COMBINING BETWEEN AND WITHIN BREED VARIATION TO MEET SPECIFIC MARKETS

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INTRODUCTION

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. Nevertheless, propensity to deposit intramuscular fat or marbling continues to be emphasized in US markets because of its perceived association with palatability characteristics of meat. Recently, consumer 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. Thus, two market targets are emerging, one the traditional target which emphasizes marbling and a growing market which emphasizes leanness. In this paper, results from the Germplasm Evaluation (GPE) program at the Roman L. Hruska US Meat Animal Research Center, Clay Center, Nebraska are reviewed to assess justification for these diverse market targets and the relative amounts of genetic variation between and within breeds for traits that play an important role in defining market target for beef carcasses, namely weight, carcass and meat composition, and palatability characteristics of retail product.

GERMPLASM EVALUATION PROGRAM

The GFE Program has been conducted in four cycles. Table I 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 F1 cross dams. These F1 cross dams were bred to Brahman, Devon and Holstein sires in Cycle I and to Santa Gertrudis and Brangus sires in Cycle.11. 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 were 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 primarily on data from twenty sire breeds involved in the first three cycles of the program. Preliminary results from Cycle IV will be reviewed briefly at rhe conclusion of the paper.

Data presenting results pooled over Cycles 1, II and III were obtained by adding the average differences between Hereford-Angus reciprocal crosses and other breed groups (2-way and 3-way F1 crosses) within each cycle to the average of Hereford-Angus reciprocal crosses over the three cycles. The pooled result will be presented for nineteen F1 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 (Smith et al., 1976a, Young et al., 1978a, Cundiff et al., 1981, Cundiff, et al., 1984) and for carcass and meat characteristics (Young et al., 1978a, Koch et al., 1976, Koch et al., 1979, Koch et al., 1981, Anonymous, 1978, Koch et al., 1982b) of steers. Mean differences between breeds will be expressed in actual units and in standard deviation units for breeding value (i.e., heritability X phenotypic standard deviation computed from the GPE program: Koch et al., 1982a, MacNeil et al., 1984, Cundiff et al., 1986b).

CARCASS AND MEAT CHARACTERISTICS

The genetic variation that exists in growth (e.g., carcass weight), weight of retail product (closely-trimmed boneless steaks, roasts and lean trim) and percentage of retail product at a constant age (e.g., 458 days) is vast, both within and between breeds. Heritability estimates and phenotypic and genetic standard deviations from the GPE program for these traits and for fat thickness and marbling are shown in Table 3. The variation observed among steers of the same breed which are fed and managed under uniform condtions and compared at the same slaughter age is highly heritable for growth and carcass traits. These estimates are in close agreement with previous reports (e.g., Cundiff et al., 1964, Swiger et al., 1965, Cundiff et al,, 1969, 1971, Dinkel and Busch, 1973, Koch, 1978, Benyshek, 1981).

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 I (Cundiff et al., 1986a). Means for F1 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 1, differences are doubled in the upper horizontal scale to reflect variation among pure breeds relative to a standard deviation change in breeding value 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 individual 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 standard deviations in breeding value 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.

Retail Product.

Throughout the GFE 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. 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 I cattle and from 5.3, 5.5 and 5.5% of the side weight of yield grades 2, 3 and 4 cattle, respectively (Crouse et al., 1988). Thus, a high degree of association exists bet:ween 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 summarised in Figure 2. 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 standard devations in breeding value between Chianina and Hereford or Angus steers and about 8.2 standard deviations in breeding value 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 3).

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 (Smith at al., 1984), while others have shown a very low or nonexistent: relationship (Smith et al., 1984; Campion et al., 1975).

Significant genetic variation exists between and within breeds for propensity to deposit marbling (Figure 4). 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.

Unfortunately, breeds that rank highest for percencage of retail product rank lowest for marbling (Figure 5). Similarly, moderate (-.37, Koch et al., 1982, GFE program) to high (e.g., -.80 Cundiff at al., 1964; -.85 Swiger et al., 1965, - .89 Cundiff et al., 1971) negative genetic correlations have been found wichin breeds between marbling and retail product percentage. Thus, only limited opportunicy 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.

Marbling and Palatability.

Concern with the antagonisim between marbling and retail product percentage is justified to the excent that a certain amout of marbling is required to ensure palatabity 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 4. 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 dererminations 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 6 for Bos taurus x Bos taurus breed crosses and Figure 7 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 (Koch et al., 1988). This in 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 (Crouse et al., 1989). Results for shear force estimates of tenderness are presented in Figure 8 for steers differing in the ratio of Bos indicus (Brahman, B; Sahiwal, S) to Bos taurus (Hereford, H; Angus, A) inheritance. Reciprocal backcross and F2 macings produced steers with 0:100 (HxAH, HxHA, AxAH, AxHA, HAxHA, AHxFA, 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 temperature 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.

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, Far 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 muscle with different USDA quality grades and degrees of marbling are shown in Table 5. 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 to12.7% fat and contain 52 to 60 kcal per oz.

Significant opportunity exists to breed and produce cattle 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 saturared 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.

Preliminary results from Cycle IV of the GPE Program.

In cycle 1V, new breeds being evaluated include the Longhorn, Salers, Piedmontese, Galloway, Nellore, and Shorthorn. New samples of Hereford, Angus, and Charolais bulls have been included to evaluate genetic trends within these breeds. Charolais, Gelbvieh, and Pinzgauer bulls have also been used to increase ties to previous cycles and facilitate pooling of results over all cycles. About 30 sires have been used per breed in AI matings for 45 days followed by 21 days clean up matings to Angus, Hereford, Charolais, Gelbvieh, and Pinzgauer bulls. Preliminary data (Cundiff et al., 1990), representing the first four of five 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 6. Progeny of current sample of Hereford and Angus sires were significantly heavier than those of original sample 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 were comparable to the original Hereford-Angus reciprocal crosses in weight of retail product produced at 417 days. Lighter final live and carcass weights of Galloway crosses relative to Hereford-Angus reciprocal crosses were offset by favorable carcass composition. Relative to results in the 60's, Shorthorn crosses have changed significantly in yearling weight. They were comparable to Angus in marbling and comparable to Hereford-Angus reciprocal crosses in carcass composition. Peidmontese crosses excel in carcase composition. They compared to Charolais crosses in weight of retail product at 417 days of age, but were comparable to current Hereford-Angus reciprocal crosses in weights at birth, weaning and yearling ages. Marbling is low but steaks were relatively tender. Salers crosses compare to Gelbvieh crosses in yearling weight and in carcass and meat characteristics. Final weights of Nellore crosses were lighter than or Gelbvieh crosses, but carcass weights were similar due to higher dressing percentages. Weight and percentage retail product was comparable to Salers and Gelbvieh crosses. Like Bos indicus crosses evaluated earlier, their steaks are significantly less tender than those of by Bos taurus sire breeds,

MATCHING GENETIC POTENTIAL TO MARKET REQUIREMENTS

The variation that exists in biological traits of economic importance to beef production, including carcass leanness, Is vast and under a hign 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 generic variation within breeds because they are more highly heritable. Also, use of genetic variation within breeds is often complicated by difficulties off measurement for characteristics such as carcass and meat traits. Breeds can be selected to optimize performance levels and match market targets with a high level of precision much more quickly than intrapopulation selection.

Market targets are usually defined by optimum. ranges in carcass weight and carcass and meat composition. Feed resources used in growing-finishing diets also play a key role in determining weiglnt and carcass composition of beef cattle. If market requirements for marbling and subcutaneous fat are relatively high, propensity to finish at a young age is important if cattle are finished on pasture. If market requiremencs favor leanness, cattle with greater lean to fat ratios and growth potential are favored, especially if cattle are finished on relatively high levels of grain.

However, no one breed excels in all traits of economic importance to beef production. Nor is it possible to expect simultaneous improvement in all traits from intrapopulation selection since similar relationships exist within breeds. Breeds (and sires within breeds) that excel in retail product growth potential also produce carcasses with lower marbling. Although not documented in this review breeds that excel in retail product growth also sire progeny with heavier birth weights and increased calving difficulty; tend to reach puberty at an older age; and generally have heavier mature weight and greater maintenance requirements. It is important to match genetic potential of cow herds to the climate and feed resources available *to* minimize costs of production and to establish or maintain a competitive marketing position relative to alternative products. 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 between traits of importance in the market (or in growing-finishing) and those of primary importance in cow herds.

Progeny produced by terminal sire breeds which excel in genetic potential for retail prodct 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 hard. 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.

Figure 1. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for carcass weight at 458 days of age (Cundiff et al., 1986). See Table 2 for abbreviations.

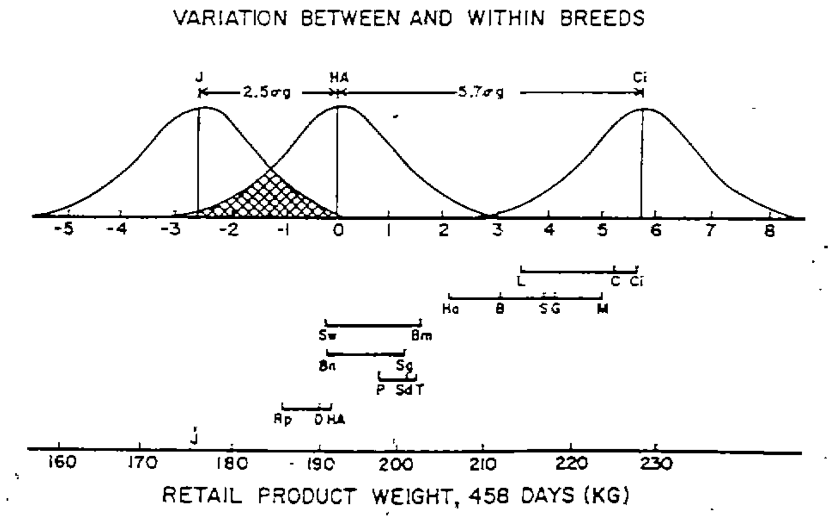

Figure 2. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for weight of retail product at 458 days of age (Cundiff et al., 1986) - See Table 2 for abbreviations.

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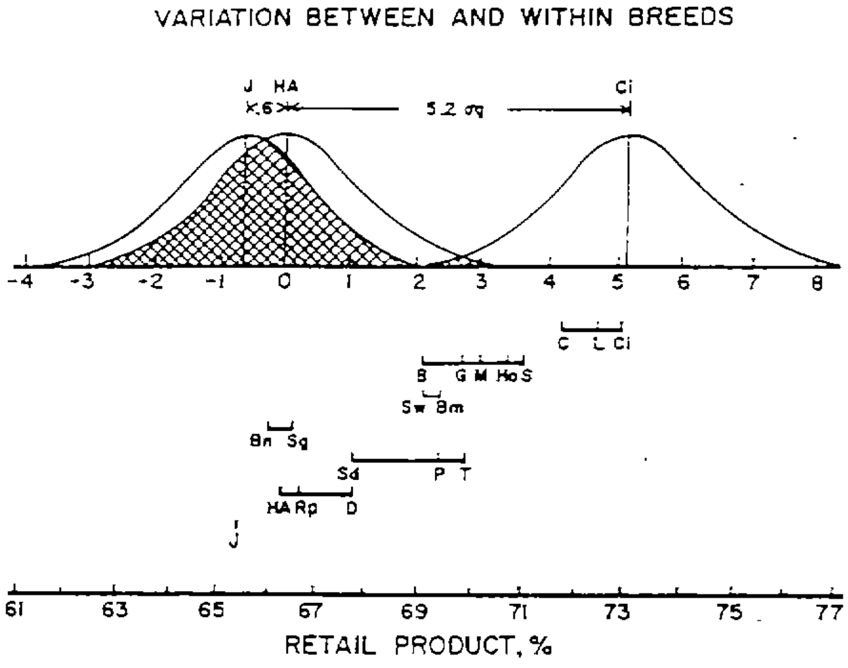

Figure 3. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for retail product as a percentage of carcass weight at 458 days of age (Cundiff et al., 1986). See Table 2 for abbreviations.

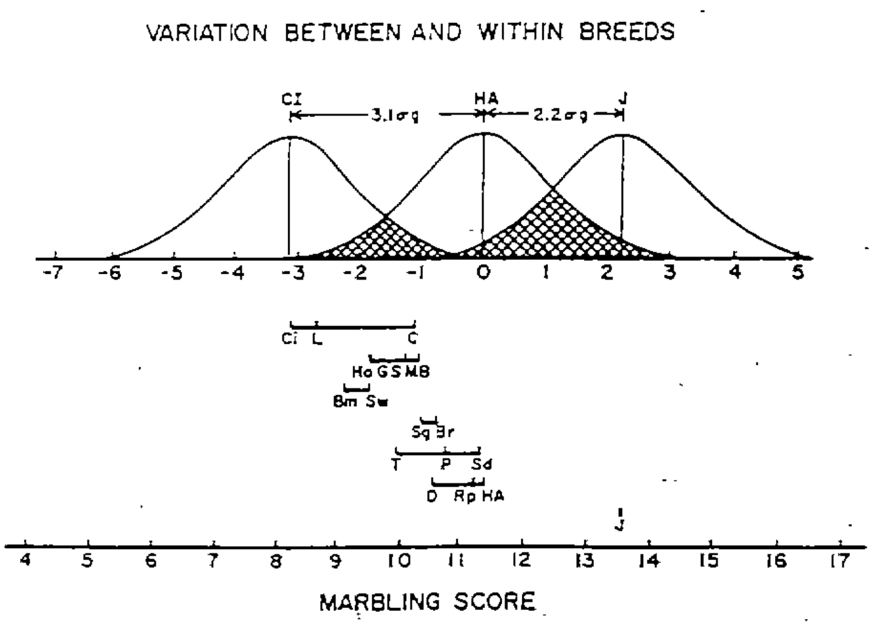

Figure 4. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for marbling score at 458 days of age (Cundiff et al, 1986). See Table 2 for abbreviations.

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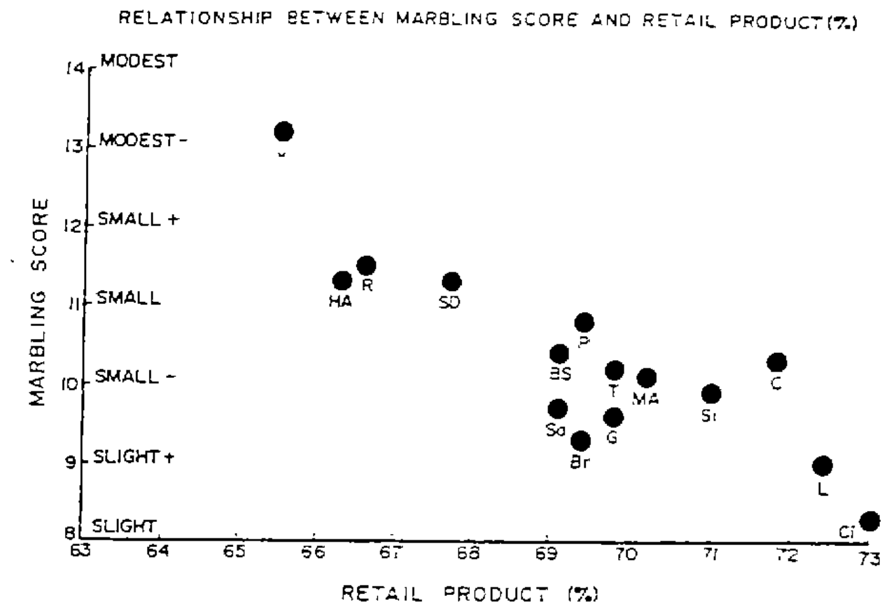

Figure 5. Breed group means for retail product percentage versus marbling score at 458 days of age (Koch et al. , 197 9; Koch et al, 1979; Koch et a!, 1982b) See Table 2 for abbreviations (except Si = Simmental, Sa = Sahiwal , Br = Brahman).

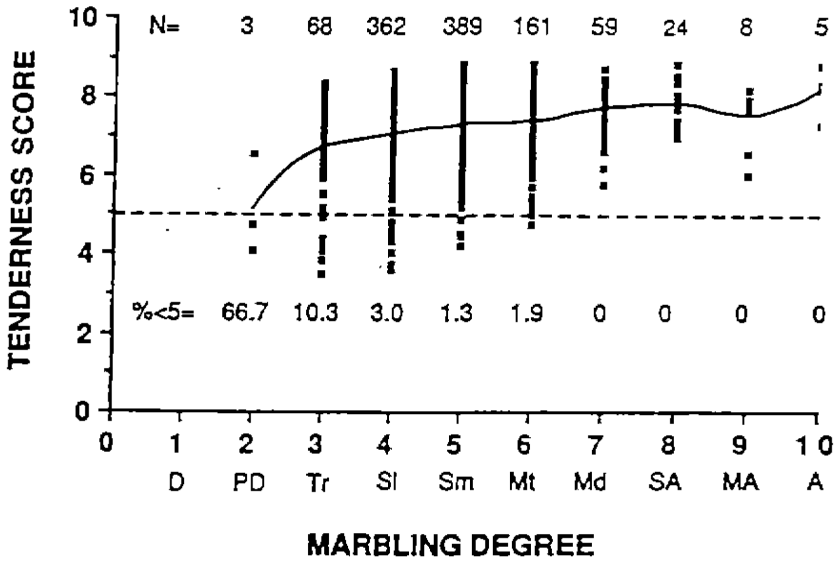

Figure 6. Effects of marbling on mean sensory panel tenderness in Bos taurus crosses (Koch et al., 1988). Sensory panel scores for tenderness ranged from 1 - extremely tender, 5 - acceptable, 9 - extremely tender. .

Bos taurus breed groups are Angus, Brown Swiss, Charolais, Chianina, Gelbvieih, Hereford, Jersey, Limousin, Maine Anjou, Pinzgauer, Red Poll, **Simmental,** South Devon and Tarentaise sired topcrosses out of Hereford and Angus dams.