Characterization of Different Biological Types of Steers (Cycle IV): Wholesale, Subprimal, and Retail Product Yields[1,2]

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ABSTRACT: Carcass cut-out yields of 888 steers obtained from mating Hereford and Angus cows to Hereford or Angus (HA), Charolais (Ch), Gelbvieh (Gb), Pinzgauer (Pz), Shorthorn (Sh), Galloway (Gw), Longhorn (Lh), Nellore (Ne), Piedmontese (Pm), and Salers (Sa) sires were compared. Data were evaluated at constant age (426 d), carcass weight (324 kg), fat thickness (1.2 cm), fat trim percentage (23%), and marbling (Small^{00}) end points. Piedmontese-sired steers excelled in total retail product and fat trim percentages at all slaughter end points except at the 23% fat trim end point. At an age end point, percentage of retail product was greater in steers sired by Continental European breeds (Gb, Ch, Sa, Pz; 63.3 to 65.5% at 0 cm trim) than in steers sired by British breeds (Sh, HA; 60.1 to 61.0%). Piedmontese-sired steers, which were expected to carry one copy of a major gene for muscle hypertrophy, had the highest ($P < .05$) retail product yields at an age end point (69.7%). At an age end point, although carcass weights were significantly heavier ($P < .05$) for Charolais-sired steers than for Piedmontese-sired steers, lean growth rate, as reflected by totally trimmed retail product at 426 d, was similar ($P > .05$) for Piedmontese and Charolais-sired steers. Differences among sire breeds were small for retail product percentage at marbling, fat thickness, and fat trim end points. Ranking of sire breeds for age-constant weight of retail product was as follows: Ch, Pm, Gb, Sa, Ne, Pz, HA, Sh, Gw, and Lh. Sire breed differences in wholesale and subprimal cut yields were similar to total retail product differences. Piedmontese-sired steers produced the most muscular, leanest, and highest-yielding carcasses, and HA- and Sh-sired steers produced the fattest, lowest-yielding carcasses.

Key Words: Beef, Breeds, Carcasses, Composition, Yields

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Introduction

Breed differences in production traits are important genetic resources for improving efficiency of beef production and carcass yields and composition, because no one breed excels in all traits that are important to beef production. Diverse breeds are required to exploit heterosis and complementarity through crossbreeding and to match genetic potential with various markets, feed resources, and climates. Evaluation of carcass yields from different breeds or breed crosses is important in determining the potential value of alternative germplasm resources for profitable beef production. Considerable variation in percentages and weights of retail product and fat trim was detected among 16 sire breeds characterized in the first three cycles of the Germplasm Evaluation (**GPE**) program at the Roman L. Hruska U.S. Meat Animal Research Center (**MARC**; Koch et al., 1976, 1979, 1981, 1982b,c; Koch and Dikeman, 1977; Cundiff et al., 1986). The objective of Cycle IV research (which includes six new breeds and five breeds repeated from earlier cycles of the GPE program) was to characterize a new sample of cattle breeds representing diverse biological types for carcass yields of wholesale, subprimal, and retail cuts, fat, and bone that influence quantity and value of production.

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Materials and Methods

Animals

Hereford or Angus dams were mated by AI to 24 Angus, 24 Hereford, 28 Longhorn, 20 Piedmontese, 23 Charolais, 23 Salers, 26 Galloway, 22 Nellore, and 24 Shorthorn bulls to produce 593 steer calves. Following an AI period of about 45 d, 12 Hereford, 10 Angus, 10 Charolais, 18 Gelbvieh, and 16 Pinzgauer bulls (1 to 3 bulls per breed per year) were used for natural service clean-up matings in single-sire breeding pastures to produce 295 steer calves. These breeds were used in clean-up matings to facilitate comparisons to previous cycles of GPE. Clean-up and AI matings produced 888 steer calves in five crops (1986 to 1990). Only data from the Hereford × Angus and Angus × Hereford (**HA**) matings are presented (straightbred Hereford and straightbred Angus were not reported) to avoid confounding sire breed effects with heterosis effects. The Hereford and Angus sires were “new” (born 1982 to 1984) relative to the original Hereford and Angus sires (born 1963 to 1970) used in Cycles I to III of GPE. Clean-up (**CU**) sires also represented “new” sires but did not have the benefit of the same level of selection for growth and milk EPD as the AI sires, and, thus, data from their progeny are reported separately from data from AI sires. Sires were partially cross-classified across years. Of the 241 sires used by AI that left steer progeny, 11 left steer progeny in 4 yr, 44 left progeny in 3 yr, 106 left progeny in 2 yr, and 84 left progeny in 1 yr. Clean-up sires (66) were nested within year except for one Gelbvieh and three Pinzgauer sires that were used to produce progeny in 2 yr. The details of sire selections, matings (number of progeny per sire breed × dam breed combination), feeding, and slaughter were reported by Wheeler et al. (1996).

Fabrication Procedures

The right side of each carcass was returned from a commercial processing plant to the meat laboratory at MARC on d 2 postmortem. Wholesale rib removal and dissection was completed on all carcass sides on d 2, 3, and 4 postmortem in order to obtain ribeye steak samples for palatability evaluations by 7 d postmortem. Cut surfaces exposed by wholesale rib removal were covered with polyvinyl chloride film to reduce evaporation. The sides were dissected (10 to 12 per day within 20 d postmortem) randomly to prevent sire breed bias. The effect of day postmortem of dissection on carcass cut-out yields was not significant and, thus, was ignored in the final analyses. Sides were cut into wholesale and subprimal cuts trimmed to .76 cm of fat, lean trim, fat trim, and bone as outlined by Koch and Dikeman (1977). In addition, after weights were recorded at .76 cm of fat, cuts were totally trimmed to 0 cm of fat and all components reweighed. Retail cuts were obtained by removing any muscle edges less than 2.54 cm in thickness. Cold carcass weight was calculated as the sum of all dissected parts, times two, to avoid confounding percentage yield differences with differences in carcass side shrink caused by varying lengths of time before carcass sides were cut. The following cuts were produced according to NAMP (1990): #114A shoulder clod; #116A chuck roll; #116B chuck tender; #120 brisket; boneless, deckle-off; #109 rib, roast ready; #123A short ribs; #167A full knuckle; #168 top round; #171A gooseneck round; #190 tenderloin; side muscle off, defatted; #179 strip loin; #184 top sirloin butt; #193 flank steak; and #1100 cube steak from the deep pectoral in the chuck. The subprimal cuts with .76 cm of fat trim were all boneless except for the #179 strip loin and the #109 rib, roast-ready (Koch and Dikeman, 1977). The subprimals subsequently were trimmed to 0 cm fat trim and made boneless, if not already (#180A strip loin and #112 ribeye roll).

Lean trim was adjusted visually to 20% fat (with the aid of frequent rapid tests for fat content), and retail product was calculated to equal the sum of lean trim and subprimal cut weights. Lean trim from each side was ground through a .95-cm plate, mixed, then reground through a .48-cm plate. Duplicate 100-g random samples were taken, wrapped in cheesecloth, and frozen at –30°C. These samples were thawed, oven-dried (100°C for 24 h), and subjected to diethyl ether extraction to obtain chemical fat content (AOAC, 1985). This fat content was used to adjust the lean trim to 20% fat and, correspondingly, to adjust the fat trim from that side.

Statistical Analyses

Data were analyzed by least squares, mixed-model procedures (Harvey, 1985) considering appropriate fixed effects (sire breed, dam breed, sire breed × dam breed, birth year); random effects (sire nested within sire breed) to test sire breed; and residual variance to test other fixed effects. Estimates of heritability (h^2) and genetic correlations and standard errors were obtained from sire and residual mean squares and mean products from these mixed-model analyses (Harvey, 1985).

In addition, linear regression of traits on differences in weaning age (caused by differences in birth date) and differences in days fed (caused by serial slaughter design) were fitted simultaneously with the main effects. Steers were slaughtered serially each year, in three slaughter groups spanning 56 d in some years, or four slaughter groups spanning 63 d in other years, to provide for estimates of breed differences at age, weight, and compositional end points. The regression of traits on days fed provides a method of adjusting the age-constant sire breed means to alternative end points. The regressions were used for estimating values that would have been obtained if all animals in

Table 1. Analysis of variance (426 d of age) for carcass yield traits

		Mean squares[a]											
Source	df	Cold carcass weight, kg	Total retail product, kg	Total retail product, %	Steaks & roasts, %	Lean trim, %	Fat trim, %	Bone, %	Round retail product, %	Loin retail product, %	Rib retail product, %	Chuck retail product, %	Minor cuts retail product, %
Sire breed (SB)	11	5,378*	3,969*	460.6*	115.3*	118.5*	491.7*	9.9*	40.3*	11.1*	5.02*	45.1*	15.26*
Sire (Sire breed)	213	181*	86*	13.4*	3.4*	4.6*	17.8*	1.0*	1.5*	.4*	.18*	1.8*	.87*
Dam breed (DB)	1	7,616*	1,055*	232.7*	20.5*	115.1*	486.0*	46.1*	27.9*	4.3*	.38	20.2*	7.76*
Year (Y)	4	2,042*	299*	628.5*	31.2*	406.7*	710.1*	3.2*	55.0*	10.0*	.59*	117.6*	19.31*
SB × DB	11	280*	95	9.1	2.1	3.4	10.5	.4	1.1	.2	.14	1.3	.89
b1 (weaning age)	1	12,333*	3,609*	52.6*	9.0*	18.1*	102.5*	8.2*	16.1*	.1	.14	1.7	1.91
b2 (days fed)	1	81,293*	16,665*	1,119.9*	263.4*	297.2*	1,825.5*	85.6*	111.4*	15.3*	12.61*	53.1*	66.73*
Residual	645	154	60	8.2	1.9	3.0	11.1	.7	.9	.3	.13	1.1	.62

[a]All yield traits are those with 0 cm fat trim.
*$P < .05$.

a sire breed had been fed fewer or more days until the breed group average reached a given end point with regard to age (426 d), carcass weight (324 kg), fat thickness (1.2 cm), fat trim percentage (23%; when cuts were trimmed to 0 cm of fat cover), or marbling (Small[00]) following procedures used in previous cycles of GPE (Koch et al., 1979, 1982b). All these end points are the age-constant mean for that trait from this experiment except marbling, which had a mean of Small[11]. Each end point has merit for specific applications, but no one basis of comparison is suitable for answering all questions related to differences among sire breeds. Age-constant contrasts measure the impact of overall growth rates to selected ages. Weight-constant contrasts accentuate the differential growth rates of lean, fat, and bone in relation to differences in maturity. Fatness end points are useful for comparisons at similar physiological maturities. The percentage fat trim end point should be a more accurate comparison at a constant degree of fatness than fat thickness; however, fat thickness provides for comparisons to other experiments and other industry applications when fat thickness, but not fat trim percentage, is available. Comparisons at marbling end points are important because of the current emphasis on USDA Choice quality grade as a marketing end point.

Regressions were calculated for each sire breed. Sampling errors of regression coefficients were large, and differences among sire breed coefficients were not statistically significant. Therefore, a common regression (average of all sire breeds) would be one alternative to using the separate sire breed regressions. However, significant differences among age-constant means for sire breeds provide evidence that progeny of different sire breeds grew at different rates. The average regression represents the average growth rate. Therefore, the average regression over all sire breeds was modified by a proportionate adjustment of the sire breed mean to the general mean (μ) as follows:

$$\hat{y}_i = \frac{y_i}{y_\mu} [y_\mu + b_\mu (D - \overline{d})],$$

where $\hat{y}_i$ is the adjusted mean of the ith sire breed, y_i is the age-constant least squares mean of the ith sire breed, y_μ is the least squares mean for all sire breeds, b_μ is the average regression coefficient over all sire breeds, D is the number of days fed required to reach a given end point, and $\overline{d}$ is the average number of days fed (272.4).

The number of days fed required to reach a given end point can be derived by substituting the end point (e.g., 324 kg in the case of constant carcass weight) in the equation for y_i and solving for D. The derived D then is used in the equation for all traits other than that end point (carcass weight in this case). For each end point, an $LSD_{.05}$ was computed for all possible pair-wise contrasts, using the sire mean square as the error term and the proportionate regression coefficients for each breed, in the linear contrast procedure of Harvey (1985). Because a table of 66 contrasts for each trait was unwieldy, only the mean $LSD_{.05}$ for each trait and end point was presented for assessing significance of sire breed differences. Sire breed differences greater than the $LSD_{.05}$ were considered statistically significant ($P < .05$).

Results and Discussion

Analysis of variance indicated that sire breed, sire within sire breed, dam breed, and year were significant ($P < .05$) sources of variation for almost all traits (Table 1). Sire breed × dam breed interaction was not ($P > .05$) a significant source of variation. Linear regression of weaning age was significant ($P < .05$) for

Table 2. Sire breed least squares means for product yields at two fat trim levels adjusted to 426 days of age

Trait	Trim level	$\mu \pm$ SEM	Sire breed[a] AI HA	CU HA	AI Ch	CU Ch	CU Gb	CU Pz	Sh	Gw	Lh	Ne	Pm	Sa	LSD[b]	b1[c] ± SE	b2[c] ± SE
Cold carcass wt, kg[d]		311.2 ± .5	325.6	307.8	340.6	326.6	321.4	312.8	324.6	292.6	272.0	322.4	315.2	325.2	10.2	.339 ± .038	.408 ± .018
Product wt, kg																	
Total retail product	.76 cm	212.2 ± .3	214.6	204.8	237.6	228.2	226.0	214.6	212.4	201.2	186.2	220.8	233.4	225.8	7.4	.205 ± .025	.208 ± .012
	0 cm	195.0 ± .3	195.4	186.8	219.6	210.6	209.0	197.6	193.8	184.6	171.4	202.6	218.8	208.2	7.0	.183 ± .024	.185 ± .011
Steaks & roasts	.76 cm	127.2 ± .2	130.2	123.2	142.2	135.4	134.8	128.8	128.8	121.0	111.2	132.4	136.6	135.8	4.2	.128 ± .015	.130 ± .007
	0 cm	105.0 ± .2	106.0	100.6	118.6	112.6	112.8	106.6	105.4	99.6	92.0	109.4	116.6	113.0	3.8	.103 ± .012	.104 ± .006
Lean trim	.76 cm	85.0 ± .2	84.4	81.6	95.4	92.8	91.0	85.8	83.6	80.2	75.0	88.4	96.8	90.0	3.4	.077 ± .011	.078 ± .005
	0 cm	89.8 ± .2	89.4	86.2	101.0	98.0	96.2	90.8	88.4	85.0	79.2	93.2	102.2	95.2	3.6	.081 ± .012	.081 ± .006
Fat trim	.76 cm	60.0 ± .3	71.2	64.4	57.6	56.4	54.0	57.8	70.6	55.2	51.6	62.0	43.4	57.6	5.6	.104 ± .018	.167 ± .009
	0 cm	73.4 ± .3	86.6	78.8	71.4	70.0	67.0	71.2	85.2	68.4	63.2	76.4	54.2	71.2	6.2	.122 ± .021	.187 ± .010
Bone	.76 cm	39.2 ± .1	39.8	38.6	45.4	42.2	41.4	40.2	41.8	36.4	34.2	39.6	38.4	41.8	1.4	.031 ± .005	.032 ± .002
	0 cm	42.6 ± .1	43.4	42.0	49.2	46.0	45.0	43.8	45.4	39.6	37.4	43.0	42.0	45.4	1.6	.034 ± .005	.036 ± .002
Product, %[e]																	
Total retail product	.76 cm	68.5 ± .1	66.1	66.8	70.0	70.2	70.6	68.8	65.7	69.0	68.7	68.7	74.3	69.6	1.3	−.020 ± .008	−.047 ± .004
	0 cm	62.9 ± .1	60.2	61.0	64.8	64.9	65.5	63.4	60.1	63.3	63.3	63.2	69.7	64.2	1.4	−.022 ± .009	−.048 ± .004
Steaks & roasts	.76 cm	41.0 ± .1	40.0	40.1	41.8	41.6	42.1	41.2	39.8	41.4	41.0	41.2	43.4	41.8	.6	−.008 ± .004	−.025 ± .002
	0 cm	33.9 ± .1	32.6	32.8	35.0	34.6	35.3	34.2	32.6	34.1	34.0	34.1	37.1	34.8	.7	−.009 ± .004	−.023 ± .002
Lean trim	.76 cm	27.5 ± .1	26.1	26.7	28.2	28.6	28.5	27.6	25.9	27.6	27.7	27.6	30.9	27.8	.8	−.012 ± .005	−.022 ± .002
	0 cm	29.1 ± .1	27.6	28.2	29.8	30.3	30.2	29.2	27.4	29.2	29.3	29.1	32.6	29.4	.8	−.013 ± .005	−.025 ± .002
Fat trim	.76 cm	18.9 ± .1	21.4	20.6	16.6	16.8	16.4	18.2	21.4	18.6	18.7	18.9	13.5	17.5	1.5	.028 ± .009	.060 ± .004
	0 cm	23.3 ± .2	26.4	25.3	20.7	20.9	20.4	22.5	25.9	23.1	22.9	23.4	16.9	21.7	1.6	.031 ± .010	.061 ± .005
Bone	.76 cm	12.63 ± .03	12.29	12.61	13.37	12.98	12.98	12.97	12.92	12.45	12.62	12.34	12.23	12.88	.38	−.008 ± .002	−.013 ± .001
	0 cm	13.77 ± .04	13.40	13.74	14.53	14.16	14.12	14.10	14.06	13.59	13.78	13.45	13.38	14.04	.35	−.009 ± .003	−.013 ± .001

[a]The Hereford and Angus sires were new (born 1982 to 1984) relative to the original Hereford and Angus sires (born 1963 to 1970) used in Cycles I to III of the Germplasm Evaluation project. Clean-up (CU) sires also represented “new” sires but did not have as much selection intensity as the AI sires, and, thus, results from their progeny were reported separately. HA = Hereford × Angus and Angus × Hereford crosses, Ch = Charolais, Gb = Gelbvieh, Pz = Pinzgauer, Sh = Shorthorn, Gw = Galloway, Lh = Longhorn, Ne = Nellore, Pm = Piedmontese, Sa = Salers.

[b]Sire breed mean differences greater than the LSD were considered significant ($P < .05$).

[c]b1 = regression coefficient for weaning age, b2 = regression coefficient for days on feed.

[d]Calculated as the sum of all dissected parts from each side (× 2 to give carcass weight) to avoid confounding percentage yield differences in side shrink due to varying lengths of time before sides were cut.

[e]Expressed as a percentage of carcass weight.

most traits, and linear regression of days fed was significant ($P < .05$) for all traits.

Total Retail Product

Weight. The AI Charolais-sired steers had the heaviest ($P < .05$) carcasses and Galloway- and Longhorn-sired steers had the lightest ($P < .05$) carcasses when the data were adjusted to 426 d of age (Table 2). Carcasses from AI Charolais- and Piedmontese-sired steers produced greater ($P < .05$) weights of retail product, steaks and roasts and lean trim than carcasses from most other sire breeds. Longhorn-sired steers had the lowest ($P < .05$) weight of retail product, at .76 and 0 cm fat trim levels, followed by Galloway- and CU HA-sired steers. The AI HA-sired steers produced significantly more ($P < .05$) retail product than CU HA-sired steers. Piedmontese-sired steers had the lowest ($P < .05$) weight of fat trim, and Shorthorn- and AI HA-sired steers had the greatest ($P < .05$) weight of fat trim. Longhorn-sired steers had the lowest ($P < .05$) weight of bone, and AI Charolais-sired steers had the most ($P < .05$) bone. Weights of the components of the carcasses, of course, were associated with sire breed differences in carcass weight. Comparisons at the age end point reflect breed differences in accretion rates of retail product, fat trim, and bone to 426 d (i.e., tissue accretion per day of age).

Percentage Yields. Expressing yields as percentages of cold carcass weight at 426 d of age, rather than product weight, improved carcass yields of total retail product, steaks and roasts, and lean trim from Piedmontese-sired steers more than that of other sire breeds. This occurred at both fat trim levels. Charolais-, Gelbvieh-, and Salers-sired steers had 4 to 5% less percentage total retail product than Piedmontese-sired steers, whereas Galloway-, Pinzgauer-, Longhorn-, and Nellore-sired steers had 6 to 7% less percentage retail product than Piedmontese-sired steers. The lowest ($P < .05$) percentage yields of total retail product, steaks and roasts, and lean trim were obtained from carcasses of AI HA-, CU HA-, and Shorthorn-sired steers and were approximately 8% less than the percentage for Piedmontese-sired steers.

When the data were adjusted to a constant carcass weight of 324 kg, Piedmontese-sired steers still produced carcasses with the highest ($P < .05$) percentages of total retail product, steaks and roasts, and lean trim, regardless of trim level (Table 3). Longhorn-, Shorthorn-, CU HA-, and AI HA-sired steers yielded lower ($P < .05$) percentages of total retail product, steaks and roasts, and lean trim than most other sire breeds. The higher percentage yield of carcasses from Piedmontese-sired steers resulted in a weight of saleable product greater ($P < .05$) than those for all sire breeds except AI Charolais, despite ranking only 8th in carcass weight. Differences among sire breeds at the weight end point reflect maximum expression of variation in carcass composition. At a carcass weight end point, variation in weight of retail product is perfectly correlated with retail product expressed as a percentage of carcass weight. Variation among sire breeds in differential accretion rates of retail product, fat trim, and bone (e.g., retail product weight divided by age in days to reach the end point, Wheeler et al., 1996) maximize the variation among sire breeds for composition at weight end points relative to age or fatness end points.

Adjusting the data to 1.2 cm of fat thickness at the 12th rib resulted in AI Charolais- and Piedmontese-sired steers producing the heaviest ($P < .05$) carcasses and CU HA-, AI HA-, Longhorn-, and Galloway-sired steers producing the lightest ($P < .05$) carcasses, which were 80 to 100 kg lighter than those from Piedmontese- or AI Charolais-sired steers. At this end point, Piedmontese-sired steers also had carcasses with the highest ($P < .05$) percentages of retail product and lowest ($P < .05$) percentages of fat trim at the 0 cm trim level, whereas Shorthorn had a lower ($P < .05$) percentage of retail product than all sire breeds except Longhorn.

At a constant marbling end point (Small^{00}), CU Charolais- and Nellore-sired steers produced the heaviest ($P < .05$) carcasses and Shorthorn-, Longhorn-, and CU HA-sired steers the lightest ($P < .05$) carcasses. Piedmontese-sired steers had the highest ($P < .05$) percentages of total retail product, steaks and roasts, and lean trim. The AI HA- and Nellore-sired steers had the lowest ($P < .05$) percentages of total retail product and lower ($P < .05$) percentages of steaks and roasts than all other sire breeds except for CU Charolais.

When the data were adjusted to a constant 23% fat trim, Piedmontese carcasses were the heaviest ($P < .05$). Longhorn- and CU HA-sired steers had the lightest ($P < .05$) carcasses at the 23% fat trim end point. Few sire breed differences existed in percentage of retail product after adjusting to 23% fat trim. No significant differences ($P > .05$) occurred in yield of steaks and roasts and few differences occurred in yield of lean trim. This result indicated that the source of most of the variation in yields at age or weight constant end points was fat. LeVan et al. (1979) found that breed (Angus vs Charolais) differences in percentage of retail lean were not apparent when cattle were slaughtered at a similar percentage of the breed's average mature cow weight (similar degree of maturity).

The adjustment to 23% fat trim end point required partial extrapolation beyond the available data for Piedmontese-sired progeny. The time on feed and weight estimated for Piedmontese progeny for this end point resulted in higher sampling errors of mean estimates relative to the age-constant end point for Piedmontese. Although the prediction error variance for Piedmontese crosses was inflated by increased

Table 3. Sire breed least squares means for percentages of product at two fat trim levels adjusted to a common carcass weight, fat thickness, marbling, or fat trim percentage

		Sire breed[a]												
End point/trait[b]	Trim level	AI HA	CU HA	AI Ch	CU Ch	CU Gb	CU Pz	Sh	Gw	Lh	Ne	Pm	Sa	LSD[c]
Carcass wt, 324 kg														
Carcass weight, kg		—	—	—	—	—	—	—	—	—	—	—	—	—
Total retail product, %	.76 cm	67.0	66.6	71.7	71.1	71.3	68.9	66.4	67.8	66.0	69.3	74.6	70.3	1.3
	0 cm	61.2	60.8	66.5	65.8	66.1	63.5	60.8	62.1	60.5	63.8	70.0	65.0	1.4
Steaks & roasts, %	.76 cm	40.4	40.0	42.7	42.1	42.4	41.3	40.2	40.8	39.6	41.5	43.6	42.2	.6
	0 cm	33.0	32.7	35.8	35.1	35.6	34.2	33.0	33.5	32.6	34.4	37.2	35.2	.7
Lean trim, %	.76 cm	26.6	26.6	29.0	29.0	28.8	27.6	26.2	27.0	26.4	27.9	31.0	28.1	.8
	0 cm	28.2	28.1	30.7	30.7	30.5	29.2	27.8	28.6	27.9	29.4	32.7	29.8	.8
Fat trim, %	.76 cm	20.3	20.9	14.8	15.8	15.7	18.1	20.3	20.1	22.1	18.2	13.3	16.7	1.5
	0 cm	25.1	25.6	18.8	20.0	19.7	22.4	24.8	24.6	26.4	22.6	16.7	20.8	1.7
Bone, %	.76 cm	12.5	12.6	13.8	13.2	13.2	13.0	13.1	12.1	11.9	12.5	12.3	13.1	.4
	0 cm	13.6	13.7	15.0	14.4	14.3	14.1	14.3	13.3	13.0	13.6	13.5	14.3	.4
Fat thickness, 1.2 cm														
Carcass weight, kg		295.1	293.0	387.2	345.0	355.3	330.2	323.6	292.1	302.7	319.0	382.6	349.8	10.9
Total retail product, %	.76 cm	67.8	67.7	67.5	69.2	68.7	67.8	65.8	69.0	66.7	68.9	70.1	68.2	1.3
	0 cm	62.0	61.8	62.2	63.9	63.5	62.4	60.1	63.4	61.2	63.4	65.4	62.8	1.4
Steaks & roasts, %	.76 cm	40.9	40.6	40.5	41.1	41.1	40.7	39.8	41.4	40.0	41.3	41.3	41.1	.6
	0 cm	33.4	33.2	33.7	34.1	34.3	33.7	32.7	34.1	33.0	34.2	35.0	34.1	.7
Lean trim, %	.76 cm	27.0	27.1	27.0	28.1	27.6	27.1	25.9	27.6	26.7	27.7	28.8	27.1	.8
	0 cm	28.6	28.6	28.5	29.7	29.1	28.7	27.5	29.2	28.3	29.2	30.3	28.7	.9
Fat trim, %	.76 cm	19.1	19.4	19.4	17.9	18.5	19.4	21.3	18.5	21.2	18.7	17.0	19.1	1.5
	0 cm	23.8	24.0	23.5	22.1	22.6	23.7	25.8	23.0	25.5	23.1	20.5	23.4	1.7
Bone, %	.76 cm	12.7	12.9	12.7	12.7	12.5	12.7	12.9	12.5	12.1	12.4	11.2	12.5	.4
	0 cm	13.8	14.0	13.8	13.9	13.6	13.8	14.1	13.6	13.2	13.5	12.3	13.7	.4
Marbling, Small^{00}														
Carcass weight, kg		279.9	248.2	324.6	344.6	319.5	270.6	246.5	270.3	255.7	339.8	321.2	323.9	11.0
Total retail product, %	.76 cm	68.7	70.2	70.9	69.2	70.7	71.3	69.9	70.3	69.8	67.8	73.9	69.7	1.3
	0 cm	62.8	64.4	65.7	63.9	65.6	65.9	64.3	64.7	64.4	62.2	69.3	64.3	1.5
Steaks & roasts, %	.76 cm	41.3	41.9	42.3	41.1	42.2	42.5	42.0	42.1	41.6	40.6	43.2	41.9	.6
	0 cm	33.8	34.5	35.4	34.1	35.4	35.4	34.7	34.8	34.5	33.6	36.9	34.9	.7
Lean trim, %	.76 cm	27.4	28.3	28.6	28.1	28.6	28.7	27.8	28.2	28.2	27.1	30.7	27.8	.8
	0 cm	29.0	29.9	30.3	29.7	30.2	30.5	29.6	29.9	29.9	28.6	32.4	29.4	.9
Fat trim, %	.76 cm	17.9	15.7	15.7	17.9	16.3	15.2	15.1	16.9	17.3	20.2	13.8	17.4	1.6
	0 cm	22.6	20.4	19.7	22.1	20.3	19.4	19.6	21.3	21.5	24.7	17.2	21.6	1.7
Bone, %	.76 cm	12.9	13.6	13.6	12.7	13.0	13.6	14.1	12.8	12.9	12.1	12.1	12.9	.4
	0 cm	14.1	14.7	14.8	13.9	14.2	14.8	15.3	14.0	14.1	13.2	13.3	14.1	.4
Fat trim, 23%														
Carcass weight, kg		285.0	280.4	378.9	359.0	361.9	320.1	288.7	291.8	273.1	317.1	428.1	344.4	11.4
Total retail product, %	.76 cm	68.4	68.4	67.9	68.4	68.3	68.4	67.6	69.0	68.7	69.0	67.3	68.5	1.4
	0 cm	62.6	62.6	62.7	63.0	63.1	63.0	62.0	63.4	63.2	63.5	62.5	63.1	1.5
Steaks & roasts, %	.76 cm	41.1	41.0	40.7	40.7	40.9	41.0	40.8	41.4	41.0	41.3	39.9	41.3	.7
	0 cm	33.7	33.6	33.9	33.7	34.1	34.0	33.6	34.1	34.0	34.2	33.6	34.3	.8
Lean trim, %	.76 cm	27.2	27.4	27.2	27.7	27.4	27.4	26.8	27.6	27.7	27.7	27.4	27.2	.9
	0 cm	28.9	29.0	28.7	29.3	28.9	29.0	28.4	29.3	29.3	29.2	28.8	28.8	.9
Fat trim, %	.76 cm	—	—	—	—	—	—	—	—	—	—	—	—	—
	0 cm	—	—	—	—	—	—	—	—	—	—	—	—	—
Bone, %	.76 cm	12.9	13.1	12.8	12.5	12.3	12.9	13.5	12.5	12.6	12.4	10.5	12.6	.4
	0 cm	14.0	14.2	13.9	13.7	13.5	14.0	14.6	13.6	13.8	13.5	11.6	13.7	.4

[a]The Hereford and Angus sires were new (born 1982 to 1984) relative to the original Hereford and Angus sires (born 1963 to 1970) used in Cycles I to III of the Germplasm Evaluation project. Clean-up (CU) sires also represented "new" sires, but did not have as much selection intensity as the AI sires, and, thus, results from their progeny were reported separately. HA = Hereford × Angus and Angus × Hereford crosses, Ch = Charolais, Gb = Gelbvieh, Pz = Pinzgauer, Sh = Shorthorn, Gw = Galloway, Lh = Longhorn, Ne = Nellore, Pm = Piedmontese, Sa = Salers.

[b]Days on feed that would have been required to reach each of the end points were reported by Wheeler et al. (1996).

[c]Sire breed mean differences greater than the LSD were considered significant ($P < .05$).

days on feed to reach the 23% fat trim end point, the mean LSD for Piedmontese relative to other breed crosses was still slightly smaller than the overall mean LSD, because the number of observations for Piedmontese (n = 88) was greater than the overall average per breed (n = 63).

When adjusted to 426 d of age, total fat trim percentage was lowest ($P < .05$) from Piedmontese-sired steers and greatest ($P < .05$) from AI HA-, CU HA-, and Shorthorn-sired steers. When the data were adjusted to a constant carcass weight of 324 kg, Piedmontese-sired steers produced the lowest ($P < .05$) percentage of fat trim and Longhorn-, AI HA-, CU HA-, Shorthorn-, and Galloway-sired steers produced the highest ($P < .05$) percentages of fat trim, regardless of trim level. After adjusting the data to 1.2 cm of fat thickness at the 12th rib, Shorthorn and Longhorn had higher ($P < .05$) percentages of fat trim

Table 4. Sire breed differences in accretion of carcass components and their proportions for each additional 30 days on feed[a]

		Sire breed[b]											
Trait	μ	AI HA	CU HA	AI Ch	CU Ch	Cu Gb	CU Pz	Sh	Gw	Lh	Ne	Pm	Sa
30-d Carcass component gain[c]													
Total retail product, kg	5.5	5.6	5.3	6.3	6.0	5.9	5.6	5.5	5.3	4.9	5.8	6.2	5.9
Fat trim, kg	5.6	6.6	6.0	5.5	5.4	5.1	5.4	6.5	5.2	4.8	5.8	4.1	5.4
Bone, kg	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.0	.9	1.1	1.1	1.2
Proportions of 30-d gain[d]													
Total retail product, %	45.3	41.9	42.9	48.2	47.9	48.7	46.2	41.9	45.7	45.8	45.4	54.5	47.3
Fat trim, %	45.8	49.8	48.6	42.1	42.8	41.9	44.7	49.4	45.5	45.3	46.0	36.2	43.5
Bone, %	8.8	8.3	8.6	9.6	9.3	9.3	9.1	8.7	8.7	8.9	8.6	9.3	9.2
Change in carcass yield[e]													
Total retail product, %	−.9	−.9	−1.0	−.9	−1.0	−1.1	−.9	−1.1	−.9	−.9	−1.0	−.8	−.8
Fat trim, %	1.1	1.1	1.2	1.0	1.3	1.2	1.1	1.3	1.1	1.2	1.1	1.0	1.0
Bone, %	−.3	−.3	−.3	−.2	−.3	−.3	−.3	−.3	−.2	−.2	−.3	−.2	−.2
% USDA Choice[f]	7.9	9.5	9.8	8.1	5.6	6.1	8.3	10.0	7.9	7.7	6.1	5.9	6.1

[a]± 15 d from the mean days of age (426 d).

[b]The Hereford and Angus sires were new (born 1982 to 1984) relative to the original Hereford and Angus sires (born 1963 to 1970) used in Cycles I to III of the Germplasm Evaluation project. Clean-up (CU) sires also represented "new" sires but did not have as much selection intensity as the AI sires and, thus, results from their progeny were reported separately. HA = Hereford × Angus and Angus × Hereford crosses, Ch = Charolais, Gb = Gelbvieh, Pz = Pinzgauer, Sh = Shorthorn, Gw = Galloway, Lh = Longhorn, Ne = Nellore, Pm = Piedmontese, Sa = Salers.

[c]Calculated using the overall regressions of days fed (b2) from Table 2 by adjusting each sire breed with this equation: $(Y_i/Y_u)b_u(D - \bar{d})$, where Yi = individual sire breed mean, Yu = the overall sire breed mean, b_u = the regression for each trait on days fed and $D - \bar{d}$ = 30 d.

[d]Individual carcass component gain as a percentage of cold carcass gain from an additional 30 d on feed.

[e]Change in carcass components as a percentage of cold carcass weight after an additional 30 d on feed.

[f]Calculated as above using the regression of days fed (b2) from Table 3 of Wheeler et al. (1996).

than all other sire breeds. At a constant marbling end point, Piedmontese-sired steers had the lowest ($P < .05$) percentage of fat trim at the 0 cm trim level and a lower ($P < .05$) percentage of fat trim at the .76 cm trim level than all other sire breeds except CU Pinzgauer and Shorthorn. Nellore-sired steers had a higher ($P < .05$) percentage of fat trim at the Small^{00} end point than all other sire breeds except AI HA.

Sire breed differences in bone percentage were less apparent than differences in bone weight when adjusted to 426 d of age. Piedmontese-, Nellore-, and AI HA-sired steers had a lower ($P < .05$) percentage of bone than other sire breeds, and AI Charolais-sired steers had the highest ($P < .05$) percentage of bone. Percentage of bone was affected only slightly by adjusting the data to different end points. At the carcass weight end point, AI Charolais-sired steers still had the highest ($P < .05$) percentage bone, and at this end point, Longhorn-sired steers had a lower ($P < .05$) percentage bone than most other sire breeds. After adjusting the data to 1.2 cm of fat thickness at the 12th rib, Piedmontese-sired steers had the lowest ($P < .05$) percentage of bone, and Longhorn-sired steers had a lower ($P < .05$) percentage of bone than CU Gelbvieh-, Galloway-, and Nellore-sired steers. At a constant marbling end point, Nellore- and Piedmontese-sired steers had the lowest ($P < .05$) percentages of bone regardless of trim level. When the data were adjusted to a constant 23% fat trim, Piedmontese-sired steers had 2 to 3% less bone than any other sire breed.

Trim level (.76 or 0 cm) had little impact on sire breed yield differences partially because all sire breeds

Table 5. Variation among sire breeds for carcass yield traits

Trait	R[a]	$h^2 \pm$ SE[b]	σ_g[c]	$2R/\sigma_g$	σ_p[d]	R/σ_p
Total retail product, kg	47.4	.50 ± .12	5.78	16.40	8.17	5.80
Total retail product, %	9.6	.62 ± .13	2.44	7.87	3.11	3.09
Fat trim, %	9.5	.59 ± .13	2.77	6.86	3.61	2.63
Bone, %	1.2	.44 ± .12	.58	4.14	.88	1.36
Hot carcass weight, kg	72	.15 ± .11	10.38	13.87	26.45	2.72

[a]R = Range in sire breed means.

[b]h^2 = Heritability.

[c]σ_g = Genetic standard deviation.

[d]σ_p = Phenotypic standard deviation.

Table 6. Genetic and phenotypic correlation coefficients among fabrication yields and carcass and meat quality traits[a]

Trait	Trait 1	2	3	4	5	6	7	8	9	10	11	12	13
1. Total retail product weight	—	.31	−.26	−.06	.79	−.03	.52	−.04	−.10	−.10	−.05	−.02	−.01
2. Total retail product percentage	.80 ± .14	—	−.98	.46	−.28	−.55	.22	−.63	−.35	−.35	.06	−.12	−.10
3. Fat trim percentage	−.77 ± .24	−.98 ± .36	—	−.64	.33	.59	−.17	.65	.36	.34	−.09	.14	.12
4. Bone percentage	.30 ± .21	.47 ± .14	−.63 ± .31	—	−.33	−.47	−.11	−.41	−.25	−.15	.14	−.18	−.14
5. Hot carcass weight	.73 ± .13	.19 ± .31	−.19 ± .26	.08 ± .34	—[c]	—	—	—	—	—	—	—	—
6. Adj. fat thickness	−.29 ± .19	−.62 ± .26	.66 ± .10	−.53 ± .28	—	—	—	—	—	—	—	—	—
7. Longissimus area	.67 ± .11	.76 ± .13	−.75 ± .19	.37 ± .19	—	—	—	—	—	—	—	—	—
8. USDA yield grade	−.41 ± .17	−.76 ± .24	.78 ± .07	−.53 ± .23	—	—	—	—	—	—	—	—	—
9. Marbling score	−.24 ± .17	−.36 ± .18	.32 ± .14	−.01 ± .18	—	—	—	—	—	—	—	—	—
10. Intramuscular lipid[b]	−.01 ± .18	−.31 ± .20	.29 ± .15	−.08 ± .20	—	—	—	—	—	—	—	—	—
11. Shear force	−.14 ± .23	.28 ± .20	−.29 ± .22	.22 ± .23	—	—	—	—	—	—	—	—	—
12. Tenderness	−.13 ± .19	−.48 ± .19	.46 ± .17	−.17 ± .21	—	—	—	—	—	—	—	—	—
13. Beef flavor intensity	−.13 ± .30	−.25 ± .29	.19 ± .27	.14 ± .33	—	—	—	—	—	—	—	—	—

[a]Genetic correlation coefficients are below the diagonal; phenotypic correlation coefficients are above the diagonal.
[b]Proximate analysis of the longissimus thoracis.
[c]Genetic and phenotypic correlations among carcass and meat quality traits were reported by Wheeler et al. (1996).

averaged at least .77 cm of adjusted fat thickness at the 12th rib (Wheeler et al., 1996). On the average, retail product was reduced by 17.2 kg or 5.6% by trimming all fat compared to leaving .76 cm of fat on cuts. Nonetheless, lower mean and within-breed distribution levels for fat thickness were associated with within-breed differences for retail product yields at .76 vs 0 cm trim, especially at the weight end point (i.e., the difference was 4.6% for Piedmontese; 5.2 to 5.4% for other Continental breeds, Charolais, Gelbvieh, Pinzgauer, and Salers; and 5.6 to 5.8% for British breeds, Shorthorn, and HA).

Koch et al. (1976) reported that Charolais-sired cattle produced carcasses with a 5% advantage in age-constant total retail product over HA cattle (Cycle I of GPE) compared to 4% in our study (Cycle IV of GPE). Relative to Charolais-sired cattle in Cycle I, we found that carcass weight was increased 20 to 35 kg, retail product yield was increased 15 to 20 kg, and fat trim was increased about 10 kg in Cycle IV. Thus, the Charolais breed had become larger at slaughter since it was evaluated in Cycle I, but it had the same percentage composition. This same trend also occurred for HA-sired steers. Other research showed that Piedmontese-sired steers had lower fat thickness and percentage of carcass fat than Gelbvieh-sired steers, which had lower fat thickness and percentage of carcass fat than Red Angus-sired steers (Tatum et al., 1990). They also reported that longissimus area and percentage carcass muscle were greater in Piedmontese- than in Gelbvieh-sired steers, which had greater percentages than Red Angus-sired steers at similar carcass weights. Purchas et al. (1992) reported that young Piedmontese × Friesian bulls had heavier carcasses, higher dressing percentages, and higher percentages of total meat yield and yield of individual cuts than Friesian bulls.

The incidence of double-muscling is reported to be high in the Piedmontese breed (Masoero, 1982). Piedmontese bulls used in this experiment are thought to be homozygous carriers of the double-muscle gene. Double-muscling can have dramatic effects on lean meat yield of carcasses from homozygous cattle (Lawrie et al., 1964; Oliver and Cartwright, 1968; Hanset and Michaux, 1985; Charlier et al., 1995). Although greatly reduced relative to homozygotes, heterozygotes generally are more heavily muscled than noncarriers (Arthur, 1995).

Damon et al. (1960) reported that percentage of fat in the 9-10-11th rib section was lower in carcasses from Charolais-sired steers than in carcasses from HA- and Shorthorn-sired steers. In Cycle II of GPE, Koch et al. (1979) reported that Gelbvieh-sired steers had a 3.5% advantage in retail product yield and 4% advantage in fat trim compared with HA-sired steers. In our study, Gelbvieh had a 4% advantage in retail product yield and 5% less fat trim than HA-sired steers; however, Gelbvieh-sired steers were 38 kg heavier in Cycle II than in our study. In Cycle III, Koch et al. (1982b) reported that Pinzgauer-sired steers had 3% greater retail product and 4% less fat trim than HA-sired steers, whereas in our study, those differences were 2% and 3%, respectively. In Cycle III, Pinzgauer- and HA-sired steers were similar in carcass weight at a constant age.

Time on Feed. Based on the regression of days fed, each 30 d additional time on feed (± 15 d from the average days of age, 426) resulted, on average, in an additional 12.2 kg carcass weight, of which 5.5 kg was totally trimmed retail product, 5.6 kg was fat trim, and 1.1 kg was bone (Table 4). Sire breed differences in accretion rates of carcass components during an additional 30 d on feed were fairly small and related to sire breed differences that already existed at 426 d of age (Table 2). At this point in their growth curves, only Piedmontese-sired steers were partitioning more than half (54.5%) of their carcass gain to retail product. Shorthorn- and AI HA-sired steers were partitioning 41.9% of gain to retail product and almost 50% to fat trim. However, when expressed as the change in carcass yield, all sire breeds had about 1% less retail product, 1.1% more fat trim, and .3% less bone after an additional 30 d on feed. Concurrent with the decreased yields with 30 d additional time on feed, the percentage of carcasses grading USDA Choice was increased. This increase was greatest for Shorthorn-sired steers (10.0%) and least for CU Charolais-sired steers (5.6%). The decreased carcass yields must be balanced with the increased percentage of Choice carcasses and the cost of gain to determine optimal slaughter end point. Thus, these data could be useful for determining the most economical slaughter point for the various sire breeds. Furthermore, these data also indicate that sire breed differences in economically important traits may be more important than decisions on how long to feed.

Heritabilities and Variation

The range of differences among sire breed means (**R**) from topcross progeny assesses half of the breed differences (Table 5). Thus, R was doubled to assess variation among pure breeds relative to genetic variation within breed (σ_g). However, phenotypic variation (σ_p) was expressed without doubling R, thus representing phenotypic variation for F_1 progeny out of similar dams. Estimates of within-breed heritabilities for carcass yield traits were all moderately high. These estimates are similar to those previously reported by Koch et al. (1982a) for Cycles I to III of GPE for percentage of retail product (h^2 = .63), percentage of fat trim (h^2 = .57), and percentage of bone (h^2 = .53). Other heritability estimates of retail product percentage in the literature are generally slightly lower: .40 (Cundiff et al., 1964); .50 (Gregory et al., 1994); .45 (Shackelford et al., 1994); and .47 (Gregory et al., 1995). The h^2 of retail product weight (.50) was slightly lower than those reported by Cundiff (1971) and Koch et al. (1982a), h^2 = .64 and .58, respectively. Heritabilities of percentages of fat trim and bone were similar to or slightly higher than values reported previously: .35 and .21 (Gregory et al., 1995) and .57 and .53 (Koch et al., 1982a), respectively.

Genetic standard deviations indicate that relatively more variation in retail product weight occurred among than within sire breeds (Table 5). Because for any given breed the mean ± $3\sigma_g$ is expected to include about 99% of the distribution, the range for within-breed additive genetic variation is approximated by $6\sigma_g$ (Cundiff et al., 1986). The range among sire breed means was about 2.7 times greater than the range expected within sire breeds (i.e., 16.4 vs $6\sigma_g$). However, percentage of retail product and percentage

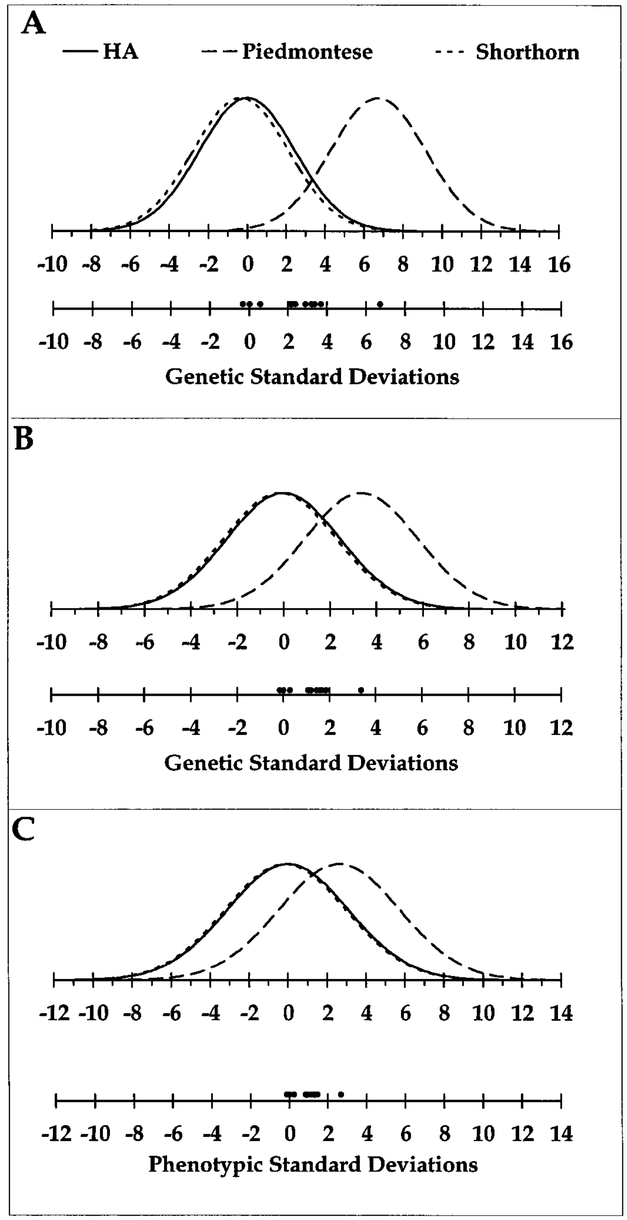

Figure 1. Genetic and phenotypic variation among and within sire breeds for boneless percentage of retail product at 0 cm fat trim. Curves for Shorthorn (lowest percentage of retail product), Piedmontese (highest percentage of retail product), and AI Hereford and Angus reciprocal crosses (HA) are shown. The HA was set to zero. Differences are expressed in standard deviation units as deviations from HA. Mean retail product yield deviations from HA for the other sire breeds are plotted immediately below the curves (ranking from lowest to highest: HA sired by clean-up (CU) bulls, Nellore, Longhorn, Galloway, CU Pinzgauer, Salers, AI Charolais, CU Charolais, and CU Gelbvieh. (A) Potential genetic variation among and within purebred progeny was obtained by doubling the differences in F_1 progeny. Genetic SD was 2.44%. (B) Genetic variation among and within sire breeds of F_1 progeny. Genetic SD was 2.44%. (C) Phenotypic variation among and within sire breeds of F_1 progeny. Phenotypic SD was 3.11%.

Table 7. Effect of sire breed on least squares means for wholesale cut components as a percentage of carcass weight at two fat trim levels adjusted to 426 days of age

Trait, %	Trim level	$\mu \pm$ SEM	Sire breed[a] AI HA	CU HA	AI Ch	CU Ch	CU Gb	CU Pz	Sh	Gw	Lh	Ne	Pm	Sa	LSD[b]
Wholesale round		23.73 ± .04	23.45	23.38	24.74	24.17	23.70	23.65	23.39	23.65	23.02	23.91	24.41	24.28	.41
Total retail product	.76 cm	18.14 ± .04	17.51	17.53	19.05	18.67	18.40	18.12	17.46	18.12	17.82	18.42	19.77	18.76	.44
	0 cm	16.86 ± .04	16.10	16.14	17.84	17.49	17.25	16.88	16.17	16.83	16.62	17.10	18.82	17.52	.47
Steaks & roasts	.76 cm	13.34 ± .03	12.97	12.90	13.90	13.61	13.62	13.34	12.89	13.21	13.15	13.67	14.49	13.79	.31
	0 cm	12.06 ± .03	11.55	11.50	12.69	12.43	12.46	12.09	11.60	11.92	11.95	12.35	13.53	12.55	.33
Lean trim	.76 cm	4.80 ± .02	4.54	4.63	5.15	5.06	4.79	4.78	4.57	4.91	4.68	4.75	5.28	4.97	.18
	0 cm	4.80 ± .02	4.54	4.64	5.15	5.06	4.79	4.79	4.58	4.92	4.68	4.75	5.28	4.97	.18
Fat trim	.76 cm	1.69 ± .02	2.13	2.01	1.42	1.43	1.28	1.50	1.92	1.72	1.38	1.61	.86	1.52	.22
	0 cm	2.96 ± .02	3.53	3.39	2.62	2.61	2.43	2.74	3.19	3.01	2.57	2.93	1.81	2.75	.26
Bone	.76 cm	3.90 ± .01	3.82	3.85	4.28	4.07	4.01	4.04	4.02	3.80	3.82	3.88	3.78	4.00	.11
	0 cm	3.90 ± .01	3.82	3.85	4.27	4.07	4.01	4.03	4.02	3.80	3.81	3.87	3.78	3.99	.11
Wholesale loin		14.04 ± .02	14.18	14.08	13.96	13.96	14.02	13.96	13.91	14.11	14.09	14.04	13.92	14.13	.24
Total retail product	.76 cm	10.36 ± .02	10.07	10.13	10.60	10.57	10.67	10.45	9.98	10.46	10.53	10.52	11.11	10.63	.22
	0 cm	8.86 ± .02	8.46	8.54	9.17	9.11	9.23	9.00	8.46	8.90	9.00	9.02	9.84	9.17	.23
Steaks & roasts	.76 cm	7.92 ± .02	7.76	7.73	8.07	8.03	8.08	7.97	7.67	8.12	8.05	7.97	8.29	8.12	.16
	0 cm	5.89 ± .01	5.64	5.66	6.07	6.03	6.13	6.00	5.64	5.97	5.97	5.97	6.42	6.11	.15
Lean trim	.76 cm	2.45 ± .01	2.31	2.40	2.54	2.54	2.59	2.47	2.31	2.34	2.48	2.54	2.82	2.52	.12
	0 cm	2.98 ± .01	2.82	2.88	3.10	3.08	3.10	3.00	2.82	2.92	3.03	3.05	3.42	3.07	.13
Fat trim	.76 cm	2.20 ± .02	2.68	2.48	1.80	1.86	1.82	2.00	2.43	2.19	2.05	2.05	1.39	1.99	.21
	0 cm	3.27 ± .02	3.87	3.65	2.79	2.89	2.84	3.05	3.53	3.32	3.11	3.13	2.25	3.02	.24
Bone	.76 cm	1.48 ± .01	1.44	1.47	1.55	1.53	1.52	1.50	1.50	1.46	1.52	1.47	1.42	1.51	.06
	0 cm	1.89 ± .01	1.85	1.89	1.99	1.94	1.94	1.90	1.92	1.89	1.97	1.88	1.83	1.93	.07
Wholesale rib		8.72 ± .02	8.86	8.66	8.61	8.62	8.68	8.64	8.60	8.78	8.80	8.82	8.88	8.78	.18
Total retail product	.76 cm	6.80 ± .01	6.66	6.58	6.92	6.91	6.92	6.80	6.55	6.89	6.98	6.88	7.36	6.99	.15
	0 cm	5.50 ± .02	5.30	5.23	5.66	5.59	5.66	5.50	5.22	5.59	5.69	5.55	6.20	5.70	.16
Steaks & roasts	.76 cm	5.51 ± .01	5.43	5.40	5.57	5.57	5.61	5.56	5.39	5.65	5.64	5.39	5.74	5.68	.11
	0 cm	3.17 ± .01	3.07	3.06	3.26	3.17	3.26	3.18	3.07	3.28	3.30	3.09	3.45	3.30	.09
Lean trim	.76 cm	1.28 ± .01	1.22	1.18	1.34	1.33	1.31	1.24	1.16	1.24	1.34	1.49	1.61	1.31	.08
	0 cm	2.32 ± .01	2.23	2.17	2.40	2.42	2.40	2.32	2.16	2.32	2.39	2.47	2.75	2.39	.10
Fat trim	.76 cm	1.42 ± .01	1.74	1.58	1.19	1.22	1.25	1.33	1.55	1.40	1.32	1.41	1.03	1.28	.14
	0 cm	1.99 ± .02	2.38	2.19	1.70	1.77	1.78	1.88	2.16	1.98	1.89	2.03	1.45	1.83	.17
Bone	.76 cm	.50 ± .003	.47	.50	.51	.49	.50	.51	.50	.50	.51	.53	.49	.51	.03
	0 cm	1.21 ± .005	1.16	1.21	1.23	1.25	1.22	1.23	1.21	1.20	1.21	1.22	1.22	1.24	.05
Wholesale chuck		25.81 ± .04	25.42	25.76	25.83	25.64	26.53	25.99	25.59	26.16	25.93	25.74	26.33	25.91	.37
Total retail product	.76 cm	19.43 ± .05	18.66	18.92	19.69	19.67	20.45	19.64	18.61	19.78	19.79	19.73	21.27	19.70	.50
	0 cm	18.71 ± .05	17.93	18.18	19.02	19.00	19.75	18.93	17.85	19.02	19.07	19.04	20.66	18.99	.50
Steaks & roasts	.76 cm	10.74 ± .02	10.46	10.49	10.87	10.78	11.26	10.87	10.46	10.95	10.84	10.77	11.37	10.90	.25
	0 cm	10.01 ± .02	9.73	9.74	10.18	10.10	10.55	10.15	9.69	10.19	10.11	10.07	10.75	10.18	.25
Lean trim	.76 cm	8.69 ± .03	8.20	8.43	8.83	8.90	9.19	8.77	8.15	8.83	8.95	8.97	9.90	8.81	.33
	0 cm	8.70 ± .03	8.20	8.44	8.83	8.90	9.20	8.78	8.16	8.83	8.96	8.97	9.90	8.81	.33
Fat trim	.76 cm	2.64 ± .04	3.11	3.10	2.22	2.18	2.21	2.52	3.17	2.63	2.37	2.42	1.44	2.37	.35
	0 cm	3.37 ± .01	3.85	3.85	2.91	2.86	2.92	3.24	3.94	3.40	3.11	3.11	2.05	3.10	.36
Bone	.76 cm	3.73 ± .01	3.63	3.72	3.90	3.77	3.85	3.81	3.80	3.74	3.76	3.58	3.62	3.82	.13
	0 cm	3.73 ± .01	3.64	3.72	3.90	3.78	3.86	3.82	3.80	3.74	3.76	3.58	3.62	3.82	.13

Minor cuts^c		24.64 ± .05	25.28	25.38	23.80	24.45	24.01	24.48	25.27	24.30	24.40	24.23	23.56	23.76	.47
Total retail product	.76 cm	13.72 ± .03	13.40	13.64	13.75	14.42	14.20	13.81	13.13	13.71	13.61	13.19	14.77	13.51	.34
	0 cm	13.01 ± .03	12.66	12.87	13.11	13.72	13.56	13.11	12.37	13.00	12.93	12.45	14.18	12.87	.35
Steaks & roasts	.76 cm	3.47 ± .01	3.42	3.62	3.41	3.63	3.55	3.50	3.41	3.48	3.35	3.35	3.53	3.35	.11
	0 cm	2.76 ± .01	2.67	2.84	2.76	2.92	2.90	2.78	2.65	2.76	2.67	2.61	2.94	2.71	.09
Lean trim	.76 cm	10.25 ± .03	9.98	10.02	10.34	10.79	10.65	10.32	9.71	10.23	10.26	9.83	11.24	10.16	.31
	0 cm	10.26 ± .03	9.99	10.03	10.34	10.80	10.66	10.33	9.72	10.24	10.26	9.84	11.25	10.16	.13
Fat trim	.76 cm	7.89 ± .06	8.94	8.65	6.90	6.90	6.71	7.55	9.02	7.63	7.76	8.15	5.85	7.20	.61
	0 cm	8.61 ± .06	9.69	9.44	7.55	7.61	7.36	8.26	9.79	8.35	8.45	8.89	6.45	7.85	.63
Bone	.76 cm	3.02 ± .01	2.93	3.07	3.14	3.13	3.09	3.11	3.11	2.95	3.02	2.89	2.94	3.04	.09
	0 cm	3.02 ± .01	2.93	3.07	3.14	3.13	3.09	3.11	3.11	2.96	3.02	2.89	2.94	3.04	.09

[a]The Hereford and Angus sires were new (born 1982 to 1984) relative to the original Hereford and Angus sires (born 1963 to 1970) used in Cycles I to III of the Germplasm Evaluation project. Clean-up (CU) sires also represented "new" sires but did not have as much selection intensity as the AI sires, and, thus, results from their progeny were reported separately. HA = Hereford × Angus and Angus × Hereford crosses, Ch = Charolais, Gb = Gelbvieh, Pz = Pinzgauer, Sh = Shorthorn, Gw = Galloway, Lh = Longhorn, Ne = Nellore, Pm = Piedmontese, Sa = Salers.

[b]Sire breed mean differences greater than the LSD were considered significant ($P < .05$).

[c]Includes brisket, plate, and flank.

of fat trim had about equal variation within and among sire breeds (i.e., ~$6\sigma_g$). These results reflect the relatively smaller amount of variation in percentage composition compared with variation in lean growth rate (retail product accretion rate) among sire breeds. Percentage of bone varied less among sire breeds than within sire breeds. These values were similar to those reported previously by Koch et al. (1982a) and Gregory et al. (1995).

Genetic and phenotypic variation within a sire breed relative to the variation among sire breeds for retail product yield is illustrated in Figure 1. These curves represent the sire breeds with the lowest percentage yield (Shorthorn) and highest percentage yield (Piedmontese) and AI HA crosses for comparison. Figure 1A indicates the amount of change that could be expected in retail product yield by selecting purebred Piedmontese instead of Shorthorn (by doubling the range in sire breed mean difference in retail yield from the F_1 progeny) cattle (7.87 genetic standard deviations) relative to the within-breed variation (6 genetic standard deviations). For F_1 progeny, this same comparison results in 3.93 genetic standard deviations between Shorthorn- and Piedmontese-sired progeny (Figure 1B) or 3.09 phenotypic standard deviations between Shorthorn- and Piedmontese-sired progeny (Figure 1C). Thus, the realized improvement in retail product yield from selecting one breed over another would be substantial (3.09% to change from half-blood Shorthorn to half-blood Piedmontese). To make as much as $3\sigma_g$ improvement within a breed requires intense selection for three generations (e.g., equivalent to mass selection of the top 10% of sires and the top 50% of dams for three generations through some direct measure on live animals selected for breeding, which is, unfortunately, not possible with present technology).

Correlation Coefficients

Among carcass yield traits, total retail product weight and percentage were strongly genetically correlated with each other and to fat trim percentage (Table 6). Bone percentage was moderately genetically correlated with retail product weight and percentage. A large proportion of the genetic variation in total retail product weight was associated with hot carcass weight and longissimus area. Adjusted fat thickness, USDA yield grade, and marbling score were associated moderately with genetic variation in total retail product weight, but intramuscular lipid percentage and palatability traits had little genetic association with total retail product weight. Adjusted fat thickness, USDA yield grade, and longissimus area were associated highly with genetic variations in total retail product and fat trim percentages. Most other carcass traits had moderate to low genetic correlations with total retail product and fat trim percentages. Bone percentage had moderate genetic correlations

Table 8. Sire breed least squares means for subprimal cut yields as a percentage of carcass weight at two fat trim levels adjusted to 426 days of age

			Sire breed[a]												
Trait	Trim level	$\mu \pm$ SEM	AI HA	CU HA	AI Ch	CU Ch	CU Gb	CU Pz	Sh	Gw	Lh	Ne	Pm	Sa	LSD[b]
Flank steak, %	.76 cm	.49 ± .002	.49	.50	.52	.54	.50	.49	.46	.50	.50	.44	.53	.50	.03
	0 cm	.49 ± .002	.49	.50	.52	.54	.50	.49	.47	.50	.50	.44	.53	.50	.03
Sirloin tip, %	.76 cm	2.94 ± .008	2.81	2.82	3.05	3.02	2.99	2.94	2.93	2.90	2.88	2.92	3.18	3.01	.09
	0 cm	2.84 ± .008	2.71	2.71	2.95	2.92	2.91	2.85	2.82	2.80	2.78	2.83	3.10	2.92	.09
Top round, %	.76 cm	4.93 ± .013	4.80	4.96	5.19	5.03	5.00	4.97	4.72	4.86	4.97	5.16	5.42	5.09	.14
	0 cm	4.52 ± .013	4.31	4.30	4.76	4.67	4.63	4.56	4.30	4.45	4.55	4.70	5.09	4.68	.14
Gooseneck, %	.76 cm	5.47 ± .013	5.35	5.36	5.67	5.57	5.63	5.42	5.23	5.45	5.29	5.60	5.89	5.69	.14
	0 cm	4.70 ± .014	4.51	4.48	4.98	4.83	4.92	4.68	4.47	4.67	4.61	4.82	5.34	4.95	.14
Tenderloin, %	.76 cm	1.38 ± .004	1.32	1.31	1.42	1.41	1.42	1.41	1.30	1.40	1.42	1.40	1.48	1.42	.04
	0 cm	1.21 ± .004	1.16	1.15	1.25	1.23	1.28	1.25	1.14	1.23	1.24	1.24	1.34	1.26	.04
Top loin, %[c]	.76 cm	3.51 ± .009	3.44	3.45	3.55	3.54	3.56	3.51	3.39	3.63	3.61	3.54	3.71	3.57	.10
	0 cm	2.04 ± .007	1.90	1.95	2.10	2.10	2.10	2.07	1.95	2.08	2.08	2.08	2.28	2.10	.07
Top sirloin, %	.76 cm	3.03 ± .007	2.97	2.97	3.10	3.08	3.09	3.05	2.98	3.09	3.02	3.03	3.10	3.12	.08
	0 cm	2.64 ± .008	2.57	2.55	2.72	2.70	2.75	2.68	2.56	2.66	2.64	2.66	2.81	2.74	.08
Clod, %	.76 cm	4.55 ± .011	4.50	4.49	4.61	4.51	4.74	4.58	4.48	4.63	4.52	4.47	4.81	4.60	.12
	0 cm	3.99 ± .011	3.93	3.90	4.09	3.99	4.18	4.01	3.90	4.05	3.96	3.95	4.31	4.05	.11
Chuck tender, %	.76 cm	.76 ± .003	.74	.73	.78	.78	.78	.78	.76	.77	.77	.79	.82	.79	.03
	0 cm	.72 ± .003	.70	.69	.74	.74	.74	.74	.72	.72	.73	.75	.78	.75	.03
Chuck roll, %	.76 cm	4.88 ± .014	4.72	4.79	4.89	4.95	5.16	4.98	4.71	4.99	4.99	4.89	5.10	4.95	.15
	0 cm	4.75 ± .013	4.58	4.66	4.77	4.83	5.05	4.86	4.57	4.84	4.86	4.76	5.01	4.82	.14
Cube steak, %[d]	.76 cm	.54 ± .003	.53	.48	.58	.54	.58	.54	.51	.57	.56	.62	.64	.56	.04
	0 cm	.54 ± .003	.53	.49	.58	.54	.58	.54	.51	.57	.56	.62	.64	.56	.04
Ribeye roll, %[e]	.76 cm	4.54 ± .010	4.48	4.44	4.57	4.64	4.65	4.62	4.44	4.65	4.64	4.34	4.70	4.71	.10
	0 cm	2.30 ± .008	2.21	2.21	2.36	2.34	2.40	2.34	2.22	2.38	2.41	2.13	2.50	2.42	.08
Short ribs, %	.76 cm	.98 ± .004	.97	.96	1.00	.93	.96	.95	.95	1.00	.99	1.06	1.04	.98	.05
	0 cm	.88 ± .004	.86	.86	.91	.83	.87	.84	.85	.90	.89	.95	.95	.88	.04
Brisket, %	.76 cm	2.98 ± .010	2.91	3.13	2.89	3.08	3.05	3.01	2.95	2.98	2.86	2.92	3.01	2.86	.11
	0 cm	2.26 ± .008	2.16	2.34	2.24	2.38	2.40	2.30	2.18	2.26	2.17	2.17	2.41	2.21	.09

[a]The Hereford and Angus sires were new (born 1982 to 1984) relative to the original Hereford and Angus sires (born 1963 to 1970) used in Cycles I to III of the Germplasm Evaluation project. Clean-up (CU) sires also represented "new" sires but did not have as much selection intensity as the AI sires, and, thus, results from their progeny were reported separately. HA = Hereford × Angus and Angus × Hereford crosses, Ch = Charolais, Gb = Gelbvieh, Pz = Pinzgauer, Sh = Shorthorn, Gw = Galloway, Lh = Longhorn, Ne = Nellore, Pm = Piedmontese, Sa = Salers.

[b]Sire breed mean differences greater than the LSD were considered significant ($P < .05$).

[c]At the .76 cm trim level, this cut is an IMPS #179 (still has lateral and dorsal spinous processes attached), except that the tail length is 3.8 cm on both ends. At the 0 cm fat trim level, this cut is an IMPS #180A, except that the flank edge is removed at the end of the longissimus, leaving no tail.

[d]Deep pectoral from the chuck.

[e]At the .76 cm trim level, this cut is an IMPS #109 (still has back ribs and dorsal spinous processes attached) except the length of the lip varies depending on carcass weight (3.8 to 6.4 cm on the loin end and 7.6 to 12.7 cm on the chuck end). At the 0 cm trim level, this cut is an IMPS #112.

with adjusted fat thickness, USDA yield grade, and longissimus area but relatively low genetic correlations with other carcass traits.

Total retail product weight was strongly phenotypically correlated with hot carcass weight and moderately phenotypically correlated with longissimus area (Table 6). Total retail product percentage was nearly perfectly phenotypically correlated with fat trim percentage. In addition, USDA yield grade, adjusted fat thickness, and bone percentage were moderately to highly phenotypically correlated with total retail product and fat trim percentages. Bone percentage was moderately phenotypically correlated with adjusted fat thickness and USDA yield grade. Palatability traits (means for and correlations among these traits were reported by Wheeler et al., 1996) were lowly phenotypically correlated to all carcass yield traits.

Wholesale Cut Yields

Sire breed effects on percentage yields of retail product, steaks and roasts, lean trim, fat trim, and bone for each of the individual wholesale cuts after adjustment to a constant 426 d of age followed a pattern similar to that for the whole carcass (Table 7).

Rounds. Piedmontese, AI Charolais, CU Charolais, and Salers progeny had carcasses with higher ($P < .05$) percentages of wholesale round than most other sire breeds. Piedmontese-sired steers had the highest ($P < .05$) percentages of retail product and of steaks and roasts from the round. The AI Charolais, CU

Charolais, and Salers progeny had higher ($P < .05$) percentages of round retail product than most other sire breeds. The AI HA-, CU HA-, and Shorthorn-sired steers had lower ($P < .05$) percentages of round retail product and of steaks and roasts than most other sire breeds. Piedmontese-sired steers had higher ($P < .05$) and AI HA- and Shorthorn-sired steers had lower ($P < .05$) percentages of lean trim from the round than most other sire breeds. Piedmontese had a lower ($P < .05$) percentage of fat trim than all other sire breeds, whereas AI HA, CU HA, and Shorthorn had higher ($P < .05$) percentages of fat trim than most of the other sire breeds. The AI Charolais-sired steers had the highest ($P < .05$) percentage of round bone. Piedmontese-, Galloway-, Longhorn-, AI HA-, CU HA-, and Nellore-sired steers had lower ($P < .05$) percentages of round bone than all other sire breeds except Salers.

Loins. Few significant differences occurred among sire breeds for percentage of wholesale loin (Table 7). Those sire breeds with the most trimmable fat tended to have the highest percentage of wholesale loin. This result was consistent with previous observations that as total carcass fat increased, fat deposition tended to increase centripetally toward the rib and loin (Belk et al., 1991). Piedmontese-sired steers had the highest ($P < .05$) percentages of loin retail product, steaks and roasts, and lean trim and the lowest ($P < .05$) percentage of fat trim. The AI HA-, CU HA-, and Shorthorn-sired steers had lower ($P < .05$) percentages of loin retail product, steaks and roasts, and lean trim and higher ($P < .05$) percentages of fat trim than steers from most other sire breeds. Piedmontese- and AI HA-sired steers had lower ($P < .05$) percentages of loin bone than AI Charolais-, CU Charolais-, Gelbvieh-, Longhorn-, and Salers-sired steers.

Ribs. Few significant differences occurred among sire breeds for percentage of wholesale rib (Table 7). Piedmontese-sired steers had the highest ($P < .05$) percentages, and AI HA-, CU HA-, and Shorthorn-sired steers had lower ($P < .05$) percentages of retail product from the rib than steers from most other sire breeds. Piedmontese-, Salers-, Galloway-, and Longhorn-sired steers had higher ($P < .05$) percentages of steaks and roasts from the rib when trimmed to .76 cm of fat than steers from most other sire breeds. However, Piedmontese-sired steers had the highest ($P < .05$) percentage of steaks and roasts from the rib when trimmed to 0 cm of fat. Regardless of trim level, AI HA-, CU HA-, Shorthorn-, and Nellore-sired steers had lower ($P < .05$) percentages of steaks and roasts from the rib than most other sire breeds. Piedmontese-sired steers had the highest ($P < .05$) percentage and CU HA- and Shorthorn-sired steers had the lowest ($P < .05$) percentage of lean trim. Piedmontese-sired steers had the lowest ($P < .05$) percentage and AI HA-sired steers had the highest ($P < .05$) percentage of fat trim (at either trim level). Few sire breed differences occurred in percentage of bone from the rib.

Chucks. Few sire breed differences occurred in percentage of wholesale chuck (Table 7). Piedmontese-sired steers had the highest ($P < .05$) percentages of chuck retail product and lean trim and the lowest ($P < .05$) percentage of fat trim. Piedmontese- and CU Gelbvieh-sired steers had higher ($P < .05$) percentages of steaks and roasts than steers from all other sire breeds. Shorthorn-, AI HA-, and CU HA-sired steers had lower ($P < .05$) percentages of total retail product, steaks and roasts, and lean trim and higher ($P < .05$) percentages of fat trim from the chuck than steers from most other sire breeds. Nellore, Piedmontese, and AI HA had lower ($P < .05$) percentages of bone than most other sire breeds.

Minor Cuts. Shorthorn, AI HA, and CU HA had higher ($P < .05$) percentages of minor cuts (brisket, plate, shank, and flank) than most other sire breeds (Table 7). Piedmontese-sired steers had the highest ($P < .05$) percentages of retail product and lean trim and the lowest ($P < .05$) percentage of fat trim from minor cuts. The CU Gelbvieh, AI Charolais, CU Charolais, and Piedmontese had higher ($P < .05$) percentages of steaks and roasts from the minor cuts than most other sire breeds. Nellore, Shorthorn, and AI HA had lower ($P < .05$) percentages of retail product than most other sire breeds. Nellore, Shorthorn, CU HA, and AI HA had lower ($P < .05$) percentages of lean trim than most other sire breeds. Shorthorn, CU HA, and AI HA had higher ($P < .05$) percentages of fat trim than most other sire breeds. Nellore-, AI HA-, Piedmontese-, and Galloway-sired steers had lower ($P < .05$) percentages of bone from the minor cuts than all other sire breeds except Longhorn and Salers.

Subprimal Yields

Yields of individual subprimal cuts as a percentage of side weight after adjusting the data to a constant 426 d of age follow a pattern similar to that seen for total and wholesale yields (Table 8). Piedmontese-sired steers had the highest ($P < .05$) percentages of sirloin tip, top round, gooseneck, top loin, clod, chuck roll, ribeye roll, and tenderloin and a higher percentage of flank steak, top sirloin, and cube steak than most other sire breeds. The CU Gelbvieh had a higher ($P < .05$) percentage of chuck roll than all other sire breeds except Piedmontese. Shorthorn, AI HA, and CU HA had lower ($P < .05$) percentages of most subprimal cuts than most other sire breeds. Longhorn-sired steers had a similar ($P < .05$) percentage of gooseneck and Galloway-sired steers had a similar ($P > .05$) percentage of top round compared to AI HA-, CU HA-, and Shorthorn-sired steers. Nellore-sired steers had lower ($P < .05$) percentages of flank steak and ribeye roll than most other sire breeds. Few sire breed differences occurred in subprimal yields for top sirloin trimmed to .76 cm fat trim or chuck tender and short ribs at either fat trim level. Previous breed comparisons conducted in a similar manner found similar sire breed differences in composition and distribution of tissues (Koch and Dikeman, 1977; Koch et al., 1981, 1982c). Those studies also detected significant breed differences in carcass composition and yields of wholesale and retail cuts.

The variation that exists in traits of economic importance to beef production, such as carcass yields of retail product and fat trim, is vast and under a high degree of genetic control. The range for differences among breeds (2R) is comparable in magnitude to the range for breeding values of individuals within breeds ($6\sigma_g$) for most compositional traits (Table 5). Thus, significant genetic change can result from selection among and within breeds. Among-breed differences may be exploited more easily than genetic variation within breeds, because they are more highly heritable, and within-breed variation is more difficult to measure for carcass traits.

However, breeds that excel in retail product should not necessarily be selected over breeds with less genetic potential without considering increased maintenance costs and effects on other important production traits. Because of the trade-offs resulting from antagonistic genetic relationships among breeds, no one breed excels in all economically important traits. Thus, crossbreeding must be used to exploit complementarity by terminal crossing of sire breeds noted for retail product growth efficiency with cows (crossbred or composite population) that optimize reproduction and lactation in their environment in order to manage genetic antagonisms.

Implications

Significant sire breed differences in carcass yield traits allow for selection and crossing among breeds to optimize these traits. Of those breeds evaluated, Piedmontese-sired steers produced the most muscular, leanest, and highest-yielding carcasses, and steers sired by Hereford-Angus reciprocal crosses or Shorthorn produced the fattest, lowest-yielding carcasses. However, percentage product yield differences among sire breeds should be balanced with other important production traits.

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