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Breeding for Lean Beef (Germ Plasm Evaluation Program)

Larry V. Cundiff
U.S. Meat Animal Research Center, Larry.Cundiff@ars.usda.gov

Michael E. Dikeman
Kansas State University

R. M. Koch
U.S. Meat Animal Research Center

John D. Crouse
U.S. Meat Animal Research Center

Keith E. Gregory
U.S. Meat Animal Research Center

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Introduction

Historically, when steers were finished on pasture, ability to finish at a young age was desirable, particularly when market requirements for fatness were great. However, ability to fatten became a handicap as we shifted to increased use of concentrate feeds in diets of growing-finishing cattle. Consequently, yield grades were added to the USDA grading system to reflect variation in carcass value associated with differences in yield of retail product. 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. Cholesterol levels are, in turn, associated with dietary intake of saturated fat. 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. The purpose of this paper is to examine genetic variation among and within breeds in the amount and distribution of fat and lean in beef carcasses and to evaluate opportunities to genetically change fat and caloric content of retail product in cattle.

[1]Cundiff is the research leader, Genetics and Breeding Unit, MARC; Dikeman is a professor of meat science, Kansas State University, Manhattan; Koch is a professor of animal science, University of Nebraska-Lincoln, stationed at MARC; Crouse is the research leader, Meats Unit; and Gregory is a research geneticist, Genetics and Breeding Unit, MARC.

[2]The authors would like to acknowledge W. Gordon Hays, cattle operations manager, MARC, and C.E. Murphey and others, Agricultural Marketing Service, USDA, who assisted with this research.

Procedure

Results reviewed are from the first three cycles of the Germ Plasm Evaluation (GPE) Program at MARC (see paper entitled "Germ Plasm Evaluation in Cattle") in which topcross performance of 19 different sire breeds have been evaluated in calves out of Hereford and Angus dams or calves out of F_1 cross dams. Data were pooled over Cycles I, II, and III by adding the avg differences between Hereford-Angus reciprocal crosses (HAx) and other breed groups (2-way and 3-way F_1 crosses) within each cycle to the avg of Hereford-Angus reciprocal crosses (HAx) over the three cycles. Data presented are for 19 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 1). Carcass and meat data, obtained in cooperation with Kansas State University under the direction of Dr. Michael E. Dikeman, are presented for 15 F_1 crosses out of Hereford and Angus dams.

Table 1—Breed crosses grouped into seven 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 (Rp)	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 Gertrudis (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	XXXXXX
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 levels of performance and older age at puberty.

Results

Percentage of retail product. Significant genetic variation exists between and within breeds for retail product percentage when comparisons are made at the same age or weight. In Figure 1, F_1 cross means for percentage of retail product at 458 days of age are shown on the lower horizontal axis. The spacing on the vertical axis is arbitrary but the ranking from the bottom to top, generally, reflects increasing increments of mature size. Steers by bulls of breeds with large mature size produced a significantly higher percentage of retail product than steers sired by breeds of small and medium mature size.

In Figure 1, differences have been doubled in the upper horizontal scale to reflect variation among pure breeds relative to a standard deviation change in breeding value [$\sigma g = (\sigma 2p)(h^2) = (3.3)(.63)$] within pure breeds. Frequency curves, shown for Jersey, the avg of Hereford and Angus, and Chianina, reflect the distribution expected for breeding values of individual animals within pure breeds (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 breeding value of the leanest Jersey is not expected to equal that of the fattest Chianina, and the leanest Hereford and Angus would only equal the fattest Chianina in genetic potential for percentage of retail product at 458 days. The range for mean differences between breeds is estimated to be about 5.2 σg (standard deviations in breeding value) between Chianina and Hereford or Angus steers, and 5.8 σg between Chianina and Jersey steers. Genetic variation, both between and within breeds, is important for percentage of retail product. 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 about 30%.

Marbling (USDA Quality Grade). In addition to cutability, as reflected by USDA yield grades, USDA quality grade is also considered in the USDA dual-grading system. Degree of marbling (i.e., deposits of fat interspersed in muscle) in the twelfth rib cross-section of the ribeye 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

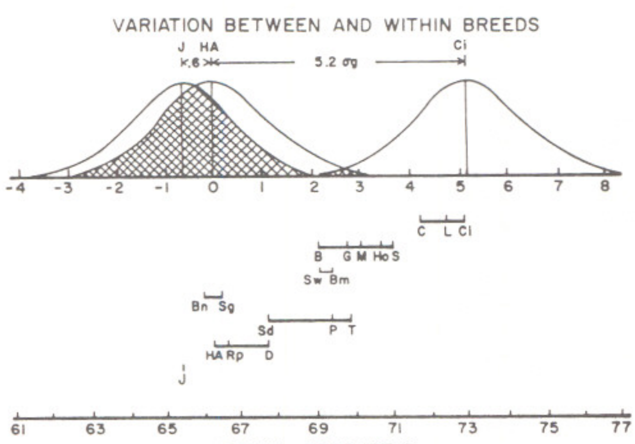

Figure 1—Breed cross means (F_1 crosses, lower axis) and genetic variation between and within breeds (σ g, standard deviation in breeding value, upper axis) for retail product percentage at 458 days. See Table 1 for abbreviations.

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.

Table 2—Sensory panel tenderness scores (means and standard deviations) within different degrees of marbling[a]

Marbling	Number	Mean	Standard deviation
Slightly Abundant	13	7.8	.56
Moderate	35	7.7	.60
Modest	95	7.3	.87
Small	180	7.3	.85
Slight	134	7.1	.78
Traces	27	7.0	.83

[a]Taste panel scores: 2 = undesirable, 5 = acceptable, 7 = moderately desirable, 9 = extremely desirable.

In data from Cycle I of the GPE Program, sensory panel tenderness tended to improve about 1 sensory panel score as marbling increased the full range from practically devoid to slightly abundant (Table 2). Marbling accounted for only 10% of the variation in tenderness. Thus, the standard deviation and range in tenderness among cattle with the same marbling score was still almost as large as that found among cattle not grouped by marbling level. Variation in tenderness scores (see standard deviations) was less at high levels of marbling (moderate and slightly abundant) than at intermediate (small and modest) or low degrees of marbling (traces and slight), indicating a greater risk of at least some steaks having less than acceptable tenderness at low degrees of marbling.

Significant genetic variation exists between and within breeds for propensity to deposit marbling (Fig. 2). 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 breeds. The tendency for progeny from individual animals to regress to their own breed group mean is much greater than any tendency to regress to the mean of all cattle.

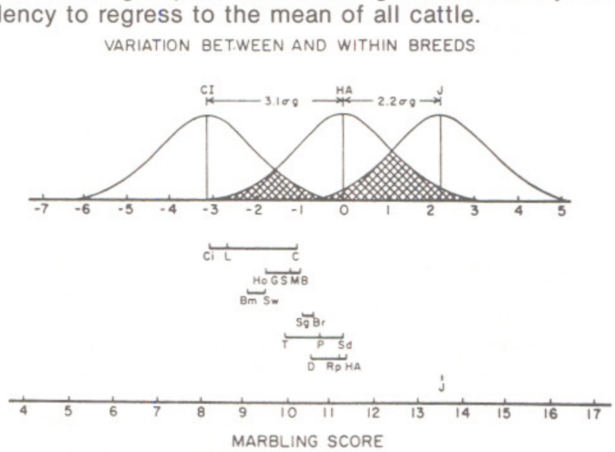

Figure 2—Breed cross means (F_1 crosses, lower axis) and genetic variation between and within breeds (σ g, standard deviation in breeding value, upper axis) for marbling score. See Table 1 for abbreviations.

Genetic Antagonism (Retail Product and Marbling). Unfortunately, breeds that rank highest for retail product percentage rank lowest for marbling (Fig. 3). 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 retail product percentage.

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 mo of age. 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 avg marbling scores and in percentage of carcasses that had adequate marbling to grade USDA Choice or better, avg sensory panel evaluations of flavor and juiciness were acceptable for all breed groups.

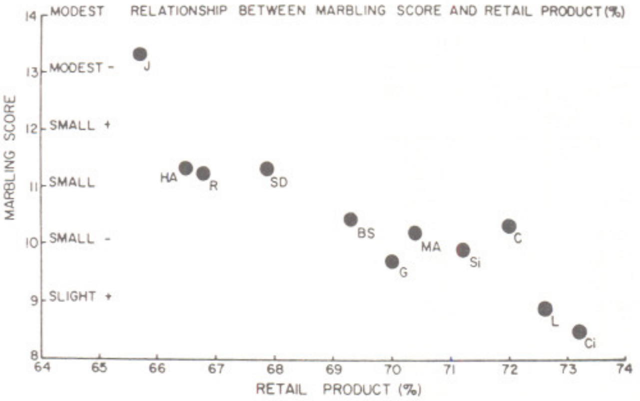

Figure 3—Breed cross means for retail product percentage *vs* marbling score at 458 days of age. See Table 1 for abbreviations.

Caloric Density of Retail Cuts. Breed group means for calories originating from the lean, intra-muscular fat, and inter-muscular fat components of 100 gram (3.5 oz) uncooked portions of retail product are presented in Table 4. External and inter-muscular fat (averaging 20.6% over all breeds) accounted for a much greater proportion of total fat in the retail product than intra-muscular (i.e., marbling) fat (averaging 4.0%). Variation among breeds was important for both percentage of external and intra-muscular fat (range 2.6 percentage units) and for percentage of inter-muscular fat (range of 3.2%).

On the average, a 100 gram portion of uncooked retail product containing a total of 280 kcal, would have 83 kcal originating from protein (29.7%), 34 kcal from intra-muscular fat (12.2%) and 163 kcal from external and inter-muscular fat (58.3%). Fat content of retail product is markedly reduced by total trimming of visible fat. Caloric content of totally-trimmed portions (lean and intra-muscular fat only) contained an avg of 117 kcal. For totally-trimmed retail product, the range among F_1 breed groups was 14 kcal (111 for Chianina crosses to 125 kcal for Jersey crosses). Since topcross comparisons estimate only half of the difference between breeds, estimates of the range between F_1 crosses can be doubled to estimate the range between pure breeds—28 kcal or from about 99 kcal for Chianina to 127 kcal for Jersey steers.

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.

Table 3—Breed cross means for factors identified with meat quality

Breed group	Marbling[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]Taste panel scores: 2 = undesirable, 5 = acceptable, 7 = moderately desirable, 9 = extremely desirable.

Table 4—Breed cross means for caloric content of retail product (3.5 oz uncooked portion)

Breed group	Lean protein, kcal	Intra-musc. fat, kcal	External & inter-musc. fat, kcal	Total kcal	Lean & intra-musc. fat only, kcal
Jersey-X	79	46	180	305	125
Hereford-Angus-X	81	42	172	294	123
Red Poll-X	80	40	177	297	120
South Devon-X	82	39	167	287	121
Tarentaise-X	84	33	159	276	117
Pinzgauer-X	83	39	160	281	122
Sahiwal-X	84	30	161	275	114
Brahman-X	84	30	164	276	113
Brown Swiss-X	83	32	164	280	116
Gelbvieh-X	84	33	160	277	117
Simmental-X	84	33	156	273	117
Maine-Anjou-X	83	32	164	280	115
Limousin-X	86	26	154	266	111
Charolais-X	84	33	156	274	117
Chianina-X	86	25	155	265	111
Range (R)	7	21	26	40	14

Table 5—Composition and caloric content of *longissimus* (ribeye) 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	Practically devoid	.7	1.9	26.8	31.3	33.2
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	43.3
Choice	Modest	6.7	17.8	25.2	29.1	46.9
Choice	Moderate	8.2	21.7	24.8	28.5	50.2
Prime	Slightly abundant	9.7	25.7	24.4	27.9	53.6
Prime	Moderately 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 and fat contains 9.3 kcal per gram.

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

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 (ribeye) 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 oz. Muscle from carcasses grading USDA Choice range from about 4.7 to 9.3% fat and contain about 43 to 51 kcal per oz. 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. Total trimming will favor production of carcasses with a higher percentage of retail product and less fat trim. Cattle with the greatest genetic potential for retail product growth and reduced fat trim levels also excel in feed efficiency from weaning to slaughter at age or wt end points.

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. Genetic variation found between breeds is comparable in magnitude to that found within breeds for most growth and carcass traits. 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 complicated by difficulties of estimating carcass characteristics in live animals used for breeding or by the increased generation interval and other costs associated with progeny testing.

The genetic variation both between and within breeds can be used to provide an array of beef products that differ widely in fat and caloric content. Cattle with the greatest retail product growth potential produce carcasses with lower levels of marbling and totally-trimmed retail cuts with lower fat and caloric content. These cattle are especially well suited for marketing opportunities for low fat or low caloric beef with acceptable palatability characterisitics. Cattle with greater marbling potential are more suited to marketing opportunities for the gourmet food trade, where the risk of occasional steaks with unacceptable tenderness must be minimized.