of Cycle II dictated that certain breeds be fed longer than others (Koch et al., 1979) and, thus, resulted in steers being slaughtered during the early fall when the peak incidence of dark-cutting is known to occur (Tarrant and Sherington, 1980). All other steers were slaughtered during the warm season (mid-May to mid-August). The only carcasses with "black" colored lean (n = 8) occurred in a single slaughter group in Cycle II. Because those steers were slaughtered in October, that slaughter group was one of five slaughter groups that were omitted from the analysis to prevent confounding of genetic and environmental effects. The other four slaughter groups that were omitted from the analysis were also from Cycle II and did not represent all breed groups in that cycle.

Statistical Analysis. Data were transformed to $\log_{10}$ scale and pooled across all four cycles to allow for comparison of breeds across cycles. Traits analyzed included mean lean color, texture, and firmness scores and the frequency of each lean color score. Because few carcasses were scored as 5 and 6 for lean color, those scores were combined for frequency analyses. Thus, there were five separate frequency analyses conducted to test for the occurrence of lean color scores of 1, 2, 3, 4, and 5 or 6. The frequency of carcasses scored 5 or 6 should be indicative of breed differences in the incidence of the DFD condition. The following model was used for ANOVA: $Y_{ijkl} = \mu$ + sire line$_i$ + sire (sire line$_i$) + dam line$_j$ + age of dam$_k$ + yr of birth$_l$ + (sire line × dam line)$_{ij}$ + β_1(weaning age) + β_2(days fed). Age of dam classes were 2, 3, 4, 5 to 9, 10, 11, and 12 yr. Birth years were 1970 through 1976 and 1986 through 1990. Linear covariates were similar within each sire-line. Thus, a single covariate was fit across all sire-lines. Correlation analysis indicated that the covariates had a weak linear effect on the dependent variables. All analyses were conducted with the mixed-model, least-squares, and maximum likelihood computer program of Harvey (1972).

Results and Discussion

Sire line, sire (sire line), dam line, and year of birth affected ($P < .05$) lean color, texture, and firmness scores (Table 1). Age of dam did not affect any trait ($P > .05$). There was a sire line × dam line interaction for lean texture score; however, no logical explanation of the interaction was readily apparent (data not reported). Regressions indicated that lean color became darker with increased weaning age and time-on-feed.

Sire line least squares means for lean color, texture, and firmness ranged approximately one unit on a 7-point scale (Table 2). Steers sired by Old Angus sires produced carcasses with lean that was brighter-colored ($P < .05$) than that of all breed groups except Old Charolais, Brahman, New Angus, and Maine Anjou. Chianina crosses had darker ($P < .05$) lean than all breed groups except Tarentaise and Simmental crosses. Moreover, a higher percentage ($P < .05$) of Chianina crosses than of all other breed groups had unacceptably dark-colored lean (Table 3). Despite the dark lean color of Chianina crosses, which would suggest an abnormally high ultimate muscle pH, Chianina crosses had softer ($P < .05$) lean than all breed groups except Limousin. Wheeler (1986) reported that fullblood Chianina carcasses did not differ from Hereford × Angus carcasses in regard to lean color, texture, or firmness.

Comparison of lines (Old, New, and MARC) within Hereford, Angus, and Charolais breeds indicated that genetic trends toward darker-colored lean have occurred in each breed. Possibly selection for growth rate resulted in cattle that were more susceptible to stress. However, the relationship of growth rate to lean color seems to be minimal; sire lines that were similar in growth rate had vastly different lean color scores (e.g., Old Charolais vs Simmental). As a part of an evaluation of factors related to meat tenderness, Jeremiah et al. (1991) reported breed differences in objective colorimeter readings and ultimate pH between breed groups. However, there was no logical pattern to the ranking of the breeds for either trait. This may have been due to a confounding of breed effects with year (conducted over a 10-yr period) or

Table 1. Analysis of variance of longissimus muscle color, texture, and firmness scores

Source	df	Mean squares	F	P	Error term
Trait: lean color					
Sire line	27	.25	9.03	.00	Sire (sire line)
Sire (sire line)	570	.03	1.18	.01	Remainder
Dam line	1	.43	18.27	.00	Remainder
Age of dam	6	.03	1.37	.22	Remainder
Year of birth	11	.25	10.49	.00	Remainder
Sire line × dam line	27	.02	.92	.58	Remainder
Weaning age	1	.15	6.24	.01	Remainder
Days fed	1	.31	13.09	.00	Remainder
Remainder	2,996	.02	—	—	—
Trait: lean texture					
Sire line	27	.20	6.56	.00	Sire (sire line)
Sire (sire line)	570	.03	1.20	.00	Remainder
Dam line	1	.35	13.69	.00	Remainder
Age of dam	6	.01	.47	.83	Remainder
Year of birth	11	.66	25.62	.00	Remainder
Sire line × dam line	27	.04	1.57	.03	Remainder
Weaning age	1	.01	.28	.60	Remainder
Days fed	1	.13	5.15	.02	Remainder
Remainder	2,996	.03	—	—	—
Trait: lean firmness					
Sire line	27	.23	6.12	.00	Sire (sire line)
Sire (Sire line)	570	.04	1.47	.00	Remainder
Dam line	1	.22	8.48	.00	Remainder
Age of dam	6	.02	.93	.48	Remainder
Year of birth	11	.55	21.79	.00	Remainder
Sire line × dam line	27	.04	1.40	.08	Remainder
Weaning age	1	.01	.33	.56	Remainder
Days fed	1	.00	.00	.99	Remainder
Remainder	2,996	.03	—	—	—

sex (bulls, steers, and heifers) effects. In the present study, within-breed regression of lean color score against hot carcass weight suggested that heavier carcasses had lighter-colored lean in the longissimus muscle. However, this relationship was not significant in 23 of the 28 lines.

Bos indicus sire lines (Brahman, Sahiwal, and Nellore) ranked favorably for mean lean color score. This was due primarily to a high incidence of "very light cherry-red" ratings and was not due to a low incidence of dark-cutting (Table 3). Crouse et al. (1989) evaluated the carcass characteristics of steers that were produced from the same germplasm that was evaluated in Cycle III. They used reciprocal backcross and F_2 matings to produce steers that were 0, 25, 50, or 75% *Bos indicus*. Lean color was lightest for 25% Brahman crosses, but all other *Bos indicus* crosses had darker lean than Hereford × Angus crosses. Huffman et al. (1990) reported that steer carcasses that were 0, 25, 50, or 75% Brahman did not differ in lean color. Similarly, Wheeler et al. (1990) reported that Hereford, Hereford × Brahman, Brahman × Hereford, and Brahman steer carcasses did not differ in lean color. Tyler et al. (1982) reported that *Bos indicus* crosses were less stress-susceptible than purebred Hereford and Shorthorn steers. Their study involved the measurement of longissimus muscle pH at 24 h postmortem for cattle produced under typical Australian conditions. In a trial that involved steers that spent 2 d in transport, 27.4% of Hereford steers and 10.4% of Brahman crossbred steers had pH values above 5.9 (considered to be DFD). It should be noted that mean pH values were lower for other groups that spent longer (up to 22 d) in transport to the packing house. However, because of the vast differences in cattle production practices between the U.S. and Australia (e.g., grain vs grass feeding), the relevance of their findings to the U.S. beef industry must be questioned.

Holmes et al. (1973) demonstrated that exercise led to exhaustion more rapidly in muscle-hypertrophied than in normal cattle. Moreover, they found

Table 2. Least squares means of longissimus muscle color, texture, and firmness scores as affected by sire line[a]

Lean color[b]		Lean texture[b]		Lean firmness[b]	
Sire line	Mean	Sire line	Mean	Sire line	Mean
Old Angus	1.82^{j}	Old Angus	1.80^{j}	Jersey	1.61^{i}
Old Charolais	1.85^{ij}	MARC Angus	1.84^{ij}	Red Poll	1.68^{hi}
Brahman	1.87^{hij}	Red Poll	1.86^{hij}	MARC Angus	1.70^{hi}
New Angus	1.93^{ghij}	Old Charolais	1.87^{hij}	Longhorn	1.70^{hi}
Maine Anjou	2.01^{fghij}	South Devon	1.88^{hij}	Old Angus	1.74^{hi}
Shorthorn	2.03^{fghi}	Old Hereford	1.89^{hij}	South Devon	1.77^{hi}
Nellore	2.06^{fghi}	Limousin	1.93^{ghij}	MARC Hereford	1.79^{ghi}
Old Hereford	2.06^{fghi}	New Angus	1.94^{fghij}	Shorthorn	1.88^{fgh}
Sahiwal	2.09^{fghi}	MARC Hereford	1.96^{fghij}	Galloway	1.89^{fgh}
Salers	2.09^{fghi}	Longhorn	1.96^{fghij}	Sahiwal	1.91^{fgh}
Red Poll	2.09^{fghi}	Sahiwal	1.98^{fghij}	Salers	1.92^{fgh}
South Devon	2.09^{fgh}	Brahman	1.99^{fghij}	Nellore	1.95^{fgh}
Limousin	2.11^{fgh}	Galloway	1.99^{fghij}	New Hereford	1.99^{efgh}
Galloway	2.14^{fgh}	Braunvieh	2.02^{efghij}	Old Hereford	2.00^{efgh}
MARC Angus	2.14^{fgh}	Maine Anjou	2.03^{efghij}	New Charolais	2.00^{efgh}
MARC Charolais	2.16^{fg}	Pinzgauer	2.06^{efghi}	Pinzgauer	2.01^{efgh}
New Hereford	2.18^{efg}	Jersey	2.09^{efghi}	Braunvieh	2.03^{efgh}
Braunvieh	2.21^{efg}	New Hereford	2.10^{efghi}	Brahman	2.06^{efg}
MARC Hereford	2.23^{efg}	Shorthorn	2.13^{efgh}	Piedmontese	2.08^{efg}
Pinzgauer	2.24^{ef}	MARC Charolais	2.16^{efgh}	Maine Anjou	2.09^{efg}
Longhorn	2.26^{ef}	Salers	2.18^{efg}	Simmental	2.09^{efg}
Piedmontese	2.28^{ef}	Simmental	2.21^{ef}	Old Charolais	2.11^{efg}
New Charolais	2.29^{ef}	Gelbvieh	2.23^{e}	New Angus	2.12^{efg}
Jersey	2.30^{ef}	Tarentaise	2.32^{de}	MARC Charolais	2.13^{ef}
Gelbvieh	2.48^{e}	New Charolais	2.37^{de}	Tarentaise	2.17^{ef}
Simmental	2.53^{de}	Nellore	2.49^{d}	Gelbvieh	2.20^{e}
Tarentaise	2.54^{de}	Chianina	2.56^{d}	Limousin	2.32^{de}
Chianina	2.85^{d}	Piedmontese	2.66^{d}	Chianina	2.60^{d}
RMSE[c]	1.02	RMSE[c]	1.04	RMSE[c]	1.04

[a]Values were transformed to $\log_{10}$ scale for analysis and then back-transformed for presentation.
[b]Lean color scored as 1 = very light cherry-red, 2 = cherry-red, 3 = slightly dark, 4 = moderately dark, 5 = dark red, 6 = very dark red, 7 = black. Lean texture scored as 1 = very fine, 2 = fine, 3 = moderately fine, 4 = slightly fine, 5 = slightly coarse, 6 = firm, 7 = very coarse. Lean firmness scored as 1 = very firm, 2 = firm, 3 = moderately firm, 4 = slightly soft, 5 = soft, 6 = very soft, 7 = extremely soft.
[c]RMSE = Root mean square error. The standard error of a least squares mean can be determined by dividing the RMSE by the square root of the effective number of steers per sire line (effective numbers are listed in Table 3).
[d,e,f,g,h,i,j]Means within a column with a common superscript letter do not differ ($P > .05$).

that antemortem fasting induced the DFD condition more readily in muscle-hypertrophied cattle. Matassino et al. (1976) reported that Piedmont crosses had darker-colored lean, as determined by reflectance spectrophotometry, than Romagna, Chianina, Marche, and Red Pied Friuli crosses out of Brown Alpine and Friesian cows. In the present experiment, mean lean color score of Piedmontese crosses was not significantly different from that of all but five other sire lines. However, Piedmontese crosses did have the second-highest frequency (7.0%) of unacceptably dark lean color scores (Table 3). Piedmontese crosses, as well as other muscle-hypertrophied breeds, may provide the beef industry a unique opportunity to maximize cutability and tenderness simultaneously (Cundiff et al., 1993). Thus, management practices must be developed to minimize the incidence of dark-cutting in muscle-hypertrophied cattle. Muscle-hypertrophied cattle had decreased heart and lung weights, which could decrease their respiratory potential (Holmes and Ashmore, 1972). Halipre (1973) demonstrated that double-muscled cattle were less heat-tolerant than were normal cattle. Moreover, Halipre (1973) found that when cattle were simply moved from one building to another, rectal temperature was increased a greater amount for muscle-hypertrophied than for normal cattle. In the present experiment, all the steers were slaughtered during the warm season. Thus, heat stress may have contributed to the increased incidence of dark-cutting for Piedmontese crosses.

Piedmontese, Chianina, and Nellore crosses had more coarsely textured lean than all breed groups except Tarentaise and New Charolais crosses (Table 2). Angus had the lowest numerical lean texture score but was similar to 14 of the 27 other sire lines. Chianina had softer lean than all breed groups except Limousin. Jersey crosses had the firmest lean but were not different from Red Poll, MARC Angus, Longhorn, Old Angus, South Devon, and MARC Hereford. It is possible that differences in lean firmness were a function of differences in longissimus muscle area, because generally those lines with the largest longissimus muscle area (see Koch et al., 1976, 1979, 1982b; Cundiff et al., 1993) also had the softest lean. The exception to this trend was Piedmontese crosses, which had the largest longissimus muscle

Table 3. Effect of sire line on longissimus muscle color score distribution

Sire line	No. of steers		Lean color score[a]				
	Actual	Effective	1	2	3	4	5 and 6
Red Poll	73	51	9.4	62.7	26.9	3.1	−2.1
Braunvieh	54	42	4.6	63.5	28.4	4.3	−.8
Maine Anjou	64	47	11.2	71.7	12.5	4.7	.0
New Angus	51	42	15.8	67.8	13.5	2.4	.4
Old Angus	424	300	22.7	64.7	9.7	2.4	.5
Old Charolais	177	105	20.0	67.0	11.2	.9	.8
Old Hereford	452	292	10.9	66.1	19.3	2.9	.8
MARC Charolais	52	44	16.5	41.1	36.1	5.4	.9
New Hereford	45	40	12.0	52.0	28.6	6.5	1.0
Limousin	174	107	11.8	60.9	20.1	6.0	1.2
Jersey	131	86	3.3	61.8	30.6	2.6	1.7
Pinzgauer	276	166	8.2	59.4	21.8	8.6	2.0
South Devon	95	70	4.8	79.1	14.0	.1	2.0
Brahman	153	82	31.6	37.1	23.2	5.8	2.2
Simmental	176	103	−3.2	60.5	32.3	7.9	2.4
Sahiwal	154	84	21.1	43.2	22.8	10.3	2.6
Longhorn	104	83	11.3	47.1	32.7	6.1	2.9
New Charolais	47	42	9.6	49.8	29.8	7.7	3.0
Tarentaise	103	61	.3	52.4	33.8	10.5	3.0
MARC Angus	57	48	11.5	60.6	19.3	5.2	3.4
Salers	86	72	17.2	50.3	25.3	3.7	3.4
Nellore	101	83	20.6	46.9	22.8	6.2	3.5
Gelbvieh	180	130	3.5	47.4	38.3	7.1	3.7
Galloway	83	68	15.0	52.3	23.9	4.9	3.8
MARC Hereford	64	51	8.1	59.8	23.1	4.8	4.2
Shorthorn	98	81	14.5	65.8	12.0	3.1	4.5
Piedmontese	93	75	16.7	41.9	21.1	13.3	7.0
Chianina	74	54	−3.9	50.1	29.4	10.5	13.8
RMSE[b]	—	—	33.0	47.4	39.5	21.6	14.8

[a]Lean color scored as 1 = very light cherry-red, 2 = cherry-red, 3 = slightly dark, 4 = moderately dark, 5 = dark red, 6 = very dark red, 7 = black. No carcasses were scored 7.
[b]RMSE = Root mean square error. The standard error of a least squares mean can be determined by dividing the RMSE by the square root of the effective number of steers per sire line.

Table 4. Heritabilities and genetic and phenotypic correlations among lean quality traits[a]

	Trait		
Trait	Lean color	Lean texture	Lean firmness
Lean color	.12 (.05)	.31 (.27)	.13 (.12)
Lean texture	.60 (.24)	.14 (.05)	.34 (.30)
Lean firmness	.19 (.20)	.52 (.16)	.30 (.05)

[a]Heritabilities are shown along the diagonal, genetic correlations are shown in the lower (left) triangle, and phenotypic correlations are shown in the upper (right) triangle. Parenthetical values are standard errors of the estimates.

area but were intermediate in lean firmness. Simple correlation coefficients between longissimus muscle area and lean color were stronger for Cycles I and II (r = .24 and .28, respectively) than for Cycles III and IV (r = .09 and .02, respectively).

Lean color and texture were lowly heritable, and lean firmness was moderately heritable (Table 4). Genetic and phenotypic correlations among the lean quality traits were low to moderate. As lean color became darker, the lean became more coarsely textured and softer. The relationship between lean color and lean firmness in this experiment did not agree with the widely accepted color/firmness relationships (Judge et al., 1989). Generally, muscles with a low ultimate pH have a low water-binding capacity, appear pale, and are soft. Conversely, muscles with a high ultimate pH have a high water-binding capacity, appear dark, and are firm. In the present experiment, it is possible that other factors that affect color, such as myoglobin concentration and oxygenation state, may have varied to a greater extent than did ultimate pH. Similarly, other factors that affect longissimus muscle firmness, such as longissimus muscle area and degree of marbling, may have varied to a greater extent than did ultimate pH. However, it is impossible to determine whether that was the case because ultimate pH was not measured in this experiment.

For the carcasses in Cycles I, II, and III, Koch et al. (1982a) reported that retail product yield was highly heritable ($h^2 = .63$). Thus, it would be much simpler to select for carcass cutability than for lean color. Moreover, lean color, texture, and firmness scores were weakly related to carcass cutability (r = −.11, −.14, −.18, respectively). Therefore, lean quality would not be expected to change greatly during selection for increased leanness.

Implications

This experiment demonstrated that genetic variation exists in the propensity of cattle to produce unacceptably dark beef. However, lean color and texture were lowly heritable and, thus, rapid selection for improvement in those traits would be difficult to achieve. Control of antemortem stress remains paramount to the elimination of variation in beef lean color.

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