THE INFLUENCE OF SIRE UPON PERFORMANCE AND CARCASS CHARACTERISTICS IN HEREFORD PROGENY

by

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TABLE OF CONTENTS

INTRODUCTION

Consumer demands for meat products with a higher proportion of lean to fat have created significant changes in the beef cattle industry in recent years. Research workers, charged with the responsibility of finding new and improved means of identifying superior, beef-type animals, have revised and refined one of the earlier tools used in selection, performance testing.

The problem encountered in the selection of these superior animals is complicated by the structure and the diverseness of the beef cattle industry. In order for a characteristic to be of practical and economic importance in a selection program, it must be genetically highly heritable, and must satisfy all segments of the industry, i.e., the producer, the feeder, the packer, the processor, and the consumer. Information is needed to the extent to which characteristics of prospective breeding cattle and slaughter cattle may be used to predict differences in carcass traits.

The generation interval for cattle is quite long (approximately five years), resulting in the most generally accepted selection practice adopted being that of sire testing. The formation of various Beef Cattle Improvement Associations (BCIA), and the adoption of various types of performance testing programs by the beef breed registry associations in recent years has strengthened the role of production testing as an aid in selection.

This study was undertaken in order to develop a better understanding of beef cattle evaluation. The objectives of this experiment were: (1) to study the relationship between conformation traits of sires of the same breed and type, and that between these traits in the sire and the carcass traits among his progeny; (2) to study the relationship between conformation traits in a sire and the weaning, yearling, and the slaughter grades and weights of his progeny; (3) to evaluate certain live animal traits for predicting carcass value; (4) to estimate heritability coefficients for all traits studied and to determine if sire differences for these traits are statistically significant; (5) to study the results of the cooking data and taste panel results for flavor, tenderness, and juiciness among the various sire groups.

REVIEW OF LITERATURE

Performance Testing

Every since man domesticated those creatures whom he felt would aid him in a constant effort for survival, he has sought to improve, by selection, those animals which gave him pleasure, comfort, or assistance. Earliest selection was probably based on personal preferences, but as man learned to evaluate animals for a specific purpose, he began "breeding the best to the best" (Rice and Andrews, 1951).

Visual appraisal of live animals by trained judges has proven to be one of the most extensively used tools in livestock improvement. One has but to study the modern meat-type animal in order to determine how successful man has been in controlling the genetic patterns of his livestock. Modern animals are the result of years of selection for those traits which the breeders have considered economically important. We seek more accurate evaluation of those characteristics by live animal and carcass research.

Edinger (1925) reported using a detailed description in which the major parts of the animal were scored in comparison to the ideal beef-type. With the exception of the neck and brisket, each portion was scored according to conformation and finish. The same procedure was used for scoring the wholesale cuts, although the number of wholesale cuts in the carcass is less than the number of major parts of the live animal, due to the combination of two or more of the portions.

Holbert (1932) proposed a Register of Merit rating similar to the one presently used by the American Hereford Association, whereby a sire is given credit for the showring winnings of his progeny. Most of the present day performance testing programs differ in some manner, depending on the number of traits being studied, sex of the animals being tested, and the period of time covered by the test. This is not considered unusual as many workers have studied performance testing and have recommended various criteria or standards of evaluation (Holbert, 1932; Winters and McMahon, 1933; Black and Knapp, 1936; Knapp _et al._, 1941; Knapp and Black, 1942).

In any type of evaluation study, some method of standardization and record keeping must be adopted; this has led to the development of various scorecards. Many workers have attempted to utilize scorecards as a basis for selection. Lush (1932) stated that no standard or scorecard based on conformation could ever accurately predict future performance of individual steers. Knapp et al. (1936) concluded that scoring as a technique of evaluation for differences between animals is subject to considerable error and is probably of very doubtful value when differences between animals are small. When the population to be studied shows large differences, the scoring technique is undoubtedly the simplest way to evaluate differences in conformation. Slaughter tests have shown repeatedly that there are material differences between the progeny of two sires, yet scores and grades have failed to show such differences (Shelby et al., 1955; Carter and Kincaid, 1959; Bradley et al., 1966).

Black and Knapp (1936) outlined a program for measuring performance in beef cattle in which certain conditions should be held constant among animals for record-of-performance tests. They proposed that weaning weight, slaughter weight, feed, and method of feeding all be held constant in an attempt to reduce environmental influence. In addition, it was believed that the period of development from feeder animal to time of slaughter should be studied most extensively.

Knapp et al. (1942) reported that when progeny testing beef bulls, there is a rapid increase in information gained from each successive animal added to the study until at least five individuals are included in the study. From five on the information gained from each successive animal becomes relatively less until, after reaching fifteen animals, each additional animal contributes very little information. It was also concluded that in order to conduct a progeny test with reliable results, some number of animals between six and ten would be satisfactory.

Krehbiel et al. (1958) was able to show that selection for beef-type improvement could be made at the rate of approximately one-third of a grade per year. A paternal half-sib estimate of heritability for beef-type improvement was found to be 0.54, indicating that selection for type on the basis of scorecard was effective. Ray and Gifford (1949) analyzed the agreement between judges and normal changes in animals during a lifetime, using fixed standards for type and body conformation, found that most animals remained in or near the same classification during their lifetime with seasonal differences in condition or finish having little influence on classification rating.

A method of recording performance based on the average daily gains of the animal from birth to one year of age and a quality score based upon slaughter grade as determined by a committee was proposed by Winter and McMahon (1933). Their recommendation was based upon work which revealed that animals of the same phenotype as determined by exterior morphology did possess marked differences in the ability to make gains economically. Sheets (1932) proposed a procedure based on the feedlot record of progeny and a quality grade based on carcass grade and tenderness. Patterson et al. (1949) found that the ability of an individual to make gains rapidly was highly heritable. Selection based on the performance of an individual should thus prove the most effective in improving rate of gain in beef cattle. Patterson et al. (1949) further reported that practically no relationship existed between type score and gain ($r = 0.41$). The correlation reported between initial grade and initial weight was -.243, while initial grade and final grade were fairly highly correlated (0.724).

Sabin *et al.* (1958) found age at weaning failed to give a significant relationship in predicting future scores and future gains; weaning score was the only independent variable significantly associated with final score. Condition scores and conformation scores at weaning were indicators of future scores, while skeletal size and development were not measured by weight. Bone measurements were capable of predicting future size, but not future weight. Kidwell *et al.* (1957) concluded that selection for heavy weaning weight on a progeny basis should be effective in improving post-weaning rate of gain. Weaning grade was found to be highly correlated with subsequent grades, as indicated by the high correlation (0.66) between weaning weight and feedlot gains.

Marlowe and Gaines (1958) concluded that type scores were not influenced sufficiently by the age of the calf to be of any practical importance. Sex of the calf influenced growth rate significantly in both creep fed and non-creep fed groups studied, but had little effect on type score. Bull calves grew approximately five percent faster than steer calves, and the steer calves grew approximately eight percent faster than the heifer calves. Season of birth had a significant influence on growth of the non-creep fed group but was of no practical importance on growth of creep fed calves or type scores of either group. Age of dam was found to be the most important source of variation studied with the largest differences occurring among the younger age groups; maximum production was obtained during the study from cows in the six- to ten-year age group.

Brown (1951) reported a downward trend in score for heifer calves from calfhood to first lactation, after which the score tended to increase to maturity (approximately five and one-half years), and remain constant until changes associated with senility began to cause a decline. The age at which a cow's score appeared to be most highly correlated with lifetime average age score was three years (0.81) and one and one-half years (0.80).

Black and Knapp (1938) studied several methods of measuring performance and concluded that differences in weight at twelve months was not significantly different in the progeny of several sires, but efficiency of gain could be best demonstrated in animals weighing from 500- to 900-pounds. Kidwell et al. (1956) compared Holstein versus conventional Hereford cattle to determine the influence of size and type, concluded that at a given weight and age, animals of larger mature size gained more rapidly on less feed than animals of smaller mature size. Also, carcasses of large animals will contain a higher proportion of bone and muscle, and a lower proportion of fat. Differences in percent of the wholesale cuts were found to be small. Woodward et al. (1942) also found that large animals gained more in the feedlot, as did Hultz (1927). Stanley and McCall (1945) reported a positive correlation between rate of feedlot gain and skeletal size.

Knox and Koger (1946) studied the relationship of type and performance, and reported no difference in carcass grade among Hereford steers classified as to rangy, medium, and compact type. Steers classified rangy gained more and weighed more than the compact steers, with the medium steers being intermediate in each case; the conclusion was that gain was due to skeletal size rather than type. These results are in agreement with reports of other workers who have reported a poor relationship between type and gain (Lush, 1932; Patterson _et al._, 1955).

Gregory _et al._ (1961) stated that record-of-performance will have its greatest impact through application by the purebred breeders or herds selling breeding stock to the commercial cattleman. At the present time there is considerable pressure being applied to such producers to supply prospective buyers with performance information of the sires.

In reporting results of performance testing, authors are continually stressing the need to remove the effect of environment from such experiments in order to more accurately evaluate the true genetic differences between animals. When the environment has been as closely standardized as possible, it is more practical to study the heritability of the various traits concerned. Warwick (1958) stated that very little research was conducted measuring beef cattle performance prior to 1930. Knapp and Nordskog (1946), using data collected at the U. S. Range Livestock Experiment Station, Miles City, Montana, presented the first estimates for the heritability of quantitative traits in beef cattle. They found small to moderate estimates for birth and weaning weight, extremely high heritability estimates for gain during a post-weaning feedlot test (0.99), for efficiency of gain during the test (0.75), and for final weight at the end of the test (0.81). Heritability estimates were above fifty percent for weaning conformation score, slaughter score, carcass grade, and area of rib eye muscle. Several of the estimates approached one hundred percent, and were thus revised by Knapp and Clark (1950). Warwich (1958) summarized numerous studies of economic traits in beef cattle in tabular form, the results appear as Table 1.

Koger and Knox (1952) reporting on heritability of grade and type in beef cattle estimated the heritability of grade at 0.24, based on half-sib correlations. The preliminary results showed selection for compactness in Hereford cattle to be highly effective, indicating a relatively high heritability for body proportions. These authors also stated that grade is one of the economic characteristics of cattle which must be considered in most cattle breeding operations.

Dawson et al. (1955) working with Milking Shorthorn steers, reported the following heritability estimates on characteristics which they considered to be high (above forty percent): dressing percentage, 0.69; carcass grade, 0.67; slaughter grade, 0.58; days to final weight, 0.57; birth weight, 0.51; and days to weaning, 0.45.

Shelby et al. (1955) stated that selection made for most of the growth characteristics should be based on the individual's own record, while selection for carcass characteristics should be based on half-sib or progeny test. Data from the Miles City, Montana Station was summarized for 635 steers from 88 sire groups and paternal half-sib correlations were used in obtaining the following heritability estimates: birth weight, 0.72; weaning weight, 0.23; gain in feedlot, 0.60; final weight at end of feeding period, 0.84; efficiency of feed utilization, 0.22; slaughter grade, 0.42; shrink, 0.91; dressing percent, 0.73;

Table 1. Heritability estimates for beef cattle characters.[1]

Character	No. of estimates	Avg. of estimates	Range of estimates
		%	%
Calving interval	3	8	0-15
Birth weight	15	41	11-100
Weaning weight	26	30	-13-100
Cow maternal ability	2	40	19-60
Post weaning feedlot gain	13	45	19-70
Post weaning pasture gain	6	30	9-43
Carcass traits:			
Dressing percent	2	71	69-73
Carcass grade	5	34	-30-84
Rib eye area	3	69	69-72
Tenderness	2	61	41-81
Conformation grades:			
Weaning	16	26	0-53
Slaughter	5	39	-13-63
Cancer eye susceptibility	2	32	23-41

[1]Warwick (1958).

carcass grade, 0.16; color of eye muscle, 0.31; area of rib eye, 0.72; and thickness of fat, 0.38.

Studies of Lindholm and Stonacker (1957) indicated that selection for weaning weight alone was an accurate basis for selecting for increased net income in Hereford calves. Kieffer et al. (1959) calculated heritability estimates from paternal half-sib correlation for maternal effects on birth weight (0.60), weaning weight (0.39), and condition score (0.04). Lehmann et al. (1961) reported that selection indexes were developed and compared, based on daily gain from birth to weaning, and a 203-day weaning weight and type score. Weaning weight in the best linear equation studied was concluded to be preferable to selecting on the basis of either growth or type singularly.

Carter and Kincaid (1959), working with calves raised over a six-year period at the Virginia Station, obtained heritability estimates for weight at six-months (0.08), feeder grade (0.41), daily gain in the feed-lot (0.38), feed efficiency (0.99), slaughter grade (0.45), and carcass grade (0.16) for the steer calves; weight at six-months (0.69), feeder grade (0.51), daily gain on pasture (0.54), and yearling grade (0.17) for the heifer calves. Shelby et al. (1960) reported estimates for gain in feedlot (0.46), final weight at thirteenth-month (0.77), and efficiency of feed utilization (0.32). Results indicate that weight at thirteenth-month appeared to be the most valuable criterion for selection.

Christians et al. (1962) reported the following heritability estimates obtained at the Fort Reno, Oklahoma Station: slaughter weight (1.00), average daily gain (0.88), dressing percent (0.74), and slaughter grade (0.49), carcass weight (0.96), carcass grade (0.78), conformation (0.29), fat thickness (0.38), and rib eye area (0.76). Heritability estimates for the percent of lean, fat and bone as determined using the 9-10-11th rib sections (Hankins and Howe, 1946), were 0.30, 0.31, and 0.41, respectively.

Koch (1951) observed weaning weight of the calf as a useful measure of a cow's annual production, since this observation is taken at the end of the period during which she exerts maximum influence on the growth of the calf. Many range calves are sold at, or shortly after weaning and their weight determines, to a large extent, the amount the owner receives. Koch (1951) determined the repeatability (0.52) for the extent to which weaning weight is a permanent characteristic of beef cows, concluded that selection for high life-time production could be made after the cow has weaned her first calf. Rollins et al. (1952) reported that there was a difference in the genetic factors operating independently for different periods of a calf's life. Factors affecting the growth of the calf's life for the first four months appear to be independent of those genetic factors which control growth from four-months to weaning. The difference in the genetic factors may be concerned with the calf's ability to adapt to post-natal conditions from birth to four-months, and for the period from four-months to weaning, the genetic factors determining ultimate size and rate of maturity may be the principle source of variation in rate of growth.

Carter and Kincaid (1957) felt that selection for heavy weaning weights on a progeny basis would be effective in improving post-weaning rate of gain. Dearborn and Dinkel (1959) found that selection for final weight at the end of the 168-day feeding period was eighty-five percent as effective as selection at the end of a 196-day feeding period. The correlation between 196-day final weight and the 196-day rate of gain was found to be 0.81, indicating that selection for either final weight should give comparable results. Brinks et al. (1962) reported that age of dam was a significant source of variation in all traits studied with the exception of the 196-day post-weaning rate of gain. Heritability estimates of 0.40 and 0.48 were obtained for feedlot gain and final weight, respectively. Negative relationships which might retard progress from selection for increased weights were not discovered.

Brinks *et al.* (1964) calculated the following heritability estimates from paternal half-sib analysis of variance: birth weight, 0.38; gain from birth to weaning, 0.40; 180-day weight, 0.43; weaning grade, 0.28; eighteen-month weight, 0.50; and eighteenth month score, 0.13. Selection for growth throughout life might best be estimated by using weight at eighteen months.

Cundiff *et al.* (1964) reported that the genetic correlations obtained at the Oklahoma Station indicate that the genes for rapid growth are not antagonistic to those for the production of desirable carcasses, except that a slight increase in fat thickness may be expected. The major genetic antagonism evidenced in this study was between carcass grade and the percent of retail cuts. Heritability estimates were reported for rib eye area (0.73), back-fat thickness (0.43), carcass grade (0.62), and estimated percent retail cuts (0.40). Results of these data indicate that selection for any of these traits should be effective.

Wilson *et al.* (1951) reported that efficiency declined as fat deposition increased in the live animal. Swiger *et al.* (1965) compiled a series of indexes for study of efficiency of beef production and reported selection for weaning weight alone is eighty-percent as effective as the best index studied. Minyard and Dinkel (1965) also noted that the ability of a beef cow to wean a heavy, vigorous, high-quality calf every twelve months is one of the most important economical traits to the beef producer. The importance of calf weaning weight was also stressed by Minyard and Dinkel (1965), who are in agreement with results obtained by Koch (1951), emphasizing the degree to which weaning weight contributes to the beef producer's income. The repeatability of weaning weight and standard error for Herefords, Angus, and a combination of the two breeds were reported as 0.42 ± 0.04, 0.52 ± 0.13, and 0.42 ± 0.04 respectively.

Table 2 contains the results of the heritability estimates found during the literature review, being similar to Table 1, as compiled by Warwick (1958). Recent studies of Shelby et al. (1966), reporting the results of ten years Record of Performance studies at the Miles City, Montana Station are included in the summary of Table 2.

Table 2. Heritability estimates for beef cattle characters.[1]

Character	No. of estimates	Avg. of estimates	Range of estimates
		%	%
Birth weight	5	53	38-72
Weaning weight	3	25	8-43
Average daily gain	3	55	28-88
Final weight	5	60	48-84
Carcass traits:			
Slaughter weight	2	85	70-100
Slaughter grade	6	46	35-58
Carcass grade	7	34	16-78
Cold carcass weight	2	76	57-96
Dressing percent	3	66	54-74
Ribeye area	5	63	26-76
Fat 12th rib	3	33	24-38

[1]Hogan (1968)

Heritability estimates of grade and type have not received special attention during this review, other than reporting heritability estimates by the various authors cited. Koger and Knox (1952) summarized the importance of grade and type in beef cattle in stating that grade is one of the economic characteristics of cattle which must be considered in most all cattle breeding operations. The success of breeders in producing cattle with the desired quality is determined largely by the heritability of the traits involved. Heritability of grade and type was estimated to be approximately 0.30, and considerable progress can be accomplished in improving the quality of beef cattle by selection. These statements are in agreement with Tyler and Hyatt (1948), who reported the official type rating for Ayrshire cattle to be 0.28 heritable.

Mention has been made previously of the difference which occurs for different sexes (Marlowe and Gaines, 1958). Bradley et al. (1966) studied differences between steers and heifers. They reported steers have significantly ($P < .05$) heavier birth, weaning, and final weights, faster pre- and post-weaning gains, larger rib eye areas, higher conformation scores and lower percentage of lean in the 9-10-11th rib cut. Using a high- and a low-gaining sire, they found progeny of the high-gaining sire to have significantly ($P < .05$) less fat thickness at the twelfth-rib and larger rib eye areas. Also, a significantly higher ($P < .05$) percent lean and a lower percent fat in the 9-10-11th rib section than did the calves by the low-gaining sire. These data suggest that selection for post-weaning gain increases carcass muscling and reduces carcass fatness.

It has become a rather common practice to adjust weaning weights of calves for sex, age of dam, creep feeding, and day of age at weaning in order that calves may be compared in their pre-weaning gains. Johnson and Dinkel (1951) cautioned that care should be taken in applying correction factors to calves raised under different management or climatic conditions, or to calves when the weaning weights have been taken more than thirty days preceding or following the standard (190-day) weaning age. Gregory (1960) also warned against setting standards, as the standards for production traits in one environment may be unattainable under another set of conditions. Environmental conditions tend to have larger difference than the true genetic differences between herds, thus absolute standards tend to recognize superior environment when the objective seems to be to recognize superior genotypes.

Carcass Characteristics

Peters (1937) stated that type, the result of breeding, and finish, the result of feeding, have changed markedly. The change in finish has been a reduction in the degree of fatness at time of slaughter. This trend has continued to the present day. We are more critical of excessive finish today than in 1937, due largely to low consumer acceptance for excessive fat in the retail cuts. Such changes in consumer demands have forced a change in beef-type; no longer do we select for the short-coupled, short-legged, extremely thick bodied steers of a decade ago, but attempt to select steers which willexcel in muscling and have a greater percentage of the carcass in the higher-priced wholesale cuts.

This type of selection has resulted in a larger framed, more upstanding, longer bodied individual.

Peters (1937) also indicated that the only damage done to a carcass by making it extremely fat is to make necessary some trimming and waste. Other characteristics reported by Peters (1937) from work at the Minnesota Station indicated that animals of small type and refinement of bone were more expensive to produce than animals of medium to large type. Earlier, Watkins (1936), commenting on finish stated that

> Consumers, to a large degree, control or determine indirectly trends in production and preparation for the market. When speaking of finish in a beef carcass we refer to the amount of fat in proportion to the lean, the evenness of distribution of fat and lean, and the quality of the fat and lean. The amount of finish in a steer is in direct proportion to the amount and kind of feed used. Beef varies in value according to the degree of finish and the demand for the various degrees of finish.

Watkins (1936) continued,

> One of the anomalies of the business is that a large percentage of consumers insist on two things which normally do not go together, tenderness and leanness. In many cases the quality of beef is given little consideration. It is the price which is the determining factor. In this case, finish gets little consideration. The consumer wants the smallest amount of fat that will produce the most palatable beef. Fat is not an end to itself--it is a means to an end. It helps to produce the most desirable beef when properly distributed through the lean meat.

Scott (1939) continued with the same theme when he reported that the consumer is looking for tenderness first, flavor second, and is not looking for fat. If the average consumer could get tender beef with some flavor and very little fat, he would be well pleased. Therefore, the producers should produce beef with the least amount of fat necessary for tenderness and flavor.

Today, it is easy to see what great prophets these authors were. Consumer preference has changed the amount of finish marketed in the modern beef animal. Brady (1957) stated that consumers generally do not wish to eat fat because they believe this may well result in a plumper figure and a shorter life, both of which are undesirable to them.

Consumer preference has changed the beef cattle market; modern technology and improved methods are continually striving to find new methods of satisfying this change. Some factors which researchers have studied include estimates on the live animal for carcass value, physical separation of the 9-10-11th rib section, rib eye area, external fat thickness, carcass grade and maturity, degree of marbling, various live- and carcass measurements, and organoleptic tests designed to score flavor, tenderness and juiciness.

Hankins and Ellis (1939) reported that fatness is a large factor affecting the proportion of the dressed carcass in our meat animals. As steers fatten, there is an increase in proportion of the rib, plate, rump, flank and short loin; a decrease in proportion of chuck, shank, round, and loin end; and very little change in proportion of chuck. These changes in proportion suggest a relatively heavy deposit of fat on the back, in general down the sides, on the belly, and in the posterior region of the body cavity. Relatively light deposits in the thigh region are suggested by the decrease in proportion of the ham, lamb leg, and beef round as fatness increases.

Hankins and Ellis (1939) have further indicated that increase in fatness contributes very little to changes in color of lean in cattle and lamb carcasses. Inconsistency among five correlations representing relationships between indexes of fatness and tenderness ranged as much as two and two-thirds degrees among the one-quarter inch, cross-cut slices within one rib eye section. The finest marbling occurred between the ribs, while the coarsest marbling occurred opposite the rib. Intermuscular fat deposits are located close to the blood vessels.

Hedrick et al. (1964) compared subcutaneous fat and the longissimus dorsi muscle at the twelfth rib of 1096 Good and Choice steer carcasses at fifty pound weight intervals (350-850 pounds). Muscle area increased one and one-half times while subcutaneous fat thickness increased three-fold. Differences which occurred between right and left side measurements were considered to be due to ribbing and measurement procedures.

Comparing "Compress" and "Regular" type Hereford steer calves from the same ranch, Willey et al. (1951) found "Compress" type steers had a greater percentage of the market weight composed of the hide, head, and shank. "Regular" type steers had more total feedlot gain, and a slight, but non-significant, advantage in feed utilization. The estimated percentages of fat, lean and bone were not significantly different in the carcasses of the two types. Stonaker et al. (1952), working with the same extreme types, did not find significant differences in efficiency of gain, days on feed, and age at slaughter. However, results indicated that conventional steers ate more per day and reached a slaughter grade of Low Choice approximately twenty-percent sooner than did the "Compress" steers. Physical separation of the 9-10-11th rib cuts into lean, fat, and bone showed almost identical composition for the two types; the percentages of the major wholesale cuts in the carcasses of the two types were also similar.

Knox (1957) found large type cattle have distinct advantages. Numerous cost of cattle production are fixed per head, regardless of size, and become less when spread over the greater productivity of large cattle. Taxes, veterinary charges, and bull services are but a few of these fixed costs. Beef may be produced more cheaply by rapid growing cattle which reach the desired weight at younger ages with less feed required per unit of gain. Durham and Knox (1953) were unable to show a significant correlation between feeder grade and carcass grade, explaining that feeder grade is as nearly independent of condition as possible, but carcass grade is largely dependent on condition. Yearling grade had a low, but significant association with carcass grade.

Kieffer et al. (1958) reported significant sire differences for carcass grade, marbling score, and percent bone of the 9-10-11th rib cuts, while differences of lean and fat from the same ribs failed to show significant differences. A correlation of 0.52 was reported between rib eye area and carcass weight. Magee et al. (1958) found the direct effect of the area of the rib eye on carcass muscling to be small (-.0016), however, the correlation between rib eye area and carcass grade was 0.20. Carcass grade was more highly correlated with final weight (0.52) than any of the other traits studied. Rib eye area was correlated with age, final weight and gain; each of these traits were positively associated with carcass grade. The high heritability estimates of loin eye area as shown in Tables 1 and 2 indicate that a breeder may increase the loin eye area of his cattle by selection, although this increase would not be accompanied by an increase in carcass grade.

Wheat and Holland (1960) found weighted average correlations between slaughter grade and carcass conformation ranged from 0.23 to 0.56. Average correlation between carcass grade before ribbing, after ribbing, and degree of marbling were 0.42, 0.24, and 0.25, respectively. Correlations between carcass grade before ribbing and after ribbing averaged 0.53; average correlation between carcass grade after ribbing and degree of marbling was 0.89.

Good _et al._ (1961) reported significant relationship between certain bone weights and bone circumference with the rib eye area and total weight of the trimmed major wholesale cuts. A negative correlation (-.34) was found between the circumference of the cannon bone and the fat cover at the twelfth-rib. These results agree with studies conducted by Orme (1958) regarding the muscle-bone relationship in beef cattle. Results of both studies indicate that cannon bone measurements are related to muscling; however, the relationship is not high enough to be useful for predictive purposes. Live weight, chilled carcass weight, primal cut weight, and estimated carcass lean in almost all instances were significantly and positively related to the weights and various linear measurements of the fore and rear cannon bones.

Cole _et al._ (1960) reported a highly significant correlation between bone weight and total lean of the carcass. The strong positive correlations obtained by Wythe et al. (1961) indicated that bones of an animal develop proportionally in length and weight, suggesting a real association exists between bone thickness and muscling in cattle studied. Orts and King (1959) found bone measurements to be positively and significantly ($P < .01$) correlated to Warner-Bratzler shear values.

Carcass Measurements

Many workers have used live animal measurements in an attempt to predict carcass characteristics and retail cuts. Good et al. (1961) analyzed data from 674-steers shown at the International Livestock Exposition in 1956-57-58 to report circumference of round had a significant positive correlation with loin eye area. Also, marbling increases with increase in fat covering, whereas loin eye area decreases as fat cover at the twelfth-rib increases. Allen (1963) found the circumference of round and the volume of round measurements highly correlated with the weight of the primal and lean cuts, however individual live animal measurements taken during this study indicated very little value in predicting carcass traits or composition of the carcass.

Birkett et al. (1963) found simple correlations between the various length and circumference measurements studied ranged from zero to slight, but negative, non-significant relationships. Cook et al. (1951) concluded that there seemed to be a slight tendency for a steer with a higher average daily gain to do better on dressing percent than one with a lower average daily gain. Steers having a higher average daily gain tended to have higher slaughter grades than those steers which failed to gain as rapidly. Slaughter grade was a fairly good indicator of carcass grade, having a low but significant positive correlation with dressing percentage; carcass grade had a higher positive association with dressing percentage.

Backus et al. (1960) reported correlations between the average width of the rib eye with the circumference of round to range from 0.25 to 0.44. Thickness of fat over the twelfth-rib was significantly correlated with all other measurements. Circumference of the round was highly significantly correlated with the width and depth of the chest, average rib eye width, rib eye length, rib eye area, and width of the round.

Physical Separation

Data studied over a period of years indicates that much work has been completed in the estimation of composition of beef carcasses and cuts. Hankins and Howe (1946) used the 9-10-11th rib cut for estimating carcass composition from the three-rib cut. Results of the study indicated that the composition of the 9-10-11th rib is closely associated with the composition of the carcass. The procedure involves the complete separation of the cut into muscle, fat, and bone. Crown and Damon (1959) were able to duplicate the results of Hankins and Howe (1946), reporting correlation coefficients between the percent separable lean, fat, and bone to be 0.94, 0.98, and 0.75, respectively. These highly significant correlations indicate that the possibility of using only the twelfth-rib cut to predict carcass composition would not only have approximately the same predictive value, but would save time and be more economical.

Ramsey _et al._ (1962) worked with 133-steers of eight breeds. He reported that fat had a more definite influence on percent separable lean than did rib eye area. A low correlation was found between rib eye area and percent separable lean of the 9-10-11th rib cut. Green (1954), Pierce (1957), and Goll _et al._ (1961), studied meat animal values built around wholesale yields, reported that higher grading carcasses which usually have greater amounts of fat also have higher yields of short loin, rib, brisket, and plate, but lower yields of round, sirloin, chuck, foreshank, and bone. These data infer that the cuts with a higher percentage of muscle take on proportionately less fat as grade increases.

King _et al._ (1959) found the four major wholesale cuts, trimmed to a uniform thickness of three-eighths of an inch of fat, very useful in predicting retail value. Blumer _et al._ (1959) found marbling measurements versus percent separable fat correlated at 0.20. Additional information from this study showed a carcass grade versus rib eye area correlation of 0.54, when the steers were finished with the use of stilbestrol. Stilbestrol reduced the amount of carcass fat, while a combination of stilbestrol and animal fat in the ration increased carcass fat.

Brungardt and Bray (1963) reported untrimmed wholesale cuts are not reliable predictors of the retail yield or of total carcass muscle. However, the percent yield of these same wholesale cuts, trimmed to a standard three-eighths of an inch of fat, accounted for seventy-four percent of the variation in the retail yield. Lewis et al. (1964) found the correlation for percent trimmed round with percent retail yield to be 0.57 for steer carcasses, and 0.83 for heifer carcasses. Bray (1963) reported the use of retail yield has the advantage of measuring the saleable portion of the carcass and should then rather accurately reflect quantitative differences. Murphey et al. (1960), using measures of specific carcass traits, reported procedures for estimating the yield of boneless trimmed retail cuts from the round, loin, rib, and chuck. Results from this procedure indicate an eighty percent effectiveness in accounting for the variation of these boneless retail cuts.

Gregory et al. (1964) concluded that until a more accurate objective procedure is available for use in practice, breeders can exert some selection pressure for cutability by critical live appraisal for this trait in prospective breeding cattle.

Tenderness Studies

Alexander (1926) reported on methods of cooking as a means of determining beef quality. The cooking procedures chief function is to prepare the meat in a way which will enable those who test it to estimate the inherent characteristics of the meat under consideration, and furthermore, to prepare it under conditions which can be standardized. Only by uniform cooking can differences be detected between two pieces of meat. If differences are found they should not be the result of differences in the method of cooking, but differences due to the variations in feeding or of some characteristic of the animals. The effect of cooking in itself must be minimized as much as possible. Cooking should be considered as just a cog in the machinery of determining palatability.

Mackintosh et al. (1936) concluded that as shear value rises, the rise is accompanied by a falling off in the palatability factor. Changes in tenderness likewise seem to be related to the grade of the carcass and the marbling in the muscle. It is generally accepted that increased finish does render the meat more tender, however, Branaman et al. (1936) found no relationship between tenderness and fatness. Barbella (1939) found the desirability of flavor of the fat and lean to increase as the age of the animal increased from eleven months to thirty months of age. The quantity of the juice increased rapidly with increase in fatness. Brady (1937) found significant differences in the diameter of muscle fiber and size of the muscle bundles for grade Hereford and grade Holstein cows; significant correlations were found between the size of the muscle bundle and tenderness score. This study indicated that texture is dependent on the size of the muscle bundle; the larger the muscle bundle, the "finer" the texture; the "finer" the texture, the more tender the meat.

Hankins and Howe (1949) did not find tenderness associated with grade of carcass to any appreciable extent, using steers of various grades and varying in age from fourteen to eighteen months. Rantsbottom and Strandine (1949) tested beef carcasses for changes from two-hours until twelve-days post-slaughter. Results indicated that the juiciness of beef did not change significantly, however, test panel ratings were higher for the Good quality beef than for Utility or Common beef.

Naumann et al. (1953) found a low correlation between taste panel scoring and Warner-Bratzler shear value. Juiciness was more closely related to the quantity of the press fluid than to the fat content of the press fluid. Means and King (1955) used a taste panel composed of forty families to evaluate loin steaks from nineteen sire groups. Analysis of variance indicated a significant difference ($P < .01$) for tenderness between sires when tested by either the family panel or Warner-Bratzler shear machine using one-half inch cores. Coefficients of correlation for panel ratings and tenderness values as measured by Warner-Bratzler shear were all significant ($P < .01$).

Palmer et al. (1958) reported that tenderness as determined by Warner-Bratzler shear value and by taste panel were related to carcass grade, degree of marbling, and rib eye area. Carcass grade accounted for about eight percent of the variability in taste panel scores, while marbling accounted for about eleven percent of the variability.

McBee and Naumann (1959) reported that freezing and frozen storage did not increase tenderness, but in some cases had a slight adverse effect. Grade had a significant effect on tenderness, with a general trend toward lowered tenderness with lowered grade. The Warner-Bratzler shear values were significantly correlated with taste panel scores. Webb et al (1964) evaluated tenderness at various times during aging and found tenderness increased with aging and was associated with changes in pH and juiciness. Other studies have shown that tenderness and juiciness decrease with advancing maturity in beef cattle (Tuma et al., 1962; Tuma et al., 1963). Dunsing (1959) reported consumer preference panels consistently favored steaks from the carcasses of younger animals.

Cover and Hosteler (1960) reported tenderness appears to be a very complex quality. Warner-Bratzler shear force as an objective measurement of tenderness depends for its usefulness on how accurately it reveals variation in tenderness. Six components have been identified and used in scoring by tenderness panels: softness to the tongue and cheek, softness to tooth pressure, ease of fragmentation of muscle fibers, mealiness, apparent adhesion between muscle fibers, and tenderness of the connective tissue. Shear force seems to be of little value in determining the toughness of connective tissue.

Tyler et al. (1964) confirmed earlier results indicating that at the same fat thickness, thickly muscled, high conformation cattle will have higher cutability than thinly muscled cattle. No significant differences were obtained in any of the individual palatability factors studied or in the overall palatability score. Similarly, no significant differences were noted in the Warner-Bratzler shear tests. Romans et al. (1965) found shear and taste panel test were not significantly correlated, and that neither maturity, marbling, nor core location had a significant effect on tenderness as determined by the Warner-Bratzler shear. Steaks from the longissimus dorsi of the more mature carcasses were generally considered less tender than those from the less mature carcasses by the taste panel. The taste panel could not detect differences in tenderness due to marbling or sample location. The flavor of the steaks from the less mature carcasses were generally preferred by the panel.

Zinn (1964) in a review of tenderness studies, reported that tenderness was considered to be sixty percent heritable.

METHODS AND MATERIALS

Data were collected from 114 calves (62 steers and 52 heifers) born in the fall of 1964 at the Clifford Houghton Stock Farms at Tipton, Kansas. Six sires were used in the study. Four of the sires, Royal Husker 3rd, R. Silver Return 632nd, Mill Iron 836E, and Onward Rupert were bred artificially, while Royal Husker K38 and M. Crusty Domino were used in natural service in the role of "clean-up" bulls. The bulls used artificially sired 68 per cent of the calves, while the bulls used in natural service sired the remaining 32 percent of the calves studied. All individuals in the herd, cows as well as the sires, were type classified according to the form used by the American Angus Association as the Herd Classification Report. An example of this form is included as Table 13 in the Appendix. All progeny were scored at time of weaning and again just prior to slaughter. An example of the form used to record this information is included as Table 14 in the Appendix.

Weaning weight and weaning score was collected on all calves in the herd. Data were not collected on the heifer calves following weaning phase of the study. All of the steer calves were placed on feed and study continued through the carcass phase of the experiment. Fifty randomly selected steers were used for detailed study of the wholesale rib cut and organoleptic study.

Weaning and slaughter scores were placed on the individual progeny by a committee comprised of Dr. Don L. Good, Mr. John R. Teagarden, Mr. Edward A. Lugo, Jr., and the author. Code sheets designed for the study are included as Tables 18 and 19 of the Appendix. All weighing and scoring was done at the Houghton Ranch using the available facilities and under normal ranch conditions. Weaning weights were obtained and later adjusted to a standard 210-day weaning weight according to the schedule compiled by Smith and McAdams (1963). Table 23 in the Appendix contains the Age Calendar Chart used, while Table 24 in the Appendix contains the Correction Values for Adjusting Weaning Weights to 210-days.

The average age at weaning was approximately 275-days; the average date of birth being September 9, 1964. All calves had access to a creep ration comprised of steam-rolled milo from shortly after birth until weaning on June 11, 1965. All of the steer calves contained on feed following weaning. The ration received for the remainder of the full-feeding period contained one and one-half pounds of forty-two percent protein supplement per head, per day, and a grain combination consisting of ten percent cracked corn and ninety percent steam-rolled milo. The ration was fed in a self-feeder throughout the feeding period. Low-quality alfalfa hay fed free-choice was included in the ration from time of weaning until October 15, 1965. Beginning October 15, 1965, all steers were changed to a ration containing good-quality sorghum silage fed free-choice, and good-quality prairie hay, also fed free-choice. The steers remained on the ration until time of slaughter.

All steers were subjectively scored for slaughter traits and individually weighed and identified on January 31, 1966. The steers were loaded on trucks for shipment to the Kansas City, Missouri Stockyards, a trip of approximately 227 miles, late in the afternoon of January 31, 1966. All grading was performed by the same committee which scored the animals at weaning.

The steers were individually weighed at the stockyards on the morning of February 1, 1966. Weighing was completed, shortly after seven A.M., and the cattle moved to the Maurer-Neurer Packing Company. Slaughter began at approximately eight A.M. Objective measurements were taken on the kill-floor of the right and left forearm and cannon bone by means of a flexible steel tape. The dressed carcasses were individually tagged with the corresponding ear tattoo of the steer and the hot carcass weights were recorded. Individual hide weights were also obtained at this time. Dressing percentage was calculated using the weights obtained at the stockyards and the hot carcass weights, allowing for a two-percent cooler shrink. Shrink was calculated using the ranch weights prior to shipment and the weights obtained at the stockyards.

Individual carcass data were obtained the following morning in the Maurer-Neurer Company coolers. Measurements of the round were taken following the recommendations of the A.S.A.P. (1959). The length of the round was determined at two points, forty and seventy percent of the distance calculated for the length of the round. The length of the round was determined by the distance between the anterior tip of the aitch bone to the highest point of the hock joint. Circumference of the round was determined by marking three point with skewers at right angles to the line used to determine the length of the round. A flexible steel tape was then used to measure the circumference of the round at the two designated points.

The carcasses were ribbed at ten A.M. on the morning of February 2, 1966. Tracings were made of the cross-sectional area of the rib eye and fat thickness at the twelfth rib recorded. The rib eye area was later determined by use of a compensating polar planimeter to measure the cross-sectional area traced on the acetate paper. Thickness of fat was determined from the tracing, using the method outlined by the A.S.A.P. (1959). A federal grader evaluated each carcass for conformation score, marbling score, maturity score and final carcass quality score. The numerical values for the various grades concerned are included in the Appendix as Tables 15, 16, and 17. Chilled carcass weight was obtained just prior to the breaking of the right side into the wholesale cuts.

The wholesale cuts, the round, loin, rib, and square-cut chuck were individually weighed as they came from the breaking-saw. The round, loin and square-cut chuck were then trimmed to the nearest three-eighths inch of fat and the weight of the fat trim recorded. The wholesale rib cut, containing the sixth through the twelfth rib, was returned to the Meats Laboratory at Kansas State University for detailed study. The wholesale rib cuts were photographed and appear grouped in the various sire groups as Plates 1 through 6 in the appendix.

The fifty randomly selected ribs were trimmed to the nearest three-eighths inch of fat and the fat trim recorded. The rib was then broken into the 6-7-8th rib cut, which was sent to the College of Home Economics, Department of Foods and Nutrition, for organoleptic studies. The twelfth rib was separated from the remaining 9-10-11th rib cut and used for laboratory studies of color, pH, and ether extract. The 9-10-11th rib cut was used for physical separation studies of lean, fat, and bone according to the procedure outlined by Hankins and Howe (1946).

The results of the study were analyzed using the IBM 650 Digital Computer for the simple correlation coefficients and the Analysis of Variance. Duncan's New Multiple Range Test (NMRT) was selected as the method of determining which of the individual sires were significantly different for a particular characteristic studied. Data for the heritability study was analyzed on the IBM 360 Digital Computer, using a paternal half-sib relationship from the Analysis of Variance according to the procedure outlined by Becker (1964).

Duncan's New Multiple Range Test does not require a prior "F" test, but does require that one obtain an unbiased estimate of sampling variance appropriate to the situation being studied, so an Analysis of Variance often is run before applying the NMRT (Fryer, 1966).

The cooking and palatability evaluations of the 6-7-8th rib roasts were studied separately by the Department of Foods and Nutrition, College of Home Economics at Kansas State University. The roasts were delivered to the Department in a frozen state. The cooking method used was initiated by a forty-eight hour thawing period in a refrigerator. The roasts were then placed on a rack in an open pan and cooked in a rotary gas oven at three hundred degrees Fahrenheit until internal temperature reached one hundred fifty-eight degrees Fahrenheit, then allowed to stand until they reached a maximum temperature. The cooking losses were determined according to the following schedule:

I. Losses in weight (in grams)

Loss due to evaporation

A. In the oven: Weight of the platter, roast and the thermometer minus the weight of pan, roast, thermometer and the drippings.

B. Outside the oven: Weight of the platter, roast, thermometer, minus the weight of platter, roast, drippings and thermometer.

C. Total volatile cooking loss: Add A and B.

Loss due to drippings

D. In the oven: Weight of the pan and drippings minus weight of the pan.

E. Outside the oven: Weight of platter and drippings collected while standing minus weight platter.

F. Total dripping loss: Add D and E.

G. Total cooking loss: Add C and F.

II. Losses as percent of weight:

Loss due to evaporation $\div$ weight of the uncooked roast.

Loss as drippings $\div$ weight of uncooked roast.

Total loss during cooking $\div$ weight of the uncooked roast.

A palatability panel of ten members scored one-half inch cubes of meat from the <u>longissimus dorsi</u> muscle and tasted a sample of inside fat.

A sample scorecard of the type used in the study is included in the Appendix as Table 21. The mean cooking time, cooking losses, and flavor scores for the roasts are included as Table 22 in the Appendix. Table 20 in the Appendix contains the numerical values for scoring the flavor, juiciness and tenderness of the roasts.

Warner-Bratzler shear values were determined by using two one-inch cores cut from the longissimus dorsi muscle (lateral and medial positions). From the two cores, four readings were made and averaged.

Approximately one hundred grams from the longissimus dorsi were ground for use in determining press fluid from the Carver Laboratory Press. These were done on the day following cooking and palatability tests. Two, twenty-five gram samples were packed in a cylinder and over a fifteen-minute period the serum was pressed out, collected in a graduated test tube and allowed to stand in the refrigerator until separated. Then the measurements were recorded and averaged for each roast.

DISCUSSION

A brief review of some of the characteristics and methods used should prove helpful in discussing the results obtained in this study which involved analyzing information collected during the period from birth to slaughter. Progeny of six sires were phenotypically studied and compared; simple correlation coefficients were calculated for each of the sixty traits studied. The correlation coefficients obtained are included as Tables 3 through 9 in the Appendix. An analysis of variance was used to show the variation between sire groups and the significance level was noted if differences were present. The mean square differences between the sires and among sire groups and the calculated "F" ratio of the analysis of variance are included as Table 10 in the Appendix.

Duncan's New Multiple Range Test (NMRT) was additionally calculated to determine between which sires significant ($P \angle .05$) differences did occur. An occasional difference will be noted if the NMRT is compared with the analysis of variance. This is emphasized by the degree or the intensity of the comparison, as the analysis of variance is considered a more conservative test. The Duncan's NMRT is included as Table 11 in the Appendix.

Concerning the six sires compared in the study, Royal Husker 3rd, R. Silver Return 632nd, Mill Iron 836E, and Onward Rupert were used artificially, while M. Crusty Domino and Royal Husker K38 were used in natural service as "clean-up" sires. It would appear that the differences in age of the calves resulting from the difference in time of mating will account for a considerable amount of the variation reported between the sires. The average age at weaning of the calves sired by the six bull was approximately 275-days; calves sired by the bulls used artificially averaged 292-days compared to 241-days for the calves sired by the "clean-up" bulls. The resulting variation in age is reflected in those characteristics which include weight and measurements as the criterion.

Heritability estimates of specific traits were calculated according to the method recommended by Becker (1964); the estimates are included as Table 12 in the Appendix. In some instances, these data may not reflect in proper perspective, the true genetic potential of some of the individual progeny included in the study. This statement must take into consideration the variation in fat thickness at the twelfth rib which ranged from 0.75 to 1.75-inches for the progeny. A number of the carcasses did carry an excessive amount of finish, which is not consistent with today's market demands. The use of a creep feeder during the preweaning phase and the use of a self-feeder during the post-weaning period did not allow for the measurement of a very economically important characteristic, feed efficiency. All steers in the study were marketed at the same time, rather than at a constant age or weight. The percentages of the trimmed wholesale cuts of beef, the round, loin, rib and square-cut chuck, were therefore lowered on those individuals carrying an excessive amount of finish. These data require careful consideration of the management practices and the environmental conditions present when comparing the various sire groups.

Average day of age at weaning was one of the characteristics included in this study. Analysis of variance shows a significant ($P < .01$) difference among sires for this particular trait, while the NMRT shows that the greatest difference occurred between the sires used artificially and those used in natural service. Bearing in mind that age at weaning is a factor under the direct control of management, it is also a factor which does have considerable importance when related to other characteristics such as weaning weight, weaning condition, and weaning grade.

Age at weaning was found to be significantly correlated with weaning weight (0.49) and age at slaughter (0.89). A low correlation (0.08) was found between age at weaning and carcass maturity score; a negative correlation (-.05) was found between age at weaning and average daily gain. Age at weaning failed to indicate future scores and future gains, as did studies by Sabin et al. (1958). Simple correlation coefficients between age at weaning with slaughter grade and carcass grade were 0.08 and 0.33, respectively.

Koch (1951) and Minyard and Dinkel (1965) stressed the importance of weaning weight as related to the income of the producer. The analysis of variance of this trait indicated a significant ($P < .01$) difference between sires. The NMRT again shows that the difference in weaning weight was largely due to the difference in age of the calves in the four artificially inseminated group versus the calves sired by the bulls used in natural service.

Simple correlation coefficients calculated between weaning weight and other characteristics studied were: adjusted weaning weight, 0.76; feeder grade, 0.65; average daily gain (at weaning), 0.80; weaning muscle score, 0.71; weaning bone score, 0.68; weaning condition score, 0.71; slaughter weight, 0.73; hide weight, 0.63; chilled carcass weight, 0.74; length of round, 0.59; and the circumference of round at seventy percent of it's length, 0.55. Kidwell et al. (1957) concluded that selection for heavy weaning weight on a progeny basis should be effective in improving post-weaning rate of gain. The heritability estimate of weaning weight was 0.31, which is identical with the average of fifty-two studies summarized by Petty and Cartwright (1966). Warwick (1958) reported an average heritability of 0.30, based on a similar summary of twenty-six reports. Lindholm and Stoneacker (1957) reported that selecting for weaning weight alone was an accurated basis for selecting for increased net income in Hereford calves.

Weaning weights were adjusted to a 210-day equivalent according to the schedule compiled by Smith and McAdams (1963). It should be noted that the means of the sire groups ranged from 236-days to 297-days at weaning. These ages go considerably beyond the recommendations of Johnson and Dinkel (1951) in applying correction factors to weaning weights.

Analysis of variance showed a non-significant difference among the six sires when weaning weights were adjusted to a 210-day equivalent. The calculated heritability estimate for the adjusted weaning weight was essentially zero. Simple correlation coefficients between adjusted weaning weight and other traits considered were: average daily gain, 0.91; feeder grade, 0.58; weaning muscle score, 0.60; weaning condition score, 0.66; chilled carcass weight, 0.50; and rib eye area, 0.50. The adjusted weaning weight was a poorer indicator of future scores and future gains than was actual weaning weight.

Average daily gain might possibly be considered a more significant characteristic than either age at weaning or weaning weight when comparing the sire groups in this study, due to the difference in age of the various sire groups. The means of the six sire groups studied should be considered acceptable to most producers, ranging from 1.54 pounds to 1.74 pounds per day. A low heritability estimate (0.06) was obtained for average daily gain.

Simple correlation coefficients between average daily gain and other characteristics studied were: feeder grade, 0.62; weaning muscle score, 0.36; weaning condition score, 0.70; slaughter weight, 0.57; chilled carcass weight, 0.57; weight of the right side of the carcass, 0.50; weight of the trimmed round, 0.53; weight of the trimmed loin, 0.50; weight of the trimmed chuck, 0.37; and weight of the trimmed rib, 0.45. Although all work reported has dealt with average daily gain during the post-weaning period, it would seem reasonable to assume that calves with a higher average daily gain during the period prior to weaning, do have the ability to gain rapidly during the post-weaning period.

Feeder grade is one of the important economic characteristics included in this study, affecting at least two of the segments of the beef cattle industry, the producer and the feeder. Minyard and Dinkel (1965) reported that weaning weight and feeder calf grade comprised the basis of many producers' annual income. The analysis of variance does not indicate a significant difference between sires, however, the NMRT indicates that Royal Husker K38 and his sire, Royal Husker 3rd, differed significantly ($P < .05$) from M. Crusty Domino when their progeny were compared.

Correlation coefficients between feeder grade and other traits considered were: weaning muscle score, 0.88; weaning bone score, 0.72; weaning condition score, 0.75; slaughter grade, 0.30; and carcass grade, 0.19. The relationship between feeder grade and final grade is much lower than the relationship (0.72) reported by Patterson et al. (1949) for these traits. In explaining the lack of agreement between the two studies, it is necessary to note that the lack of marbling in the carcasses lowered the final carcass grade.

A heritability estimate of 0.19 was obtained for feeder grade. Petty and Cartwright (1966) in a review of several studies, reported the average heritability estimate of feeder grade to be 0.32. Carter and Kincaid (1959) obtained an estimate of 0.41 while Brinks et al. (1964) reported an estimate of 0.28.

Weaning muscle score was one of the traits which received considerable attention throughout this study, as muscling is becoming increasingly important as a factor in determining the value of the beef carcass. The weaning muscling score was a combination of three subjective observations of the forearm, round and over-the-top (loin) evaluations by the grading committee. The statistical data did not indicate a significant difference between the sires studied. A rather low, non-significant (0.09) heritability estimate was obtained for the trait. It is necessary to emphasize that the sires used in this study were selected sires, resulting in a very small variation between the means of the sire groups. The method employed in calculating the heritability estimates (Becker, 1964) requires a wide range in sire means in order to obtain a high heritability estimate for a characteristic.

Correlations between weaning muscling score and other characteristics studied were: weaning bone score, 0.78; weaning condition score, 0.78; chilled carcass weight, 0.50. Weaning muscling score did not prove to be an efficient indicator of future grades and of carcass muscling.

Weaning bone score is another of the characteristics studied which the analysis of variance indicated had a significant sire difference. Royal Husker 3rd had a significantly higher ($P < .05$) weaning bone score than did M. Crusty Domino and Mill Iron 826E. Studies by Cole _et_ _al_. (1960) indicated a strong relationship between bone weight and total lean of the carcass. Wythe _et_ _al_. (1961) suggested that bone of an animal develop proportionately in length and weight, suggesting a real association exists between bone thickness and muscling. A heritability estimate of 0.23 was obtained for weaning bone score, but again it should be noted that the individual sires in the study were selected sires and excelled in many of the traits undergoing study. Although one sire was significantly different, the range of the scores were not widely dispersed, thus lowering the estimate.

Weaning bone score was found to have the following simple correlation coefficients with other characteristics studied: weaning condition score, 0.61; slaughter grade, 0.30; slaughter bone score, 0.26; slaughter weight, 0.44; hide weight, 0.52; chilled carcass weight, 0.43; circumference of cannon bone, 0.49; weight of the trimmed round, 0.50; weight of the trimmed chuck, 0.42; weight of the lean-9-10-11th rib, 0.31; weight of bone-9-10-11th rib, 0.29; and weight of the _longissimus_ _dorsi_ muscle-9-10-11th rib, 0.43. Although the correlations between weaning bone score and slaughter bone score (0.45) and weaning muscling score and slaughter bone score (0.45) may indicate a lack of continuity, the correlations are higher than those reported by Lugo (1967) in a previous group of individuals from the same herd. These data would seem to indicate that some selection progress can be made in the characteristics as indicators of future scores and grades.

Weaning condition score is generally accepted as the product of genetic potential and the environment provided. The analysis of variance did not indicate a significant difference berween the various sires when considering weaning condition. The NMRT indicated that, despite being significantly older than the other calves, the progeny of Mill Iron 836E scored significantly lower scores than did other progeny groups. The difference in the ages of the calves create some difficulty in explaining the differences in weaning condition. These differences may lie in the milking ability of the dams, the season of birth, or may indicate a lack of inherited ability to make rapid gains during this period. Lower condition scores apparently did not influence the feeder grade, but would tend to influence weaning weight.

Durham and Knox (1953) reported that feeder grade is as nearly independent of condition as possible, but carcass grade is largely dependent on condition. When comparing the weaning condition and slaughter condition scores, Mill Iron progeny were again scored lower for slaughter condition with a significant difference ($P < .05$) obtained between Mill Iron and several other sires. These data would therefore indicate that the progeny of Mill Iron do lack the ability to make as rapid gains as progeny of other selected sires.

The heritability estimate of weaning condition score was found to be 0.12. Weaning condition score may be used to indicate future ability to fatten rapidly, but this ability is dependent upon the environmental conditions imposed on the individual.

Weaning condition score was found to be correlated with slaughter grade, 0.41; slaughter condition score, 0.34; slaughter weight, 0.37; hide weight, 0.48; chilled carcass weight, 0.38; depth of fat at the twelfth rib, 0.18; dressing percent, 0.24; weight of the trimmed round, 0.35; weight of the trimmed loin, 0.30; and weight of the trimmed chuck, 0.36. With the exception of the chews score (0.37) the correlations between weaning condition score and the physical separation and cooking characteristics were low and non-significant.

Slaughter grade remains one of the very important economic characteristics related to the carcass value as it is the most common estimator of carcass value used today in buying market cattle. Many livestock judges have been trained to evaluate the amount of finish which an animal carries subcutaneously, but slaughter grade cannot evaluate internal marbling, the intermingling of the fat between the muscle bundles, and therefore often fails as an indicator of final carcass grade. Animals slaughtered during this study failed to achieve the predicted carcass grade due to lack of internal marbling, resulting in a negative and non-significant correlation (-.03) between the two characteristics. Ross (1963) using calves from the Houghton herd reported the correlation of 0.13 for calves born in 1961.

Ross (1963) reported a significant correlation between slaughter grade and carcass conformation score of 0.47, while Wheat and Holland (1960) reported the correlation to be 0.56. The correlation obtained during this study is slightly higher (0.61) than the previously reported studies, indicating progress on the part of the scoring committee in predicting carcass values. The heritability estimate of slaughter grade was 0.12, again emphasizing that slaughter grade is largely dependent upon fatness or condition. The NMRT indicates that a significant difference ($P < .05$) occurred between Onward Rupert and Mill Iron 826E for slaughter grade. The difference was felt to be due to condition as indicated earlier in the discussion.

Correlations between slaughter grade and other characteristics were: slaughter muscle score, 0.75; slaughter condition score, 0.81; slaughter weight, 0.33; hide weight, 0.46, chilled carcass weight, 0.31; and depth of fat thickness, 0.24.

Slaughter muscling score was a combination of several subjective scores as was weaning muscling score. The analysis of variance indicated a significant difference ($P < .05$) did exist between some sires. The NMRT indicated that the progeny of R. Silver Return 632nd and Onward Rupert were significantly heavier muscled than the progeny of Mill Iron 836E. Slaughter muscling score was calculated to be 0.22 heritable.

Slaughter muscling score was found to be positively correlated with the following characteristics: slaughter bone score, 0.33; slaughter condition score, 0.72; slaughter conformation score, 0.66; hide weight, 0.48; and weight of the trimmed round, 0.38.

The heritability estimate of slaughter bone score proved to be slightly negative and was considered to be essentially zero. Sires used in this study were selected sires, and one of the characteristics in which all sires might be considered above average was substance or the amount of bone of each sire. As mentioned previously, when the variation between sires was small, the resulting heritability estimates are low.

Simple correlation coefficients between slaughter bone score and other related carcass characteristics were: slaughter conformation score, 0.34; slaughter weight, 0.44, hide weight, 0.57; chilled carcass weight, 0.41, circumference of round at forty percent of it's length, 0.41; circumference of shank, 0.52; circumference of forearm, 0.47; weight of the trimmed round, 0.52; and weight of the trimmed chuck and rib 0.43. These correlations are slightly higher than those reported by Lugo (1967) in a previous study with cattle from the same herd.

Analysis of variance indicated a non-significant difference between sires for slaughter condition. These results were not as expected due to the age difference in the calves. Slaughter condition was based upon the apparent amount of finish which the committee subjectively scored. Correlations between slaughter condition score and other characteristics were: slaughter grade, 0.81; slaughter conformation score, 0.58; slaughter muscling score, 0.72; and chilled carcass weight, 0.09. Negative, non-significant correlations were obtained between slaughter condition score and marbling score, -.00; carcass quality score, -.06; and dressing percent, -.13. The heritability estimate of slaughter condition score was found to be 0.19.

The analysis of variance indicated a significant difference between sires for total slaughter conformation score. Progeny of R. Silver Return and Onward Rupert had significantly higher ($P < .05$) conformation scores than the other four sires included in the study. Progeny of these two sires were larger framed than progeny of the other sires, and consequently received higher scores. The higher scores are reflected somewhat in the scores for slaughter weight, slaughter muscling, slaughter condition, and slaughter grade. The correlation between total conformation score and slaughter conformation score was low (0.07), indicating that many of the characteristics considered important in the live animal are not important to the shape of the carcass.

The heritability estimate of total slaughter conformation score was found to be 0.26, indicating that some progress can be made in selecting superior phenotype. The lack of higher correlations between total conformation score and other correlations was very disappointing. Hide weight was the most highly correlated (0.44) characteristic found. Studies by Lugo (1967) indicated that conformation score was a very good indicator of carcass muscling and was not influenced by sex of the progeny. A brief look at the scorecard used to formulate the slaughter conformation score (Table 14) may explain the lack of significant correlations. Total conformation score included type, size, quality, feet and legs, and head and neck as five of the ten factors used. Slaughter weight would mask the effect of type, and depending on the amount of finish, would tend to mask the effect of size. Feet and legs, and head and neck are removed at time of slaughter and thus are not considered a part of the beef carcass.

Slaughter weight was found to be one of the most significant characteristics of the study, and should continue to be a very economically important characteristic as long as livestock is sold on a price-per-pound basis. The analysis of variance indicated highly significant differences ($P < .01$) between sires for slaughter weight. Duncan's NMRT indicated that R. Silver Return and Onward Rupert were significantly heavier at slaughter than the progeny of the remaining four sires tested. Slaughter weight was found to have a very low (0.03) heritability estimate.

Slaughter weight was found to be highly correlated with the following characteristics: hide weight, 0.71; chilled carcass weight, 0.99; depth of fat at the twelfth rib, 0.40; dressing percent, 0.62; length of round, 0.79; forty percent circumference of round, 0.61; seventy percent circumference of round, 0.76; weight of the right side of the carcass, 0.82; weight of the trimmed round, loin, rib, and chuck; 0.84, 0.87, 0.86, and 0.95, respectively; weight of the lean, fat, bone, and longissimus dorsi muscle of the 9-10-11th rib, 0.64, 0.67, 0.65, and 0.66, respectively; dripping percent of the total cooking loss, 0.55; flavor score of the fat and lean, 0.38, and 0.35, respectively.

Hide weight, corrected for animal weight at slaughter, was one of the characteristics receiving special attention during the course of this study. The range for the hide weights was from eighty- to one hundred sixteen pounds among the individuals progeny, while the means of the sire groups ranged from ninety-one to one hundred-seven pounds. Onward Rupert calves had a significantly heavier ($P < .05$) hide weight than did four of the sires studied, being closely followed by progeny of R. Silver Return 632nd. The heritability of hide weight was estimated to be 0.34, suggesting that this trait might well be considered at time of sire selection.

Simple correlation coefficients obtained between hide weight and other traits studied were: chilled carcass weight, 0.68; dressing percent, 0.37; circumference of round at forty and seventy percent of it's length, 0.51 and 0.53, respectively; circumference of the forearm, 0.64; circumference of cannon bone, 0.67; weight of the right side of the carcass, 0.63; and weight of the trimmed round, loin, chuck, and rib, 0.68, 0.56, 0.67, and 0.58, respectively.

The analysis of variance indicated a significant difference ($P < .05$) between sires when comparing the sire's progeny for age at time of slaughter. Progeny of Mill Iron 836E were significantly older than calves sired by the other five bulls during the weaning phase of the study, but were only significantly different than calves sired by M. Crusty Domino and Royal Husker K38 at time of slaughter. When chronological age was compared to physiological age (age at slaughter versus carcass maturity score), no significant differences were found among the six sires. The correlation between age at slaughter and carcass maturity score was very low (0.05) and non-significant.

Chilled carcass weights were obtained twenty-four hours after slaughter. The analysis of variance indicated a significant sire difference ($P < .01$) between sires for chilled carcass weight. Progeny of R. Silver Return were significantly heavier than progeny of Mill Iron 836E, M. Crusty Domino and Royal Husker K38. Progeny of Royal Husker K38 were also considered significantly lighter than progeny of R. Silver Return, Onward Rupert, and Royal Husker 3rd, but were not significantly different than progeny of Mill Iron 836E or M. Crusty Domino.

Correlations of interest between chilled carcass weight and other characteristics were: weaning weight, 0.74; weaning muscling score, 0.50; average daily gain, 0.57; weaning bone score, 0.43; hide weight, 0.68; dressing percent, 0.70; length of round, 0.81; circumference of round at forty and seventy percent of it's length, 0.61, and 0.76, respectively; weight of the trimmed round, loin, chuck, and rib, 0.84, 0.88, 0.96, and 0.86 respectively; and weight of the lean, fat, bone, and longissimus dorsi muscle of the 9-10-11th rib cut, 0.69, 0.63, 0.66, and 0.66 respectively. The heritability of chilled carcass weight was estimated to be 0.29.

Statistical analysis did not reveal a significant difference between sires for carcass conformation. All progeny studied had an acceptable live conformation score, and two of the sires, R. Silver Return and Onward Rupert, were significantly different when animals were scored on a live basis. Several factors which make up the live score are not considered when scoring the carcass conformation and account for the lack of agreement between the two traits. A positive, but low (0.20) correlation was found between live conformation score and carcass conformation score. In general, carcass conformation score did not achieve high significant correlations with other traits considered. The heritability of the trait was estimated to be essentially zero, a fact best explained by the lack of variation in the scores of the progeny.

The analysis of variance and the NMRT indicated a significant difference between the progeny of the sires when carcass marbling scores were compared. Calves sired by M. Crusty Domino failed to achieve the marbling scores of the other scores of the other sires. The emphasis placed on marbling grade in determining final carcass quality grade is reflected in the price differences which occur between the various federally graded beef carcasses. A study of the physical separation data indicated that calves sired by M. Crusty Domino were not carrying the amount of fat exhibited by progeny of the other sires. Comparing Crusty calves with calves of the same age sired by Royal Husker K38, it is noted that Crusty progeny were significantly lower ($P < .05$) in marbling scores. It would therefore seem reasonable to conclude that one sire included in the study lacked the genetic ability to transmit to his offspring, the inherent potential to deposit fat within the muscle bundles. It is interesting to note that the progeny of M. Crusty Domino did not differ significantly from other sires when fat-thickness at the twelfth rib was compared, yet had the least amount of fat and the highest amount of lean and bone in the physical separation studies. Tenderness studied failed to indicate that the additional marbling found in the offspring of the other five sires increased palatability.

Heritability of marbling was estimated to be 0.23, causing selection for the trait to be rather marginal. The increased economic benefits, or the lack of these benefits would certainly be a consideration in selecting sires when performance testing information is available to the buyer.

Simple correlation coefficients between carcass marbling score and other traits considered were: final carcass grade, 0.90; fat thickness at the twelfth rib, 0.07; rib eye area, -.02; weight of the fat in the 9-10-11th rib, 0.20; and the dripping percentage of the total cooking loss, 0.32. Marbling score had a low (0.16) correlation with Warner-Bratzler shear value, and a correlation of -.00 with chews score. These results are in general agreement with previous studies of Ross (1963) and Lugo (1967).

Carcass maturity scores did not indicate a significant sire difference in physiological age of the offspring. A correlation between maturity score and rib eye area was found to be 0.40. The only significant correlation of importance between maturity score and tenderness studies was a correlation of 0.34 between maturity score and the lean flavor score. The heritability estimate of the trait was estimated to be essentially zero.

A significant difference ($P < .05$) occurred between sires when their progeny were compared for final carcass grade or quality score. It is interesting to note when comparing off-spring of the six sires that Mill Iron ranked last when weaning and slaughter condition were scored, ranked second when marbling scores of the same progeny were compared; ranked second for fat-thickness at the twelfth rib, and ranked third when the weight of the fat in the 9-10-11th rib cuts were compared. Mill Iron, Royal Husker 3rd, and Royal Husker K38 had a significantly higher ($P < .05$) carcass quality score than did R. Silver Return 632nd, Onward Rupert, and M. Crusty Domino. M. Crusty Domino progeny were also significantly lower in final carcass grade than were progeny of Mill Iron and Royal Husker 3rd. The correlation between final carcass grade and marbling score was 0.90, again emphasizing the importance placed on the amount of marbling present in the *longissimus dorsi* muscle.

Simple correlation coefficients between carcass quality score and characteristics related to tenderness were: flavor score of the fat, 0.26; juiciness score, 0.34; Warner-Bratzler shear value, 0.19; and press fluid, 0.03. A correlation of 0.16 was found between carcass quality score and weight of the fat in the 9-10-11th rib cut. The heritability estimate of carcass quality was 0.19.

Magee *et al*. (1958) found final carcass grade more highly correlated with slaughter weight (0.52) than any other trait studied. A lower correlation (0.12) was observed in this study. Wheat and Holland (1960) reported the correlation between carcass grade and marbling score to be 0.89, which compares with 0.90 found in this study.

The *longissimus dorsi* muscle in slaughter animals has played an increasingly important role in recent years as an indicator of total muscle of the beef carcass. Statistical analysis of these data showed a non-significant difference between the six sires for rib eye area. The narrow range among the means of the sire progeny resulted in a heritability estimate of essentially zero. The results are in disagreement with the results reported by Warwich (1958), who reported a range of 0.69 to 0.72 in a review of heritability estimates.

The *longissimus dorsi* muscle, more commonly referrred to as loin eye or rib eye area, was found to have the following correlations with other characteristics included in the study: adjusted weaning weight, 0.50; feeder grade, 0.21; weaning bone score, 0.26; slaughter weight, 0.31; slaughter grade, 0.17; hide weight, 0.31; chilled carcass weight, 0.40; maturity score, 0.40; weight of the trimmed round, loin, chuck, and rib, 0.44, 0.41, 0.36, and 0.38, respectively; and weight of the _longissimus dorsi_ muscle in the 9-10-11th rib cut, 0.44. Other correlations of interest in the effect of the _longissimus dorsi_ muscle on factors affecting carcass grade were: conformation score, 0.20; marbling score, -.02; carcass quality score, -.08; fat thickness at the twelfth rib, -.13; and dressing percent, 0.29.

These data are in agreement with studies of Kieffer _et al_. (1958) and Magee _et al_. (1958), both of whom reported correlations of 0.52 between rib eye area and carcass weight. Magee _et al_. (1958), however, reported a correlation of 0.20 between rib eye area and carcass quality score, compared to a -.08 correlation for this study. Rib eye area would be considered as an indicator of total carcass muscling but increasing the rib eye area alone would not be accompanied by an increase in carcass grade.

Fat thickness as measured at the twelfth rib has become increasingly important to the feeder, the packer and the consumer in recent years. Increased production, feeding, and processing costs are naturally reflected in increased costs to the consumer. This in turn has led to increased consumer demand for closely trimmed retail cuts. Statistical analysis of these data do not indicate a significant sire difference in the amount of fat in the carcass, as determined by the measurement at the twelfth rib. It is interesting to note that the sire whose progeny had the greatest amount of fat covering at the twelfth rib, had the least amount of marbling of the six sires studied. The heritability of fat thickness was estimated to be 0.07, suggesting that the amount of subcutaneous fat present in the carcass is probably due to the length of time animals are fed and the ration fed. Miller et al. (1964) concluded that muscle area increased one and one-half times and subcutaneous fat increased three-fold when animals increased in weight from three hundred and fifty to eight hundred and fifty pounds. One would expect this ratio to increase further until market weight is reached.

Fat thickness at the twelfth rib was found to have the following correlations with other factors studied: marbling score, 0.07; chilled carcass weight, 0.38; carcass quality score, 0.15; rib eye area, 0.13; slaughter weight, 0.40; weight of the trimmed round, loin, chuck, and rib, 0.20, 0.32, 0.30, and 0.30 respectively; dressing percent, 0.24; and weight of the fat in the 9-10-11th rib cut, 0.38. The correlation between fat thickness at the twelfth rib with Warner-Bratzler shear value was higher (0.21) than the correlation between marbling score and Warner-Bratzler shear value (0.16).

Dressing percent continues to be one of the standards by which we evaluate slaughter animals. Royal Husker K38 progeny were found to have a significantly lower ($P < .05$) dressing percent than progeny of the other five sires. One of the five individuals comprising the Royal Husker K38 sire group had a low (52.9) dressing percentage, thus lowering the means for the entire group. The heritability of dressing percent was estimated to be 0.03, a much lower estimate than those reported by Warwick (1958).

Simple correlation coefficients between dressing percent and other traits studied were: weaning weight, 0.46; slaughter weight, 0.62; hide weight, 0.37; age at slaughter, 0.33; length of the round, 0.67; circumference of the round at forty and seventy percent of it's length, 0.43 and 0.53 respectively; weight of the trimmed round, loin, chuck, and rib, 0.59, 0.63, 0.66, and 0.61 respectively; weight of the lean, fat, bone, and eye muscle of the 9-10-11th rib cut, 0.40, 0.57, 0.50, and 0.48 respectively.

Dressing percent would therefore be considered a very good indicator of those traits which use weights and measurements as the evaluation standard. Dressing percent had a low, but positive correlation with slaughter grade (0.12) and final carcass grade (0.15), agreeing with results obtained by Cook et al. (1951).

Progeny of M. Crusty Domino and Royal Husker K38 were found to be statistically different ($P < .05$) from the progeny of the other sires included in the study when the length of the rounds were compared. The manner in which this measurement was obtained was related to skeletal size, and again might be best explained by the difference in the age of the various progeny groups.

The length of round as measured from the tip of the hock to the anterior edge of the aitch bone was calculated to have a heritability estimate of 0.17. Correlation coefficients between length of the round and other traits were: weaning weight, 0.59; average daily gain from birth until weaning, 0.46; slaughter weight, 0.79; hide weight, 0.41; chilled carcass weight, 0.81; weight of the right side, 0.76; dressing percent, 0.67; circumference of the round at seventy percent, 0.71; and weight of the trimmed round, loin, chuck, and rib, 0.65, 0.71, 0.80, and 0.66 respectively.

Significant differences ($P < .05$) were found between the sires when the circumference of round measurements of their progeny were compared. Progeny of R. Silver Return 632nd were again significantly higher in the circumference measurements than were calves sired by M. Crusty Domino and Royal Husker K38. The heritability for the circumference of round measurements were estimated to be 0.16 for the circumference at forty percent and 0.22 for the circumference at seventy percent of the length of the round. The measurements were taken with the carcass suspended from the rail. The forty percent measurement would therefore indicate that selection for fullness in the lower portion of the round is more difficult than selection for muscling in the upper portion of the beef round.

The following correlations were found between the round circumference at forty and seventy percent, respectively, of it's length with the following characteristics: weaning weight, 0.36 and 0.55; weaning muscling score, 0.23 and 0.34; weaning bone score, 0.37 and 0.31; slaughter muscling score, 0.34 and 0.34; slaughter bone score, 0.41 and 0.35; slaughter weight, 0.61 and 0.76; hide weight, 0.51 and 0.53; chilled carcass weight, 0.61 and 0.76; dressing percent, 0.43 and 0.53; weight of the trimmed round, loin, chuck, and rib, 0.67 and 0.67; 0.52 and 0.70; 0.56 and 0.74; and 0.57 and 0.67.

These data agree with results reported by Allen (1963) indicating that the circumference of round measurements were highly correlated with the weight of the primal wholesale cuts, and are in disagreement with results of Birkett et al. (1963), who reported that the correlations between the various length and circumference measurements ranged from zero to slight, non-significant relationships. Birkett et al. (1963) used many measurements taken both on the live animal and the carcass. Data from this study disagrees slightly with results reported by Good et al. (1961), who reported a significant positive correlation between circumference of the round and loin eye area. Results from this study indicated a positive correlation between the traits, but the correlation was not considered significant.

Other measurements taken at time of slaughter included those of the right and left forearm and the right and left cannon bone of the fore legs. These measurements were obtained just prior to the removal of the head from the carcass and were difficult to obtain accurately. Some slight difference will be noted between the individual measurements which should be regarded as experimental error in obtaining the measurements, and to some degree, to accumulation of foreign material attached to the hair. M. Crusty Domino progeny had significantly smaller ($P < .05$) forearm measurements than the progeny of the other sires. The age of the sire's progeny should receive consideration when comparing the objective measurements. The results of the subjectively scored weaning and slaughter muscling scores, as well as the physical separation data fail to verify the indication of lighter muscling for this sire.

An average of the two forearm measurements indicated a heritability of 0.19 for the circumference of the forearm.

The measurement of the cannon bone indicated that smaller circumference measurements were obtained for the younger calves sired by M. Crusty Domino and Royal Husker K38. M. Crusty Domino progeny had significantly lighter ($P < .05$) bone weights of the 9-10-11th rib cuts, but had a higher percentage of bone in these cuts than did Royal Husker 3rd or R. Silver Return 632nd.

Positive significant correlations were obtained between the circumference of the forearm and the circumference of the cannon bone measurement and between these measurements and weaning weight, feeder grade, weaning muscling score, slaughter muscling score, slaughter bone score, slaughter weight, hide weight, carcass conformation score, chilled carcass weight, dressing percent, weight of the trimmed wholesale cuts, and the physical separation characteristics.

Results of these data agree with the results of Orme et al. (1959) who reported that cannon bone measurements were related to carcass muscling, but that the relationship was not high enough to be useful for predictive purposes. Cole et al. (1960) reported a highly significant correlation between bone weight and the total lean of the carcass, while Wythe et al. (1961) suggested that a real association exists between thickness and muscling in beef cattle. Results of these data indicate that such an association does exist, and while total physical separation was not done, the use of the 9-10-11th rib cut as an indicator of total carcass lean would indicate that the relationship does exist. Results of this study are not in agreement with studies reported by Orts and King (1959) who reported bone measurements to be highly correlated with Warner-Bratzler shear values.

Weights of the individual right sides were recorded and included in these data as a means of comparing the weights of the closely trimmed wholesale cuts on a percentage basis. Carcasses from progeny of R. Silver Return 632nd were found to be significantly heavier ($P < .05$) than progeny of the other sires of the study. Progeny of Royal Husker K38 were also significantly lighter than calves sired by Royal Husker 3rd and Onward Rupert. The heritability estimate for the weight of the side (0.35) was higher than the heritability estimate for the chilled carcass weight (0.29), but the correlation coefficients between the weight of the side and chilled carcass weights with other characteristics of the study are very similar.

Bray (1963) reported that the use of retail yield has the advantage of measuring the salable portion of the carcass and should then rather accurately reflect quantitative differences. The analysis of variance indicated a significant difference ($P < .01$) between sires when the weight of the closely trimmed loin and square-cut chuck were compared and a significant difference ($P < .05$) between sires when the weight of the closely trimmed round and rib were compared.

Reviewing the NMRT, indications were that progeny of R. Silver Return 632nd were significantly heavier ($P < .05$) than the progeny of the other sires, while the younger progeny of M. Crusty Domino and Royal Husker K38 were significantly lighter than the other four sires.

The use of the weights of the closely trimmed wholesale cuts calculated as a percentage of the weight of the side are therefore of some importance in comparing the progeny. Data indicated that the younger calves, although lighter, compared favorably with the other groups when the wholesale cuts were compared on a percentage basis.

The heritability estimates for the weight of the closely trimmed round was 0.22; trimmed loin, 0.31; trimmed chuck, 0.31; and the trimmed rib, 0.46. Heritability estimates for the weight of the trimmed wholesale cuts are of greater magnitude than are the heritability estimates of the trimmed wholesale cuts when expressed as a percentage of the side. These data indicate that the heritability estimates are of sufficient magnitude to influence some selection improvement by producers.

The individual correlations between the weights of the various trimmed wholesale cuts with other characteristics have been discussed earlier. In general, the closely trimmed cuts were found to have high correlations between weaning weight, slaughter muscle score, slaughter bone score, slaughter weight, hide weight, chilled carcass weight, rib eye area, dressing percent, length of the round, circumference of the round, fore arm, and cannon bone, and the weight of the fat, lean, bone, and <u>longissimus</u> <u>dorsi</u> muscle of the 9-10-11th rib cut. Results of these data would tend to be in agreement with results of Gregory <u>et</u> <u>al</u>. (1964) who concluded that until a more accurate objective procedure is available for use in practice, breeders may exert some selection pressure for cutability by critical live appraisal for muscling in prospective breeding cattle.

Progeny sired by Royal Husker K38 were found to have significantly less ($P < .05$) weight of fat in the 9-10-11th rib than did R. Silver Return 632nd or Royal Husker 3rd. No significant differences were found between the sires when comparing the weight of the lean from the three-rib cut, but Royal Husker 3rd had significantly less lean ($P < .05$) than Royal Husker K38 and Onward Rupert when the sires were compared on a percentage of separable lean to fat and bone in the weight of the 9-10-11th rib cut. Identical comparisons were found to exist when weight and percentage of bone were compared in the various progeny groups. Significant differences were not found between sires when the weight of the _longissimus_ _dorsi_ muscle of the 9-10-11th rib cuts were compared, but R. Silver Return had significantly less ($P < .05$) muscle than did Royal Husker K38 when the percentage of eye muscle was compared.

Heritability estimates were calculated for both the weight and the percentage of lean, fat, bone, and _longissimus_ _dorsi_ muscle in the 9-10-11th rib cut; weight of the lean was estimated to be 0.09 heritable, while the percent of lean was estimated to be 0.19 heritable; weight of fat was estimated to be 0.22 heritable, compared to a heritability estimate of 0.17 for the percent of fat contained in the three-ribs; the weight of the separable bone was estimated to be 0.15 heritable estimate of 0.01; the weight of the _longissimus_ _dorsi_ muscle was estimated to be only 0.02 heritable, while the percentage of the total weight of the 9-10-11th rib cuts comprised by the _longissimus_ _dorsi_ muscle was estimated to be 0.23 heritable.

Rather high correlations coefficients were found between the weight of the separable lean, fat, bone, and _longissimus dorsi_ muscle and the chilled carcass weight. These correlations were 0.69, 0.63, 0.66 and 0.66, respectively. The weight of the fat in the 9-10-11th rib was found to be correlated with the fat thickness at the twelfth rib, 0.38; marbling score, 0.20; and dripping losses during cooking, 0.57. Negative correlations were found between weight of the fat in the 9-10-11th rib cut and juiciness score, -.14; shear value, -.21; and press fluid, -.05. Almost identical correlations were found when the percentage of fat was compared to the weight of the fat in the 9-10-11th rib cut. Branaman _et al_. (1936) found no relationship between tenderness and fatness.

The weight of the lean and the weight of the _longissimus dorsi_ muscle were found to have positive significant correlations with weaning weight (0.50 and 0.55 respectively). Weight of the _longissimus dorsi_ muscle of the 9-10-11th rib cuts were positively correlated with weaning bone score, 0.43; weaning muscling score, 0.29; slaughter bone score, 0.38; and slaughter weight, 0.66. The correlation between weight of the _longissimus dorsi_ muscle in the 9-10-11th rib cut with rib eye area was 0.44. Correlations between the weights of the lean, fat, bone, and the _longissimus dorsi_ muscle were found to be positively correlated with the various length and circumference measurements used during the study ranged from 0.28 to 0.56. Correlation coefficients between the physical separation weights and the weights of the closely trimmed wholesale cuts were the most highly correlated traits measured when the various phases of the study were compared.

Mention has been made earlier in the discussion regarding the rather low marbling scores obtained by the animals included in the study. These lowered score perhaps account for the lack of agreement of these data with studies of Blumer _et al._ (1959), who reported a correlation coefficient between marbling score and percent separable lean of 0.20, compared to the -.17 correlation for these traits found during this study. Hankins and Howe (1946) and Crown and Damon (1959) also reported higher correlations between the percent of separable lean, fat, and bone than were found in this study. The most logical explanation for the lack of agreement between the studies would seem to lie in the fact that significant differences were not found between the selected sires when the rib eye areas were compared.

The results of the tenderness studies were unable to show significant differences between the progeny of the various sires other than a difference in cooking losses. Flavor scores of the lean and fat were each more highly correlated with the weight of the chilled carcass and dressing percent than any other characteristic of either the carcass or slaughter phase of the study. Flavor scores of the fat and the lean were more highly correlated with the weight of the _longissimus dorsi_ muscle in the 9-10-11th rib cut than of any other characteristics of the physical separation phase of the study. A correlation coefficient of 0.57 was found between the flavor score of the fat and the flavor score of the lean. A correlation of 0.55 was found between the chews score as evaluated by the taste panel with Warner-Bratzler shear score.

Romans et al. (1965) reported shear and taste panel scores were not significantly correlated. The taste panel used to evaluate the beef roasts in this study did not indicate that carcass grade influenced the tenderness of the 6-7-8th rib roasts. The narrow range of the carcass grade score did not allow for extreme difference in carcass grades. The same narrow range between the means of the progeny groups will perhaps account for the disagreement with studies of Zinn (1964), who indicated that tenderness is sixty percent heritable.

SUMMARY

Fifty randomly selected steers born and fed at the Clifford Houghton Ranch of Tipton, Kansas, were used in this study. The steers were the progeny of six selected sires. Four of the sires were used by means of artificial insemination for approximately three heat periods. The remaining two sires were used in natural service as "clean-up" bulls. The resulting progeny were born in the fall of 1964. All calves had access to a creep feeder until weaned, and were then placed on a self-feeder until slaughtered on Feburary 1, 1966.

The study included several phases, beginning with the weaning traits and continuing through slaughter, carcass study, detailed physical separation of the fifty rib cuts, and organoleptic studies designed to evaluate tenderness. Live animal scores were placed on the individuals by a committee recording weaning and slaughter weights, weaning and slaughter muscling, bone, and condition scores; an overall-conformation score was placed on the individuals and individual hide weights were recorded at time of slaughter. Chilled carcass weight, dressing percent, weight of the right side, carcass conformation, marbling, maturity, and final carcass quality grades were recorded for each individual. The objective measurements taken included the length of the round, circumference of the round at forty- and seventy-percent of it's length, and forearm and cannon bone circumference of the fore limb.

The weights of the four major wholesale cuts, the round, loin, chuck, and rib, were recorded as the carcass was broken down, then the outside fat was trimmed to a uniform depth of three-eighths of an inch; the fat trim was recorded. The wholesale rib cut was returned to the Meats Laboratory at Kansas State University for physical separation studies. The 6-7-8th rib cut was used by the Department of Foods and Nutrition for tenderness studies; the twelfth rib was removed for laboratory analysis for pH, color, and ether extract studies; the 9-10-11th rib cuts were used to determine the weight and the percentage of lean, fat, bone, and longissimus dorsi muscle of the individual steers.

Simple correlation coefficients were calculated between each of the characteristics studied. Duncan's New Multiple Range Test (NMRT) was calculated to show significant differences between the progeny of the individual sires for each characteristic of the study. Heritability estimates were also calculated for the individual characteristics according to the method of Becker (1964).

Heritability estimates of sufficient magnitude which could be considered as having some influence during sire selection included: weaning weight, 0.31; feeder grade, 0.19; weaning bone score, 0.23; slaughter muscling score, 0.22; slaughter conformation score, 0.22; hide weight, 0.34; age at slaughter, 0.46; carcass quality score, 0.19; seventy percent circumference of round, 0.22; cannon bone circumference, 0.19; weight of the trimmed round, 0.22; trimmed loin, 0.31; trimmed chuck, 0.31; trimmed rib, 0.45; the percentage of the longissimus dorsi muscle in the 9-10-11th rib cut, 0.23; taste panel tenderness score, 0.21; and Warner-Bratzler shear value, 0.20.

Statistical analysis of these data, using the analysis of variance, indicated a significant difference between the sires at the ($P < .01$) level for the following characteristics: weaning and slaughter age and weight, chilled carcass weight, dressing percentage, weight of the right side of the carcass, and the weight of the trimmed loin and chuck. Additional differences found between sires at the ($P < .05$) level were: weaning bone score, slaughter conformation score, slaughter muscling score, marbling score, seventy percent circumference of the round, weight of the trimmed round and rib, weight of the fat and weight of the longissimus dorsi muscle in the 9-10-11th rib cut, and the percentage of weight loss during cooking due to dripping.

Duncan's NMRT indicated between which of the sires significant differences ($P < .05$) did occur. Mill Iron 836E progeny were found to be the oldest calves in the study, had the lowest average daily gains, had the lowest feeder grades of the four older progeny groups, were lowest in muscling scores, had the lowest weaning and slaughter condition scores, and had the lowest slaughter grades. Mill Iron progeny also had the lowest percentage of trimmed loin and rib, and the highest percentage of trimmed chuck and round.

Steers sired by Royal Husker 3rd were more consistent in their scores and performance than were other sires. Royal Husker 3rd progeny had the highest feeder grades, weaning muscling scores, weaning bone scores, weaning condition scores, and achieved the highest marbling scores. The steers ranked second in weaning weight, slaughter grade, final carcass grade, dressing percent, and Warner-Bratzler shear value.

Progeny sired by Onward Rupert were found to have the highest slaughter grades, slaughter muscling and condition scores, weight of *longissimus dorsi* muscle from the 9-10-11th rib cut, carcass conformation scores, and the greatest circumference of forearm and cannon bone. The steers ranked second in slaughter conformation scores and slaughter weight. However, the Onward Rupert progeny ranked fifth on marbling scores and final carcass grades. Tenderness studies revealed that Onward Rupert steers had the greatest number of chews, as evaluated by the taste panel, and suffered the greatest loss during cooking.

Steers sired by R. Silver Return 632nd were found to have the heaviest weaning weights and the highest average daily gain at weaning of the groups studied. The heavier weights at weaning were indicative of the heavier slaughter and carcass weights achieved by the steers. Steers from this progeny group had the highest conformation scores at time of slaughter, the highest dressing percentage, and were the highest ranking when the weights of the closely trimmed wholesale cuts were compared. These progeny also had the greatest length and circumference of round.

Steers sired by R. Silver Return 632nd also had the greatest amount of fat covering at the twelfth rib and a higher percentage of fat in the 9-10-11th rib cut. However, the Silver steers had the most lean and bone in the 9-10-11th rib cut. Tenderness studies revealed that Silver progeny had the lowest number of chews score, required slightly less time to cook, and had the least amount of press fluid.

Calves sired by M. Crusty Domino and Royal Husker K38 were significantly ($P < .05$) younger than the other progeny groups and were considered to be at a disadvantage when the characteristics which use weight alone as a criteria were studied. When percentage figures were used, Royal Husker K38 was found to have the greatest percent of trimmed loin and rib, as well as having the greatest percentage of longissimus dorsi muscle of the 9-10-11th rib cut. Taste panel scores indicated that the panel considered progeny of the two sires less tender than progeny of the other sires.

Weaning weight was found to be a reliable indicator of future weights and therefore useful in predicting future performance, but was not correlated to future conformation type scores. The 210-day adjusted weaning weight was less closely related to future weight and performance than was the actual weaning weight. The lack of agreement may have been due to the age of the calves at weaning.

Feeder grade was not a reliable indicator of actual slaughter grade or final carcass grade. Feeder grade was independent of condition, while slaughter grade and final carcass grade were very dependent on condition, with a great deal of emphasis placed on the deposition of fat between the muscle bundles.

Weaning bone, muscle, and condition scores did not have the high correlation with slaughter bone, muscle, and condition score which one might expect. Slaughter bone scores had a higher correlation with factors comprising "cutability" than did slaughter muscling scores. These data indicate that the size of the bone does have a significant relationship with the amount of lean, red meat of the beef carcass.

A correlation of 0.00 was found between slaughter grade and marbling grade, while the correlation between slaughter grade and final carcass grade was -.03. The correlation between carcass grade and marbling grade was 0.90. With the exception of the final carcass grade, marbling had a non-significant influence on other characteristics which influence the value of the carcass. Non-significant correlations were found between marbling and tenderness, juiciness, and flavor. A significant difference ($P < .05$) was noted between sire groups for marbling.

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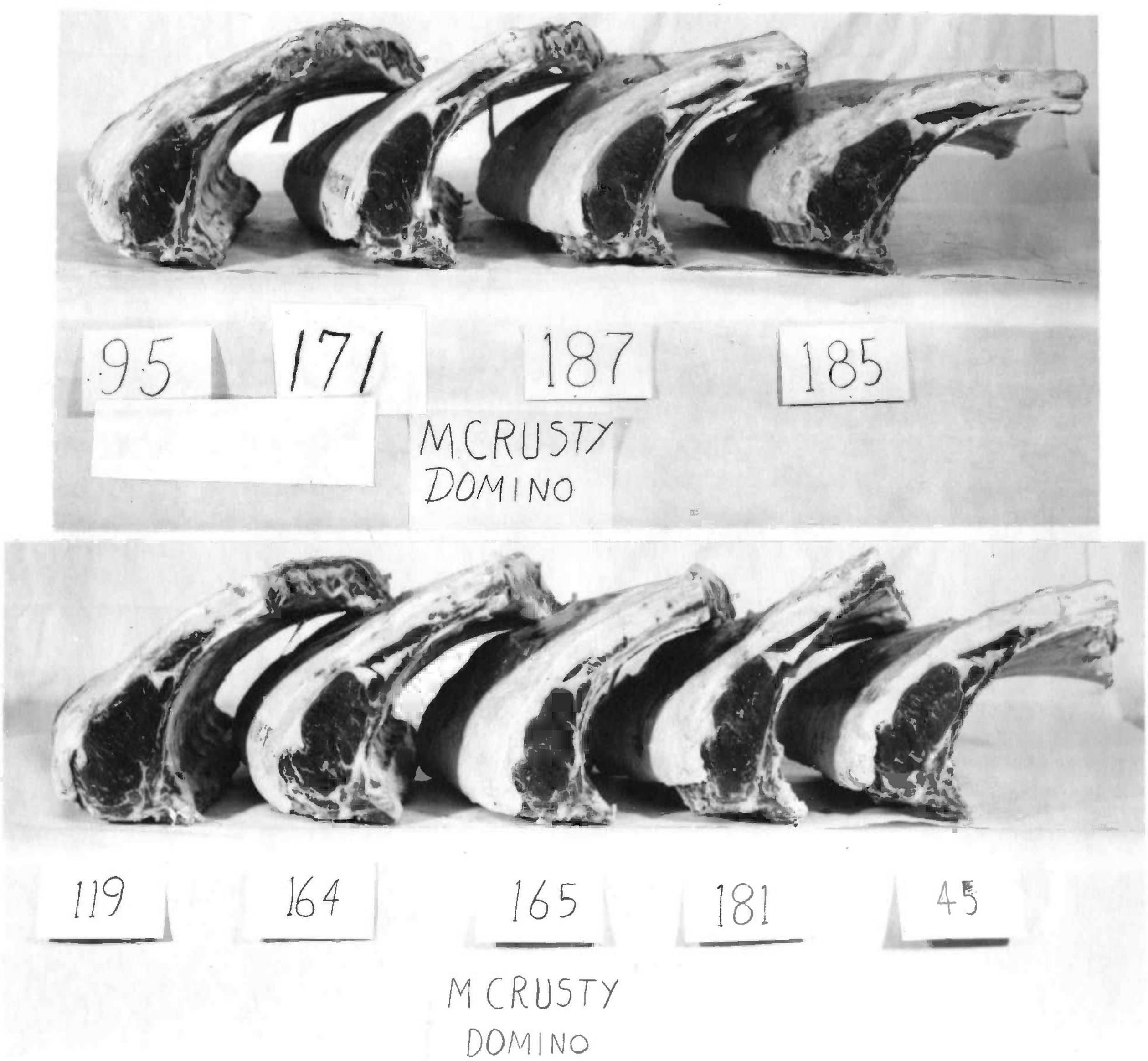
APPENDIX

EXPLANATION OF PLATE I

Wholesale rib cuts from M. Crusty Domino Progeny

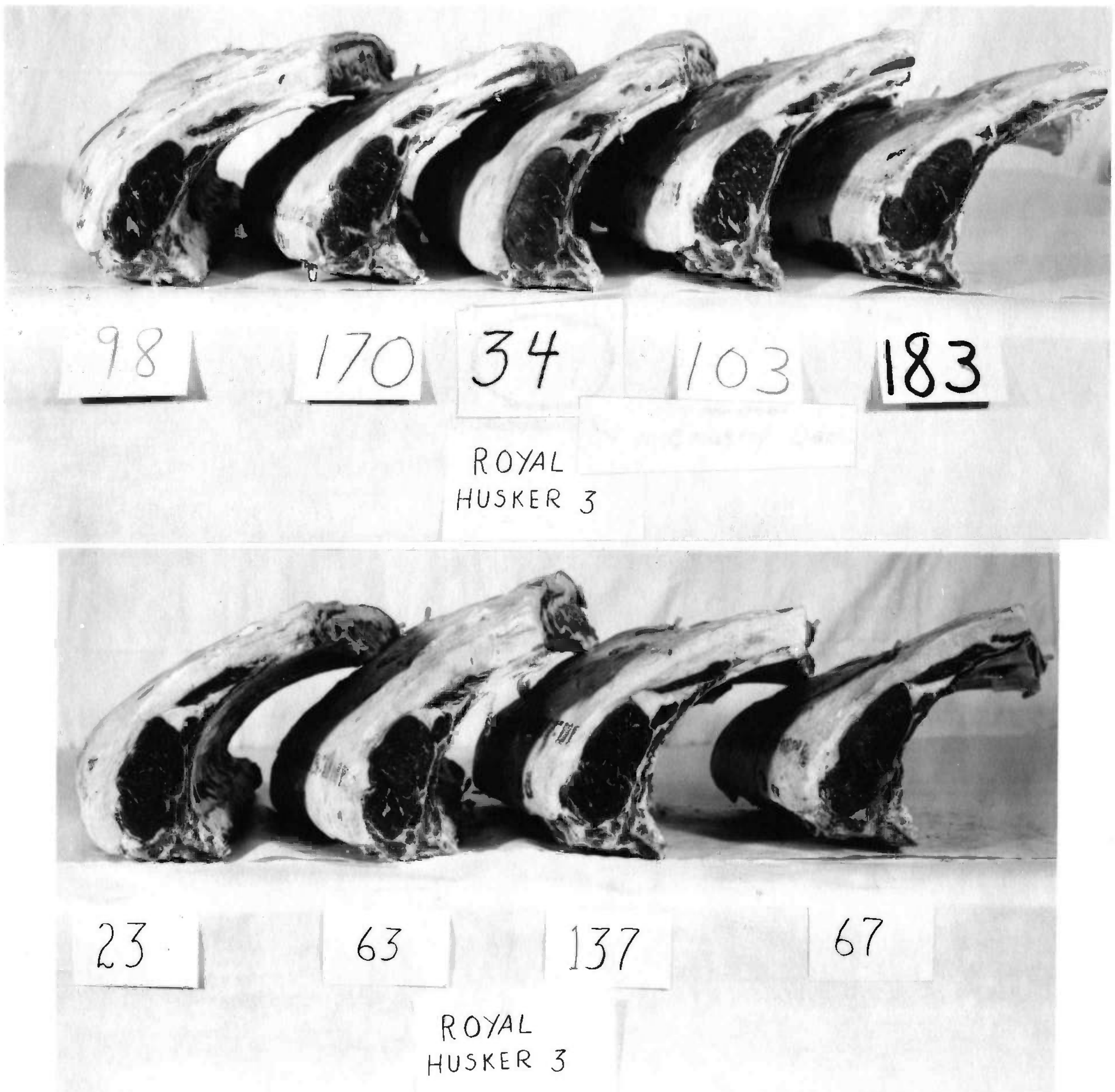
PLATE I


95
171
187
185
MCRUSTY
DOMINO
119
164
165
181
45
M CRUSTY
DOMINO

EXPLANATION OF PLATE II

Wholesale rib cuts from Royal Husker 3rd Progeny

PLATE II



EXPLANATION OF PLATE III

Wholesale rib cuts from R. Silver Return 632nd Progeny

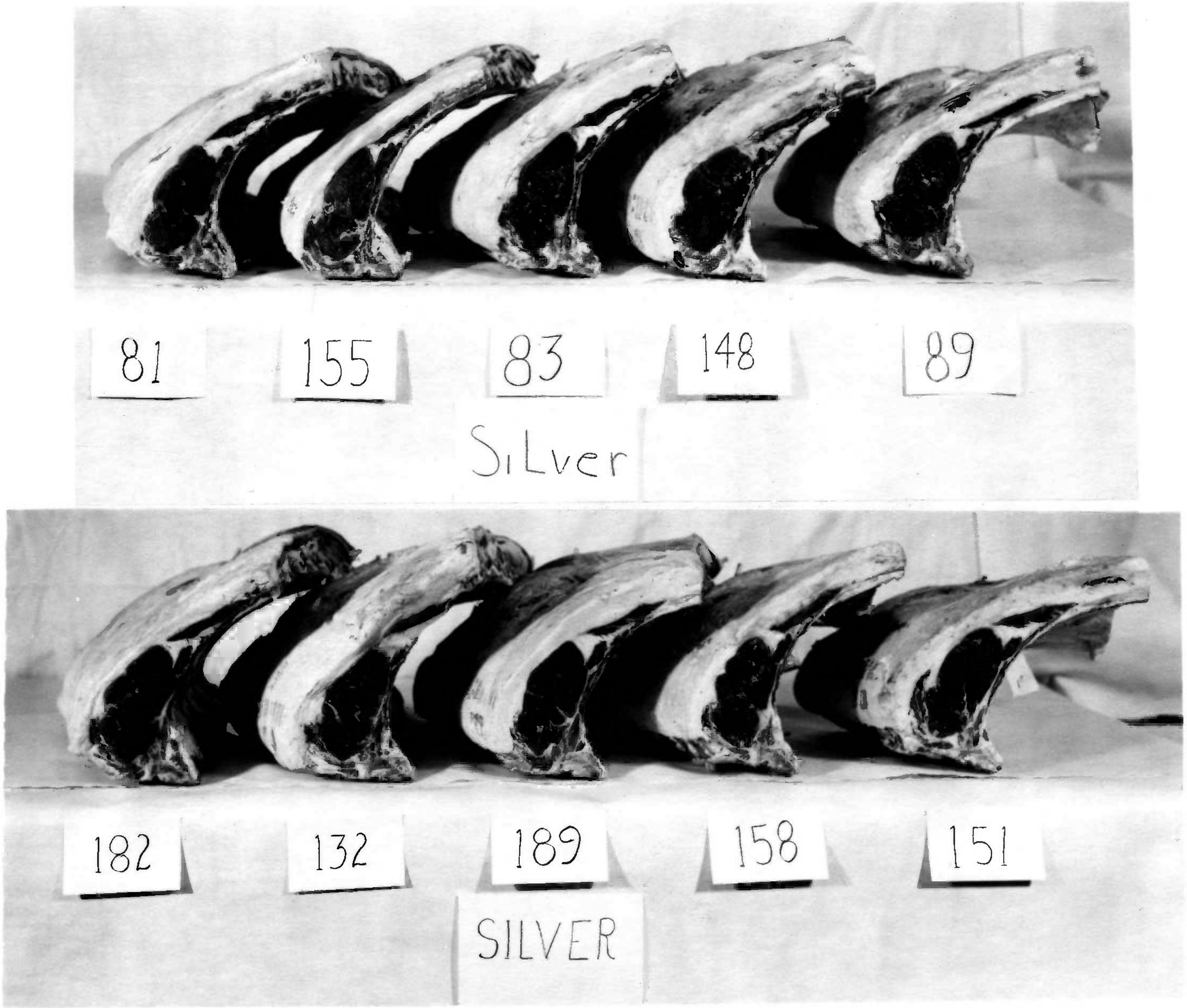
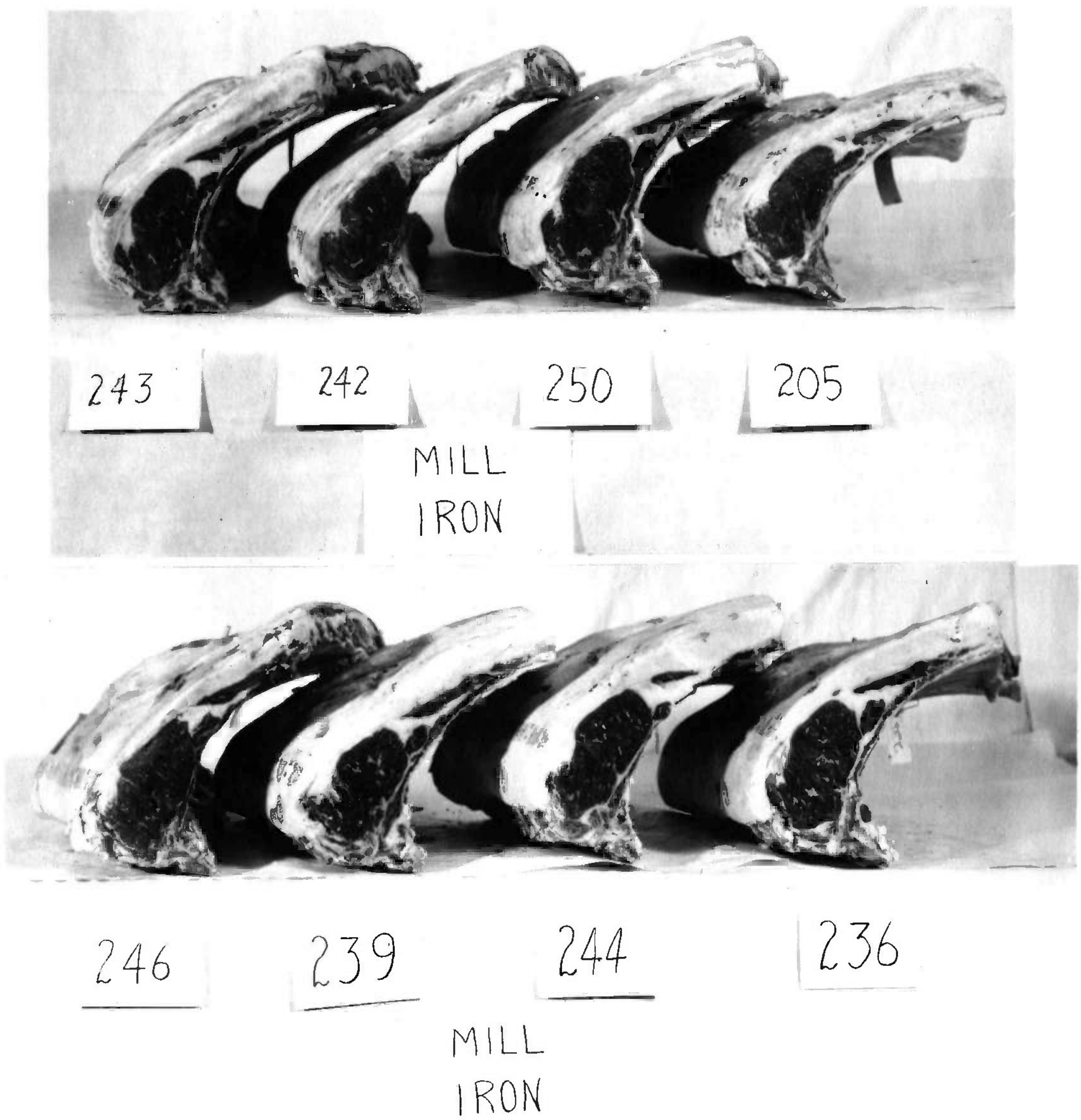


PLATE III

EXPLANATION OF PLATE IV

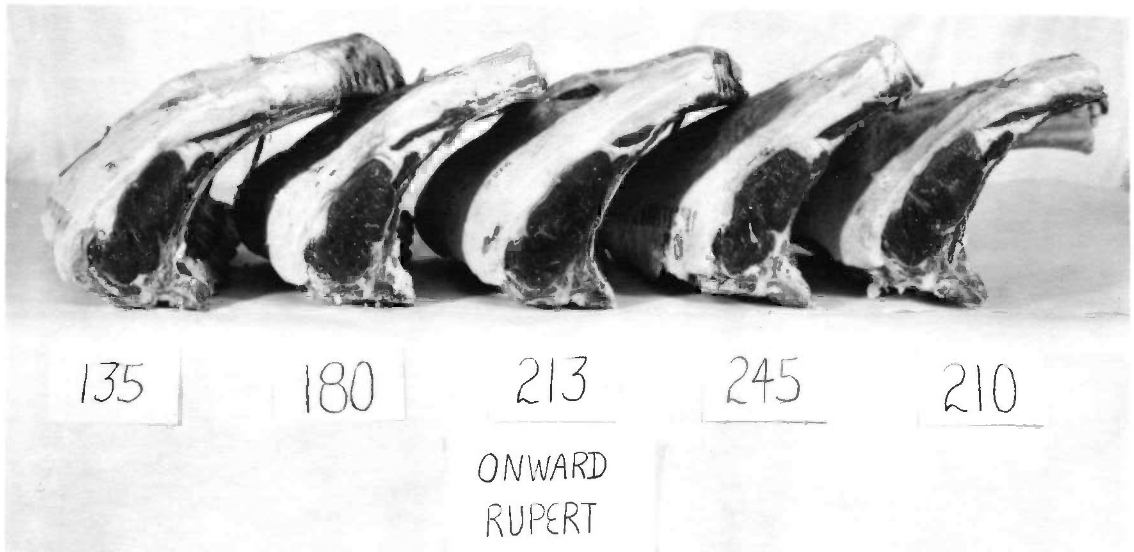
Wholesale rib cuts from Mill Iron 836E Progeny

PLATE IV



EXPLANATION OF PLATE V

Wholesale rib cuts from Onward Rupert Progeny


135
180
213
245
210
ONWARD
RUPERT

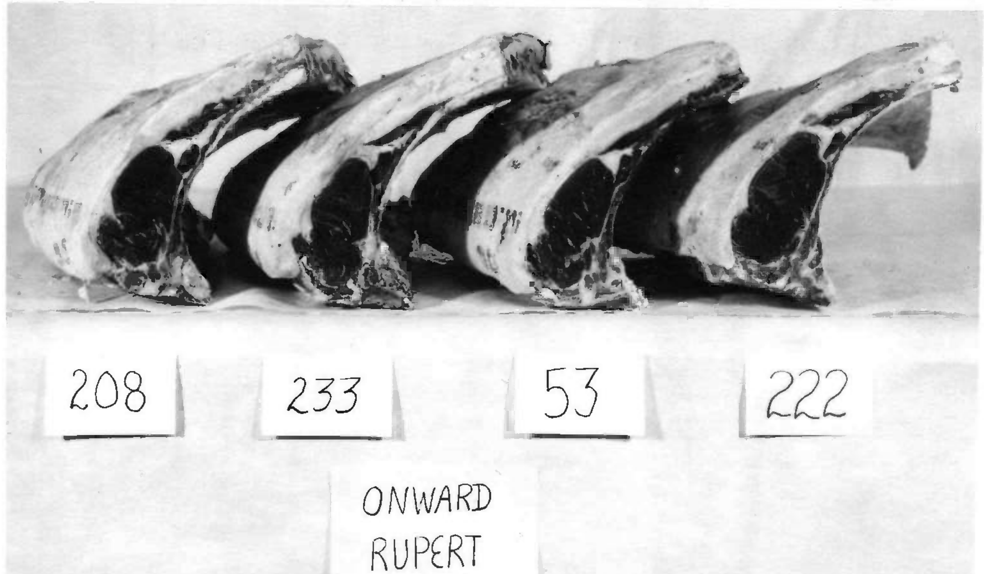

208
233
53
222
ONWARD
RUPERT

PLATE V

EXPLANATION OF PLATE VI

Wholesale rib cuts from Royal Husker K38 Progeny

PLATE VI

Table 3a. Simple correlation coefficients between weaning and slaughter characteristics.

Trait	Day of age at weaning	Weaning weight	210 day adj. wean. wt.	ADG/day of age	Feeder Grade	Wean. muscling score	Wean. bone score	Wean. cond. score	Slaughter Grade	Slaughter muscling score	Slaughter bone score	Slaughter cond. score	Conformation score	Slaughter weight	Hide weight	Day of age at slaughter
Day of age at weaning		0.49	0.04	-.05	0.19	0.15	0.26	0.16	0.08	0.02	0.10	-.19	-.08	0.39	0.32	0.89
Weaning wt.			0.76	0.80	0.65	0.71	0.68	0.71	0.34	0.28	0.34	0.14	0.06	0.73	0.63	0.56
210 day adj. weaning wt.				0.91	0.58	0.60	0.50	0.66	0.16	0.10	0.25	0.01	-.07	0.48	0.43	0.03
ADG/day of age					0.62	0.66	0.56	0.70	0.26	0.22	0.30	0.15	0.03	0.57	0.44	-.35
Feeder Grade						0.88	0.72	0.75	0.30	0.30	0.13	0.32	0.03	0.32	0.41	0.26
Wean. muscling score							0.78	0.78	0.41	0.45	0.31	0.38	0.15	0.39	0.15	0.39
Wean. bone score								0.61	0.30	0.26	0.48	0.26	0.06	0.44	0.52	0.34
Wean. cond. score									0.41	0.37	0.14	0.34	0.10	0.37	0.48	0.24

Table 3b. Simple correlation coefficients between weaning and carcass weights and measurements.

Trait	Chilled carcass weight	Carcass conform. score	Carcass marbling score	Carcass maturity score	Carcass quality score	Rib eye area	Depth of back-fat	Dressing percentage	Length of round	Circ. of round (40%)	Circ. of round (70%)	Circ. of right forearm	Circ. of left forearm	Circ. of right shank	Circ. of left shank	Weight of right side of carcass
Day of age at weaning	0.40	0.12	0.24	0.08	0.33	0.15	0.11	0.38	0.32	0.40	0.36	0.35	0.32	0.31	0.29	0.41
Weaning wt.	0.74	0.05	0.22	0.33	0.21	0.42	0.29	0.46	0.59	0.36	0.55	0.42	0.45	0.40	0.41	0.69
210 day adj. wean. wt.	0.50	0.03	0.07	0.35	-.01	0.50	0.16	0.30	0.38	0.09	0.30	0.29	0.29	0.24	0.20	0.43
ADG/day of age	0.57	0.01	0.10	0.38	0.02	0.43	0.21	0.30	0.46	0.16	0.43	0.24	0.25	0.21	0.24	0.50
Feeder Grade	0.31	0.26	0.26	0.21	0.19	0.21	0.14	0.06	0.15	0.15	0.24	0.31	0.35	0.33	0.25	0.19
Wean. muscling score	0.50	0.27	0.38	0.11	0.05	0.11	-.01	0.17	0.17	0.23	0.34	0.33	0.36	0.40	0.32	0.27
Wean. bone score	0.43	0.14	0.08	0.22	0.06	0.26	0.02	0.15	0.28	0.37	0.31	0.38	0.44	0.49	0.45	0.33
Wean. cond. score	0.38	0.11	0.11	0.19	0.03	0.24	0.18	0.24	0.28	0.15	0.35	0.20	0.21	0.22	0.18	0.33

Table 3c. Simple correlation coefficients between weaning characteristics and primal wholesale cuts.

Trait	Weight trimmed round	Weight trimmed loin	Weight trimmed chuck	Weight trimmed rib	Trimmed round as % of side	Trimmed loin as % of side	Trimmed chuck as % of side	Trimmed rib as % of side	Weight of fat 9-10-11 rib	Percent fat in 9-10-11 rib	Weight of lean 9-10-11 rib	Percent of lean 9-10-11 rib	Weight of bone 9-10-11 rib	Percent bone 9-10-11 rib	Wt. ribeye muscle 9-10-11 rib	% ribeye muscle 9-10-11 rib
Day of age at weaning	0.37	0.41	0.34	0.39	-.09	-.02	-.16	-.05	0.26	0.04	0.32	-.13	0.41	-.09	0.21	-.29
Weaning wt.	0.69	0.62	0.72	0.62	-.06	-.16	-.01	-.15	0.39	0.05	0.50	-.14	0.56	-.16	0.55	-.08
210 day adj. wean. wt.	0.51	0.48	0.47	0.40	0.08	0.08	0.02	-.09	0.13	-.10	0.36	0.07	0.37	0.01	0.45	0.18
ADG/day of age	0.53	0.50	0.57	0.45	-.01	-.04	0.04	-.11	0.22	-.01	0.35	-.04	0.36	-.09	0.47	0.13
Feeder Grade	0.31	0.22	0.30	0.21	0.14	0.01	0.16	-.02	0.13	0.01	0.15	-.10	0.27	0.02	0.23	0.00
Wean. muscling score	0.41	0.29	0.39	0.26	0.17	-.01	0.17	-.06	0.11	-.01	0.20	-.03	0.26	-.01	0.29	0.07
Wean. bone score	0.50	0.29	0.42	0.32	0.20	-.10	0.10	-.07	0.16	-.03	0.31	0.01	0.29	-.10	0.43	0.15
Wean. cond. score	0.35	0.30	0.36	0.23	-.00	-.07	-.02	-.18	0.13	0.00	0.17	-.06	0.22	-.02	0.21	-.00

Table 3d. Simple correlation coefficients between weaning and cooking characteristics.

Trait	Cooking time 6-7-8 rib	Cooking loss volatile %	Cooking loss dripping %	Total cooking losses	Flavor score fat	Flavor score lean	Juiciness score	Initial tenderness	No. of chews	Chews score	Shear value	Press fluid
Day of age at weaning	-.01	-.09	0.21	0.06	0.18	0.08	0.03	-.20	0.27	0.19	0.10	0.04
Weaning wt.	-.15	-.06	0.34	0.17	0.27	0.25	-.07	0.14	0.03	0.14	-.19	-.00
210 day adj. wean. wt.	-.20	-.01	0.15	0.09	0.19	0.14	0.01	0.28	-.28	0.30	-.20	-.08
ADG/day of age	-.22	-.10	0.17	0.03	0.18	0.20	-.02	0.35	-.33	-.34	-.34	0.06
Feeder Grade	-.17	-.11	0.12	-.01	-.07	0.04	-.06	0.26	-.19	0.28	-.12	-.19
Wean. muscling score	-.22	-.05	0.17	0.06	-.02	-.05	-.05	0.24	-.21	0.27	-.23	-.10
Wean. bone score	-.11	-.06	0.26	0.12	0.08	0.12	0.05	0.18	-.16	0.24	-.20	0.03
Wean. cond. score	-.15	-.11	0.21	0.04	0.13	0.07	-.02	0.34	-.26	0.37	-.28	0.04

Table 4a. Simple correlation coefficients between slaughter and carcass characteristics.

Trait	Slaughter Grade	Slaughter muscle score	Slaughter bone score	Slaughter cond. score	Slaughter conf. score	Slaughter weight	Hide weight	Day of age at slaughter	Chilled carcass wt.	Conformation score	Marbling score	Maturity score	Quality score	Rib eye area	Depth of back-fat	Dressing percent
Slaughter Grade		0.75	0.22	0.81	0.61	0.33	0.46	0.19	0.31	-.06	0.00	0.12	-.03	0.17	0.24	0.12
Slaughter muscle score			0.33	0.72	0.66	0.36	0.48	0.15	0.30	-.07	-.01	0.09	-.14	0.07	0.13	0.06
Slaughter bone score				0.06	0.34	0.44	0.57	0.12	0.41	0.10	-.25	-.01	-.20	0.13	-.06	0.16
Slaughter cond. score					0.58	0.13	0.31	0.00	0.09	-.02	-.00	0.07	-.06	-.01	0.16	-.13
Slaughter conf. score						0.35	0.44	0.06	0.31	0.07	-.05	-.02	-.08	0.09	0.01	0.10
Slaughter weight							0.71	0.41	0.99	0.19	0.17	0.32	0.12	0.38	0.40	0.62
Hide weight								0.41	0.68	0.17	-.06	0.04	-.05	0.31	0.17	0.37
Day of age at slaughter									0.41	0.09	0.26	0.05	0.34	0.12	0.19	0.33

Table 4b. Simple correlation coefficients between slaughter characteristis and carcass weights and measurements.

Trait	Length of round	Circ. of round (40%)	Circ. of round (70%)	Circ. right forearm	Circ. left forearm	Circ. right shank	Circ. left shank	Wt. right side	Wt. trimmed round	Wt. trimmed loin	Wt. trimmed chuck	Wt. trimmed rib	Trim. round as % side	Trim. loin as % side	Trim. chuck as % side	Trim. rib as % side
Slaughter Grade	0.09	0.27	0.19	0.19	0.15	0.20	0.31	0.29	0.29	0.26	0.24	0.16	-.03	-.04	-.17	-.24
Slaughter muscle score	0.13	0.34	0.34	0.27	0.24	0.29	0.36	0.30	0.38	0.28	0.33	0.18	0.10	-.09	0.01	-.21
Slaughter bone score	0.29	0.41	0.35	0.47	0.45	0.52	0.49	0.31	0.52	0.29	0.43	0.43	0.28	-.05	0.22	0.17
Slaughter cond. score	-.09	0.08	-.00	0.05	0.04	0.15	0.24	0.08	0.08	0.05	0.06	-.00	-.00	-.02	-.10	-.15
Slaughter conf. score	0.20	0.31	0.32	0.12	0.08	0.22	0.29	0.30	0.37	0.29	0.29	0.27	0.08	-.09	-.03	-.04
Slaughter weight	0.79	0.61	0.76	0.57	0.59	0.54	0.63	0.92	0.84	0.87	0.95	0.86	-.20	-.17	-.01	-.14
Hide weight	0.41	0.51	0.53	0.64	0.64	0.67	0.61	0.63	0.68	0.56	0.67	0.58	0.02	-.16	-.00	-.11
Day of age at slaughter	0.32	0.33	0.32	0.33	0.34	0.32	0.29	0.43	0.40	0.32	0.38	0.38	-.08	-.19	-.08	-.07

Table 4c. Simple correlation coefficients between slaughter characteristics and physical separation 9-10-11th rib cut.

Trait	Weight fat 9-10-11 rib	Percent fat 9-10-11 rib	Weight lean 9-10-11 rib	Percent lean 9-10-11 rib	Weight bone 9-10-11 rib	Percent bone 9-10-11 rib	Wt. ribeye muscle 9-10-11 rib	% ribeye muscle 9-10-11 rib
Slaughter Grade	0.21	0.13	0.23	-.05	0.07	-.27	0.23	-.06
Slaughter muscle score	0.11	0.09	0.15	0.02	0.01	-.08	0.20	0.06
Slaughter bone score	0.13	0.02	0.26	0.00	0.31	-.02	0.38	0.15
Slaughter cond. score	0.15	0.14	0.08	-.07	-.06	-.25	0.08	-.08
Slaughter conf. score	0.23	0.15	0.24	-.05	0.13	-.22	0.28	-.01
Slaughter weight	0.67	0.36	0.64	-.33	0.65	-.40	0.66	-.26
Hide wt.	0.36	0.15	0.42	-.14	0.49	-.09	-.38	0.04
Day of age at slaughter	0.29	0.04	0.34	-.14	0.43	-.10	0.24	-.30

Table 4d. Simple correlation coefficients between slaughter and cooking characteristics.

Trait	Cook time 6-7-8 rib	Cook. loss volatile %	Cook. loss drip %	Total cook. losses	Flavor score fat	Flavor score lean	Juiciness score	Initial tenderness	Number of chews	Chews score	Shear value	Press fluid
Slaughter Grade	0.02	0.06	0.14	0.16	0.17	0.07	-.17	-.02	0.05	-.07	0.06	-.01
Slaughter muscle score	-.02	0.12	0.19	0.24	0.12	0.05	-.24	-.09	0.11	-.13	-.12	-.13
Slaughter bone score	-.41	-.07	0.33	0.14	0.19	0.20	0.01	-.06	-.06	0.00	-.23	0.02
Slaughter cond. score	0.06	0.04	0.03	0.07	0.02	-.08	-.19	-.01	0.09	-.09	0.15	-.04
Slaughter conf. score	-.13	0.02	0.11	0.10	0.08	-.01	-.18	-.19	0.07	-.18	-.12	-.06
Slaughter weight	-.33	-.12	0.55	0.27	0.38	0.35	-.07	-.02	0.06	-.03	-.18	-.06
Hide wt.	-.38	0.04	0.43	0.32	0.31	0.17	-.09	0.01	0.00	0.03	-.13	-.15
Day of age at slaughter	0.09	0.03	0.27	0.21	0.14	0.10	-.07	0.24	0.39	-.23	0.17	-.09

Table 5a. Simple correlation coefficients between carcass characteristics and weights and measurements.

Trait	Chilled carcass wt.	Conformation score	Marbling score	Maturity score	Quality score	Ribeye area	Back-fat thickness	Dressing percent	Length of round	Circ. round (40%)	Circ. round (70%)	Circ. right forearm	Circ. left forearm	Circ. right shank	Circ. left shank	Weight of right side
Chilled carcass wt.		0.20	0.18	0.35	0.14	0.40	0.38	0.70	0.81	0.61	0.76	0.56	0.58	0.54	0.65	0.92
Conformation score			0.06	0.18	0.02	0.20	0.05	0.11	0.02	0.18	0.17	0.38	0.35	0.34	0.32	0.03
Marbling score				0.13	0.90	-.02	0.07	0.12	0.22	0.12	0.15	0.04	0.06	-.10	-.01	0.20
Maturity score					0.00	0.40	-.02	0.10	0.23	0.01	0.06	0.09	0.08	0.05	0.19	0.26
Quality score						-.08	0.08	0.15	0.17	0.02	0.05	-.04	-.04	-.10	-.04	-.16
Ribeye area							-.13	0.29	0.31	0.19	0.31	0.29	0.34	0.15	0.22	0.31
Back-fat thickness								0.24	0.19	0.16	0.27	0.11	0.12	0.07	0.17	0.35
Dressing percent									0.67	0.43	0.53	0.29	0.32	0.29	0.41	0.62

Table 5b. Simple correlation coefficients between carcass characteristics and primal wholesale cuts.

Trait	Wt. trimmed round	Wt. trimmed loin	Wt. trimmed chuck	Wt. trimmed rib	Trim. round as % side	Trim. loin as % side	Trim. chuck as % side	Trim. rib as % side	Weight fat 9-10-11 rib	Percent fat 9-10-11 rib	Weight lean 9-10-11 rib	Percent lean 9-10-11 rib	Weight bone 9-10-11 rib	Percent bone 9-10-11 rib	Wt. ribeye muscle 9-10-11 rib	% ribeye muscle 9-10-11 rib
Chilled carcass wt.	0.84	0.88	0.96	0.86	-.20	-.16	-.00	-.14	0.69	0.40	0.63	-.40	0.66	-.40	0.66	-.27
Conformation score	0.21	0.16	0.16	0.29	0.24	0.19	0.25	0.37	0.27	0.31	0.14	-.25	0.22	-.13	0.20	-.15
Marbling score	0.04	0.08	0.17	0.15	-.26	-.26	-.06	-.08	0.20	0.11	0.12	-.17	0.20	-.10	-.07	-.22
Maturity score	0.32	0.31	0.32	0.26	0.06	0.06	0.05	-.04	0.16	-.01	0.24	-.00	0.15	-.16	0.35	0.14
Quality score	-.02	0.05	0.13	0.15	-.28	-.22	-.05	-.02	0.16	0.02	0.14	-.14	0.25	-.06	0.09	-.22
Ribeye area	0.44	0.41	0.36	0.38	0.16	0.18	0.02	0.07	0.12	-.06	0.33	0.12	0.20	-.12	0.44	0.23
Back-fat thickness	0.20	0.32	0.30	0.30	-.25	0.05	-.12	-.09	0.38	0.20	0.35	-.23	0.24	-.36	0.14	-.44
Dressing percent	0.59	0.63	0.66	0.61	-.13	0.08	0.00	-.07	0.57	0.42	0.40	-.39	0.50	-.30	0.48	-.23

Table 5c. Simple correlation coefficients between carcass and cooking characteristics.

Trait	Cooking time 6-7-8 rib	Cooking loss volatile %	Cooking loss drip %	Total cook. losses	Flavor score fat	Flavor score lean	Juiciness score	Initial tenderness	Number of chews	Chews score	Shear value	Press fluid
Chilled carcass wt.	-.32	-.14	0.57	0.26	0.40	0.36	-.05	-.03	0.07	-.06	-.19	0.05
Conformation score	-.20	-.16	0.32	0.08	-.04	-.10	-.13	-.11	0.06	-.04	0.03	-.01
Marbling score	0.16	0.27	0.09	-.16	0.23	0.08	0.23	0.09	0.14	-.00	0.16	-.08
Maturity score	0.05	-.11	0.18	0.03	0.04	0.23	0.10	0.15	-.06	0.11	0.02	0.08
Quality score	0.17	-.23	0.08	-.15	0.26	0.11	0.34	0.13	0.09	0.01	0.19	0.03
Ribeye area	-.10	-.03	-.01	-.02	0.21	-.08	0.07	-.03	-.07	0.07	-.10	0.24
Back-fat thickness	-.00	0.10	0.28	0.28	0.01	0.08	0.20	0.11	0.14	0.01	0.21	-.07
Dressing percent	-.18	-.11	0.43	0.20	0.27	0.28	0.12	-.15	0.18	-.24	-.13	-.01

Table 6a. Simple correlation coefficients between carcass weights and measurements.

Trait	Length of round	Circ. round (40%)	Circ. round (70%)	Circ. right forearm	Circ. left forearm	Circ. right shank	Circ. left shank	Wt. right side	Wt. trimmed round	Wt. trimmed loin	Wt. trimmed chuck	Wt. trimmed rib	Trim. round as % side	Trim. loin as % side	Trim. chuck as % side	Trim. rib as % side
Length of round		0.43	0.71	0.37	0.43	0.26	0.42	0.76	0.65	0.71	0.80	0.66	0.23	-.19	0.01	-.19
Circ. round (40%)			0.72	0.48	0.53	0.46	0.48	0.53	0.67	0.52	0.56	0.57	0.16	-.09	-.00	0.01
Circ. round (70%)				0.54	0.55	0.34	0.39	0.67	0.67	0.70	0.74	0.67	-.05	-.05	-.08	-.03
Circ. right forearm					0.94	0.68	0.64	0.44	0.57	0.44	0.54	0.50	0.13	-.01	0.12	0.03
Circ. left forearm						0.68	0.64	0.46	0.59	0.39	0.58	0.50	0.14	-.12	0.18	0.10
Circ. right shank							0.84	0.44	0.57	0.44	0.54	0.50	0.12	-.04	0.16	0.03
Circ. left shank								0.55	0.65	0.48	0.60	0.57	0.08	-.06	0.04	-.02
Wt. right side									0.78	0.84	0.89	0.79	-.39	-.36	-.28	-.35

Table 6b. Simple correlation coefficients between carcass weights and measurements and physical separation 9-10-11 rib cut.

Trait	Weight fat 9-10-11 rib	% fat 9-10-11 rib	Weight lean 9-10-11 rib	% lean 9-10-11 rib	Weight bone 9-10-11 rib	% bone 9-10-11 rib	Wt. ribeye muscle 9-10-11 rib	% ribeye muscle 9-10-11 rib
Length of round	0.53	0.31	0.43	-.34	0.56	-.22	0.51	-.17
Circ. round (40%)	0.45	0.21	0.54	-.09	0.50	-.32	0.47	-.17
Circ. round (70%)	0.48	0.27	0.48	-.25	0.48	-.29	0.41	-.27
Circ. right forearm	0.31	0.22	0.28	-.20	0.39	-.10	0.31	-.15
Circ. left forearm	0.34	0.23	0.31	-.21	0.45	-.09	0.37	-.11
Circ. right shank	0.33	0.20	0.30	-.21	0.52	0.00	0.40	-.07
Circ. left shank	0.47	0.32	0.36	-.31	0.51	-.18	0.50	-.10
Wt. right side	0.61	0.30	0.57	-.30	0.62	-.32	0.59	-.25

Table 6c. Simple correlation coefficients between carcass weights and measurements and cooking characteristics.

Trait	Cooking time 6-7-8 rib	Cooking loss volatile %	Cooking loss drip %	Total cooking losses	Flavor score fat	Flavor score lean	Juiciness score	Initial tenderness	Number of chews	Chews score	Shear value	Press fluid
Length of round	-.14	-.12	0.35	0.13	0.37	0.44	-.04	-.17	0.15	-.17	-.26	0.10
Circ. round (40%)	-.22	0.04	0.30	0.23	0.22	0.13	-.02	-.15	0.13	-.06	-.16	-.03
Circ. round (70%)	-.27	-.08	0.30	0.13	0.23	0.16	-.13	-.21	0.12	-.11	-.26	0.10
Circ. right forearm	-.43	-.08	0.37	0.17	0.32	0.21	-.05	-.18	0.19	-.12	0.12	-.25
Circ. left forearm	-.36	-.03	0.38	0.22	0.32	0.22	-.06	-.19	0.19	-.10	0.08	-.27
Circ. right shank	-.36	-.07	0.46	0.24	0.26	0.06	-.10	-.07	-.05	-.00	0.03	-.18
Circ. left shank	-.30	-.11	0.49	0.23	0.30	0.16	-.10	-.23	0.13	-.22	0.06	-.11
Wt. right side	-.29	-.15	-.48	0.20	0.39	0.34	-.06	-.03	0.06	-.05	-.19	0.11

Table 7. Simple correlation coefficients between weights and measurements of the wholesale cuts and physical separation 9-10-11 rib cut.

Traits	Wt. trimmed round	Wt. trimmed loin	Wt. trimmed chuck	Wt. trimmed rib	Trimmed round as % side	Trimmed loin as % side	Trimmed chuck as % side	Trimmed rib as % side	Wt. fat 9-10-11 rib	Percent fat 9-10-11 rib	Wt. lean 9-10-11 rib	Percent lean 9-10-11 rib	Wt. bone 9-10-11 rib	Percent bone 9-10-11 rib	Wt. ribeye 9-10-11 rib	% ribeye 9-10-11 rib
Wt. trimmed round		0.72	0.81	0.75	0.26	-.18	0.03	-.09	0.47	0.13	0.64	-.08	0.58	-.28	0.71	0.01
Wt. trimmed loin			0.80	0.76	-.25	0.18	-.14	-.16	-.57	0.30	0.54	-.27	0.50	-.37	0.53	-.25
Wt. trimmed chuck				0.87	-.22	-.25	0.16	-.08	0.69	0.39	0.61	-.39	0.71	-.34	0.67	-.25
Wt. trimmed rib					0.12	-.10	0.16	0.30	0.75	0.40	0.69	-.39	0.73	-.42	0.72	-.27
Trimmed round as % side						0.26	0.34	0.39	-.28	-.32	0.05	0.37	-.12	0.10	0.11	0.40
Trimmed loin as % side							0.20	0.36	-.17	-.12	-.08	0.14	-.19	0.01	-.14	0.05
Trimmed chuck as % side								0.64	0.10	0.13	0.04	-.17	0.20	0.05	0.12	-.01
Trimmed rib as % side									0.17	0.10	0.15	-.10	0.15	-.11	0.20	-.03

Table 8a. Simple correlation coefficients between physical separation characteristics of 9-10-11th rib cut.

Trait	Weight fat 9-10-11 rib	Percent fat 9-10-11 rib	Weight lean 9-10-11 rib	Percent lean 9-10-11 rib	Weight bone 9-10-11 rib	Percent bone 9-10-11 rib	Wt. ribeye 9-10-11 rib	Percent ribeye 9-10-11 rib
Weight fat 9-10-11 rib		0.81	0.54	-.73	0.50	-.73	0.54	-.61
Percent fat 9-10-11 rib			-.00	-.90	0.11	-.58	0.11	-.58
Weight lean 9-10-11 rib				0.13	0.64	-.50	0.81	-.16
Percent lean 9-10-11 rib					-.24	0.35	-.01	0.65
Weight bone 9-10-11 rib						0.07	0.67	-.19
Percent bone 9-10-11 rib							-.35	0.48
Weight ribeye 9-10-11 rib								0.21
Percent ribeye 9-10-11 rib								

Table 8b. Simple correlation coefficients between physical separation 9-10-11 rib and cooking characteristics.

Trait	Cooking time 6-7-8 rib	Cooking loss volatile %	Cooking loss drip %	Total cooking losses	Flavor score fat	Flavor score lean	Juiciness score	Initial tenderness	Number of chews	Chews score	Shear value	Press fluid
Weight fat 9-10-11 rib	-.29	0.34	0.57	0.09	0.19	0.29	-.14	-.13	-.18	-.21	-.05	-.01
Percent fat 9-10-11 rib	-.32	-.37	0.51	0.07	0.12	0.21	-.21	-.18	0.16	-.28	-.11	-.17
Weight lean 9-10-11 rib	-.06	0.03	0.17	0.13	0.20	0.21	-.07	-.01	0.12	-.01	0.07	0.24
Percent lean 9-10-11 rib	0.32	0.40	-.56	-.04	-.02	-.19	0.19	0.13	-.08	0.21	0.10	0.16
Weight bone 9-10-11 rib	-.23	-.04	0.31	0.16	0.16	0.30	0.04	0.02	-.08	0.08	-.08	-.07
Percent bone 9-10-11 rib	0.08	0.23	-.32	-.03	-.13	-.12	0.06	0.15	-.33	0.29	-.12	-.25
Wt. ribeye 9-10-11 rib	-.17	0.02	0.34	0.20	0.25	0.37	0.12	0.01	-.08	0.03	-.12	0.10
% ribeye 9-10-11 rib	0.12	0.26	-.26	0.05	0.03	0.04	0.22	0.16	-.36	0.25	-.19	-.02

Table 9. Simple correlation coefficients between cooking characteristics.

Trait	Cooking time 6-7-8 rib	Cooking loss volatile %	Cooking loss drip %	Total cooking loss	Flavor score fat	Flavor score lean	Juiciness score	Initial tenderness	Number of chews	Chews score	Shear value	Press fluid
Cooking time 6-7-8-rib		0.52	-.26	0.48	-.11	-.05	-.10	-.20	0.35	-.27	0.26	-.01
Cooking loss, volatile %			-.15	0.75	-.03	-.01	-.37	-.19	-.16	-.10	-.05	-.31
Cooking loss, dripping %				0.54	0.38	0.43	-.06	0.10	-.02	0.02	-.18	-.11
Total cooking losses					0.23	0.28	-.35	-.10	0.13	-.08	-.07	-.34
Flavor score, fat						0.57	0.16	0.14	0.01	0.14	-.13	-.06
Flavor score, lean							0.23	0.18	0.01	0.12	-.24	-.11
Juiciness score								0.38	-.23	0.30	0.13	0.19
Initial tenderness									-.75	0.90	-.37	0.15
Number of chews										-.85	0.55	-.17
Chews score											-.46	0.13
Shear value												-.22
Press fluid												

Table 10a. Analysis of variance of weaning and slaughter characteristics.

Trait	MS_{Sires}	MS_{Error}	F-ratio
D. F.	5	44	
Age at weaning	6997.7400	293.4750	23.8444**
Weaning weight	19481.6000	4417.9545	4.4096**
210 day adj. weaning weight	878.6000	2571.4545	0.3417
ADG/day age	0.0646	0.0528	1.2224
Feeder Grade	4.0351	1.7396	2.3194
Wean. muscle score	5.9951	4.3101	1.3909
Wean. bone score	2.2529	0.7990	2.8197*
Wean. cond. score	0.9462	0.6020	1.5717
Slaughter Grade	1.1538	0.7162	1.6110
Slaughter muscle score	8.1979	3.1507	2.6019*
Slaughter bone score	0.4840	0.5091	0.9507
Slaughter cond. score	1.1115	0.5960	2.2412
Slaughter conf. score	32.5260	10.9857	3.3249*
Slaughter wt.	29301.6000	7096.8863	4.1288**
Hide weight	429.5160	74.9773	5.7286**
Day of age at slaughter	5942.0000	183.2727	32.4216**

*$P < .05$
**$P < .01$

Table 10b. Analysis of variance of carcass characteristics and measurements.

Trait	MS_{Sires}	MS_{Error}	F-ratio
D. F.	5	44	
Chilled carcass wt.	15394.2000	3817.0227	4.0330**
Conformation score	.1788	.2997	.5964
Marbling score	14.0378	4.9162	2.8554*
Maturity score	.0218	.2616	.0832
Quality score	3.1049	1.0513	2.9535*
Ribeye area	.5881	.6513	.9031
Backfat thickness	.0702	.0523	1.3432
Dressing %	10.2600	2.7930	3.6735**
Length of round	1.3748	.6696	2.0531
Circ. Round (40%)	3.2502	1.5994	2.0321
Circ. Round (70%)	7.0088	2.6801	2.6151*
Circ. right forearm	1.9828	.8193	2.3458
Circ. left forearm	1.5766	.7355	2.1436
Circ. right shank	.2968	.1350	2.1980
Circ. left shank	.3421	.1438	2.3789

*$P < .05$ level
**$P < .01$ level

Table 10c. Analysis of variance of carcass characteristics and physical separation of 9-10-11 rib cut.

Trait	MS_{Sires}	MS_{Error}	F-ratio
D.F.	5	44	
Wt. right side	5226.2600	822.5750	6.3535**
Wt. trim. round	137.6320	52.0814	2.6426*
Wt. trim. loin	99.1580	21.6364	4.5996**
Wt. trim. chuck	263.6280	61.3489	4.2972**
Wt. trim. rib	12.7698	4.3366	2.9447*
Trim. round as % side	.0005	.0002	1.9268
Trim. loin as % side	.0002	.0001	1.7392
Trim. chuck as % side	.0001	.0002	.7819
Trim. rib as % side	.00003	.00001	1.5604
Wt. fat 9-10-11 rib	514118.0000	197531.1300	2.6027*
Percent fat 9-10-11 rib	.0038	.0018	2.0470
Wt. lean 9-10-11 rib	130886.0000	89204.7720	1.4673
Percent lean 9-10-11 rib	.0027	.0012	2.2381
Wt. bone 9-10-11 rib	12571.4000	6565.7272	1.1947
Percent bone 9-10-11 rib	.0002	.0002	1.0598
Wt. ribeye muscle 9-10-11 rib	9579.4000	12941.5680	.7402
% ribeye muscle 9-10-11 rib	.0007	.0002	2.7646*

*$P < .05$ level **$P < .01$ level

Table 10d. Analysis of variance of cooking characteristics.

Trait	MS_{Sires}	MS_{Error}	F-ratio
D.F.	5	44	
Cooking time 6-7-8 rib	14.0810	16.7723	.8395
Cooking loss volatile %	3.4126	2.1233	1.6072
Cooking loss drip %	3.3854	1.1319	2.9908*
Total cooking losses	6.4560	2.8150	2.2934
Flavor score fat	.0553	.2729	.2028
Flavor score lean	.0870	.1105	.7870
Juiciness score	.2302	.2383	.9660
Initial tenderness	.4137	.2159	1.9165
No. of chews score	22.5608	8.7676	2.5732
Chews score	.2921	.1577	1.8522
Shear value	21.6100	8.8354	2.4459
Press fluid	.4755	.5943	.8001

*P ∠ .05 level
**P ∠ .01 level

Table 11. Duncan's New Multiple Range Test (NMRT) for significant (P ∠.05) sire difference.

Characteristic	Ordered array of sires by means of their progeny					
Age at weaning	4[a]	3[b]	5[bc]	2[bcd]	6[e]	1[e]
Weaning weight	3[a]	2[ab]	4[abc]	5[abcd]	6[cde]	1[e]
210-day adjusted weaning weight	6[a]	3[a]	2[a]	4[a]	1[a]	5[a]
Average daily gain per day of age	3[a]	2[a]	6[a]	1[a]	5[a]	4[a]
Feeder grade	2[a]	6[ab]	3[abc]	5[abc]	4[abc]	1[c]
Weaning muscle score	2[a]	3[a]	5[a]	1[a]	6[a]	4[a]
Weaning bone score	2[a]	5[ab]	3[ab]	6[ab]	4[b]	1[b]
Weaning condition score	2[a]	3[ab]	5[ab]	6[ab]	1[ab]	4[b]
Slaughter grade	5[a]	2[ab]	3[ab]	1[ab]	6[ab]	4[b]
Slaughter muscle score	5[a]	3[ab]	2[abc]	1[abc]	6[abc]	4[c]
Slaughter bone score	1[a]	3[a]	5[a]	2[a]	6[a]	4[a]
Slaughter condition score	5[a]	1[ab]	2[abc]	3[abcd]	6[abcd]	4[d]
Conformation score	3[a]	5[ab]	2[b]	4[b]	1[b]	6[b]
Slaughter weight	3[a]	5[ab]	2[b]	4[b]	1[b]	6[b]
Hide weight	5[a]	3[ab]	2[c]	4[c]	6[c]	1[c]
Day of age at slaughter	4[a]	3[ab]	5[abc]	2[abcd]	6[e]	1[e]
Chilled carcass weight	3[a]	5[ab]	2[abc]	4[bcd]	1[bcd]	6[d]

Table 11 (continued)

Characteristic	Ordered array of sires by means of their progeny					
Carcass conformation score	5^{a}	4^{a}	6^{a}	2^{a}	3^{a}	1^{a}
Carcass marbling score	2^{a}	4^{ab}	6^{abc}	3^{abc}	5^{abc}	1^{c}
Carcass maturity score	6^{a}	2^{a}	5^{a}	4^{a}	3^{a}	1^{a}
Carcass quality score	4^{a}	2^{ab}	6^{abc}	3^{bc}	5^{bc}	1^{c}
Ribeye area	5^{a}	4^{a}	6^{a}	3^{a}	1^{a}	2^{a}
Fat thickness 12th rib	3^{a}	4^{a}	5^{a}	1^{a}	2^{a}	6^{a}
Dressing percent	3^{a}	2^{ab}	4^{abc}	5^{abcd}	1^{abcde}	6
Length of round	3^{a}	2^{ab}	4^{ab}	5^{ab}	1^{b}	6^{b}
Circumference of round (40%)	3^{a}	5^{ab}	2^{ab}	4^{ab}	1^{b}	6^{b}
Circumference of round (70%)	3^{a}	5^{ab}	2^{ab}	4^{ab}	1^{b}	6^{b}
Circumference of right forearm	5^{a}	3^{ab}	4^{ab}	6^{ab}	2^{b}	1^{b}
Circumference of left forearm	5^{a}	3^{ab}	4^{ab}	2^{b}	6^{ab}	1^{b}
Circumference of right shank	5^{a}	3^{ab}	2^{abc}	4^{abc}	1^{c}	6^{abc}
Circumference of left shank	5^{a}	3^{ab}	2^{ab}	4^{ab}	1^{b}	6^{b}
Weight of the right side	3^{a}	2^{b}	5^{bc}	4^{bcd}	1^{bcd}	6^{d}
Weight of the trimmed round	3^{a}	5^{ab}	2^{abc}	4^{abc}	1^{c}	6^{c}

Table 11 (continued)

Characteristic	Ordered array of sires by means of their progeny					
Weight of the trimmed loin	3[a]	5[ab]	4 [b]	2 [b]	1 [b]	6 [b]
Weight of the trimmed chuck	3[a]	2 [b]	5 [b]	4 [b]	1 [b]	6 [b]
Weight of the trimmed rib	3[a]	4[ab]	5 [b]	2 [b]	1 [b]	6 [b]
Trimmed round as percent of side	4[a]	5[ab]	2 [b]	3 [b]	1 [b]	6 [b]
Trimmed loin as percent of side	6[a]	1[ab]	3[ab]	2[ab]	5[ab]	4 [b]
Trimmed chuck as percent of side	4[a]	5[ab]	1 [b]	2 [b]	6 [b]	3 [b]
Trimmed rib as percent of side	6[a]	3[a]	1[a]	2[a]	5[a]	4[a]
Weight of fat 9-10-11th rib	3[a]	2[ab]	4[abc]	1[abc]	5[abc]	6 [c]
Percent fat of 9-10-11th rib	3[a]	2[ab]	1[abc]	4[abc]	5 [c]	6 [c]
Weight of lean 9-10-11th rib	3[a]	5[a]	4[a]	2[a]	1[a]	6[a]
Percent lean of 9-10-11th rib	6[a]	5[ab]	4[abc]	1[abc]	3 [bc]	2 [c]
Weight of bone 9-10-11th rib	3[a]	4[ab]	5[ab]	2[ab]	1 [b]	6[ab]
Percent of bone 9-10-11th rib	6[a]	4[ab]	5[abc]	1[abc]	2 [bc]	3 [bc]
Weight of eye muscle 9-10-11th rib	5[a]	3[a]	2[a]	4[a]	1[a]	6[a]

Table 11 (continued)

Characteristic	Ordered array of sires by means of their progeny					
Percent of eye muscle 9-10-11th rib	6[a]	1[ab]	5[abc]	2[abc]	4[ab]	3 [b]
Cooking time 6-7-8th rib	2[a]	5[a]	4[a]	6[a]	1[a]	3[a]
Cooking loss (volatile %)	5[a]	6[ab]	2[ab]	3[ab]	4[ab]	1 [b]
Cooking loss (drip %)	2[a]	3[ab]	1[abc]	5[abc]	4[abc]	6 [c]
Total cooking loss	5[a]	2[ab]	3[ab]	1[ab]	4 [b]	6 [b]
Initial tenderness	6[a]	1[ab]	3[ab]	2[ab]	5[ab]	4 [b]
Number of chews	5[a]	6[a]	4[a]	1[a]	2[a]	3[a]
Chews score	4[a]	1[a]	6[a]	5[a]	3[a]	2[a]
Shear value	6[a]	2[a]	1[a]	4[a]	3[a]	5[a]
Press fluid	4[a]	1[a]	6[a]	5[a]	2[a]	3[a]

a, b, c, d, e : sires with the same superscript are not significantly different (P .05).

Sire designation:

1	M. Crusty Domino
2	Royal Husker 3rd
3	R. Silver Return 632nd
4	Mill Iron 836E
5	Onward Rupert
6	Royal Husker K38

Table 12. Heritability estimates.

	Trait	Estimate
1.	Day of age at weaning	.4885
2.	Weaning weight	.3048
3.	Adjusted weaning weight	-.2372
4.	ADG	.0621
5.	Feeder grade	.1922
6.	Weaning muscling score	.0791
7.	Weaning bone score	.2304
8.	Weaning condition score	.1075
9.	Slaughter grade	.1195
10.	Slaughter muscling score	.2151
11.	Slaughter bone score	-.0122
12.	Slaughter condition score	.1852
13.	Slaughter conformation score	.2603
14.	Slaughter weight	.0295
15.	Hide weight	.3398
16.	Age at slaughter	.4546
17.	Chilled carcass weight	.2915
18.	Carcass conformation score	-.1222
19.	Carcass marbling score	.2327
20.	Carcass maturity score	-.4093
21.	Carcass quality score	.1926
22.	Rib eye area	-.0025
23.	Back-fat thickness	.0708
24.	Dressing percent	.0277
25.	Length of round	.1668
26.	Circumference of round (40%)	.1647
27.	Circumference of round (70%)	.2200
28.	Circumference of right forearm	.1990
29.	Circumference of left forearm	.1759
30.	Circumference of right shank	.1812
31.	Circumference of left shank	.1974
32.	Weight of right side	.3520
33.	Weight of trimmed round	.2186
34.	Weight of trimmed loin	.3109
35.	Weight of trimmed chuck	.3099
36.	Weight of trimmed rib	.4557
37.	Trimmed round as percent of side	.1446
38.	Trimmed loin as percent of side	.1209
39.	Trimmed chuck as percent of side	.0069
40.	Trimmed rib as percent of side	.2418
41.	Weight of fat 9-10-11th rib	.2151
42.	Percent of fat 9-10-11th rib	.1664
43.	Weight lean 9-10-11th rib	.0916
44.	Percent lean 9-10-11th rib	.1849

Table 12 (continued)

	Trait	Estimate
45.	Weight of bone 9-10-11th rib	.1499
46.	Percent bone 9-10-11th rib	.0112
47.	Weight of longissimus dorsi 9-10-11th rib	-.0145
48.	Percent of longissimus dorsi 9-10-11th rib	.2313
49.	Cooking time 6-7-8th rib	-.0422
50.	Cooking loss (volatile %)	.1126
51.	Cooking loss (drip %)	.1342
52.	Total cooking loss	.1900
53.	Flavor score (fat)	-.3205
54.	Flavor score (lean)	-.0567
55.	Juiciness score	-.0084
56.	Initial tenderness score	.1520
57.	Tenderness score	.2129
58.	Chews score	.1445
59.	Warner-Bratzler shear score	.2029
60.	Press fluid	-.0537

Table 13. Herd classification report.

AMERICAN ANGUS ASSOCIATION

SPEEDIFLEX® MOORE BUSINESS FORMS, INC. 25 PATENTED

HC-1B

HERD CLASSIFICATION REPORT

TYPE SCORE

OWNER REPORT NO. CONDITION (1-5)

TATTOO: LEFT EAR RIGHT EAR

CHAIN NO. REGISTRATION NO. SEX BIRTH DATE (MO. DAY YR.) AGE (YRS. MOS.)

SIRE DAM DATE OF LAST CALF (MO. DAY YR.) CLASSIFIER DATE

One Tick (√) Slight Degree — Two Ticks (√ √) Pronounced Degree

GENERAL APPEARANCE					BEEF CHARACTER					
CONFORMATION 20	SIZE 10	HEAD & BREED CHARACTER 8	FEET & LEGS 12	TOTAL 50	SHOULDER & FORE RIB 8	RIB & BACK 10	LOIN 10	RUMP 10	REAR QUARTERS (ROUND) 12	TOTAL 50
LACK BALANCE	SMALL	LACKS SEX CHARACTER	SUBSTANCE:		SHOULDER:	RIB:	LOW	NARROW	NARROW	
SHALLOW		NARROW	FINE		NARROW	NARROW	NARROW	SLOPES	SHALLOW	
UPSTANDING		LONG	COARSE		COARSE	SHALLOW	ROUGH	SHORT	LACKS FULLNESS	
COMPACT		COARSE	HOCKS:		OPEN	BACK:		ROUGH HOOKS	LIGHT LOWER QUARTER	
HORSEY		NECK:	SICKLE		TOO STRAIGHT	WEAK		ROUGH TAILHEAD		
QUALITY:	UDDER:	LOW	STRAIGHT		FORE RIB:	ARCHED	REMARKS			
ROUGH	UNSOUND	COARSE	BOWED		SHALLOW	NARROW				
PATCHY	LARGE TEATS	EXCESS DEWLAP	CLOSE		FLAT	UNEVEN				
	LACK CAPACITY	THROATY	UNSOUND FEET							

Table 14. Scorecard for feeder and slaughter characteristics.

Tattoo__________________ Weight__________________ Price__________________

Yield grade__________________ Slaughter grade__________________ Feeder grade__________________

Rounds score__________________ Forearm score__________________ Over top score__________________

Bone score__________________ Condition score__________________ Coat color score__________________

CLASSIFICATION SCORE

Type	Size	Quality	Shoulder & Chest	Rib & Back	Loin	Rump	Thighs & Rounds	Feet & Legs	Head & Neck	Total score

Table 15. Numerical values for feeder grade, slaughter grade and carcass grade scoring system.

	Minus	Average	Plus
Prime	15	16	17
Choice	12	13	14
Good	9	10	11
Standard	6	7	8
Commercial	3	4	5
Utility, Cutter and Canner	0	1	2

Table 16. Numerical values for marbling scoring system.

	Minus	Average	Plus
Extremely Abundant	34	35	36
Very Abundant	31	32	33
Abundant	28	29	30
Moderately Abundant	25	26	27
Slightly Abundant	22	23	24
Moderate	19	20	21
Modest	16	17	18
Small	13	14	15
Slight	10	11	12
Traces	7	8	9
Practically Devoid	4	5	6
Devoid	1	2	3

Table 17. Numerical values for carcass maturity score system.

	Minus	Average	Plus
A-maturity	1	2	3
B-maturity	4	5	6
C-maturity	7	8	9

Table 18. Numerical values for feeder and slaughter muscling scores.

	Minus	Average	Plus
Very Heavy Muscle	16	17	18
Heavy Muscle	13	14	15
Moderately Heavy Muscle	10	11	12
Medium Muscle	7	8	9
Slightly Light Muscle	4	5	6
Light Muscle	1	2	3

Table 19. Numerical values for feeder and slaughter visual bone score.

Very Rugged	6
Rugged	5
Moderately Rugged	4
Medium	3
Slightly Light	2
Light	1

Table 20. Numerical values for scoring flavor, juiciness, and tenderness of beef lean.

Flavor	Juiciness	Tenderness	Score
Very Desirable	Very Juicy	Very Tender	7
Desirable	Juicy	Tender	6
Moderately Desirable	Moderately Juicy	Moderately Tender	5
Slightly Desirable	Slightly Dry	Slightly Tough	4
Neutral	Dry	Tough	3
Slightly Undesirable	Very Dry	Very Tough	2
Undesirable	Extremely Dry	Extremely Tough	1

Table 21. Score card for beef.

Judge____________________Code____________________Date____________________

Sample No.	Desirability of Flavor		Juiciness	Tenderness			Comments
					Chews		
	Fat	Lean		Initial	No. Chews	Score	
1							
2							
3							
4							

Descriptive terms for scoring:

Desirability of Flavor

7. Very desirable
6. Desirable
5. Moderately desirable
4. Acceptable
3. Slightly undesirable
2. Undesirable
1. Very Undesirable

Juiciness

7. Very juicy
6. Juicy
5. Moderately juicy
4. Acceptable
3. Slightly dry
2. Dry
1. Very dry

Tenderness

7. Very tender
6. Tender
5. Moderately tender
4. Acceptable
3. Slightly tough
2. Tough
1. Very tough

Table 22. Mean cooking time, cooking losses and flavor scores for roasts.

Code and number of animals used		Cooking time min/lb	Cooking losses			Flavor scores[1]	
			Volatile (%)	Dripping (%)	Total (T)	Fat	Lean
OR	9	39.3	18.0	6.1	24.1	5.1	5.4
SR	10	37.1	16.6	6.8	23.4	5.0	5.5
MCD	9	37.4	16.3	6.2	22.5	5.0	5.5
RH	9	40.4	16.7	6.8	23.5	5.0	5.6
MI	8	39.2	16.4	5.7	22.2	5.1	5.3
RHK	5	38.6	16.8	4.9	21.7	4.8	5.3

[1]Maximum possible score, 7.

Table 23. Mean tenderness and juiciness scores and shear values and press fluid yields for roasts.

Code and number of animals used		Tenderness scores[1] Initial score	No. of chews	Chews score	Shear value lbs[2]	Juiciness score[1]	Press fluid ml/25 g
OR	9	5.4	25	5.4	16.7	5.5	6.6
SR	10	5.6	25	5.6	14.8	5.2	7.0
MCD	9	5.7	23	5.6	15.7	5.4	6.8
RH	9	5.5	25	5.5	15.2	5.5	6.7
MI	8	5.2	27	5.2	19.2	5.5	6.4
RHK	5	5.9	22	5.9	15.2	5.4	7.1

[1]Maximum possible score, 7.

[2]Core used = 1".

Table 24. Age calendar chart.

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	126	153	183	214	245	275	306	336
3	3	34	62	93	127	154	184	215	246	276	307	337
3	4	35	63	94	128	155	185	216	247	277	308	338
5	5	36	64	95	129	156	186	217	248	278	309	339
6	6	37	65	96	130	157	187	218	249	279	310	340
7	7	38	66	97	131	158	188	219	250	280	311	341
8	8	39	67	98	132	159	189	220	251	281	312	342
9	9	40	68	99	133	160	190	221	252	282	313	343
10	10	41	69	100	134	161	191	222	253	283	314	344
11	11	42	70	101	135	162	192	223	254	284	315	345
12	12	43	71	102	136	163	193	224	255	285	316	346
13	13	44	72	103	137	164	194	225	256	286	317	347
14	14	45	73	104	138	165	195	226	257	287	318	348
15	15	46	74	105	139	166	196	227	258	288	319	349
16	16	47	75	106	140	167	197	228	259	289	320	350
17	17	48	76	107	141	168	198	229	260	290	321	351
18	18	49	77	108	142	169	199	230	261	291	322	352
19	19	50	78	109	143	170	200	231	262	292	323	353
20	20	51	79	110	144	171	201	232	263	293	324	354
21	21	52	80	111	145	172	202	233	264	294	325	355
22	22	53	81	112	146	173	203	234	265	295	326	356
23	23	54	82	113	147	174	204	235	266	296	327	357
24	24	55	83	114	148	175	205	236	267	297	328	358
25	25	56	84	115	149	176	206	237	268	298	329	359
26	26	57	85	116	150	177	207	238	269	299	330	360
27	27	58	86	117	151	178	208	239	270	300	331	361
28	28	59	87	118		179	209	240	271	301	332	362
29	29		88	119		180	210	241	272	302	333	363
30	30		89	120		181	211	242	273	303	334	364
31	31		90				212	243		304		365

Table 25. Correction values for adjusting weaning weight to 210 days.

Age of Calf	Steer Calves					Heifer Calves				
	Age of Dam					Age of Dam				
	3	4	5	6	7	3	4	5	6	7
150	131	113	105	82	82	155	137	129	106	106
151	129	111	103	80	80	153	135	127	104	104
152	128	110	102	79	79	152	134	126	103	103
153	127	109	101	78	78	151	133	125	102	102
154	125	107	99	76	76	149	131	123	100	100
155	124	106	98	75	75	148	130	122	99	99
156	122	104	96	73	73	146	128	120	97	97
157	121	103	95	72	72	145	127	119	96	96
158	120	102	94	71	71	144	126	118	95	95
159	118	100	92	69	69	142	124	116	93	93
160	117	99	91	68	68	141	123	115	92	92
161	116	98	90	67	67	140	122	114	91	91
162	114	96	88	65	65	138	120	112	89	89
163	113	95	87	64	64	137	119	111	88	88
164	112	94	86	63	63	136	118	110	87	87
165	110	92	84	61	61	134	116	108	85	85
166	109	91	83	60	60	133	115	107	84	84
167	107	89	81	58	58	131	113	105	82	82
168	106	88	80	57	57	130	112	104	81	81
169	105	87	79	56	56	129	111	103	80	80
170	103	85	77	54	54	127	109	101	78	78
171	102	84	76	53	53	126	108	100	77	77
172	101	83	75	52	52	125	107	99	76	76
173	99	81	73	50	50	123	105	97	74	74
174	98	80	72	49	49	122	104	96	73	73
175	97	79	71	48	48	121	103	95	72	72
176	95	77	69	46	46	119	101	93	70	70
177	94	76	68	45	45	118	100	92	69	69
178	93	75	67	44	44	117	99	91	68	68
179	91	73	65	42	42	115	97	89	66	66
180	90	72	64	41	41	114	96	88	65	65
181	88	70	62	39	39	112	94	86	63	63
182	87	69	61	38	38	111	93	85	62	62
183	86	68	60	37	37	110	92	84	61	61
184	84	66	58	35	35	108	90	82	59	59
185	83	65	57	34	34	107	89	81	58	58
186	82	64	56	33	33	106	88	80	57	57
187	80	62	54	31	31	104	86	78	55	55
188	79	61	53	30	30	103	85	77	54	54
189	78	60	52	29	29	102	84	70	53	53

Table 25 (continued)

Age of Calf	Steer Calves, Age of Dam: 3	4	5	6	7	Heifer Calves, Age of Dam: 3	4	5	6	7
190	76	58	50	27	27	100	82	74	51	51
191	75	57	49	26	26	99	81	73	50	50
192	73	55	47	24	24	97	79	71	48	48
193	72	54	46	23	23	96	78	70	47	47
194	71	53	45	22	22	95	77	69	46	46
195	69	51	43	20	20	93	75	67	44	44
196	68	50	42	19	19	92	74	66	43	43
197	67	49	41	18	18	91	73	65	42	42
198	65	47	39	16	16	89	71	63	40	40
199	64	46	38	15	15	88	70	62	39	39
200	63	45	37	14	14	87	69	61	38	38
201	61	43	35	12	12	85	67	59	36	36
202	60	42	34	11	11	84	66	58	35	35
203	59	41	33	10	10	83	65	57	34	34
204	57	39	31	8	8	81	63	55	32	32
205	56	38	30	7	7	80	62	54	31	31
206	54	36	28	5	5	78	60	52	29	29
207	53	35	27	4	4	77	59	51	28	28
208	52	34	26	3	3	76	58	50	27	27
209	50	32	24	1	1	74	56	48	25	25
210	49	31	23	0	0	73	55	47	24	24
211	48	30	22	-1	-1	72	54	46	23	23
212	46	28	20	-3	-3	70	52	44	21	21
213	45	27	19	-4	-4	69	51	43	20	20
214	44	26	18	-5	-5	68	50	42	19	19
215	42	24	16	-7	-7	66	48	40	17	17
216	41	23	15	-8	-8	65	47	39	16	16
217	39	21	13	-10	-10	63	45	37	14	14
218	38	20	12	-11	-11	62	44	36	13	13
219	37	19	11	-12	-12	61	43	35	12	12
220	35	17	9	-14	-14	59	41	33	10	10
221	34	16	8	-15	-15	58	40	32	9	9
222	33	15	7	-16	-16	57	39	31	8	8
223	31	13	5	-18	-18	55	37	29	6	6
224	30	12	4	-19	-19	54	36	28	5	5
225	29	11	3	-20	-20	53	35	27	4	4
226	27	9	1	-22	-22	51	33	25	2	2
227	26	8	0	-23	-23	50	32	24	1	1
228	25	7	-1	-24	-24	49	31	23	0	0
229	23	5	-3	-26	-26	47	29	21	-2	-2

Table 25 (continued)

Age of Calf	Steer Calves					Heifer Calves				
	Age of Dam					Age of Dam				
	3	4	5	6	7	3	4	5	6	7
230	22	4	-4	-27	-27	46	28	20	-3	-3
231	20	2	-6	-29	-29	44	26	18	-5	-5
232	19	1	-7	-30	-30	43	25	17	-6	-6
233	18	0	-8	-31	-31	42	24	16	-7	-7
234	16	-2	-10	-33	-33	40	22	14	-9	-9
235	15	-3	-11	-34	-34	39	21	13	-10	-10
236	14	-4	-12	-35	-35	38	20	12	-11	-11
237	12	-6	-14	-37	-37	36	18	10	-13	-13
238	11	-7	-15	-38	-38	35	17	9	-14	-14
239	10	-8	-16	-39	-39	34	16	8	-15	-15
240	8	-10	-18	-41	-41	32	14	6	-17	-17
241	7	-11	-19	-42	-42	31	13	5	-18	-18
242	5	-13	-21	-44	-44	29	11	3	-20	-20
243	4	-14	-22	-45	-45	28	10	2	-21	-21
244	3	-15	-23	-46	-46	27	9	1	-22	-22
245	1	-17	-25	-48	-48	25	7	-1	-24	-24
246	0	-18	-26	-49	-49	24	6	-2	-25	-25
247	-1	-19	-27	-50	-50	23	5	-3	-26	-26
248	-3	-21	-29	-52	-52	21	3	-5	-28	-28
249	-4	-22	-30	-53	-53	20	2	-6	-29	-29
250	-5	-23	-31	-54	-54	19	1	-7	-30	-30

THE INFLUENCE OF SIRE UPON PERFORMANCE AND CARCASS CHARACTERISTICS IN HEREFORD PROGENY

by

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B. S., Oklahoma State University, 1951

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Fifty randomly selected steers born and fed at the Clifford Houghton Ranch of Tipton, Kansas were used in this study. The steers were the progeny of six selected sires. Four of the sires were used by means of artificial insemination for approximately three estrous cycles. The remaining two sires were used in natural service as "clean-up" bulls. The resulting progeny were born in the fall of 1964. All calves had access to a creep feeder until weaned, and were then placed on a self-feeder until slaughtered on February 1, 1966.

The study included several phases, beginning with the weaning traits and continuing through slaughter, carcass study, detailed physical separation of the 9-10-11th rib cut, and organoleptic studies of the 6-7-8th rib cut. Live animals were subjectively scored for weaning and slaughter muscling, bone, and condition; an over-all condition score was placed on the animals at time of slaughter. Weaning weight, slaughter weight, hide weight, chilled carcass weight, weight of the right side, and weight of the trimmed wholesale cuts were recorded. Shrink dressing percent, carcass conformation, maturity, marbling, and final quality grade were also recorded. Other objective measurements included the length and circumference of the round, fore-arm, and cannon bone circumference of the fore limb.

Heritability estimates were calculated for each of the sixty characteristics studied. Estimates of sufficient magnitude to perhaps exert some selection pressure at time of sire selection included: weaning weight, 0.31; feeder grade, 0.19; weaning bone score, 0.23; slaughter muscling score, 0.22; slaughter conformation score, 0.22; hide weight, 0.34; age at weaning, 0.46; carcass quality score, 0.19; and weight of the trimmed wholesale round, loin, chuck, and rib, 0.22, 0.31, 0.31, and 0.45 respectively.

Significant differences were found between the sires at the ($P < .01$) level and included: weaning and slaughter weight and age, weight of the right side of the carcass, dressing percent, and the weight of the trimmed wholesale loin and chuck. Additional differences occurring at the ($P < .05$) level included: weaning bone score, slaughter conformation score, seventy percent round circumference, marbling score, weight of the fat and weight of the *longissimus dorsi* muscle in the 9-10-11th rib cut, and the percentage of weight lost during cooking due to dripping.

Weaning weight was found to be a reliable indicator of future weights and therefore useful in predicting performance, but was not correlated to future conformation type scores. The 210-adjusted weaning weight was less closely related to future weight and performance than was the actual weaning weight.

Feeder grade was not a reliable indicator of actual slaughter grade or final carcass grade. Feeder grade was felt to be independent of condition, while slaughter grade and final carcass grade were very dependent on condition, with a great deal of emphasis placed on the intermuscular deposition of fat.

A correlation of 0.00 was found between slaughter grade and marbling score, while the correlation between slaughter grade and final carcass grade was -.03. The correlation between marbling score and final carcass grade was 0.90. With the exception of the final carcass grade, marbling had a non-significant influence on other characteristics which influence the value of the beef carcass. Non-significant correlations were found between marbling score and tenderness, juiciness, and flavor. A significant difference ($P < .05$) was noted between sire groups for marbling.