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To the Graduate Council:

I am submitting herewith a thesis written by Muthuswamy Pillai Ranganathan entitled "Relationship of Sires to Eating Quality of Beef," I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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RELATIONSHIP OF SIRES TO EATING QUALITY OF BEEF

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Muthuswamy Pillai Ranganathan

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CHAPTER I

INTRODUCTION

Meat is the foundation of the American diet and beef forms the major portion of the meat consumed. The consumer is the ultimate judge in determining the quality of beef. He desires tenderness and flavor in beef more than any other qualities. The livestock producer has the onerous duty of producing beef cattle that have desirable eating quality. Though many factors have been found to exert an influence on the eating quality of beef, the most important seems to be tenderness. Also, tender beef should not be "off-flavor" nor should it lack flavor in order to be acceptable to the consumer. Hence it would be desirable for the livestock producer to know which of his animals produced beef with acceptable eating quality.

A myriad of factors, both antemortem and post-mortem, influence the eating quality of beef. Some of the antemortem factors are species, breed, age, sex, feed and grade. The post-mortem factors are (1) location of the muscle in the carcass, (2) time and temperature of aging, (3) method and duration of cooking and (4) inherent consumer differences. In short, for beef to be satisfactory it must be tender, juicy and flavorful.

Some of the factors influencing the eating quality of beef have been found to be heritable in varying degrees. In order to assess the heritability of different characteristics which influence the eating quality, it becomes necessary to evaluate the carcasses of the progeny

of the individual sires under study. However, the beef cattle producer has to sacrifice the progeny to get reliable data on the beef quality. In spite of intense research, it is doubtful whether there is a single factor which can be assessed or measured in the living animal that can be reasonably correlated with the eating quality of beef. Moreover, the evaluation of the carcass by physical, chemical or histological analyses cannot always be relied upon as such. To arrive at a real significant value, it is incumbent to use a trained taste panel to assess the eating quality.

The carcass characteristics which are believed to exert an influence on the eating quality of beef are marbling, firmness, texture, color of fat and lean, and youthness. There is no critical objective test for tenderness. Mechanical techniques must be compared with the subjective test scores of a trained taste panel. For the taste panel, the selected cut of beef is cooked by a standard method and scores for tenderness, juiciness and flavor are obtained to determine eating quality.

In a sound breeding program, one should select breeding stock not only for factors leading to improved efficiency of production, but also for improved carcass merit. At present it is not possible to get direct carcass appraisals on prospective breeding animals. Therefore, the only practical method of selecting a sire capable of improving the tenderness of his offspring is by progeny testing. Other suggested techniques are (1) examination of biopsy material from the sire and (2) preserving germ plasm by freezing, then slaughtering the sire and making direct measurements on his carcass.

The object of this study was to determine differences in eating quality of beef from various sire progenies. Thus the sires which are known to produce progeny having beef with high eating quality could be used intensively for breeding. It was assumed that heredity has a great role in the production of the desired tender beef. By locating sires that produce progeny with tender meat, the task of the beef cattle producer can be made easier and more profitable.

CHAPTER II

REVIEW OF LITERATURE

Eating quality is a complex factor and is affected both by hereditary and environmental factors. Research workers have made many attempts to unearth the fundamental causes of what makes beef desirable. Factors affecting the eating quality of beef, or, in other words, affecting the value of a beef animal from a consumer's standpoint, can be divided roughly into two categories. First, there are those factors which affect yield of both the total carcass and preferred cuts, and secondly, those factors which affect the consumer desirability of the finished product.

Lush (1940) pointed out that every characteristic is both hereditary and environmental since its expression can be altered by appropriate changes either in its heredity or environment. He defined the degree of heritability as that fraction of the observed variance which is caused by differences in heredity. This fraction is a statistic describing a particular population. It can be made larger or smaller if either the numerator or the other ingredients in the denominator can be altered. Thus, it may vary from population to population for the same characteristic and may vary from one characteristic to another in the same population. In a later article Lush (1948) described methods of estimating heritability of quantitative characters. These methods were based on the likeness between individuals which are related in many ways. He suggested that the resemblance may be measured either

by comparing the variances between the individuals related in various ways or as a correlation. He stressed the discounting of that part of the resemblance caused by environment before interpreting resemblance as heredity. He also pointed out that allowance has to be made for non-randomness in mating systems.

The first estimates of heritability of economic characteristics in beef cattle were published by Knapp and Nordskog (1946a, 1946b). These first estimates were based on 177 steers from 23 bulls. They calculated the estimates of heritability in the same population by using two different methods, namely the half-sib correlation method and the parent-offspring regression method. By the former method Knapp and Nordskog (1946a) found birth weight to be 23 per cent heritable; weaning weight, 12 per cent; weight at 15 months, 81 per cent; rate of gain in the feed lot, 99 per cent; and efficiency of gain, 75 per cent. By using the latter method they found that birth weight was 34 per cent heritable; weaning weight, 30 per cent; weight at 15 months, 94 per cent; daily gain in the feed lot, 97 per cent; and efficiency of gain, 48 per cent.

Knapp and Nordskog (1946b) also reported estimates of heritability of live animal type scores, grades and certain carcass characteristics in beef cattle. Heritability of weaning score was 53 per cent; slaughter grade, 63 per cent; carcass grade, 84 per cent; area of eye muscle, 59 per cent; and carcass yield, 1 per cent.

Koger and Knox (1952) described grade as one of the economic characteristics of cattle to be considered in breeding operations. By analyzing the records of 1257 range Hereford calves and their dams, they

arrived at a heritability of 24 per cent. They found that selection for compactness in Hereford cattle was highly effective, indicating a relatively high heritability of body proportions. They concluded that the mating should be random if heritability estimates were to be reliable.

Knapp and Clark (1950) determined the following heritability estimates by the half-sib correlation method from the analysis of variance: birth weight, 53 per cent; weaning weight (age corrected), 28 per cent; final feed lot weight at 15 months, 86 per cent; gain in the feed lot, 65 per cent; weaning score, 28 per cent; slaughter steer grade, 45 per cent; carcass grade, 33 per cent; and area of eye muscle, 68 per cent. They concluded that growth measures were more highly influenced by heredity than were measures of quality and conformation.

Shelby et al. (1955) analyzed beef cattle data covering a ten-year period at the Montana Agricultural Experiment Station and arrived at the following heritability estimates in per cent by the paternal half-sib correlation method: birth weight, 72; weaning weight, 23; gain, 60; efficiency, 22; final weight, 84; slaughter grade, 42; pre-slaughter shrink, 91; dressing percentage, 73; carcass grade, 16; color of eye muscle, 31; area of eye muscle, 72; and thickness of fat, 38. They observed that the effects of differences between years were highly significant for all characteristics. The effects of differences between lines within years were significant for efficiency of feed. Those between sires within lines were not significant for carcass grade but were significant for weaning weight and highly significant for other

characteristics. They advocated that selection for most growth characteristics should be based on the individual's own record, while selection for carcass characteristics must be based on a sib or progeny test.

Kieffer et al. (1959) studied the influence of sire upon some carcass characteristics of Angus steers and heifers. They found that the differences among sire groups were highly significant ($P < .01$) for tenderness as estimated by the shear force technique. The intraclass half-sib correlation of average shear force values was 0.23 which yielded a heritability estimate of 0.92. Important sire differences were found for pre-weaning growth rate. Large sire differences were also noted for rate of feed lot gain on standard rations and for dressing percentage and carcass grades. Small sire differences were shown for percentage of fat, lean and bone in the 9-10-11 rib section.

Kincaid and Carter (1958) estimated heritability of growth rate by the parent-offspring regression method, a method used by Lush, Norton and Arnold (1941). Carter and Kincaid (1959b) determined genetic and phenotypic correlations among various traits in beef cattle using data from 195 steers and 190 heifers sired by 36 bulls. These progeny were born over a five-year period. The genetic correlations were all positive. The correlation between pre-weaning growth rate and subsequent rate of gain was 0.69 for the steers and 0.51 for the heifers. Carter and Kincaid (1959a) while comparing the two methods commonly used to determine heritability, namely the regression of the offspring on either parent and the half-sib correlation method, pointed out that the former method is not biased by selection among the parents as is the

case with the half-sib correlation method.

Cartwright (1959) reported the following heritability estimates by the half-sib correlation method for six characteristics he studied in beef cattle: gain on test, 0.58; chilled carcass weight per day, 0.11; rib eye area, 0.73; U. S. D. A. grade, 0.15; ether extract, 0.64; and shear force, 0.59. He found significant differences due to years in all the characters except rib eye area and ether extract.

Tallis and Klosterman (1959) stressed the need for collecting data from an optimum number of offspring from each sire to get reliable heritability estimates. Butler (1960) reported that five to ten progeny from a sire gave statistically satisfactory data for calculating heritability estimates.

Cover et al. (1957) stated that differences in eating quality might be expected among animals differing in heredity or level of concentrates fed. They found no significant differences in juiciness scores of beef from steers within breeds. However, tenderness scores were significantly different.

Cole and Orme (1959, unpublished data), working on the influence of type and breed on certain beef palatability factors, found significant differences in the tenderness, as measured by shear value, between Angus and Hereford steers. While the average shear force value of Angus beef was 13.4 pounds, that of Hereford beef was 14.9 pounds. The mean marbling score of Angus steers was one degree higher than that of Herefords and a corresponding increase in ether extract was noticed in the Angus steers (Angus, 29.6 per cent; Hereford, 26.6 per cent ether extract). Cole,

Backus and Orme (1960) observed a linear decrease in flavor of lean, tenderness, juiciness and total palatability with a lowering of the grade. However, they found an overlapping among grades. The Texas workers (Cover et al., 1960) did not find any close or consistent relation between carcass grade and marbling. Brannan (1957) observed the percentage of lean to increase as the grade decreased from Choice to Standard.

Simone et al. (1958) determined the quality factors of beef varying in degree of finish and age. Their results indicated that differences in tenderness, juiciness and flavor became more apparent with increasingly wider differences in degree of finish and carcass grade. The relationship of per cent carcass fat to quality scores did not reveal any significant correlations. Warwick (1953) drew particular attention to "finish" as the only factor which can be evaluated in live animals that can be related to the ultimate carcass quality by visual measurements of the live beef animal. Many workers [Johnson (1940), Lush (1928), Barton (1938), Wanderstock and Salsbury (1946), Kidwell (1955), Severson and Gerlaugh (1917), Lush (1932), Hankins and Beard (1944), Yao, Dawson and Cook (1953) and Orme (1953)] have reported width, depth and circumference measurements to be indicative of the amount of finish. Helser et al. (1930) reported that finish of a carcass has a decided influence upon the palatability. They found that roasts with extra finish seemed to have a very pronounced fatty odor and flavor which were not pleasing to the majority of the members of the taste panel.

Marbling is the term used to indicate the presence of flecks or streaks of fat within muscles. The fat deposited in the muscles was supposed to distend them and make them more tender. Cole, Backus and Orme (1960) observed a decrease in marbling as the carcass grade decreased from Prime to Standard. They also found that differences among grades in fat thickness and subjective marbling were highly significant. Harrison et al. (1959) observed that tenderness scores were more closely correlated with ether extract than marbling as determined by physical separation. Cartwright (1958) reported that neither fatness per se, marbling as indicated by ether extract, nor U. S. D. A. carcass grade accounted for a large enough fraction of the variability of the tenderness of beef to recommend any of them as an adequate independent criterion of beef quality. His estimate of heritability of ether extract was 64 per cent. Kieffer et al. (1958) found significant sire differences for marbling scores and per cent of fat in 9-10-11 rib sections. They reported intrasire phenotypic correlations of marbling score with tenderness as -8 per cent and with depth of fat over rib eye as +22 per cent.

Helser et al. (1930) observed that the flavor of the lean became more desirable when additional excess fat (marbling) was embedded within the muscle rather than when it was found on the muscle (finish). Although published correlation coefficients between marbling and tenderness have been low and in some cases non-significant, Butler (1954) found that these characteristics can be estimated objectively with respectable repeatability. The relationship of marbling to juiciness, however, has been found experimentally to be significant, but statistical analyses of

data have bred doubt in the minds of research workers concerning the importance of marbling. Earlier instruction and training had left no room for doubt.

Barbella et al. (1939), working on the relationship of flavor and juiciness of beef to fatness, found a small but statistically significant association. Breeding and age had a highly significant effect on aroma, flavor and juiciness, independent of the amount of fat determined by ether extraction. Cover et al. (1957) observed that, irrespective of the method of cooking, loin steaks from Hereford steers were significantly more juicy than loin steaks from the Brahman x Hereford crossbreeds. They also observed that sires within breeds had no significant effect on juiciness though the effect on tenderness was significant. Kidwell et al. (1958) found the flavor of the muscle to be associated with per cent fat, average daily gain and quality of juice. Their data indicated quality of juice was more dependent on muscle constituents than on fatness. Weir (1960) considered meat flavor to be very difficult to evaluate. Age of the animal, type of feed, the length of time in feed lot and conditions of storage after slaughter are factors influencing the flavor of cooked meat. Also, well-marbled beef from mature animals with a relatively high degree of finish is juicier than that from young animals with less marbling. Crocker (1948) reported that flavor in raw meat was resident in the juice and not in the fiber. He also observed that meaty flavor which developed on cooking apparently was due to chemical changes taking place in the fiber rather than in the juices.

CHAPTER III

MATERIALS AND METHODS

The University Hereford herd at Alcoa location and the Angus herd at the University of Tennessee Agricultural Experiment Sub-Station at Crossville were used for this study.

A. BACKGROUND AND PRE-SLAUGHTER TREATMENT

Alcoa Hereford Steers

Ten purebred Hereford bulls at the Alcoa farm sired the purebred and crossbred calves born during the winter and spring of 1958. Fifty-nine bull calves of this calf crop were selected for this study. They were castrated before they were three months old. These calves were allowed to remain with their dams with no creep feeding. They were weaned November 1, 1958 and group-fed through winter for 151 days. The ration consisted of 5 pounds of corn and cobmeal, one pound of cottonseed meal, 4 to 5 pounds of mixed legume and grass hay and a full feed of grass silage. They were turned to pasture April 1, 1959 and remained on pasture for 135 days. They were not given any supplemental feed while on pasture. Early in August, 1959 each steer was implanted with 24 mg. of stilbestrol and put on a full feed of corn and cottonseed meal (8:1) on pasture for eighty-two days.

At the end of the feedlot period, the Alcoa steers were weighed and trucked to a local commercial packing plant in two groups at an

interval of seven days during November, 1959. The animals were kept off-feed for twenty-four hours before slaughter, but were given water ad libitum.

Crossville Angus Steers

Five purebred Aberdeen Angus bulls sired the Angus calves at the Crossville sub-station. Nineteen bull calves born during the winter and spring of 1958 were the animals used in this study. They were classified and numbered as the progeny of these five bulls. The calves were castrated before they were three months of age. Their treatment was similar to that of the Hereford steers at the Alcoa station except for the fact that they received 36 mg. of stilbestrol implantation before they were put on a full feed of corn and cottonseed meal (8:1) on pasture. In addition, they were used as test animals in antibiotic and enzyme feeding trials during the winter of 1959.

At the end of the feedlot period, these animals were weighed and trucked in two groups to the same commercial packing plant at Knoxville, a distance of 100 miles, during November, 1959.

The age range of the steers from these two stations varied from eighteen to twenty-two months.

B. SLAUGHTER PROCEDURE - ALCOA AND CROSSVILLE STEERS

The steers were slaughtered in a commercial packing plant and the hot carcasses were marked with identification tags and left in the cooler at 34 ± 3°F. for forty-eight hours. Chilled carcass weight and carcass

measurements were taken by a team of trained personnel from the Animal Husbandry Department. Dressing percentage and yield were calculated. The right rib from each carcass was purchased and brought to the meat laboratory for detailed analyses. All ribs were aged at 34 ± 3°F. for fourteen days.

C. PROCEDURE FOR COLLECTING DATA IN THE MEAT LABORATORY

This wholesale cut was further divided into three pieces as twelfth rib, 6-7-8 rib, and 9-10-11 rib sections.

Marbling Score

A careful survey of the marbling in the cut surface of the Longissimus dorsi at the twelfth rib was made and a subjective marbling score was given for each animal. The U. S. D. A. marbling scores ranging from one to twelve - one denoting "devoid" and twelve denoting "extremely abundant" - were used (Appendix 1).

Fat Thickness

The fat thickness over the ribeye was measured as per procedure suggested by Naumann (1951).

Area of Loin Eye

The cut surface of the Longissimus dorsi in the twelfth rib section was traced and the area was measured with a compensating planimeter.

Per Cent of Lean, Fat and Bone

The 9-10-11 rib section was physically separated into lean, fat and bone. Per cent of lean, fat and bone in this section were calculated.

Specific Gravity of Loin Eye Muscle

The excised Longissimus dorsi of the 9-10-11 rib section was used for determining the specific gravity of the muscle by the hydrostatic weighing technique described by Rathburn and Pace (1945).

Shear Value of the Twelfth Rib

The twelfth rib section was saved for determining the shear value of the Longissimus dorsi and stored in the freezer. It was removed from the freezer a day prior to the cooking and allowed to thaw in the constant temperature room at 68-69°F. overnight. The twelfth rib section was wiped thoroughly with a cloth and weighed. It was then placed, fat side up, on a rack in a roasting pan and the whole placed in a Despatch oven preheated to 300°F. A thermometer was inserted into the thickest portion of the roast and the initial temperature was recorded. The roast was cooked until the internal temperature reached 72°C. (161.6°F.). It was then removed from the oven and allowed to cool to room temperature. Cores of one inch diameter from the Longissimus dorsi were taken at three locations for measuring the shear value. The shear value on each of the cores was determined at three places by use of a Warner-Bratzler shear machine. The average of these nine values expressed in pounds of pressure to shear the core was taken as the shear value of the Longissimus dorsi.

Taste Panel and Shear Value of 6-7-8 Rib

The 6-7-8 rib section was frozen and stored for organoleptic tests. It was removed from the freezer one day prior to cooking and was thawed overnight at room temperature (68-69°F.). It was made into a boneless rib roast by removing the piece of scapula and was cooked in a Despatch oven preheated to 300°F. until the internal temperature reached 68°C. (154.4°F.).

A trained taste panel consisting of six members of the Animal Husbandry Department and the Home Economics staff was used to evaluate the roasts. Each roast was scored for tenderness, juiciness and flavor. Ratings were scored on a numerical scale of one through nine with nine representing the highest value which each characteristic could receive (Appendix II). The final rating for each roast was the average of the scores of all the six members.

A mechanical test for tenderness was made on each roast by the Warner-Bratzler Shear.

All cooking for organoleptic tests and shear value by mechanical test was done by the Food Research Section of the College of Home Economics.

Analysis of variance for unequal sub-class numbers as outlined by Snedecor (1956) was used to obtain mean squares. Components of variance were estimated by equating the mathematical expectation of each classification to the mean squares and by solving this system of equations by ordinary computational procedure. The assumptions necessary to use this type of analysis are given by Henderson (1953).

CHAPTER IV

RESULTS AND DISCUSSION

The beef herds at Alcoa and Crossville were used for this investigation. There were ten Hereford bulls stationed at Alcoa and five Angus bulls at Crossville. It was proposed to study the progeny of these fifteen bulls, and with the carcass data collected from their progeny, estimate the heritability of various traits and see whether there were any significant differences between locations and sires within breeds. It would have been more desirable to have had a uniform number of five to ten steers from each bull, but the 1958 calf crop did not give the desired number. Hence all the available bull calves which were the progeny of these fifteen bulls were allotted to the experiment.

Although the pre-slaughter treatment was quite similar for both locations, there were some slight deviations which will be mentioned here. The Crossville Angus steers were used for an experiment, during the winter of 1959, to test the efficacy of some feed additives. The results indicated no significant difference between the treated and control groups and this trial is not expected to contribute any variation to the results of this experimental study. The Hereford steers at Alcoa received a 24 mg. implantation of stilbestrol before they were put on full feed on pasture, whereas the Crossville Angus steers received a 36 mg. implantation of stilbestrol. This difference in dosage of stilbestrol implantation did not materially alter their average daily gain or type grades. It was assumed that this difference in treatment did not

significantly affect the data obtained in this experiment.

The Angus steers were trucked a distance of 100 miles to the packing plant, but the Hereford steers were trucked only twelve miles before they were slaughtered. This might have caused a slight variation in their yield and dressing percentage which were not a part of this study. It was assumed that the difference in the number of miles trucked before slaughter did not affect any of those characters under study.

Except for these minor differences, both herds were managed quite similarly for this project.

A. SLAUGHTER GRADE

The slaughter grade of the Alcoa Hereford steers varied from 10.2 to 12.0, the mean being 10.9 (Table I). Those of Crossville Angus steers ranged from 9.3 to 10.8 with a mean value of 10.2. There was a significant difference in the slaughter grade between the two locations ($P < .05$). The analysis of variance (Table II) did not reveal any significant difference among sire groups at both locations either when taken alone or when data were pooled. This may be due to the similar environmental conditions under which these animals were raised and fed. The sire components of variance for both breeds were negative, namely -0.022 for Herefords and -0.013 for Angus. The heritability estimates for slaughter grade calculated by the half-sib correlation method were -0.11 for Herefords and -0.06 for Angus. The pooled data gave an estimate

TABLE I

THE MEAN VALUES OF SLAUGHTER GRADE AND CARCASS GRADE WITH THE NUMBER OF PROGENY FROM EACH SIRE

Location	Sire	No. of Progeny	Slaughter Grade[a] Mean	Carcass Grade[a] Mean
Alcoa	9075	11	11.1	9.0
	9416	2	11.2	9.2
	9023	11	10.8	9.0
	9217	5	11.2	9.6
	9120	8	10.8	9.2
	9000	2	10.2	9.8
	9611	5	11.2	9.8
	9046	12	10.6	9.5
	9505	1	12.0	9.0
	4033	2	11.0	10.8
	Total	59	10.9	9.4
Crossville	5244	5	10.4	10.6
	5435	3	10.8	11.3
	5345	3	10.3	10.3
	5284	3	9.3	10.0
	5063	5	10.2	11.0
	Total	19	10.2	10.7

[a] 12 = Low choice
11 = High good
10 = Average good
9 = Low good.

TABLE II

ANALYSIS OF VARIANCE, SIRE COMPONENT OF VARIANCE AND HERITABILITY ESTIMATES OF SLAUGHTER GRADE AND CARCASS GRADE

	Slaughter Grade			Carcass Grade		
	Alcoa	Crossville	Pooled	Alcoa	Crossville	Pooled
Between Locations						
Mean Square			6.82[a]			43.34[b]
Among Sires						
D. F.	9	4	13	9	4	13
Mean Square	0.891	0.918	0.899	0.980[a]	0.878	0.948
Within Sires						
D. F.	49	14	63	49	14	63
Mean Square	1.014	0.965	1.003	0.426	1.043	0.563
k	5.59	3.74	5.41	5.59	3.74	5.41
Sire Component of Variance	-0.022	-0.013	-0.019	0.099	-0.442	0.071
Heritability Estimate	-0.11	-0.06	-0.08	0.75	-0.18	0.22

[a]Denotes significance at 5 per cent probability level.

[b]Denotes significance at 1 per cent probability level.

of -0.08. The negative heritability estimate is in sharp contrast to the positive heritability estimates reported by Shelby et al. (1955) and Knapp and Nordskog (1946b). The former authors reported an estimate of 0.42 with a range of 0.25 to 0.57 while the latter authors reported a value of 0.63. Knapp and Clark (1950) reported the heritability estimate as 0.45. The negative heritability value can be considered as zero heritability for practical purposes. This may be due to the extensive selection practiced in breeding stock at both locations and possibly due to the smaller number of progeny examined under some sires.

B. CARCASS GRADE

The mean data from each sire are furnished in Table I. The Alcoa Hereford steers had a mean carcass grade of 9.4 with a range of 9.0 to 10.8, whereas the Crossville Angus steers had a mean carcass grade of 10.7 with a range of 10.0 to 11.3. It is interesting to note that while the mean carcass grade is lower than the slaughter grade in the Alcoa steers, that of the Crossville steers was higher than the corresponding slaughter grade. The reason for this is dealt with in detail under marbling. A highly significant difference was found between the carcass grade of steers from the two locations. There was a significant difference ($P < .05$) in the grades among sire groups at Alcoa, while there was none among sire groups at Crossville (Table II). The pooled data showed no significant differences among sire groups. The results of Alcoa steers are in line with the findings of Kieffer et al. (1959). The carcass

grade in Alcoa steers had a heritability of 0.75 while the Crossville steers yielded a negative value of 0.18. However, the analysis of pooled data resulted in a positive heritability estimate of 0.22. This value is between the values of 0.15 reported by Cartwright (1958) and 0.33 reported by Knapp and Clark (1950).

C. FAT THICKNESS

Table III shows the mean fat thickness of steers from each sire. The range was 10.2 to 15.5 mm. with a mean of 13.3 mm. for the Alcoa steers. In the Crossville steers the range was 6.0 to 10.4 mm. with a mean value of 8.4 mm. The Alcoa Herefords put on more finish than the Crossville Angus though both breeds were fed for a similar period. There was a highly significant difference between fat thickness of steers in the two locations (Table IV). Analysis of variance indicated no significant differences among sire groups at Alcoa, whereas a significant difference was noticed among sire groups at Crossville. However, the pooled data did not show any significant difference among sire groups. Heritability estimates of fat thickness were 0.22 and 1.77, respectively, for the Hereford and Angus steers. The pooled data gave a heritability estimate of 0.33. The heritability estimates of the Alcoa Hereford steers as well as the result of the combined data of Hereford and Angus fall within the range of 0.20 to 0.38 reported by Shelby et al. (1955). The heritability estimate for fat thickness of Angus steers which is more than 1.00 can be ascribed to the small number of steers used.

TABLE III

THE MEAN VALUES OF FAT THICKNESS, MARBLING SCORE AND AREA OF LOIN EYE WITH THE NUMBER OF PROGENY FROM EACH SIRE

		Fat Thickness		Marbling Score		Area of Loin Eye	
Location	Sire	No. of Progeny	Mean Value in mm.	No. of Progeny	Mean Value[a]	No. of Progeny	Mean Value in sq. in.
Alcoa	9075	11	11.4	8	3.0	11	11.70
	9416	2	14.5	2	3.5	2	11.12
	9023	11	12.3	10	3.3	11	10.68
	9217	5	13.4	5	4.2	5	11.87
	9120	8	15.1	8	3.8	8	10.56
	9000	2	13.5	2	3.0	2	10.44
	9611	5	10.2	5	4.0	5	12.10
	9046	12	15.2	12	3.6	12	10.93
	9505	1	14.0	1	2.0	1	11.02
	4033	2	15.5	--	---	2	10.58
	Total	59	13.3	53	3.5	59	11.13
Crossville	5244	5	6.0	5	6.6	5	12.92
	5435	3	9.3	3	5.7	3	11.64
	5345	3	9.7	3	5.3	3	11.14
	5284	3	7.0	3	4.3	3	12.75
	5063	5	10.4	5	5.4	5	11.91
	Total	19	8.4	19	5.6	19	12.14

[a]U. S. D. A. marbling score with 1 denoting devoid and 12 denoting extremely abundant.

TABLE IV

ANALYSIS OF VARIANCE, SIRE COMPONENT OF VARIANCE AND HERITABILITY ESTIMATES OF FAT THICKNESS, MARBLING AND AREA OF LOIN EYE

	Fat Thickness			Marbling			Area of Loin Eye		
	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled
Between Locations									
Mean Square			338.0[a]			59.50[a]			9.44[a]
Among Sires									
D. F.	9	4	13	8	4	12	9	4	13
Mean Square	19.30	15.53[b]	18.14	1.18[b]	2.28	1.55	2.25	2.05	2.19
Within Sires									
D. F.	49	14	63	44	14	58	49	14	63
Mean Square	14.53	3.90	12.16	0.495	1.96	0.85	1.52	1.61	1.55
k	5.59	3.74	5.41	5.61	3.74	5.41	5.59	3.74	5.41
Sire Component of Variance	0.850	3.109	1.106	0.12	0.086	0.129	0.130	0.115	0.118
Heritability Estimate	0.22	1.77	0.33	0.78	0.16	0.53	0.32	0.26	0.28

[a]Denotes significance at 1 per cent probability level.

[b]Denotes significance at 5 per cent probability level.

D. MARBLING

The mean marbling scores for steers from each sire are presented in Table III. The scores ranged from 2.0 to 4.2 in the Alcoa Hereford carcasses with a mean score of 3.5. In the Crossville Angus carcasses the marbling scores ranged from 4.3 to 6.6 with a mean value of 5.6. Although the Alcoa steers had a higher slaughter grade and a greater fat thickness than the Crossville steers, because of lack of marbling they graded lower than the latter by the U. S. D. A. standards. On the other hand, in spite of the slightly lower slaughter grade and a lower fat thickness, the Crossville steers graded higher than the Alcoa steers. This was mainly due to the uniform higher degree of marbling. Of course, they possessed the minimum requirement of other factors, namely conformation, finish and youthness which are essential standards in deciding U. S. D. A. grade.

A highly significant difference was noticed between the marbling scores of the steers from the two locations. There were significant differences ($P < .05$) among the marbling scores of the progeny of the Hereford sires. In Angus, the differences were not significant. Heritability estimates of marbling score were 0.78, 0.16 and 0.53 for the Hereford, Angus and combined data of Alcoa and Crossville animals.

E. AREA OF LOIN EYE

The Alcoa Hereford steers had a mean loin eye area of 11.13 sq. in. with a range of 10.44 to 12.10 (Table III). The Crossville Angus steers,

however, showed a larger mean area of 12.14 with a range of 11.14 to 12.92. A highly significant difference was noticed between the loin eye areas of steers from the two locations (Table IV). There were no significant differences among sire progenies either in the Alcoa or in the Crossville steers. Heritability estimates of 0.32 and 0.26 were obtained for area of loin eye in the two breeds. The pooled data indicated a heritability estimate of 0.28 for the area of loin eye. This estimate is lower than the estimate of 0.73 reported by Cartwright (1959) and 0.72 with a range of 0.60 to 0.80 reported by Shelby et al. (1955).

F. PERCENTAGE OF SEPARABLE LEAN, FAT AND BONE IN THE 9-10-11 RIB SECTION

These data are furnished in Table V. The percentage of lean ranged from 48.0 to 54.1 with a mean of 51.6 in the Alcoa steers. The value ranged from 49.3 to 58.6 in the Crossville steers with a mean of 53.6. A significant difference ($P < .05$) was found between the percentage of lean in the steers from the two locations (Table VI). Differences in the percentage of separable lean among the sire groups at Alcoa were not significant. However, the differences were significant ($P < .01$) among sire groups at Crossville. The pooled data also showed highly significant differences among sire groups. Heritability estimates of 0.06 and 2.34, respectively, were obtained for the steers in the two locations. The pooled data showed a heritability estimate of 1.05. Theoretically, the heritability estimate of any characteristic varies from zero to one. In practice, estimates more than one are obtained and in such instances the

TABLE V

THE MEAN PERCENTAGE OF SEPARABLE LEAN, FAT AND BONE IN THE 9-10-11 RIB SECTION AND THE SPECIFIC GRAVITY OF THE EXCISED LONGISSIMUS DORSI FROM THE SAME SECTION WITH THE NUMBER OF PROGENY FROM EACH SIRE

Location	Sire	No. of Progeny	Mean Percentage in the 9-10-11 Rib Section			Specific Gravity
			Lean	Fat	Bone	
Alcoa	9075	11	51.8	31.8	16.4	1.0610
	9416	2	53.0	31.2	15.8	1.0662
	9023	11	53.0	30.8	17.0	1.0654
	9217	5	53.4	31.5	15.0	1.0640
	9120	8	51.5	33.0	15.5	1.0633
	9000	2	51.8	32.6	15.4	1.0654
	9611	5	50.4	33.9	15.7	1.0647
	9046	12	50.7	34.3	15.0	1.0637
	9505	1	54.1	29.6	16.3	1.0668
	4033	2	48.0	36.4	15.8	1.0630
	Total	59	51.6	32.6	15.8	1.0637
Crossville	5244	5	55.8	29.9	14.4	1.0630
	5435	3	49.3	36.0	14.8	1.0640
	5345	3	55.7	28.8	15.6	1.0656
	5284	3	58.6	26.2	15.8	1.0626
	5063	5	49.6	36.5	13.8	1.0624
	Total	19	53.6	31.8	14.7	1.0633

TABLE VI

ANALYSIS OF VARIANCE, SIRE COMPONENT OF VARIANCE AND HERITABILITY ESTIMATES OF PERCENTAGE OF SEPARABLE LEAN, FAT AND BONE IN THE 9-10-11 RIB SECTION AND SPECIFIC GRAVITY OF THE LONGISSIMUS DORSI IN THE SAME RIB SECTION

	Separable Lean in 9-10-11 Rib Section			Separable Fat in 9-10-11 Rib Section			Separable Bone in 9-10-11 Rib Section			Specific Gravity of the Longissimus dorsi in 9-10-11 Rib Section		
	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled
Between Locations Mean Square			54.98[a]			7.86[a]			18.08[b]			0.000239
Among Sires D. F.	9	4	13	9	4	13	9	4	13	9	4	13
Mean Square	8.88	61.21[b]	24.98[b]	17.39	75.99[b]	3.54[b]	3.52	2.65	3.26	0.001660	0.000575	0.001249
Within Sires D. F.	49	14	63	49	14	63	49	14	63	49	14	63
Mean Square	8.16	9.79	8.53	12.97	13.77	1.32	2.48	1.15	2.03	0.002755	0.003099	0.002863
k	5.59	3.74	5.42	5.59	3.74	5.42	5.59	3.74	5.42	5.59	3.74	5.42
Sire Component of Variance	0.127	13.8	3.04	0.792	16.62	0.411	0.186	0.401	0.226	-0.000196	-0.000675	-0.000298
Heritability Estimate	0.06	2.34	1.05	0.23	2.19	0.95	0.28	1.03	0.40	-0.31	-1.11	-0.46

[a]Denotes significance at 5 per cent probability level.

[b]Denotes significance at 1 per cent probability level.

heritability can be taken as one or, in other words, 100 per cent heritable.

The percentage of separable fat in the 9-10-11 rib section ranged from 29.6 to 36.4 with a mean value of 32.6 in the Alcoa Hereford steers. In the Crossville steers, it ranged from 26.2 to 36.5 with a mean of 31.8. The difference between the percentage of fat in the two breeds was significant ($P < .05$). There were no significant differences in the percentage of fat among the different sire groups at Alcoa. Highly significant differences were noticed in the percentage of separable fat both among the various sire groups at Crossville and in the pooled data. Estimates of 0.23 and 2.19 were obtained for heritability of this characteristic. Calculation from the pooled data gave an estimate of 0.95. Referring to Table III, we find the mean fat thicknesses for the Alcoa Hereford steers and the Crossville Angus steers are 13.5 and 8.5 mm., respectively, with a corresponding separable fat percentage of 32.5 and 31.5. The lean to fat ratio is also affected by the fat thickness. It will be observed that the Hereford steers had a higher fat thickness, higher separable fat percentage and a lower separable lean percentage; whereas the Angus steers had a lower fat thickness, lower separable fat percentage but higher lean percentage.

The percentage of bone in the 9-10-11 rib section ranged from 15.0 to 17.0 with a mean of 15.8 in the Alcoa steers. In Crossville steers the percentage ranged from 13.8 to 15.8 with a mean value of 14.7. There were no significant differences in the percentage of bone among sire groups either at Alcoa or at Crossville. Heritability estimates for the percentage of bone in this section were 0.28 and 1.03 for the two

breeds, with a pooled estimate of 0.40. These estimates are in conformity with the results reported by Kieffer et al. (1959).

G. SPECIFIC GRAVITY

The specific gravity of the excised Longissimus dorsi in the 9-10-11 rib section was used to estimate the marbling in the muscle. The specific gravity of muscle having little marbling is higher than that of muscle having an appreciable quantity of marbling, because lean has a higher specific gravity than fat. The mean values for specific gravity are presented in Table V. In Alcoa Hereford steers the specific gravity ranged from 1.0610 to 1.0668 with a mean of 1.0637. In Crossville Angus steers, it ranged from 1.0624 to 1.0656 with a mean of 1.0633. Analysis of variance and heritability estimates are furnished in Table VI. There was no significant difference between the specific gravity values of Alcoa and Crossville steers. Also, the differences were not significant among sire groups both in Alcoa and Crossville steers. Heritability estimates for the specific gravity were negative with values of 0.31 and 1.11 for the two breeds with an estimate of -0.46 for the pooled data.

It will be seen that the Hereford steers with less marbling had a higher specific gravity of the excised Longissimus dorsi, whereas in the Angus with higher marbling scores, the specific gravity was comparatively lower. This is in line with the inverse relationship described by Cole, Backus and Orme (1960) between marbling and specific gravity.

H. TENDERNESS, FLAVOR AND JUICINESS SCORES

The subjective evaluation of the eating quality of beef was conducted with the help of a trained taste panel using the boneless rib roast from the 6-7-8 rib section. The roast was scored for tenderness, flavor and juiciness using a one to nine point scale (Appendix II). Number one in this scale indicated extremely poor quality and number nine indicated excellent quality under these three headings. The data are given in Table VII. The tenderness scores for the Alcoa steers ranged from 6.9 to 8.4 with a mean of 7.3. In the Crossville steers, the scores ranged from 5.9 to 7.3 with a mean of 6.6. A highly significant difference was found between the tenderness scores of Alcoa and Crossville steers ($P < .01$). On the other hand, there was no significant difference in the scores among sire groups either in the Alcoa or in the Crossville steers. This is in contrast to the findings of Cover et al. (1957) who found significant differences in the tenderness scores within breeds. By comparing the mean tenderness scores, it is observed that the Hereford steers were rated nearly one point more tender than the Angus steers. Though the Angus steers had a higher degree of marbling than the Hereford, they did not score as high in tenderness by organoleptic tests.

Heritability estimates gave a negative value of 0.26 in the case of Alcoa steers, whereas it was a positive 0.73 in the case of Crossville steers. Analysis of the pooled data resulted in a negative value of 0.01 (Table VIII).

TABLE VII

THE MEAN VALUES OF TENDERNESS, FLAVOR AND JUICINESS SCORES OF THE 6-7-8 RIB ROAST WITH THE NUMBER OF PROGENY FROM EACH SIRE

Location	Sire	No. of Progeny	Tenderness Scores	Flavor Scores	Juiciness Scores
Alcoa	9075	10	6.9	7.3	7.2
	9416	2	6.9	7.1	6.9
	9023	9	7.5	7.4	7.1
	9217	5	7.5	7.4	7.1
	9120	7	7.4	7.5	7.0
	9000	2	7.2	7.5	6.9
	9611	5	7.0	7.6	7.2
	9046	11	7.1	7.4	7.1
	9505	1	8.4	7.2	6.4
	4033	2	7.9	7.3	7.5
	Total	54	7.3	7.4	7.1
Crossville	5244	5	6.4	7.4	7.4
	5435	3	5.9	7.3	6.9
	5345	3	7.3	7.2	6.9
	5284	3	6.9	7.1	7.3
	5063	5	6.7	7.3	7.2
	Total	19	6.6	7.3	7.2

TABLE VIII

ANALYSIS OF VARIANCE, SIRE COMPONENT OF VARIANCE AND HERITABILITY ESTIMATES OF TENDERNESS SCORES, FLAVOR SCORES AND JUICINESS SCORES

	Tenderness Scores			Flavor Scores			Juiciness Scores		
	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled
Between Locations									
Mean Square			5.78[a]			0.23			0.07
Among Sires									
D. F.	9	4	13	9	4	13	9	4	13
Mean Square	0.58	0.83	0.66	0.068	0.052	0.061	0.13	0.42	0.22
Within Sires									
D. F.	44	14	58	44	14	58	44	14	58
Mean Square	0.85	0.45	0.76	0.088	0.117	0.095	0.25	0.25	0.25
k	5.15	3.74	5.10	5.15	3.74	5.10	5.15	3.74	5.10
Sire Component of Variance	-0.052	0.101	-0.018	0.0038	-0.017	0.007	-0.023	0.437	0.006
Heritability Estimate	-0.26	0.73	-0.01	-0.16	0.69	-0.9	-0.40	0.59	-0.01

[a]Denotes significance at 1 per cent probability level.

Flavor scores ranged from 7.1 to 7.6 with a mean of 7.4 in the Alcoa steers. In the Crossville steers, the scores ranged from 7.1 to 7.4 with a mean of 7.3. There was no significant difference between the scores of the steers of the two locations. No significant differences could be found among sire groups either at Alcoa or at Crossville. The pooled data also did not show any significant differences among sire groups. The heritability estimates were all negative (Table VIII).

Juiciness scores ranged from 6.4 to 7.5 with a mean of 7.1 in the Alcoa steers; whereas the range was 6.9 to 7.4 with a mean of 7.2 in the Crossville steers. No significant difference was found between the scores of the two breeds at the 5 per cent probability level. There were no significant differences in the juiciness scores among sire groups in the two breeds. This is in line with the findings of Cover et al. (1957) who found no significant differences in juiciness scores within breeds. The heritability estimate for juiciness scores was -0.40 in the case of Alcoa steers. The estimate was positive (0.59) in the Crossville steers. However, the pooled data indicated a negative heritability of 0.01.

A careful study of these three scores obtained by organoleptic tests indicated that flavor and juiciness scores varied little for all the steers, whereas tenderness scores gave indications of differences in eating quality. The fairly uniform conditions under which these steers were raised may be the probable cause for the uniformity of the flavor and juiciness scores. In other words, it appears that environment has a greater role in determining flavor and juiciness while heredity has a greater role in determining tenderness.

I. TENDERNESS AND SHEAR VALUES

Tenderness was measured objectively by use of the Warner-Bratzler shear machine. Roasts from the 6-7-8 rib section and twelfth rib section were used. The mean shear force values of the Longissimus dorsi from these two cuts are shown in Table IX.

The shear force values for the twelfth rib section ranged from 12.6 to 17.8 with a mean value of 14.1 in the Alcoa steers, whereas in the Angus steers the shear value ranged from 14.0 to 17.1 with a mean of 15.6. Analysis of variance, sire component of variance and heritability estimates are furnished in Table X. A significant difference in the shear values was found between Alcoa and Crossville steers. Although the shear force value of Alcoa Hereford steers is comparable to that of 14.9 reported by Cole and Orme (1959, unpublished data), the shear force value of Crossville Angus steers in this study exceeded their reported value for Angus by 2.3. There were no significant differences ($P < .05$) in the shear values among sire groups in the Alcoa steers. However, there was a significant difference at the 10 per cent probability level among sire groups at Crossville. The pooled data did not show any significant differences among sire groups. Heritability estimates for the twelfth rib shear value were 0.30 and 1.10 for the Alcoa and Crossville steers. An estimate of 0.41 was obtained for the pooled data. Kieffer et al. (1959) found highly significant differences for shear force values among sire groups in Angus cattle and reported a heritability estimate of 0.92. The estimate obtained for Angus cattle in this study exceeds one, indicating a value near the one reported by Kieffer et al.

TABLE IX

THE MEAN SHEAR VALUES OF THE TWELFTH RIB SECTION AND THE 6-7-8 RIB SECTION WITH THE NUMBER OF PROGENY FROM EACH SIRE[a]

Location	Sire	No. of Progeny	Mean Shear Value		Combined Mean Shear Value for Both Cuts
			12th Rib	6-7-8 Rib	
Alcoa	9075	10	14.2	15.3	29.5
	9416	2	17.8	13.2	31.0
	9023	8	12.6	14.4	27.0
	9217	5	14.4	13.4	27.8
	9120	6	13.7	14.2	27.9
	9000	2	16.6	12.8	29.4
	9611	5	15.1	16.4	31.5
	9046	11	13.7	15.3	29.0
	9505	1	13.3	16.0	29.3
	4033	2	13.8	14.6	28.4
	Total	52	14.1	14.8	28.9
Crossville	5244	5	16.5	19.3	35.8
	5435	3	16.3	19.9	36.2
	5345	3	14.5	16.5	31.0
	5284	3	17.1	18.7	35.8
	5063	5	14.0	16.8	30.8
	Total	19	15.6	18.2	33.8

[a]Longissimus dorsi was the only muscle sheared.

TABLE X

ANALYSIS OF VARIANCE, SIRE COMPONENT OF VARIANCE AND HERITABILITY ESTIMATES OF SHEAR VALUES OF THE TWELFTH RIB SECTION AND THE 6-7-8 RIB SECTION

	12th Rib Section			6-7-8 Rib Section		
	Alcoa	Cross-ville	Pooled	Alcoa	Cross-ville	Pooled
Between Locations						
Mean Square			31.63[a]			165.44[b]
Among Sires						
D. F.	9	4	13	9	4	13
Mean Square	7.42	7.29[c]	7.38	5.01	8.42	6.06
Within Sires						
D. F.	42	14	56	42	14	56
Mean Square	5.31	3.01	4.73	8.48	6.01	7.87
k	4.95	3.74	4.96	4.95	3.74	4.96
Sire Component of Variance	0.426	1.146	0.534	-0.701	0.644	-0.365
Heritability Estimate	0.30	1.10	0.41	-0.36	0.39	-0.19

[a]Denotes significance at 5 per cent probability level.

[b]Denotes significance at 1 per cent probability level.

[c]Denotes significance at 10 per cent probability level.

The shear force values of the 6-7-8 rib sections ranged from 12.8 to 16.4 with a mean value of 14.8 in the Alcoa steers. The corresponding values in the Crossville steers were 16.5, 19.9 and 18.2, respectively. A highly significant difference was found between the shear values of the 6-7-8 rib sections of Alcoa Hereford and Crossville Angus steers. There was no significant difference between the shear values of the twelfth rib section and the 6-7-8 rib section in the Alcoa steers. In contrast to this, the Crossville steers showed a highly significant difference between the shear values of the twelfth rib section and the 6-7-8 rib section. The shear value of the 6-7-8 rib section of Angus steers was higher than the shear value of the corresponding twelfth rib section shear value by 2.6. In other words, the muscle was less tender anteriorly in the 6-7-8 rib section. This finding was corroborated by the taste panel. The mean tenderness score for the 6-7-8 rib cuts from Angus steers was 6.6. Heritability estimate of the shear value of the 6-7-8 rib section was a negative 0.36 in the case of Alcoa steers, whereas it was a positive 0.39 in the case of Angus steers. The pooled data, however, gave a negative estimate of 0.19.

Table XI shows the analysis of variance of the combined mean shear values of the two cuts. A significant difference was found between the shear values for the two breeds. No significant differences were found between the shear values of steer groups among sires or steers within sires. The sire components of variance were -1.16 and 5.128 for the Alcoa and Crossville steers. The combined data gave a sire component of variance of 0.335. Heritability estimates calculated from the combined

TABLE XI

ANALYSIS OF VARIANCE, SIRE COMPONENT OF VARIANCE AND HERITABILITY ESTIMATES OF THE COMBINED MEAN SHEAR VALUES OF THE TWELFTH AND 6-7-8 RIB SECTIONS

	Combined Shear Value		
	Alcoa	Crossville	Pooled
Between Locations			
D. F.			1
Mean Square			341.74[a]
Among Sires			
D. F.	9	4	13
Mean Square	9.68	29.54	15.79
Within Sires			
D. F.	42	14	56
Mean Square	15.40	10.36	14.13
k	4.95	3.74	4.96
Sire Component of Variance	-1.16	5.128	0.335
Heritability Estimate	-0.33	1.32	0.09

[a]Denotes significance at 1 per cent probability level.

shear values were -0.33 and 1.32 for the Alcoa and the Crossville steers. However, the pooled data from the two locations gave an estimate of 0.09.

CHAPTER V

SUMMARY AND CONCLUSIONS

Fifty-nine steers from Alcoa, the progeny of ten Hereford bulls, and nineteen steers from Crossville, the progeny of five Angus bulls, were used to study the relationship of sires to eating quality of beef. These steers were given approximately the same treatment before slaughter, and fourteen different carcass characteristics were studied in detail. Heritability estimates were calculated for all these fourteen characters; slaughter grade, carcass grade, fat thickness, marbling, area of loin eye, specific gravity of the Longissimus dorsi and separable lean, fat and bone of the 9-10-11 rib section. Eating quality of beef was determined subjectively by organoleptic tests using a trained taste panel, and objectively by use of the Warner-Bratzler Shear.

Significant or highly significant differences were found between the steers from the two locations for all fourteen characteristics except specific gravity, flavor scores and juiciness scores.

Significant differences ($P < .05$) were found among sire groups at Alcoa for carcass grade and marbling only.

Highly significant differences ($P < .01$) among sire groups were found for percentage of separable lean and fat at Crossville. Sire differences at the 5 per cent probability level were found for fat thickness, whereas sire differences at the 10 per cent probability level were observed for shear value of the twelfth rib section. There was also a highly

significant difference between the shear values of the twelfth rib section and the 6-7-8 rib section in the Angus steers.

When the data from these two locations were pooled and analyzed for sire differences, there were highly significant differences for percentage of lean and fat only. No significant differences among sire groups were found when the shear values of the two cuts were combined and analyzed; but highly significant differences in the combined shear values were found between two breeds.

Compared to Crossville Angus steers, the Alcoa Hereford steers graded higher on foot but slightly lower on the rail, because of the greater fat thickness and less marbling.

Although the Alcoa Hereford steers had less marbling and graded lower, they scored higher on the organoleptic tests for tenderness. This was corroborated by lower shear values. On the other hand, in spite of a higher marbling, the Crossville Angus steers graded lower in the organoleptic tests with low scores for tenderness. This was corroborated by a higher shear force value indicating that the beef was less tender in spite of a higher degree of marbling. The flavor and juiciness scores did not show significant differences between steers in both locations. However, tenderness scores showed significant differences.

Heritability estimates calculated by the half-sib correlation method showed a considerable variation, ranging from negative values to values more than one. For a few characters (fat thickness, percentage of lean, fat and bone), the value corresponds to the estimates reported in the literature. For many characters, there are no published heritability

estimates. The inconsistency in the estimates probably may be ascribed to the small number of animals used in the study.

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LITERATURE CITED

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APPENDIX

ILLUSTRATIONS OF THE LOWER LIMITS OF CERTAIN DEGREES OF TYPICAL MARBLING REFERRED TO IN THE OFFICIAL UNITED STATES STANDARDS FOR GRADES OF CARCASS BEEF

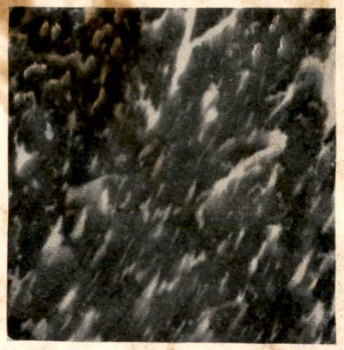
A - Extremely abundant
B - Very abundant
C - Abundant
D - Moderately abundant
E - Slightly abundant
F - Moderate
G - Modest
H - Small
I - Slight
J - Traces
(Practically devoid not shown)

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE
LIVESTOCK DIVISION

Illustrations adapted from negatives furnished by New York State College of Agriculture, Cornell University



A



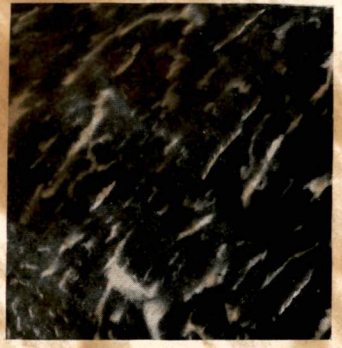
B



C



D



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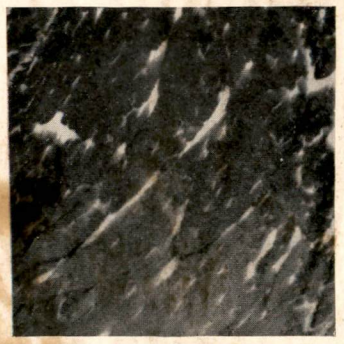
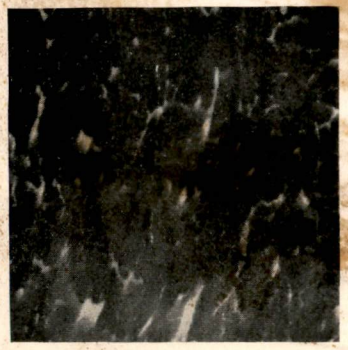


F



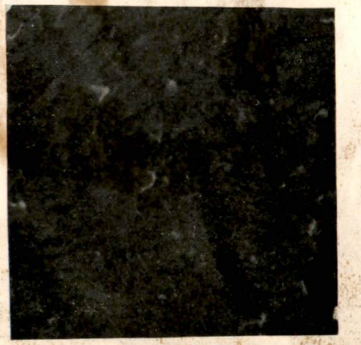
G



H



I



J

NEG. NO. DN-1594 DECEMBER 1958

APPENDIX I

APPENDIX II

GRADING CHART FOR MEAT

Date _____ Name _____

Directions: Give full value for excellent quality.
Do not use fractional points.

Values:
9-Excellent
8-Very good
7-Good
6-Fair plus
5-Fair
4-Fair minus
3-Poor
2-Very poor
1-Extremely poor

Sample No.				
Odor				
Appearance				
Flavor of lean				
Juiciness				
Tenderness				
Flavor of fat				

Comments: