Growth and Carcass Characteristics of Diverse Breeds Of Cattle used for Beef Production

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Introduction

Rate and efficiency of postweaning growth are important components of beef production. About 30% of the energy requirements and about 45% of the total feed costs are incurred in the period between weaning and slaughter. Historically, when steers were finished on pasture, propensity to finish at a young age was desirable, particularly when market requirements for fatness were great. However, propensity to fatten became a handicap as we shifted to increased use of grains in diets of growing-finishing cattle. Recently, customer pressure to reduce caloric and fat content of beef and other red meats has intensified because coronary heart disease is believed to be associated with elevated blood cholesterol levels. Dietary control of the type and amount of fat consumed is strongly recommended by members of the medical profession in an attempt to regulate blood cholesterol levels. In this paper, results from the Germ Plasm Evaluation (GPE) program at the Roman L. Hruska U. S. Meat Animal Research Center, Clay Center, Nebraska are reviewed on relative amounts of genetic variation between and within breeds in growth, feed efficiency and quantity and distribution of lean, inter- and intramuscular fat, and caloric content of retail cuts of beef with different degrees of trimming.

Germ Plasm Evaluation Program

The GPE Program has been conducted in four cycles. Table 1 shows the mating plan for Cycles I, II, III and IV. Topcross performance of 26 different sire breeds have been, or are being, evaluated in calves out of Hereford and Angus dams or calves out of F_1 cross dams. These F_1 cross dams were bred to Brahman, Devon and Holstein sires in Cycle I to Santa Gertrudis and Brangus sires in Cycle II. Semen from the same Hereford and Angus bulls has been used throughout to produce a control population of Hereford-Angus reciprocal crosses in each Cycle of the program. In addition to the repeated use of semen from control Hereford and Angus bulls, new samples of Hereford, Angus, and Charolais bulls born since 1982 are being added in Cycle IV to evaluate genetic trends within these breeds. To date, complete data are available only from the first three cycles of the program. Thus, this review will focus only on data from twenty sire breeds involved in the first three cycles of the program.

TABLE 1. Sire breeds used in germ plasm evaluation pro gram

Cycle I (1970-72)	Cycle II (1973-74)	Cycle III (1975-76)	Cycle IV (1986-90)
F1 crosses from Hereford or Angus dams (Phase 2)			
Hereford	Hereford	Hereford	Hereford[a]
Angus	Angus	Angus	Angus[a]
Jersey	Red Poll	Brahman	Longhorn
S. Devon	Brown Swiss	Sahiwal	Salers
Limousin	Gelbvieh	Pinzgauer	Galloway
Simmental	Maine Anjou	Tarentaise	Nellore
Charolais	Chianina		Shorthorn
			Piedmontese
			Charolais
			Gelbvieh
			Pinzgauer
3-way crosses out of F1 dams (Phase 3)			
Hereford	Hereford		
Angus	Angus		
Brahman	Brangus		
Devon	Santa Gertrudis		
Holstein			

[a]Hereford and Angus sires, originally sampled in 1969, 1970 and 1971, have been used throughout the program. In Cycle IV, a new sample of Hereford and Angus sires produced after 1982 are being used and compared to the original Hereford and Angus sires.

Data presenting results pooled over Cycles I, II and III were obtained by adding the average differences between Hereford-Angus reciprocal crosses and other breed groups (2-way and 3-way F_1 crosses) within each cycle to the average of Hereford-Angus reciprocal crosses over the three cycles. The pooled results will be presented for nineteen F_1 crosses (2-way and 3-way) grouped into seven biological types based on relative differences (X lowest, XXXXXX highest) in growth rate and mature size, lean-to-fat ratio, age at puberty and milk production (Table 2). The breed group means presented in this review are from previous reports for postweaning growth and feed efficiency[1, 2, 3, 4] and for carcass and meat characteristics[2, 5, 7, 8, 9, 10] of steers. Mean differences between breeds will be expressed in actual units and in standard deviation units for breeding value ($\sigma_g = \sigma_p h$; the phenotypic standard diviation, σ_p, and heritability, h^2, were computed from paternal half sib analyses of variance of data from the GPE program[11, 12, 13].

TABLE 2. Breed crosses grouped into six biological types on the basis of four major criteria[a]

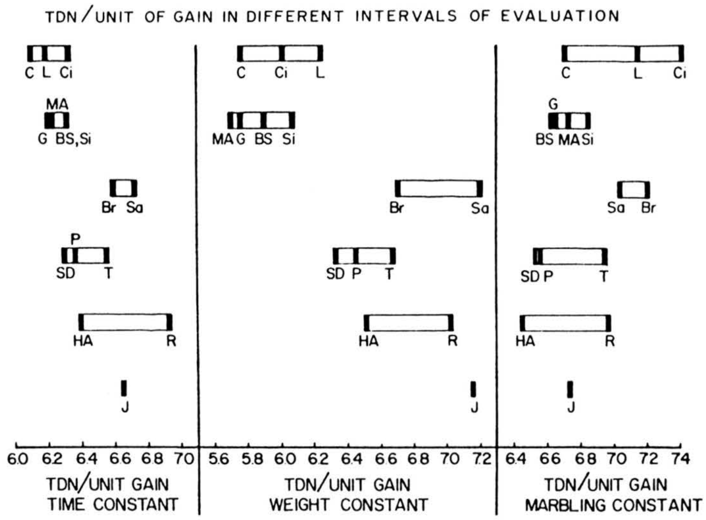
Breed group	Growth rate & mature size	Lean to fat ratio	Age at puberty	Milk production
Jersey (J)	X	X	X	XXXXX
Hereford-Angus (HA)	XX	XX	XXX	XX
Red Poll (R)	XX	XX	XX	XXX
Devon (D)	XX	XX	XXX	XX
South Devon (Sd)	XXX	XXX	XX	XXX
Tarentaise (T)	XXX	XXX	XX	XXX
Pinzgauer (P)	XXX	XXX	XX	XXX
Brangus (Bn)	XXX	XX	XXXX	XX
Santa Gert. (Sg)	XXX	XX	XXXX	XX
Sahiwal (Sw)	XX	XXX	XXXXX	XXX
Brahman (Bm)	XXXX	XXX	XXXXX	XXX
Brown Swiss (B)	XXXX	XXXX	XX	XXXX
Gelbvieh (G)	XXXX	XXXX	XX	XXXX
Holstein (Ho)	XXXX	XXXX	XX	XXXXX
Simmental (S)	XXXXX	XXXX	XXX	XXXX
Maine Anjou (M)	XXXXX	XXXX	XXX	XXX
Limousin (L)	XXX	XXXXX	XXXX	X
Charolais (C)	XXXXX	XXXXX	XXXX	X
Chianina (Ci)	XXXXX	XXXXX	XXXX	X

[a]Increasing number of X's indicate relatively higher values.

Feed Efficiency

Feed efficiency from weaning to different slaughter end points are summarized in Figure 1. Feed efficiency (lb TDN per lb live weight gain) was evaluated for replicated pens (2 pens per sire breed group per year). Thus, heritability could not be computed for individual steers and breed group differences are not shown in σ_g units. Steers sampled from each pen were slaughtered serially in 3 or 4 slaughter groups per year spaced at about 28 to 36 days between intervals. Linear and quadratic regression procedures were used to estimate changes in live weight, feed consumption and carcass composition associated with time on feed. These estimates were in turn used to adjust efficiency to different time, weight and carcass composition end points. Choice of interval of evaluation or end point greatly influenced rankings among breeds for feed efficiency from weaning to slaughter. Steers from faster gaining breed groups characterized by larger mature size were more efficient to time and especially to weight end points. The breed differences to a weight constant end point were especially large because fewer days and less total feed were required for maintenance of faster gaining breed groups compared to slower gaining breed groups. However, feed efficiency to a marbling end point corresponding to USDA Choice quality grade was not favorably associated with size. Breed groups with the greatest propensity to deposit marbling in the fewest days tended to be most efficient to the grade end point. However, if differences in carcass composition are considered, the larger, leaner breed groups still produced more retail product per unit of feed cost than breed groups of smaller size even to a grade constant end point[14].

Figure 1. TDN/unit gain in different intervals of evaluation [15]. See Table 2 for abbreviations.

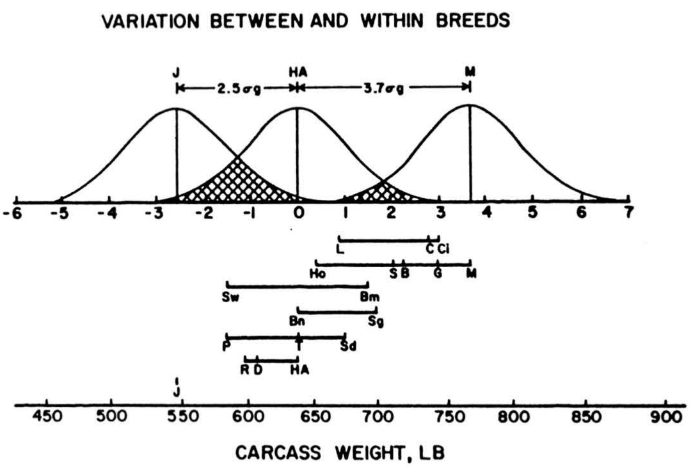


Carcass and Meat Characteristics

Carcass weight.

Genetic variation among breeds relative to that within breeds for carcass weight of steers adjusted to the average slaughter age of 458 days is shown in Figure 2[15]. Means for F_1 crosses are shown on the lower horizontal axis. The spacing on the vertical axis is arbitrary but the ranking of biological types (separate bars) from the bottom to top reflect, generally, increasing increments of mature size. Breed rankings within each biological type are noted within each bar. In Figure 2, differences are doubled in the upper horizontal scale to reflect variation among pure breeds relative to a standard deviation change in breeding value [$o_g = (o_p)$ (h)] within pure breeds. Frequency curves, shown for Jersey, the average of Hereford and Angus and Maine Anjou, reflect the distribution expected for breeding values of individuals animals within pure breeds, assuming a normal distribution (i.e., 68, 95 or 99.6% of the observations are expected to lie within the range bracketed by the mean ± 1, 2 or 3 standard deviations, respectively). The range for mean differences between breeds is estimated to be about 6.2 o_g between Jersey and Maine Anjou breeds. The breeding value of the heaviest Jersey is not expected to equal that of the lightest Maine Anjou. Only the heaviest 17% of Hereford and Angus would equal the lightest 17% of Maine Anjou in growth as reflected by carcass weight at 458 days of age. Both between and within breed sources of genetic variation were large and important for this measure of growth.

Figure 2. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for carcass weight at 458 days[15]. See Table 2 for abbreviations.



Retail Product.

Throughout the GPE program, we have obtained closely trimmed-boneless retail product, i.e., steaks and roasts (trimmed to .3 in of external fat and boneless except for the short loin and rib roasts) and lean trim (trimmed and processed into ground beef with 25% fat content based on chemical analysis) from the right side of each carcass. In the first three cycles of the program, these data were obtained at Kansas State University under the direction of Dr. Michael E. Dikeman. In Cycle IV of the program these data are being obtained in our own laboratory, with Dr. Dikeman still collaborating to assure continuity with previous cycles of the program. Recently, in the GPE program we have obtained data on retail product with two levels of trim. After weights for closely trimmed retail product from each wholesale cut are recorded, retail cuts are trimmed to 0 in outside fat and made entirely boneless. The fat trim removed between 3 in and .0 in accounted for 4.6% of the side weight of yield grade 1 cattle and from 5.3, 5.5 and 5.5% of the side weight of yield grades 2, 3 and 4 cattle, respectively[16] . Thus, a high degree of association exists between closely trimmed and zero trimmed retail product, especially in cattle of yield grades 2, 3 and 4. In this presentation, variation in growth and distribution of muscle will be assessed as reflected by variation in growth and distribution of closely trimmed retail product.

Results for growth of retail product to 458 days of age are summarized in Figure 3. Steers sired by bulls of breeds with large mature size produced significantly more retail product than steers sired by bulls of breeds with small mature size. The breeding value of the heaviest Jersey is not expected to equal that of the lightest Chianina and the heaviest Hereford and Angus would only equal the lightest Chianina in genetic potential for retail product growth to 458 days. The range for mean differences between breeds is estimated to be about 5.7 o_g between Chianina and Hereford or Angus steers and about 8.2 o_g between Chianina and Jersey steers. Genetic variation, both between and within breeds, is considerable for this important measure of output. When both between and within breed genetic variation are considered, the range in breeding value from the smallest Jersey steers to the heaviest Chianina steers is estimated to be 180 kg, or 88% of the overall mean. About half of the variation among breeds in retail product at 458 days of age is associated with variation in carcass weight and half is associated with composition or percentage of the carcass accounted for by retail product (Figure 4).

Figure 3. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for weight of retail product at 458 days of age[15] See Table 2 for abbreviations.

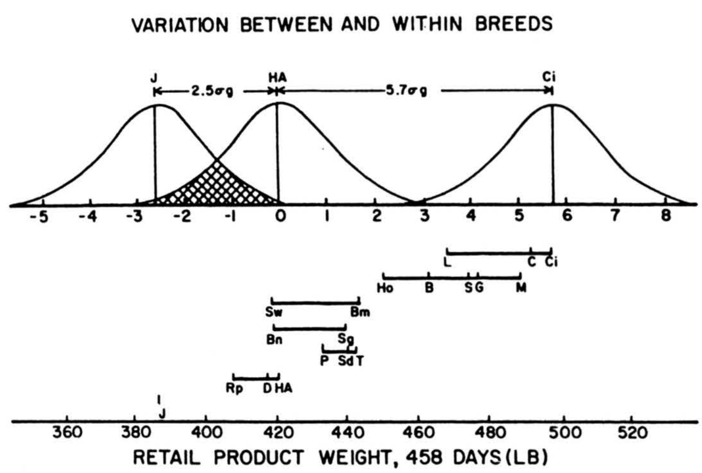
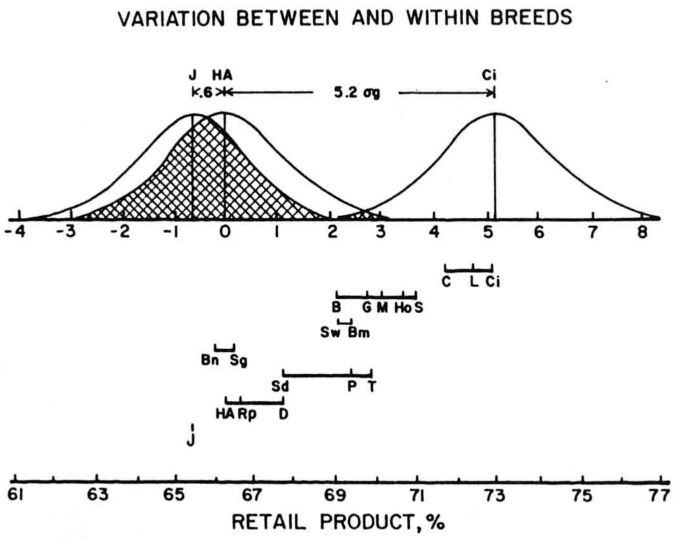


Figure 4. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for retail product as a percentage of carcass weight at 458 days of age [15]. See Table 2 for abbreviations.



Antagonistic Relationships.

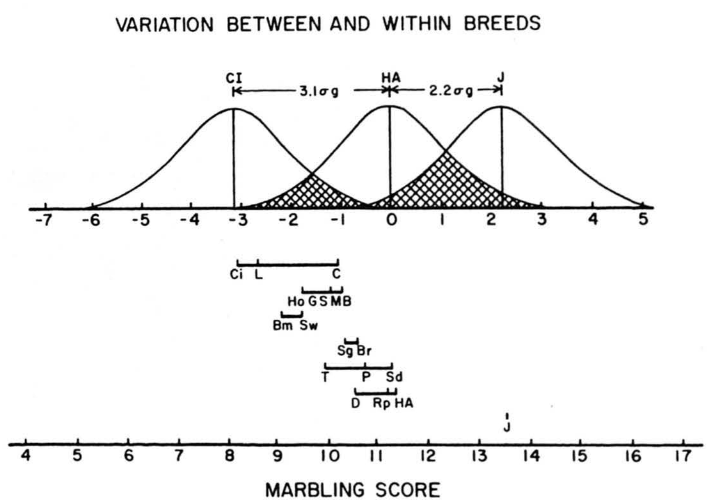
With so much genetic variation between breeds for retail product growth to a constant age (Figure 3), it is valid to ask why hasn't more been done to exploit this variation. In dairy production in the United States, Holsteins which excel in fluid milk yield have replaced the vast majority of cows of other breeds with lower genetic potential for fluid milk yield. It is estimated that Holsteins produce 90% of the milk marketed in the United States. In beef production in the United States, breeds that excel in output of retail product have not been substituted nearly to this extent for those with lower output potential--Why? In part, the answer lies in trade-offs resulting from antagonistic genetic relationships between retail product growth and other traits important to efficiency of beef production. Breeds (and sires) that excel in retail product growth potential also 1) sire progeny with heavier birth weights and increased calving difficulty, 2) tend to be older at puberty, and 3) have heavier mature weight increasing nutrient requirements for maintenance. Results for these traits were discussed in our previous contribution to these proceedings concerning reproduction and maternal traits. In this paper, only the relationships between retail product growth and other carcass characteristics will be emphasized. The antagonistic relationship between marbling, which primarily determines quality grade, and retail product expressed as a percentage of carcass weight or as yield grade is another major trade-off that has significantly deterred breed substitution.

Marbling

Degree of marbling (i.e., deposits of fat interspersed in muscle) in the twelfth rib cross-section of the rib eye muscle is currently the primary determinant of USDA quality grade among carcasses of cattle of the same age. Traditionally, marbling has been emphasized because it was believed to be associated with palatability characteristics of meat. Some studies have shown a low, but positive relationship between marbling and palatability characteristics, especially sensory panel ratings for tenderness or Warner-Bratzler shear force, while others have shown a very low or nonexistent relationship[17].

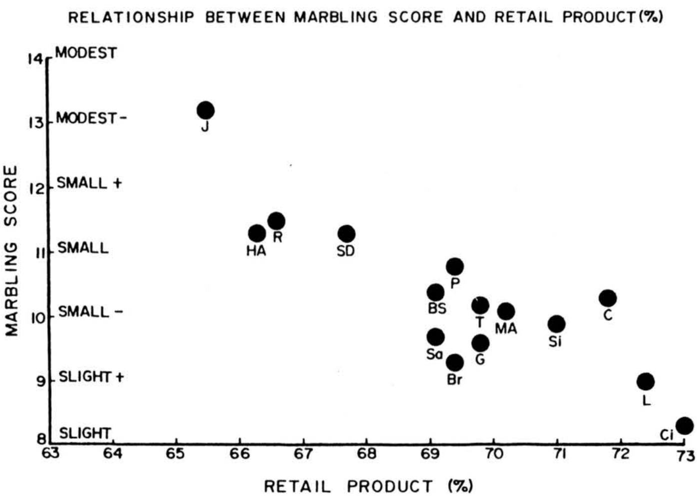
Significant genetic variation exists between and within breeds for propensity to deposit marbling (Figure 5). Again, the range for differences between breeds is about equal to the range for breeding value of individual animals within breeds for marbling. Within breeds, variation in marbling was highly heritable (.40). However, it is much easier to use information on variation among breeds than within breeds for marbling because of the difficulty of measuring marbling levels in live bulls and heifers used for breeding. Also, heritability of breed differences is high (approximately 100%), provided the breed means are estimated with an adequate sample to average out errors of sampling individual animals within breed. Progeny from individual sires tend to regress to their own breed group mean rather than to the mean of all cattle.

Figure 5. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for marbling score at 458 days of age[15]. See Table 2 for abbreviations.



Unfortunately, breeds that rank highest for percentage of retail product rank lowest for marbling (Figure 6). Similarly, high negative genetic correlations have been found within breeds between marbling and retail product percentage. Thus, only limited opportunity exists from between breed selection or from within breed selection for genetically increasing marbling without increasing fat trim and reducing percentage of retail product. This antagonistic relationship between percentage of retail product and marbling, has deterred the substitution of breeds that excel in leanness for those with lower yield grades but higher USDA quality grades.

Figure 6. Breed group means for retail product percentage versus marbling score at 458 days of age [5, 7, 10]. See Table 2 for abbreviations.



Marbling and Palatability.

Concern with the antagonism between marbling and retail product percentage is justified to the extent that a certain amount of marbling is required to ensure palatability of the retail product. Sensory panel evaluations of uniformly cooked 10th rib steaks from about 1,230 steers produced in the GPE program are summarized in Table 3. High levels of acceptance were found for steaks from all *Bos taurus* breed groups when the steers were fed and managed alike and slaughtered at 14 to 16 months of age. In these studies, sensory scores were assigned on a 9 point scale from 1 = extremely undesirable (e.g., extremely tough), 5 = acceptable, up to 9 = extremely desirable (e.g., extremely tender). Average taste panel scores and Warner-Bratzler shear determinations for tenderness did tend to improve as marbling increased when comparisons were at the same age, but the change was very small. Although breed groups differed significantly in average marbling scores and in percentage of carcasses that had adequate marbling to grade USDA Choice or better, average sensory panel evaluations of tenderness, flavor and juiciness were acceptable for all breed groups.

However, variation in sensory panel tenderness scores (see ranges in Figure 7 for *Bos taurus x Bos taurus* breed crosses and Figure 8 for *Bos indicus x Bos taurus* breed crosses) tends to be greater in cattle with low levels of marbling than in cattle with high levels of marbling[18]. This in

TABLE 3. Breed group means for factors identified with meat quality

Breed group	Marbling score[a]	Percent USDA Choice	Warner-Bratzler shear[b] (lb)	Sensory panel scores[c] Tenderness	Flavor	Juiciness
Chianina-X	8.3	24	7.9	6.9	7.3	7.2
Limousin-X	9.0	37	7.7	6.9	7.4	7.3
Brahman-X	9.3	40	8.4	6.5	7.2	6.9
Gelbvieh-X	9.6	43	7.8	6.9	7.4	7.2
Sahiwal-X	9.7	44	9.1	5.8	7.1	7.0
Simmental-X	9.9	60	7.8	6.8	7.3	7.3
Maine-Anjou-X	10.1	54	7.5	7.1	7.3	7.2
Tarentaise-X	10.2	60	8.1	6.7	7.3	7.0
Charolais-X	10.3	63	7.2	7.3	7.4	7.3
Brown Swiss-X	10.4	61	7.7	7.2	7.4	7.2
Pinzgauer-X	10.8	60	7.4	7.1	7.4	7.2
South Devon-X	11.3	76	6.8	7.4	7.3	7.4
Hereford-Angus-X	11.3	76	7.3	7.3	7.3	7.3
Red Poll-X	11.5	68	7.4	7.3	7.4	7.1
Jersey-X	13.2	85	6.8	7.4	7.5	7.5

[a]Marbling: 8 = slight, 11 = small, 14 = modest, 17 = moderate.
[b]Shear force required for a 1 in core of cooked steak.
[c]Sensory panel scores: 2 = undesirable, 5 = acceptable, 7 = moderately desirable, 9 = extremely desirable.

Figure 7. Effects of marbling on mean sensory panel tenderness in *Bos taurus* crosses[18]. Sensory panel scores for tenderness ranged from 1 = extremely tender, 5 = acceptable, 9 = extremely tender. *Bos taurus* breed groups are Angus, Brown Swiss, Charolais, Chianina, Gelbvieh, Hereford, Jersey, Limousin, Maine Anjou, Pinzgauer, Red Poll, Simmental, South Devon and Tarentaise sired topcrosses out of Hereford and Angus dams.

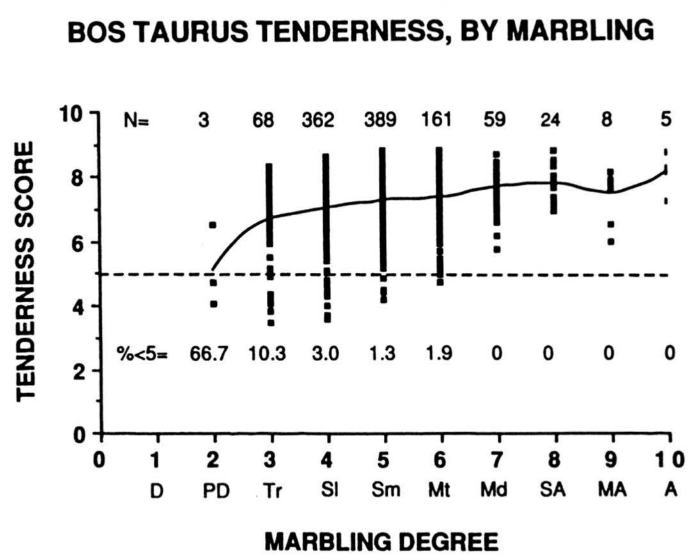
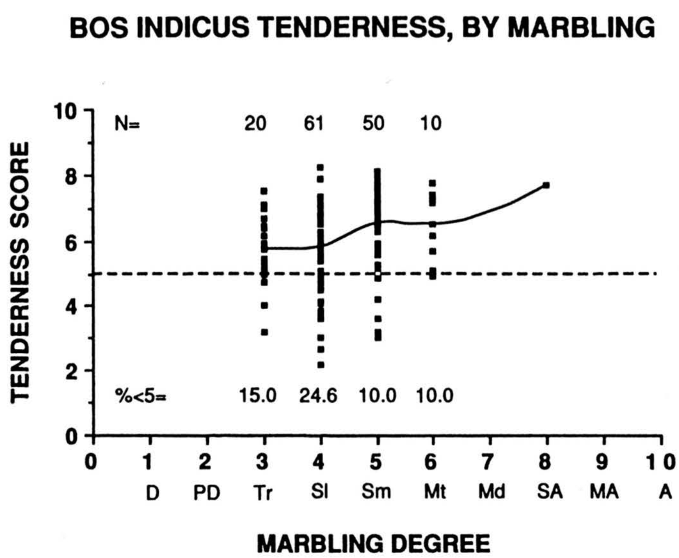


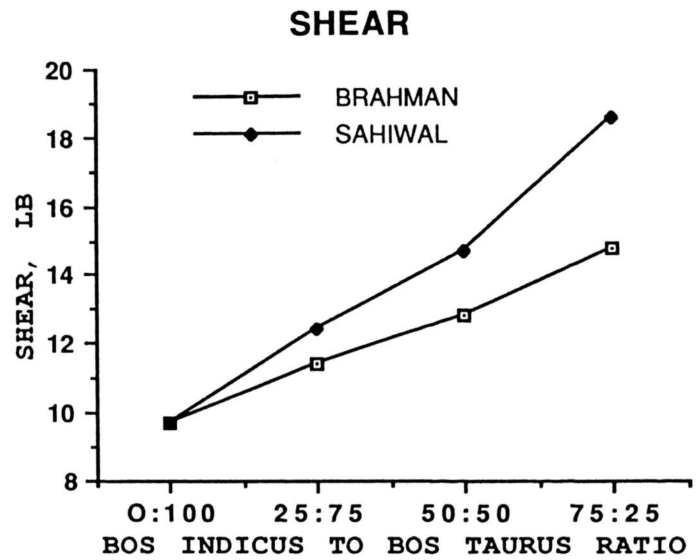
Figure 8. Effects of marbling on sensory panel tenderness, the range in sensory panel tenderness score (vertical bars) and percentage scoring less than acceptable (< 5) in *Bos indicus* crosses[18]. Sensory panel scores for tenderness ranged from 1 = extremely tender, 5 = acceptable, 9 = extremely tender. *Bos indicus* breed groups are Brahman and Sahiwal sire topcrosses out of Hereford and Angus dams.



turn leads to greater risk of at least some steaks having less than acceptable tenderness at low levels of marbling. In *Bos taurus* sired cattle with a slight degree of marbling (USDA Select), 3% of the steaks were scored as less than acceptable (sensory panel scores of 5) in tenderness. In *Bos taurus* sired cattle with moderate or greater degrees of marbling (USDA high Choice or Prime), 0% of the steaks were scored as less than acceptable (i.e., 100% had scores 5). Sensory panel scores for steaks from *Bos indicus* sired steers were lower for tenderness than those from *Bos taurus* sired steers, even at the same degree of marbling.

As the proportion of *Bos indicus* inheritance increases meat tenderness is reduced[19] . Results for shear force estimates of tenderness are presented in Figure 9 for steers differing in the ratio of *Bos indicus* (Brahman, B; Sahiwal, S) to *Bos taurus* (Hereford, H; Angus, A) inheritance. Reciprocal backcross and F_2 matings produced steers with 0:100 (HxAH, HxHA, AxAH, AxHA, HAxHA, AHxHA, HAxAH, AHxAH, HxPH), 25:75 (HxBH, AxBA, HxSH, AxSA), 50:50 (BHxBH, BAxBA, SHxSH, SAxSA) and 75:25 (BxBH, BxBA, SxSH, SxSA) *Bos indicus* to *Bos taurus* inheritance. Shear force required to slice through .5 inch cores from rib steaks cooked to an internal temprature of 158° F increased 1.6 lb for each 25% increase in Brahman inheritance and 2.9 lb for each 25% increase in Sahiwal inheritance.

Figure 9. Shear force estimates of tenderness in rib steaks from steers differing in the ratio of *Bos indicus* (Brahman, B; Sahiwal, S) to *Bos taurus* (Hereford, H; Angus, A) inheritance[19].



Caloric Density of Retail Product.

Dairy processors have developed and effectively marketed products with a similar range in caloric content to that found between Chianina and Jersey steers. Low fat milk (2% fat content) contains 20% fewer calories per one cup serving than regular milk (3.5% fat content). Similar ranges can be achieved in beef products by fabrication and marketing of totally-trimmed retail cuts. The key to production of low calorie beef products is total trimming. Fat contains 225 calories per ounce. Caloric content of totally-trimmed beef varies depending on the level of intramuscular fat (marbling) in the lean. Composition and estimates of caloric content in 1 oz portions of uncooked longissimus (rib-eye) muscle with different USDA quality grades and degrees of marbling are shown in Table 4. Muscle with a slight degree of marbling (USDA Select quality grade) is about 3.7% fat and contains about 40 kcal per ounce. Muscle from carcasses grading USDA Choice range from about 4.7 to 9.3% fat and contain about 43 to 51 kcal per ounce. Muscle from carcasses in the USDA prime grade range from about 9.2 to 12.7% fat and contain 52 to 60 kcal per oz.

Significant opportunity exists to breed and produce catlle which will provide for two types of beef: 1) lean beef that is low in fat and caloric content more suited to customers seeking to limit dietary intake of saturated fats, and 2) highly marbled beef that is well suited to the gourmet food trade where customers are more concerned about the risk of serving or consuming an occasional steak with less than acceptable tenderness than they are about the risk of consuming too much fat.

TABLE 4. Composition and caloric content of L. Dorsi (rib eye) muscle with different degrees of marbling (1 oz uncooked portion)

Quality grade	Marbling	Chem. Fat[a] %	Chem. Fat[a] kcal	Protein[b] %	Protein[b] kcal	Total kcal
	Fat free	0	0	27.0	31.5	31.5
Standard	Pract. devoid	.7	1.9	26.8	31.3	33.1
Standard	Traces	2.2	5.8	26.4	30.7	36.5
Select	Slight	3.7	9.8	26.0	30.2	40.0
Choice	Small	5.2	13.7	25.6	29.6	43.4
Choice	Modest	6.7	17.8	25.2	29.1	46.8
Choice	Moderate	8.2	21.7	24.8	28.5	50.2
Prime	Slight. abundant	9.7	25.7	24.4	27.9	53.6
Prime	Mod. abundant	11.2	29.7	24.0	27.4	57.1
Prime	Abundant	12.7	33.7	23.6	26.8	60.5

[a]Chemical fat, % = -.3 + .5(M) where M = 5 for traces, 8 for slight, ..., and 17 for moderate degrees of marbling[20] and fat contains 9.3 kcal per gram[21].

[b]Lean is 27% protein[22] and protein contains 4.1 kcal per gram[21].

Preliminary results from Cycle IV of the GPE Program.

In cycle IV, new breeds being evaluated include the Longhorn, Salers, Piedmontese, Galloway, Nellore, and Shorthorn. New samples of Hereford, Angus, and Charolais bulls are being included to evaluate genetic trends within these breeds. Charolais, Gelbvieh, and Pinzgauer bulls are also being used to increase ties to previous cycles and facilitate pooling of results over all cycles. About 30 sires are being used per breed in AI matings for 45 days followed by 21 days clean up matings to Angus, Hereford, Charolais, Gelbvieh, and Pinzgauer bulls. Consistent with procedures throughout the GPE Program, calving is in spring (mid-March to late-May), calves are dehorned (paste) and tattooed at birth and male calves are castrated at birth. Following weaning at about 7 months of age, steers are implanted with synovex, and fed in separate pens by sire breed mixed corn silage and corn diets containing about 2.69 Mcal ME until they reach about 700 lbs and then about 3.04 Mcal ME to slaughter. Steers were slaughtered at 221, 242, 270, and 291 days post weaning, beginning in late May and ending in late July. The right side of each carcass is fabricated into closely trimmed, boneless retail cuts and lean trim (ground beef = 25% fat) and then into totally trimmed (0.3 inches fat), boneless retail cuts and lean trim. Warner-Bratzler shear and sensory panel tenderness are being determined for uniformly cooked rib steaks from each steer carcass.

Preliminary data [23], representing the first 2 of 5 calf crops to be slaughtered, for final weights and carcass characteristics of steers adjusted to an average slaughter age of 418 days are shown in Table 5. Progeny of current sample of Hereford and Angus sires are significantly heavier than those of original samples of sires. Carcass composition and marbling has not changed significantly.

Breeds differ significantly in growth, carcass composition, marbling and meat tenderness. Longhorn crosses have a relatively light slaughter weight, but relatively low fat thickness and rank intermediate among other breeds in carcass composition. Galloway crosses are comparable to the original Hereford x Angus crosses in weight of retail product produced at 417 days. Lighter final live and carcass weights of Galloway crosses relative to Hereford x Angus crosses are offset by favorable carcass composition. Relative to results in the 60's, Shorthorn crosses have changed significantly in yearling weight. They are comparable to Angus in marbling and comparable to Hereford x Angus crosses in carcass composition. Peidmontese crosses excel in carcass composition. They compare to Charolais crosses in weight of retail product produced to 417 days of age, but are comparable to current Hereford x Angus crosses in live weights at birth, weaning and yearling ages. Marbling is low but steaks are relatively tender. Salers crosses compare to Gelbvieh crosses in yearling weight and in carcass and meat characteristics. Nellore crosses are comparable to Charolais crosses in weight at birth and weaning ages. Final weights are lighter than Charolais or Gelbvieh crosses, but carcass weights are similar due to higher dressing percentages. Weight and percentage retail product is comparable to Salers and Gelbvieh crosses. Like *Bos indicus* crosses evaluated earlier, their steaks are significantly less tender than those by *Bos taurus* sire breeds.

TABLE 5. Breed group means for final weight and carcass characteristics of steers born in first two of five calf crops (1986 and 1987) to be produced in cycle IV of GPE Program at the Roman L. Hruska U.S. Meat Animal Research Center

Breed group	No.	Final weight lb	Dress. perct %	USDA Choice %	WB shear lb	Fat thickness in	Rib eye area sq in	Kidney pelvic & heart fat %	Retail product .3 in trim %	Retail product .0 in trim %
Original HA-x	32	1,064	62.5	71	12.0	.60	11.1	2.8	70.5	64.6
Current HA-x	41	1,122	62.2	67	13.7	.56	11.0	2.5	71.0	65.2
Charolais	36	1,186	62.1	40	13.8	.41	12.5	2.9	73.3	68.1
Gelbvieh	65	1,139	62.3	32	13.5	.36	12.2	2.6	73.8	68.5
Pinzgauer	50	1,129	61.1	47	12.3	.41	11.4	2.9	72.3	67.0
Shorthorn	43	1,149	62.2	83	13.3	.51	11.1	2.8	70.6	65.0
Galloway	32	1,012	63.0	49	13.3	.47	11.1	2.6	73.4	67.8
Longhorn	38	961	61.9	52	13.4	.38	10.8	2.8	73.2	67.7
Nellore	44	1,100	65.3	29	16.3	.53	11.7	2.8	73.1	67.6
Piemontese	37	1,060	64.4	28	11.6	.27	13.4	2.3	77.8	73.3
Salers	36	1,122	62.9	35	14.0	.43	11.9	2.8	73.6	68.2

Conclusions

The variation that exists in biological traits of economic importance to beef production, including carcass leanness, is vast and under a high degree of genetic control. The range for differences between breeds is comparable in magnitude to the range for breeding value of individuals within breeds for most bioeconomic traits important to beef production. Thus, significant genetic change can result from selection both between and within breeds.

Between breed differences are more easily exploited than genetic variation within breeds because they are more highly heritable. Also, use of genetic variation within breeds is often complicated by difficulties of measurement for characteristics such as carcass and meat traits. Breeds can be selected to optimize performance levels for important bioeconomic traits with a high level of precision much more quickly than intrapopulation selection.

However, breeds that excel in output should not necessarily be substituted for breeds with less genetic potential because of trade-offs resulting from antagonistic relationships among traits. Breeds (and sires) that excel in retail product growth potential also: 1) sire progeny with heavier birth weights and increased calving difficulty; 2) produce carcasses with lower marbling but very acceptable meat tenderness; 3) tend to reach puberty at an older age; and 4) generally have heavier mature weight. Heavier mature weight increases output per cow, but also increases nutrient requirements for maintenance. Thus, differences in output tend to be offset by input differences for maintenance and lactation so that differences in life cycle efficiency are generally small.

Because of trade-offs resulting from antagonistic genetic relationships among breeds, it is not possible for any one breed to excel in all characteristics of economic importance to beef production. Nor is it possible to expect simultaneous improvement in all characteristics from intrapopulation selection since similar relationships exist within breeds. Use of crossbreeding systems that exploit complementarity by terminal crossing of sire breeds noted for lean tissue growth efficiency with crossbred cows of small to medium size and optimum milk production provide the most effective means of managing trade-offs that result from genetic antagonisms. Progeny produced by terminal sire breeds which excel in genetic potential for retail product growth potential produce carcasses with lower levels of marbling and totally-trimmed retail cuts with lower fat and caloric content. Terminal crosses are especially well suited for marketing of low fat or low caloric beef with acceptable palatability characteristics. Maternal breeds to provide female replacements can be selected to optimize milk production and size in the cow herd. If marbling is also considered in selection of maternal breeds, steers produced from matings required to produce female replacements can be well suited to the gourmet food trade where the risk of occasional steaks with unacceptable tenderness must be minimized.

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