A SIRE EVALUATION STUDY IN BEEF CATTLE WITH EMPHASIS ON RELATIONSHIPS BETWEEN PROGENY PERFORMANCE, CONFORMATION AND CARCASS CHARACTERISTICS

by

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INTRODUCTION

With the constant striving for improvement of beef cattle and beef production methods, much emphasis has been placed on production testing, performance records and progeny evaluation by many segments of the beef cattle industry.

Performance testing is not a new concept in animal breeding. The earliest forms of performance testing began when breeders started mating animals with the idea of producing improved progeny. As the science of animal breeding became more exact, performance testing became more involved and began to take on a definite meaning.

In an effort to obtain greater financial returns from their operations, producers have searched for methods of identifying superior performing seed stock. Also in recent years, there has been a very definite demand by the consumer for meat products that have a higher ratio of lean to fat. As a result, livestock producers are placing more emphasis on selecting breeding animals whose progeny not only excel in performance, but also yield carcasses with more muscling and less fat.

The producers of purebred breeding stock who supply the commercial breeder with seed stock, particularly sires, hold the key to the rate of improvement of market animals. In order to remain in a competitive position, purebred breeders must be able to provide seed stock that produce superior performing progeny for the commercial producer which also meet consumer demand. The problem remains to evaluate and identify live animals that are genetically superior to use as seed stock.

With these problems in mind, this project was undertaken with the following objectives: (1) to test sires of the same breed and type to determine if the offspring of certain bulls performed superiorly alive and produced more desirable carcasses compared to progeny of the other bulls tested; (2) to try to identify live characteristics of the sire and dam which could be used to predict the live and carcass characteristics of their progeny; and (3) to determine if certain live characteristics of the progeny would accurately predict desirable carcass characteristics of that animal.

REVIEW OF LITERATURE

Live Animal Evaluation

Visual appraisal of livestock at the market, stock show, and on farms and ranches is the most practical and, without a doubt, has been the most extensively used device through the years in selecting seed stock. Since visual evaluation by cattle breeders has been the most used tool in selection, it is primarily responsible for the beef type that has been established in our breeding herds.

Robert Bakewell is credited with being the first great improver of cattle. He developed a low-set, blocky, quick-maturing type of cattle through selection. As quoted by Ensminger (1955), "His objective was to breed cattle that would yield the greatest quantity of good beef rather than to obtain great size."

The accuracy of visual appraisal of live animals as means of predicting live performance and carcass characteristics has been studied by many investigators. Lush (1932) stated that no score card or standard based on conformation could ever be so accurate that the future performance of individual steers could successfully be predicted from it.

Knapp et al. (1959) analyzed scores by seven experienced judges of twelve characters in beef cattle in a study of scoring as a technique of evaluating differences of animals. They concluded that scoring or evaluation of differences of 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, stated Knapp et al. Slaughter tests have shown repeated material differences between the progeny of two bulls, yet scores and grades have failed to show many differences.

Gifford et al. (1951) analyzed subjective conformation scores of individual Hereford cows as given by four judges to determine the agreement between judges, the repeatability of a judge on the same cow at different scoring dates, and to study the variation in scores of seven items of conformation. Within-season correlations indicated that judges were in general agreement on the points of conformation scored, with the judges agreeing more closely for items on which they must consider the entire animal. The correlations between repeated scores of a cow, by the same judge, were generally between 0.4 and 0.5.

Judges were able to agree more closely with one another on a particular classification date than they were able to agree with their previous scores. According to Gifford et al. (1951), seasonal differences in scoring level and the interaction of cows with season were important sources of variation, indicating a need for careful consideration of temporary environmental conditions in the evaluation of beef animals.

Krehbiel et al. (1958) studied the annual records (1941 to 1957) of evaluation of type by scorecard in a small purebred Angus herd to determine the effectiveness of selection for type. The average type score of at least three judges, working independently each year, was used to evaluate type. Selection for improvement in type among females in the herd studied was at the rate of approximately one third of a grade per year. Data indicated that selecting for type, on the basis of a scorecard, was effective in improving the type of the Angus herd studied.

Orme et al. (1958) correlated objective and subjective live animal evaluation and in turn correlated each of these to objective measurements and grade of the carcasses from the same live animals. The relationships between subjective live animal scores and comparable live animal measurements were quite low in most cases; whereas, the correlation coefficients between subjective live animal scores and actual values for such items as rib-eye area, fat thickness at 12th rib, and dressing percentage were highly significant. When calculated with live weight constant, standard partial regression coefficients of .89, .57, .58 and -.57 were obtained for rib-eye area and circumference of fore and hind flank, circumference of middle and circumference above the hock, respectively.

Wheat and Holland (1960) studied the slaughter grades placed on 688 Hereford heifers and steers by twelve graders and the corresponding carcass grades. Weighted average correlations between slaughter grade and carcass grade (conformation score) ranged from .23 to .56. The correlations dropped to a range of .07 to .39 when final carcass grade was compared to the live grade, indicating the appraisers could not accurately predict quality factors of the carcass.

Gregory et al. (1962) studied the subjective evaluation results and carcass data from three groups of yearling steers appraised by three graders. Results indicated that experienced cattle appraisers can subjectively estimate group means for carcass weight, fat thickness at 12th rib, percent kidney fat, rib-eye area at 12th rib, cutability and carcass grade reasonably accurately, provided the graders have a knowledge of the feeding and management program to which the cattle have been subjected and a knowledge of live weight. It seemed apparent that groups of live cattle can be appraised more accurately on the basis of quantitative (cutability) differences than qualitative (primarily marbling) differences. The results of this study indicated that graders can account for only about 20 to 25 percent of the variation on carcass traits, on the basis of subjective live scores and estimates.

Wilson et al. (1964), using six judges, studied the subjectively estimated fat thickness, rib-eye area, percent kidney fat, dressing percent and quality grade on 135 grade Hereford steers. The correlation between live estimated and fat thickness (average of three measurements) and single adjusted thickness was 0.38 and 0.51, respectively, suggesting that fatness of the entire carcass may be predicted with moderate accuracy. The correlation between live estimated and carcass cutability was 0.44. A multiple correlation of 0.51 was obtained between carcass cutability and a prediction equation based on live weight and live estimates of fat thickness, rib-eye area and percent kidney fat. The correlation between estimated and actual quality grade was 0.25, suggesting that the prediction of yield of edible portion on a percent basis may be more accurate than estimation of quality grade. The correlation between live estimated fat thickness and carcass cutability was 0.65, suggesting that a single estimate for fat thickness is of as much predictive value in relation to carcass cutability as any of the equations studied.

Performance Testing

Many investigators have studied performance testing and several have proposed different performance testing programs. Holbert (1932) suggested that sires be evaluated in accordance with their show ring winnings and the show ring winnings of their progeny. The three English breed associations have a form of ratings based on show ring results in use at the present time. 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 influences. In addition to this, it was believed that the period of development from the feeder animal to the time of slaughter should be studied most extensively.

Knapp and Black (1942) reported that, when progeny testing beef bulls, there is a rapid increase in information gained for each animal added to the test up to five. From five progeny on the information gained from each successive animal added becomes relatively less until, after reaching fifteen animals, each additional animal added per sire group contributes very little information. They also concluded that, in order to conduct a progeny test with reliable results, some number of animals per sire group between six and ten would be satisfactory. Knapp and Black (1942) determined that a feeding period of 168 days was adequate to measure the total performance of a steer, if corrected to a standard weight and gain from a short-time feeding period. In studying the effects of limited versus full feeding in performance tests, Knapp and Baker (1943) reported that genetic variation in the ability to use unlimited quantities of feed tended to be masked when all of the animals were fed alike.

Winters and McMahon (1933) stated that studies have revealed that differences in economy of gain are inherited and that it is possible to develop lines which are superior in this regard.

Winters and McMahon (1933) further stated that daily gain has long been recognized as a good criterion of feed efficiency and concluded that selling price and daily gain are the two most important factors affecting net profit. They proposed a relatively simple and accurate record of performance based upon an animal's final evaluation, considering daily rate of gain from birth to 365 days and the final appraisal or body score taken at 365 days of age.

Woodward and Clark (1950) studied performance of steer progenies of eleven bulls that were bred to randomly selected "herds" of cows at the U. S. Range Station, Miles City one year and then bred to "herds" at the North Montana Branch Station at Havre a following year. The steer progenies of the eleven bulls were fed out at Miles City the first year while the Havre-produced calves were fed at the Montana Experiment Station at Bozeman. There was not a significant sire x station interaction which meant that sires producing fast gaining calves at one station tended to do likewise at the other station.

Kock and Clark (1955) used records on 4234 dam-offspring pairs and on 85 sire-offspring groups in estimating the correlations between parent and offspring for various economic traits in beef cattle. Correlations between traits in the sire and traits in the offspring, considering birth weight, weaning weight, gain from birth to weaning and weaning score, ranged from .02 to .18. Correlations between traits in the dam and traits in the calf were also of rather low magnitude, ranging from .01 to .23. Cow-offspring traits studied included the preceding four sire-offspring traits studied plus yearling weight, yearling score and yearling gain.

Kincaid and Carter (1958) reported on the progeny testing of 388 steer and heifer calves that were sired by 19 high-gaining bulls and 19 low-gaining bulls over a six year period. The high-gaining bulls averaged 2.24 lbs. per day on a feedlot performance test while the low-gaining bulls averaged 1.65 lbs. gain per day for a 0.59 lb. difference between the two groups. Differences between the averages of the progenies of the high and low-gaining sires were 0.1 lb. per day for the steers on a 200 day full-feed test following weaning and 0.06 lb. for the heifers tested for pasture gain.

Lindholm and Stonaker (1957), using data from 118 Hereford steers by 19 sires, conducted a study to determine the relative economic importance of traits affecting net income in beef cattle. Multiple correlation studies, using net income per hundredweight as the dependent variable, indicated that weaning weight was the most important trait affecting net income. Weaning weight and daily gain gave the highest multiple correlation with net income per hundredweight of any combination of two independent variables. Other important traits, as indicated by the standard partial regression coefficients, were slaughter grade, feed per pound gain and 18-month weight of dam.

Kieffer _et al_. (1958) studied sire influence upon carcass characteristics of 60 Angus steers and heifers produced by seven different sires. Significant sire differences were found for carcass grade, slaughter grade, marbling score, and percent bone of the 9-10-11th ribs. Sire differences for fat and lean percentage of the 9-10-11th ribs were nonsignificant.

Gregory _et al_. (1961) stated that record-of-performance will have its greatest impact through application by purebred breeders on seedstock herds to which the range bull producers and commercial cattlemen can come for replacement animals.

According to these workers, differences between animals are due to two major causes--genetic and environmental. When environmental influences are standardized as nearly as possible, the remaining differences should be more to genetic variance than where no attempt is made to standardize environment. Therefore, adhering to a strict record-of-performance program should supply the breeder with a sound basis for selecting seed stock.

Gregory and Stewart (1962) compared the 182-day weights and 154-day post-weaning feedlot gains of 29 bulls with the 182-day weights and grades and 18-month weights and grades of their progeny. The 154-day post-weaning feedlot gains of bulls gave a higher predictive value of the performance of the progeny than the 182-day weights. The authors also stated that ten progeny were needed to adequately test a bull. Heritability estimates obtained were 182-day weights and grades 0.54 and 0.23, respectively, and 18-month weights of and grade of 0.14 and zero, respectively.

Relationship Between Type and Performance

Lush (1932) stated that steers which gain the same may be of many different shapes.

Winters and McMahon (1933) stated that cattle producers and feeders had rather generally assumed that improvement in body type carried with it a similar improvement in economy of converting feedstuffs into animal products useful to man. However, these two investigators, in three years' work, showed very clearly that animals of the same phenotype or grade do possess marked differences in ability to make gains economically.

Knapp and Clark (1951) studied 613 steers from 83 Hereford sires in an attempt to determine if there is any relationship between type or grade and gains in the feedlot. They found a genetic correlation of 0.300 between weaning score and feedlot gain and an environmental correlation of -.304 for the traits. A gross correlation of 0.0001 was observed between weaning score and gains in the feedlot. The authors concluded that this lack of gross correlation in some respects works to the advantage of the beef cattle breeder. Since there is little or no gross correlation and relatively low genetic correlation between scores and gains, it is possible for the beef cattle breeder to select, within any type of animal, for greater rate of gain, without materially affecting the type or conformation of his herd. Or he may select for both conformation characteristics and rate of gain and make the progress expected, since in selecting for one characteristic, he is not unduly influencing the other characteristic.

Willey _et al_. (1951) compared "Comprest" and "Regular" type Hereford steer calves as to rate and efficiency of gain under feedlot conditions. They found "Regular" type steers taller at the shoulders, longer of body, greater in depth of chest, and taller off ground than "Comprest" type steers. "Regular" steers made more total and daily gain and had a slight, but nonsignificant advantage in feed efficiency. The percent of market weight composed of untrimmed hide, untrimmed head, and shanks was greater in the case of the "Comprest" type steers.

Butler et al. (1956) studied performance and carcass characteristics of 59 Hereford and 90 Brahman X Hereford steers from Hereford dams that were raised under the same management and found that the crossbred steers weighed approximately 40 lbs. more at slaughter, had 55 lbs. more in the carcass and out-performed the straightbreds prior to weaning. The crossbred steers yielded 2.7% more while there was little difference in carcass grade or yield of wholesale cuts, although the crossbred carcasses were longer bodied and longer of leg. The investigators concluded that results of the test reflected considerable doubt on the importance of compactness as a conformation factor in beef steers.

Kidwell et al. (1957) reported no relation between feeder grade and subsequent rate or economy of gain after studying conformation scores and production factors in a group of 98 yearling steers.

Heritability and Repeatability Estimate of Characteristics

Heritability is that portion of the variation between related animals which is due to genetic differences. When the environment has been standardized as nearly as possible, it is easier to observe the genetic differences which exist. Knowing this, a breeder is better able to determine which traits he can expect improvement in through selection. Heritability estimates have been obtained for most of the economically important traits in beef cattle. Birth weight, weaning weight and grade, final slaughter weight and grade, daily gain and efficiency of gain, and carcass grade have all been considered economically important traits in performance trials (Black *et al.*, 1936; Black, 1938; Knapp *et al.*, 1941; Knapp *et al.*, 1942; Knapp and Clark, 1950; Carter and Kincaid, 1959b; Warwick, 1958; Shelby *et al.*, 1960; Gregory *et al.*, 1961). These traits have been studied extensively by many workers and heritability estimates have been established for them (Knapp and Nordskog, 1946; Knapp and Clark, 1950; Koch and Clark, 1955; Carter and Kincaid, 1959a; Warwick, 1958; Shelby *et al.*, 1960; Gregory *et al.*, 1961).

As performance testing became more advanced and complicated, other traits were added which were considered important. These traits included: length of calving interval, cow maternal ability, dressing per cent, rib eye area, tenderness, and cancer eye susceptibility. Heritability estimates were also established for these traits (Knapp and Clark, 1950; Clark, 1954; Warwick, 1958; Gregory *et al.*, 1961).

Warwick (1958), using estimates of previous workers and calculating the average of these estimates, arrived at the heritability estimates given in Table 1.

A few of the early workers with heritability estimates also reported estimates for important carcass traits along with the production traits (Knapp and Nordskog, 1946; Knapp and Clark, 1950; and Clark, 1954). In recent years heritability estimates for important carcass traits have received special emphasis by several workers including Warwick (1958), Gregory *et al.* (1961), Christians *et al.* (1962), and Cundiff *et al.* (1964). These carcass traits and ranges in heritability estimates for the various traits, as reported by the workers, are found in Table 1.

Table 1. Heritability estimates for production traits and ranges in heritability estimates for carcass traits.

Production trait	Heritability estimate
Calving interval	.08
Birth weight	.41
Weaning weight	.30
Cow maternal ability	.40
Postweaning feedlot gain	.45
Postweaning pasture gain	.30
Efficiency of feedlot gain	.39
Weaning grade	.26
Slaughter grade	.39
Cancer eye susceptibility	.30

Carcass traits	Range in heritability estimates
Rib eye area	.67 - .73
Tenderness	.60 - .61
Dressing per cent	.01 - .73
Fat thickness 12th rib	.32 - .43
Carcass grade	.16 - .62

Repeatability of production in beef cattle has been studied in an effort to determine the predictability of performance of subsequent offspring from a parent. Botkin and Whatley (1953) used data from 603 weaning weights and 620 birth weights of calves produced by 151 range Hereford cows in the experimental herd at Stillwater, Oklahoma, and weaning and birth weights of 98 calves from 49 cows in the experimental herd at the Fort Reno Experiment Station to study repeatability of production in beef cows. Repeatability was determined by two methods: interclass correlation between calves by the same cow, and regression of subsequent records on earlier records by the same cow. Ranges in repeatability estimates found by using the two methods for the various traits on the two herds were as follows: weaning weight 0.43 to 0.66; birth weight 0.14 to 0.25; and gain from birth to weaning 0.38 to 0.69. The researchers concluded that considerable progress can be made in selecting cows on the basis of their first records, particularly by using weaning weights.

Koch and Clark (1955) calculated estimates of repeatability of several economic characteristics using data from 4553 calves raised at the U. S. Range Livestock Experiment Station, Miles City, Montana. The repeatability estimates they obtained, which were lower than those obtained by Botkin and Whatley (1953), are as follows: birth weight .26, weaning weight .34, gain from birth to weaning .34, weaning score .22, yearling score .02, gain from weaning to yearling age .09, and yearling weight .20.

The analysis indicated to the investigators that maternal environment is quite important for birth weight, gain from birth to weaning and weaning score but had little importance in relation to yearling gain or score.

Relationship Among Production Traits

Relationships among heritable traits have been studied quite extensively to determine whether selection for specific traits would be favorable or detrimental to other traits. Carter and Kincaid (1959b) found no correlations which would handicap selection for any of the following traits: weaning weight, feeder grade, daily gain in the feedlot, feed efficiency, slaughter grade and carcass grade. Gregory (1960) stated that, even though the relationship between many production traits and carcass traits was not very high, they were at least not negatively related and direct selection can be made for desirable carcass traits with no apparent negative effects upon production traits.

Rate of gain and efficiency of gain are highly correlated (Winters and McMahon, 1933; Stanley and McCall, 1945; Woodward _et al._, 1954; Gaines _et al._, 1958; Carter and Kincaid, 1959b). This has led workers to conclude that selection for growth rate will bring about an increase in feed efficiency. This is not surprising since animals of the same size would tend to have similar maintenance requirements.

Correlations between weights at various ages and periods have been analyzed by many workers to determine the effect of selection for growth at a particular stage on subsequent stages of growth (Black and Knapp, 1936; Koger and Knox, 1951; Yao _et al._, 1953; Koger _et al._, 1957; Carter and Kincaid, 1957; Carter and Kincaid, 1959). These workers have studied all combinations of the following traits: birth weight, gain from birth to weaning, weaning weight, yearling gain, weight at 365 days, gain in the feedlot and gain from weaning to slaughter. All correlations were found to be positive and highly significant (range .31 to .69). These results have led the researchers to conclude the following: (1) when environment is constant for different animals, there is a positive relationship between gains made at different periods; (2) heavier calves at birth gain faster throughout life; and (3) selection for heavy weaning weights on a progeny basis should be effective in improving post-weaning rate of gain.

Carcass and Production Relationships

Black and Knapp (1936) found weaning weight (at 252 days) negatively correlated with subsequent fatness (-.62) and concluded that the heavier steers at weaning put on the least fat.

Burns et al. (1958), working with 41 15-month-old steers of five different breeds, found that an implant of 30 mg. stilbestrol significantly increased average daily gain 0.4 lb. above non-implanted steers, significantly decreased carcass grade 1/3 grade and had no effect on tenderness.

A genetic correlation of 0.66 was obtained between carcass weight per day of age and rib eye area by Cundiff et al. (1964), suggesting that selection for growth rate would increase the absolute size of the rib-eye muscle. Correlations between carcass weight per day of age and fat thickness and carcass grade were 0.15 and 0.47, respectively.

These investigators concluded that the genetic correlations obtained indicate that selection for growth rate would lead to increased muscular development, improved carcass grade, and a slight increase in carcass fatness, and that selection for growth rate would be compatible with the production of desirable carcasses.

Carcass Relationships

Marbling of lean, firmness of fat and lean and color of fat and lean have been reported to be highly related to carcass grade, the lowest correlation being .88 (Hankins and Burke, 1938). This is to be expected, however, since these factors are all considered by the meat grader in determining grade.

Wheat and Holland (1959) reported that the correlation between carcass grade before ribbing (separation of a side of beef between the 12th and 13th rib exposing the rib eye area) and after ribbing was .53, between carcass grade before ribbing and degree of marbling was .45, and between carcass grade after ribbing and degree of marbling was .89. This would indicate that there is a high relationship between marbling and carcass grade.

Woodward *et al.* (1954) found that carcass grade was associated with final weight and was significantly correlated also with area of the rib eye muscle, thickness of fat, and dressing per cent. They reported that final weight was more closely related to the thickness of fat over the rib eye muscle than it was to area of rib eye muscle. Furthermore, they found that area of rib eye muscle and thickness of fat over the rib eye muscle were not closely related.

Cole et al. (1960) stated that, although rib eye area and separable carcass lean were highly associated, rib eye area was found to be associated with only 18 per cent of the variation in separable carcass lean. Separable lean of the round, chuck, and foreshank, however, were all associated with a higher percentage of the variation in total separable carcass lean than was rib eye area.

Brungardt and Bray (1963) reported significant, positive, correlation coefficients (0.40 to 0.60) between L. dorsi muscle area (rib eye area) and retail yield (muscle trimmed to .3 inch fat depth). However, these same authors showed that on a carcass weight and fat constant basis, the correlation coefficients were significantly reduced. Since area of L. dorsi muscle is at least partially a function of weight, this would be expected.

Briskey and Bray (1964) concluded that although the influence of area of L. dorsi muscle upon retail yield is small compared to that of fat, emphasis upon size of this muscle may be justified because it comprises a large proportion of two of the high priced cuts of the beef carcass.

Cover et al. (1958) reported that tenderness was not affected by either carcass grade or degree of fatness. Crown and Damon (1959) reported correlations between indexes of fat and tenderness were so low that it would seem to suggest that the majority of the variation in tenderness is due to factors other than degree of fatness. Cole and Badenhop (1958) reported that there was a definite preference for steaks from higher grading carcasses and that the choice and good grades were scored higher by both family panels and a trained taste panel, as being more tender than the standard and commercial grades.

Allen (1963) reported that there is a rather low positive correlation (0.20) between fat thickness at the 12th rib and marbling score.

Henderson et al. (1966) reported significant correlations ($P<.01$) between percent total carcass bone and percent total retail yield (0.64) and percent total retail yield of the four major wholesale cuts (0.68).

Good et al. (1961) found that circumference of cannon bone negatively correlated to fat cover at the 12th rib (-.34) and positively correlated to area of loin eye (0.13).

Fattening

Hankins and Titus (1939) stated that in young growing animals weight gains are composed largely of protein and water; whereas, those of the mature or nearly mature animal consist primarily of fat. These workers reported that one of the best known and most obvious changes, which accompanies growth and fattening, is the increase in the ratio of carcass weight to the weight of the entire body (dressing percent). Warner et al. (1934) reported that as the hog grows and fattens, the percent ham, loin, shoulder and head decrease. They also reported an increase in the percent bacon and fat trim. Hankins and Titus (1939) found that in beef, the percent rib, short loin, plate and flank increased as the animal fattened and the percent round, sirloin and foreshank decreased. The chuck and rump showed very little change.

Physical Methods for Estimating Carcass Composition

Physical separation data of entire beef carcasses are limited because such studies are laborious, time consuming and involve economic loss of product. However, physical separation of wholesale cuts or parts thereof has been used rather extensively to measure beef carcass composition.

The most widely used method of estimating beef carcass composition is physical separation of the 9-10-11th rib section as described by Hankins and Howe (1946). They reported correlation coefficients between the percent separable muscle, fat and bone from the 9-10-11th rib section with the same components from the entire carcass of 0.85, 0.93 and 0.83, respectively. The conclusions of these workers were supported by the findings of Crown and Damon (1959) who reported correlation coefficients of 0.94, 0.98 and 0.73 for muscle, fat and bone, respectively, between these components in the 9-10-11th rib section and the same components in the carcass.

EXPERIMENTAL PROCEDURE

Source of Material

Data from two successive calf crops born the spring of 1962 and the spring of 1963 at the Jim and Clifford Houghton Stock Farm, Tipton, Kansas, were used in this study. The calves were the progeny of four bulls and 70 cows in 1962 and five bulls and 51 cows in 1963.

The dams were good commercial Hereford cows. The cows were similar in type and beefiness and since no new females have been introduced into the herd for 20 years, the cows were similar in ancestral female lines.

The sires used in this study were registered Hereford bulls of superior type. The sires of the 1962 calves were Onward Rupert (1), Onward Rupert 2nd (2), Royal Prince 22nd (3), and M. Crusty Domino (4). The sires of the 1963 calves were Onward Rupert (1), Onward Rupert 2nd (2), Royal Husker 3rd (3), Royal Husker K-38th (4), and M. Crusty Domino (5).

Royal Husker 3rd, Royal Husker K-38th, Onward Rupert and Onward Rupert 2nd were used through artificial insemination. These bulls are owned by the Animal Husbandry Department, Kansas State University and the Kansas Artificial Breeders Service Unit, Manhattan. Royal Prince 22nd and M. Crusty Domino are owned by the Houghton Stock Farm and were used naturally as "clean up" bulls following the artificial insemination of the cow herd to the other bulls.

Method of Handling

Artificial insemination was accomplished through the cooperation of the Kansas Artificial Breeders Service Unit. The cows were randomly inseminated to the various bulls by Clifford Houghton for a breeding period of approximately 45 days, after which the cleanup bull or bulls were turned in. The cows were divided into two groups in 1961 following the artificial insemination period and a cleanup bull was turned in with each group. All cows were exposed to M. Crusty Domino at the end of the 1962 insemination period (for 1963 calves).

The calves were assigned an ear tattoo number at birth and identified as to dam and sire. The calves were weighed and graded at weaning time. The weaning weights were adjusted to 210 day weights using the Kansas Extension weaning weight schedule shown in Appendix Table 1. Houghton Ranch facilities were used for all weighing and grading.

After weaning, the steer calves used in this study were placed on a wintering ration consisting of five pounds of rolled milo per head per day plus all sorghum silage and loose alfalfa hay the calves would readily consume. This was a 156 day period in 1962 and a 150 day period in 1963. At the completion of the wintering phase, the steers were again weighed and graded (yearling grades and weights).

After a brief warmup period, the steers were placed on full feed and allowed access to self feeders. The full feeding ration consisted of rolled milo with approximately 1.5 pounds per head per day of a 42% protein. The roughage consisted of prairie hay.

Live Animal Scoring

The steers were graded at weaning, the termination of the wintering phase and at the completion of the full feeding phase just prior to slaughtering. A numerical score was used to represent the grades. The grades and corresponding numerical scores are found in Appendix Table 2. In addition to live slaughter grades placed on the steers at the completion of the full feeding phase, the steers were individually classified using the system outlined in the Herd Classification Program of the American Angus Association. The classification system is found in Appendix Table 3. Also just prior to slaughtering, the steers were scored on muscling over the top, muscling in the rounds, forearm score, bone score and condition score. The scores were numerical, ranging from 1 to 6. The higher value indicated the more desirable condition or score. This score card is found in Appendix Table 4.

All cows and bulls in this study were also scored on the herd classification scoring system.

All scoring and grading was done by a committee of three experienced judges working independently with an average of their scores used as the subjective score. The scoring committee consisted of Dr. Don L. Good of the Animal Husbandry Department at Kansas State University; Gene Ross, Animal Husbandry graduate student, and the author, for the 1962 calves. Ed Lugo, Kansas State Animal Husbandry Graduate student, replaced Mr. Ross in scoring the 1963 calves.

Slaughter Data

The individual weights obtained at the Houghton Ranch at the end of the full feeding phase were used as slaughter weights and end of test weights. After the slaughter weights, grades and scores were obtained, the cattle were shipped in the evening approximately 225 miles to the Kansas City Stockyards. The cattle were penned in the Stockyards without feed or water until the following morning. At 7:00 A.M. the steers were weighed individually on Stockyard scales by a certified weighmaster. The difference between the Kansas City weight and the ranch weight was used to determine shrink.

The steers were driven to the Mauer-Neuer Packing Company where they were slaughtered. On the kill floor, each carcass was tagged with an identical number as that on the hide for identification purposes. Also, circumference measurements were obtained on each shank and forearm. The forearm circumference was taken midway between the elbow and the knee joint where the shank circumference was obtained at the smallest diameter of the cannon bone. The average of the two forearm measurements and the two shank measurements from each carcass were used in this study.

Hides were weighed individually and the hot carcass weights were taken.

Carcass Information

The following day, the carcasses were ribbed, graded and scored for various traits by a federal grader. Information obtained included marbling score, maturity, carcass conformation and final carcass grade. The numerical values for marbling scores are found in Appendix Table 5. The numerical values for maturity scores are found in Appendix Table 6. Also, tracings of the cross-sectional area of the longissimus dorsi and fat cover at the 12th rib were made on acetate paper. Area of the loin eye muscle was determined from tracings with a compensating polar planimeter. Fat depth over the 12th rib was measured at three sites, averaged and recorded to the nearest tenth of an inch as described by Naumann (1951). Chilled carcass weight was obtained on each carcass.

Four wholesale cuts, the round, loin, rib and chuck were tagged from randomly selected carcasses within each sire group. The weight of each of these cuts was obtained in the Mauer-Neuer Plant and then the external fat cover of each cut was trimmed to .25 inch and the trimmed cut and fat trim of each individual cut was recorded. The trimmed cut weight was used to determine the trimmed wholesale cut weights.

The wholesale rib cut from steers within each sire group were sent to the meats laboratory of the Animal Husbandry Department, Kansas State University, for further study.

9-10-11th Rib Analysis

The 9-10-11th rib section was removed from each wholesale rib as described by Hankins and Howe (1946) and was physically separated into lean, fat and bone. The weights and percentages of lean, fat and bone were recorded.

6-7-8th Rib Analysis

After removal of the 9-10-11th rib sections from the wholesale ribs, the 6-7-8th rib sections were boned, wrapped and frozen for subsequent cooking and tenderness studies. This analysis was conducted in the Meats Research Laboratory of the Home Economics Department, Kansas State University. Information obtained on each cut included shear value using the Warner-Bratzler Shear Test. Each rib cut was cooked and the press fluid and dripping loss percentage were obtained. A representative sample of each rib was evaluated by a taste panel for juiciness score and number of chews. The numerical scores for juiciness are found in Appendix Table 7. The numerical values for tenderness score are found in Appendix Table 8.

GROSS DATA

Sire groups averages and ranges for all traits studied for both the 1962 and the 1963 calf crops are presented in Tables 2 through 11. The means and ranges for live animal grades and scores for the 1962 sire groups are included in Table 2, and the 1963 figures for these traits are in Table 3. The means and ranges for 1962 and 1963 weights and gains by sire groups are found in Tables 4 and 5. Sire group means and ranges for 1962 and 1963 slaughter data represented in Tables 6 and 7. Carcass data means and ranges by sire groups are found in Tables 8 and 9 for the two years. Means and ranges of physical separation and cooking data from the rib cut are found in Tables 10 and 11.

ANALYSIS OF VARIANCE

Analysis of variance for each trait by sire groups was determined on a within-year basis. The results of the analysis of variance for the traits studied on the 1962 calves are found in Table 12. Results for 1963 are presented in Table 13. An ordered array of sire group means for each trait is also included.

Table 2. Means and ranges of certain live animal grades and scores by 1962 sire groups.

Characteristics	Maximum Score	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Weaning grade	16	12.5	11-14	12.1	9-14	11.4	10-13	12.4	10-15
Yearling grade	16	12.9	12-14	12.1	10-14	11.4	10-12	12.3	10-13
Slaughter grade	16	12.7	12-14	11.9	9-14	11.8	9-14	12.0	8-14
Combined muscle score	18	15.0	12-17	13.4	9-17	13.6	10-16	13.7	9-16
Classification at slaughter	100	85.9	77-90	82.9	78-90	82.7	76-90	83.3	74-68
Steer's type	14	12.8	12-13	12.6	11-13	12.4	10-13	12.6	11-13
Steer's size	10	9.3	9-10	8.7	6-9	8.9	8-10	8.7	8-10
Steer's quality	6	5.2	4-6	5.2	5-6	5.2	4-6	5.1	4-6
Steer's shoulder and chest	8	6.6	6-7	6.3	5-7	6.5	6-7	6.5	5-7
Steer's rib	10	8.4	8-9	8.0	7-9	8.0	7-9	7.9	7-9
Steer's loin	10	8.7	8-9	8.6	8-9	8.5	7-9	8.6	7-9
Steer's rump	10	7.8	6-9	7.6	7-9	7.9	7-9	7.8	7-9
Steer's round	12	10.5	9-11	9.9	8-11	9.9	8-11	10.1	8-11
Steer's feet and legs	12	9.9	9-11	9.4	8-10	9.3	7-10	9.7	8-10
Steer's neck	8	6.6	6-7	6.6	5-7	6.2	6-7	6.4	6-7
Dam's type	14	11.6	11-13	12.1	11-13	12.0	10-13	12.7	11-14
Dam's size	10	8.5	7-10	8.3	7-9	8.4	7-10	8.6	7-10
Dam's round	12	9.0	8-10	9.0	8-10	8.8	8-10	9.2	8-10
Dam's total classification	100	79.0	71-87	79.2	69-85	77.5	67-85	81.9	72-89
Sire's type	14	12.0		13.0		12.0		13.0	
Sire's size	10	8.0		8.0		9.0		8.0	
Sire's round	12	12.0		12.0		9.0		11.0	
Sire's total classification	100	86.0		88.0		80.0		85.0	

Table 3. Means and ranges of certain live animal grades and scores by 1963 sire groups.

Characteristics	Maximum Score	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4		Sire Group 5	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Weaning grade	16	11.7	9-14	12.0	11-13	12.6	12-13	12.4	9-14	12.3	10-14
Yearling grade	16	11.8	10-14	12.0	11-13	12.4	12-13	11.9	11-13	11.8	10-13
Slaughter grade	16	11.4	9-13	11.4	9-13	12.1	11-13	11.8	10-14	11.3	10-13
Combined muscle score	18	12.9	9-16	13.8	11-16	14.4	12-16	14.4	11-17	13.4	11-16
Classification at slaughter	100	80.3	13-89	82.8	76-89	83.3	78-87	83.0	75-91	81.9	76-87
Steer's type	14	11.6	10-13	12.0	10-13	12.6	11-13	12.4	11-13	12.2	11-13
Steer's size	10	8.8	8-9	8.8	8-9	9.0	-9	8.8	8-9	8.1	7-9
Steer's quality	6	4.9	4-6	5.2	4-6	4.7	4-5	5.1	4-6	5.2	5-6
Steer's shoulder and chest	8	6.1	6-7	6.2	6-7	6.3	6-7	6.2	6-7	6.1	6-7
Steer's rib	10	7.4	7-8	7.4	7-8	7.4	7-8	7.8	7-9	7.4	7-8
Steer's loin	10	8.1	7-9	8.6	8-9	8.7	8-9	8.5	7-9	8.7	7-9
Steer's rump	10	7.4	6-9	7.6	7-8	7.6	7-9	7.5	6-9	7.7	7-8
Steer's round	12	9.8	8-11	10.0	9-11	10.6	10-11	10.1	9-11	10.4	9-11
Steer's feet and legs	12	9.6	8-11	10.2	10-11	10.1	9-11	10.1	9-11	10.0	9-11
Steer's neck	8	6.4	5-7	6.8	6-7	6.3	5-7	6.5	5-7	6.3	5-7
Dam's type	14	12.1	11-13	12.8	12-13	11.9	11-13	11.9	11-13	12.2	11-13
Dam's size	10	8.6	7-9	8.4	8-9	8.3	7-9	8.7	8-9	8.2	7-9
Dam's round	12	9.0	8-10	9.4	9-10	8.9	7-10	9.2	8-10	9.0	8-10
Dam's total classification	100	79.4	72-86	84.0	81-88	78.4	73-81	80.1	74-88	78.5	67-88
Sire's type	14	12.0		13.0		13.0		12.0		13.0	
Sire's size	10	8.0		8.0		10.0		9.0		8.0	
Sire's round	12	12.0		12.0		11.0		10.0		11.0	
Sire's total classification	100	86.0		88.0		90.0		85.0		85.0	

Table 4. Means and ranges of certain weights and gains by 1962 sire groups.

Characteristics	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Weaning weight	523	500-550	475	400-535	451	405-550	460	415-540
Adjusted weaning weight	470	421-507	447	356-508	457	397-569	452	377-497
Yearling weight	754	690-815	674	595-755	649	590-760	665	600-790
Slaughter weight	1152	1100-1280	1056	860-1175	1064	930-1220	1057	910-1190
Chilled carcass weight	683	629-788	617	497-720	627	548-715	616	513-714
Wintering gain	231	175-265	199	130-235	197	160-270	207	155-255
Full feeding gain	398	345-475	382	250-570	416	315-475	397	290-500
Total gain on feed	629	570-730	581	380-740	613	520-705	597	480-710
Weight per day of age	1.94	1.81-2.15	1.84	1.48-2.04	1.95	1.69-2.23	1.93	1.65-2.13
Carcass weight per day of age	1.15	1.06-1.33	1.08	0.85-1.23	1.15	1.00-1.33	1.11	0.92-1.27
A.D.G. birth to weaning	1.64	1.51-1.81	1.60	1.36-1.89	1.69	1.45-2.07	1.71	1.38-1.97

Table 5. Means and ranges of certain weights and gains by 1963 sire groups.

Characteristics	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4		Sire Group 5	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Weaning weight	497	380-575	420	385-460	538	470-620	481	430-580	418	290-520
Adjusted weaning weight	440	312-5-5	458	409-503	477	389-550	449	403-555	437	396-509
Yearling weight	729	630-815	689	630-730	753	705-825	728	650-820	638	530-730
Slaughter weight	1052	940-1215	1029	954-1075	1082	955-1240	1086	950-1240	992	905-1120
Chilled carcass weight	611	551-704	599	564-625	637	585-719	625	530-720	570	506-666
Wintering gain	238	160-295	271	245-290	215	200-235	247	205-305	220	165-310
Full feeding gain	323	250-435	339	315-360	344	240-415	358	300-420	354	280-420
Total gain on feed	561	430-725	610	570-650	559	445-630	604	520-700	574	445-685
Weight per day of age	1.9	1.66-2.16	2.0	1.85-2.10	2.0	1.74-2.20	2.0	1.77-2.22	2.0	1.73-2.25
Carcass weight per day of age	1.11	.94-1.24	1.16	1.10-1.20	1.16	1.07-1.27	1.14	.99-1.29	1.13	.96-1.29
A.D.G. birth to weaning	1.58	1.40-1.81	1.72	1.59-1.94	1.75	1.49-1.93	1.60	1.40-1.81	1.63	1.31-1.92

Table 6. Means and ranges of certain slaughter data by 1962 sire groups.

Characteristics	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dressing percent	62.2	60.9-64.0	61.9	58.0-64.6	62.4	60.6-63.8	61.3	59.0-64.4
Shrink	52.7	35-70	56.5	25-80	58.2	40-75	53.1	35-85
Shank circumference	16.0	15.2-17.3	15.3	14.5-15.7	15.5	14.7-16.4	15.4	14.6-16.6
Forearm circumference	34.5	33.3-36.3	32.5	30.6-34.2	32.4	30.2-34.2	32.3	29.7-34.6
Hide weight	91.2	81-99	90.7	82-97	91.2	83-101	93.2	83-110

Table 7. Means and ranges of certain slaughter data by 1963 sire groups.

Characteristics	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4		Sire Group 5	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dressing per	61.5	60.9-63.4	62.3	61.2-62.8	62.3	60.3-63.4	61.2	59.2-62.8	61.2	58.6-63.7
Shrink	53.1	25-105	67.0	45-80	47.1	30-105	65.5	35-90	61.1	40-80
Shank circumference	15.7	14.9-16.7	15.7	15.3-16.2	15.7	15.4-16.6	15.8	14.4-17.0	15.3	14.5-16.0
Forearm circumference	32.9	31.6-34.0	32.7	32.0-33.4	32.6	30.6-34.2	33.1	30.3-34.7	31.4	30.0-33.9
Hide weight	90.3	80-100	90.0	82-95	91.0	84-102	96.6	83-117	86.5	77-100

Table 8. Means and ranges of certain carcass data by 1962 sire groups.

Characteristics	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Carcass conformation grade	12.0	11-13	11.5	10-12	11.6	11-13	11.5	10-12
Marbling score	11.8	11-14	10.2	8-14	10.1	9-14	11.6	9-16
Final carcass grade	8.5	8-10	8.2	7-10	8.1	7-10	8.7	8-11
Loin eye area	11.4	10.0-13.2	10.7	9.6-11.5	10.6	9.4-11.8	10.3	8.5-12.7
L.E.A. per 100 lb. carcass	1.66	1.50-1.96	1.73	1.51-2.06	1.69	1.53-1.84	1.68	1.41-1.96
Fat thickness	.60	.38-.87	.51	.13-.87	.47	.28-.68	.57	.32-.83
Fat per 100 lb. carcass	.088	.060-.112	.081	.023-.124	.075	.048-.104	.092	.059-.132
Primal cuts weight	247	224-277	234	217-249	224	206-237	225	190-248
% Primal cuts	73.3	71.4-76.7	73.1	71.6-76.4	74.0	70.1-75.7	72.6	70.0-75.3
Trimmed round weight	74	68-84	71	65-76	67	63-74	66	59-75
% Trimmed round	22.1	20.3-24.1	22.2	20.9-24.0	22.0	21.1-23.1	21.3	19.3-23.3
Total lbs. fat trim	18.4	12.4-25.0	17.5	13.6-24.8	15.2	11.6-19.3	17.0	11.8-23.5

Table 9. Means and ranges of certain carcass data by 1963 sire groups.

Characteristics	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4		Sire Group 5	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Carcass conformation grade	11.7	11-13	12.4	12-13	12.1	12-13	11.9	11-13	12.0	11-13
Marbling score	11.7	8-15	10.4	9-15	12.9	9-16	12.4	11-15	12.3	9-16
Final carcass grade	9.2	8-11	8.8	8-11	9.7	8-11	9.5	9-11	9.5	8-11
Loin eye area	10.6	9.2-12.0	11.1	9.5-12.1	10.4	9.1-11.8	10.4	9.7-11.2	10.3	8.8-12.1
L.E.A. per 100 lb. carcass	1.73	1.51-2.06	1.86	1.53-2.02	1.62	1.55-1.72	1.68	1.52-1.97	1.82	1.49-2.21
Fat thickness	.59	.33-.83	.53	.40-.70	.61	.50-.80	.62	.47-.87	.63	.33-1.30
Fat per 100 lb. carcass	.10	.06-.14	.09	.07-.11	.10	.08-.12	.10	.08-.12	.11	.05-.22
Primal cut weight	228	205-254	227	222-234	233	214-261	229	205-247	210	193-244
% Primal cuts	75.7	73.5-78.4	76.9	75.3-80.0	74.3	73.5-76.1	74.9	72.9-77.5	75.4	72.7-77.6
Trimmed round weight	70.8	65.5-76.3	70.7	67.2-75.2	71.3	66.4-78.5	69.5	62.8-76.2	64.4	58.7-72.3
% Trimmed round	23.5	21.2-25.4	23.9	22.1-24.6	22.8	22.0-23.8	22.8	21.6-23.8	23.2	21.3-25.0
Total lbs. fat trim	5.9	3.1-11.1	4.7	3.7-5.7	6.8	4.2-8.4	6.2	3.5-8.9	5.7	3.5-11.0

Table 10. Physical separation and cooking data from the rib by 1962 sire groups.

	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Separation data								
Grams 9-10-11th rib lean	2781	2404-3068	2716	2305-3053	2682	2403-3015	2658	2146-3176
% 9-10-11th rib lean	48.4	42.2-52.5	49.3	45.9-57.0	51.6	42.5-55.8	48.6	44.6-52.6
Grams 9-10-11th rib fat	2179	1763-2667	2015	1623-2548	1768	1423-1940	2072	1507-2708
% 9-10-11th rib fat	37.7	31.8-44.4	36.3	26.7-41.8	33.5	28.4-46.7	37.4	31.1-41.7
Cooking data								
Juiciness score	6.0	5.5-6.3	5.9	5.5-6.2	5.8	5.4-6.2	5.8	5.3-6.2
Shear value	18.5	12.6-25.8	20.4	14.0-24.6	18.4	13.9-21.8	17.3	14.6-23.3
Number of chews	27.7	23-34	27.7	24-31	28.4	24-33	27.5	23-33
Cook loss % drippings	4.6	3.4-6.3	3.7	2.9-4.2	4.0	3.1-5.4	4.4	2.8-6.1
Press fluid	7.5	6.5-8.2	7.6	6.8-8.5	7.8	6.9-8.9	7.3	6.6-8.2

Table 11. Physical separation and cooking data from the rib by 1963 sire groups.

	Sire Group 1		Sire Group 2		Sire Group 3		Sire Group 4		Sire Group 5	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Separation data										
Grams 9-10-11th rib lean	2447	2049-2663	2486	2386-2582	2493	2179-2949	2289	2016-2555	2133	1993-2319
% 9-10-11th rib lean	52.1	48.2-57.0	55.1	51.3-58.5	52.0	48.2-58.8	50.6	40.0-56.9	50.7	40.7-55.4
Grams 9-10-11th rib fat	1520	972-2078	1329	1057-1592	1557	1242-1939	1517	1106-1881	1450	1045-2312
% 9-10-11th rib fat	32.0	24.9-38.2	29.3	24.8-34.2	32.4	26.5-35.3	33.3	27.0-37.4	33.7	28.9-44.4
Cooking data										
Juiciness score	5.6	5.0-6.6	5.6	5.2-6.0	5.8	5.4-6.1	5.9	5.6-6.5	5.4	4.8-5.8
Shear value	19.6	14.9-27.0	18.8	14.5-26.3	16.7	11.8-18.7	16.1	12.2-24.2	18.8	11.8-24.0
Number of chews	31.0	25-39	29.0	25-34	29.1	25-32	28.4	24-34	31.8	25-35
Cooking loss % drippings	4.6	3.1-5.2	4.0	3.1-4.4	5.1	4.5-5.9	4.8	3.2-6.0	4.6	3.8-5.2
Press fluid	6.9	5.5-7.8	6.8	6.0-7.3	7.3	6.7-8.5	7.4	6.6-7.8	6.9	6.5-7.3

Analysis of Variance of Live Grades and Scores

There was a significant difference between sire groups for weaning grades and yearling grades in 1962 (Table 12). However, there was no significant difference for these two traits in 1963. The difference in slaughter grade, classification score at slaughter and combined muscle score was nonsignificant for sires within these years. Sire did not have a significant effect on classification of individual conformation points except for steer's size in 1962 ($P<.05$) and 1963 ($P<.01$). The steer's size difference may be explained in part by significant differences in slaughter weight. The ordered array of sire group means for size and slaughter weight was quite similar within years.

There was a significant difference in the same ordered array for both dam's type and sire's type in 1962. However, mating sires with a higher type score to dam groups with a higher type score average failed to produce a significant difference in steer type.

Analysis of Variance of Live Weights and Gains

Sire within year had a significant effect on weaning weight in 1962 ($P<.05$) and 1963 ($P<.01$). The difference in weaning weight was primarily due to age difference at weaning as the sire effect on adjusted weaning weight and ADG from birth to weaning was not significant both years (Tables 12 and 13). There was a significant sire effect within years for yearling weight, slaughter weight and chilled carcass weight. Again this difference was chiefly due to age variation between the sire groups rather than the effect of sires as there was no significant effect of sires within years on weight per day of age and carcass weight per day of age.

There was a significant sire group difference in wintering gain for 1962 ($P<.05$) in favor of the heaviest weaning sire group. The wintering gain difference for 1963 sire groups was not significant. The sire effect within years for full feeding gain and total gain on feed (from weaning to slaughter) was nonsignificant both years (Tables 12 and 13).

Analysis of Variance of Slaughter Data

The sire effect within year or dressing percent and transit shrink was not significant for both years. The difference in shank circumference and forearm circumference in 1962 and forearm circumference in 1963 was significant ($P<.01$) in favor of the sire groups with significantly heavier slaughter weights (Tables 12 and 13). The sire effect on hide weight was nonsignificant in 1962, but significant at the $P<.05$ level in 1963, again in favor of sire groups with heavier slaughter weight.

Analysis of Variance of Carcass Data

The sire effect within year on carcass conformation was not significant in either the 1962 or 1963 calf crops. There was a significant difference ($P<.01$) between sire groups for marbling score in 1962; however, this did not result in significant difference in final carcass grade. Sires had a non-significant effect on marbling score and final carcass grade in 1963 (Tables 12 and 13). The sire group difference for loin eye area was significant ($P<.05$) in 1962. The 1962 sire effect on loin eye area per hundredweight of chilled carcass, fat thickness, total pounds of fat trim and fat thickness per hundredweight of carcass was nonsignificant. Sires had a significant effect on loin eye area per hundredweight in 1963. However, the sire effect on loin eye area and all measures of carcass fatness was nonsignificant for 1963.

Sire group differences for primal cut weight in 1962 was significant as was trimmed round weight for both years. When primal cut weight and trimmed round weight was expressed as percent of side weight, sire effect for these traits was not significant (Tables 12 and 13).

Analysis of Variance of Rib Data

Sires had a significant effect ($P<.01$) on the weight of the 9-10-11th rib separable lean in 1963. The difference in the separable lean weight generally corresponded to difference in sire group carcass weight. There was no significant 1963 sire effect on 9-10-11th rib lean when expressed as a percentage of total rib weight. The sire effect on weight and percent of separable lean in 1962 was not significant as was the weight and percent of 9-10-11th rib separable fat for both years (Tables 12 and 13).

There was no significant sire effect on tenderness either year in this study, evaluated by the shear value method and number of chews.

Also, sires had a non-significant effect on juiciness score, press fluid reading or cooking losses for both years.

CORRELATION ANALYSIS

Relationships Among Live Grades and Between Live Grades and Carcass Grades

Correlations between subjective weaning grades, yearling grades and slaughter grades were all positively significant and relatively similar (range .38 to .48, Table 14). This indicated that a steer remained at or near the same grade throughout the three live grading periods.

The correlations between the weaning and yearling grades and carcass conformation (grade before ribbing) ranged from .17 to .33. The correlations between slaughter grades and carcass conformation grades for the two years were considerably higher as would be expected (.51 and .52).

Slaughter grades and carcass marbling scores were positively correlated in 1962 ($r = .46$), but the correlation was considerably lower for the 1963 steers ($r = -.08$). Since the relationship between marbling score and final carcass grade was quite high for both years (.84 and .96), a significantly positive correlation resulted in 1962 between slaughter grade and final carcass grade (.34) while the relationship between the two grades in 1963 was negative (-.13). These results indicate that experienced graders can rather accurately predict the carcass conformation grade of a live steer. However, success in predicting the final carcass grade of live steers depends to a large extent

Table 12. 1962 Analysis of variance of traits studied and ordered array of sire group means for each trait.

Trait	F-test	Significance	Ordered Array of Sire Group Means
Live grades and scores			
1. Weaning grade	3.676	P < .05	1 4 2 3
2. Yearling grade	7.184	P < .01	1 4 2 3
3. Slaughter grade	1.393	N.S.	1 4 2 3
4. Classification score at slaughter	1.930	N.S.	1 4 2 3
5. Combined muscle score	1.686	N.S.	1 4 3 2
6. Steer's type	1.167	N.S.	1 2 4 3
7. Steer's size	2.877	P < .05	1 3 4 2
8. Steer's quality	0.321	N.S.	3 1 2 4
9. Steer's shoulder and chest	0.866	N.S.	1 4 3 2
10. Steer's rib	0.847	N.S.	1 2 4 3
11. Steer's loin	0.476	N.S.	1 2 4 3
12. Steer's rump	0.698	N.S.	3 1 4 2
13. Steer's round	1.388	N.S.	1 4 3 2
14. Steer's feet and legs	2.210	N.S.	1 4 2 3
15. Steer's neck	2.255	N.S.	1 2 4 3
16. Dam's type	5.067	P < .01	4 2 3 1
17. Dam's size	0.630	N.S.	4 1 3 2
18. Dam's round	1.081	N.S.	4 2 1 3
19. Classification score of dam	2.877	P < .05	4 2 1 3
20. Sire's type	5.600	P < .01	4 2 3 1

Table 12 (cont'd).

Trait	F-test	Significance	Ordered Array of Sire Group Means
21. Sire's size	4.290	P < .01	3 4 2 1
22. Sire's round	34.329	P < .01	2 1 4 3
23. Classification score of sire	217.316	P < .01	2 1 4 3
Weights and gains			
24. Weaning weight	11.678	P < .05	1 2 4 3
25. Adjusted weaning weight	0.854	N.S.	1 3 4 2
26. Yearling weight	11.419	P < .05	1 2 4 3
27. Slaughter weight	3.892	P < .05	1 3 4 2
28. Chilled carcass weight	4.206	P < .01	1 3 2 4
29. Wintering gain	3.692	P < .05	1 4 2 3
30. Full feeding gain	1.061	N.S.	3 1 4 2
31. Total gain on feed	1.449	N.S.	1 3 4 2
32. Weight per day of age	2.167	N.S.	3 1 4 2
33. Carcass weight per day of age	2.423	N.S.	1 3 4 2
34. A.D.G. birth to weaning	2.074	N.S.	4 3 1 2
Slaughter data			
35. Dressing percent	1.811	N.S.	3 1 2 4
36. Shrink	0.739	N.S.	3 2 4 1
37. Shank circumference	4.691	P < .01	1 3 4 2
38. Forearm circumference	11.595	P < .01	1 2 3 4
39. Hide weight	1.365	N.S.	1 3 4 2

Table 12 (cont'd).

Trait	F-test	Significance	Ordered Array of Sire Group Means
Carcass data			
40. Carcass conformation grade	2.054	N.S.	1 3 4 2
41. Marbling score	4.487	P < .01	1 4 2 3
42. Final carcass grade	2.205	N.S.	4 1 2 3
43. Loin eye area	3.773	P < .05	1 2 3 4
44. Loin eye area per hundred wt. of chilled carcass	0.652	N.S.	2 3 4 1
45. Fat thickness	1.942	N.S.	1 4 2 3
46. Fat thickness per hundred wt. of chilled carcass	2.062	N.S.	4 1 2 3
47. Primal cut weight	5.188	P < .01	1 2 4 3
48. Percent primal cuts of side weight	1.473	N.S.	3 2 1 4
49. Trimmed round weight	8.029	P < .01	1 2 3 4
50. Percent trimmed round of chilled side weight	1.497	N.S.	2 1 3 4
51. Total pounds of fat trim	1.394	N.S.	1 2 4 3
9-10-11th rib data			
52. Wt. of 9-10-11th rib separable lean	0.565	N.S.	1 2 3 4
53. % 9-10-11th rib lean	1.956	N.S.	3 2 4 1
54. Wt. of 9-10-11th rib separable fat	1.800	N.S.	1 4 2 3
55. % 9-10-11th rib fat	1.982	N.S.	1 4 2 3

Table 12 (concl.).

Trait	F-test	Significance	Ordered Array of Sire Group Means
6-7-8th rib data			
56. Juiciness score	1.072	N.S.	1 2 4 3
57. Shear value	1.534	N.S.	2 1 3 4
58. Number of chews	0.197	N.S.	3 2 1 4
59. Cooking loss, % drippings	2.759	N.S.	1 4 3 2
60. Press fluid	1.283	N.S.	3 2 1 4

Table 13. 1963 Analysis of variance of traits studied and ordered array of sire group means for each trait.

Trait	F-test	Significance	Ordered Array of Sire Group Means
Live grades and scores			
1. Weaning grade	.935	N.S.	3 4 5 2 1
2. Yearling grade	.911	N.S.	3 2 4 1 5
3. Slaughter grade	.981	N.S.	3 4 2 1 5
4. Classification score at slaughter	.821	N.S.	3 4 2 5 1
5. Combined muscle score	1.130	N.S.	3 4 2 5 1
6. Steer's type	1.422	N.S.	3 4 5 2 1
7. Steer's size	8.723	$P < .01$	3 1 4 2 5
8. Steer's quality	0.791	N.S.	2 5 4 1 3
9. Steer's shoulder and chest	0.708	N.S.	3 4 2 5 1
10. Steer's rib	1.034	N.S.	4 1 3 2 5
11. Steer's loin	1.487	N.S.	3 5 2 4 1
12. Steer's rump	0.223	N.S.	5 2 3 4 1
13. Steer's round	1.725	N.S.	3 5 4 2 1
14. Steer's feet and legs	1.022	N.S.	2 3 4 5 1
15. Steer's neck	0.576	N.S.	2 4 1 5 3
16. Dam's type	1.556	N.S.	2 5 1 4 3
17. Dam's size	1.215	N.S.	4 1 2 3 5
18. Dam's round	0.485	N.S.	2 4 5 1 3
19. Classification score of dam	1.572	N.S.	2 4 1 5 3
20. Sire's type	3.186	$P < .05$	5 3 2 4 1

Table 13 (cont'd).

Trait	F-test	Significance	Ordered Array of Sire Group Means
21. Sire's size	6.676	P < .01	3 4 5 2 1
22. Sire's round	7.157	P < .01	2 1 5 3 4
23. Classification score of sire	37.648	P < .01	3 2 1 5 4
Weights and gains			
24. Weaning weight	7.734	P < .01	3 1 4 2 5
25. Adjusted weaning weight	1.038	N.S.	3 2 4 1 5
26. Yearling weight	8.018	P < .01	3 1 4 2 5
27. Slaughter weight	2.924	P < .05	4 3 1 2 5
28. Chilled carcass weight	3.089	P < .05	3 4 1 2 5
29. Wintering gain	2.449	N.S.	2 4 1 5 3
30. Full feeding gain	0.897	N.S.	4 5 3 2 1
31. Total gain on feed	1.022	N.S.	2 4 5 1 3
32. Weight per day of age	.932	N.S.	2 4 3 5 1
33. Carcass weight per day of age	.731	N.S.	3 2 4 5 1
34. A.D.G. birth to weaning	1.791	N.S.	3 2 5 4 1
Slaughter data			
35. Dressing percent	1.749	N.S.	3 2 1 4 5
36. Shrink	1.567	N.S.	2 4 5 1 3
37. Shank circumference	2.248	N.S.	4 3 2 1 5
38. Forearm circumference	4.504	P < .01	4 1 2 3 5
39. Hide weight	2.652	P < .05	4 3 1 2 5

Table 13. (cont'd).

Trait	F-test	Significance	Ordered Array of Sire Group Means
Carcass data			
40. Carcass conformation grade	1.247	N.S.	2 3 5 4 1
41. Marbling score	1.332	N.S.	3 4 5 1 2
42. Final carcass grade	0.772	N.S.	3 4 5 1 2
43. Loin eye area	0.710	N.S.	2 1 4 3 5
44. Loin eye area per hundred wt. of chilled carcass	2.591	P < .05	2 5 1 4 3
45. Fat thickness	0.287	N.S.	5 4 3 1 2
46. Fat thickness per hundred wt. of chilled carcass	0.652	N.S.	5 4 1 3 2
47. Primal cut weight	2.324	N.S.	3 4 1 2 5
48. Percent primal cuts of chilled side weight	2.298	N.S.	2 1 5 4 3
49. Trimmed round weight	2.986	P < .05	3 1 2 4 5
50. Percent trimmed round of chilled side weight	1.548	N.S.	2 1 5 3 4
51. Total pounds of fat trim	0.895	N.S.	3 4 1 5 2
9-10-11th rib data			
52. Wt. of 9-10-11th rib separable lean	4.712	P < .01	3 2 1 4 5
53. % 9-10-11th rib lean	1.286	N.S.	2 1 3 5 4
54. Wt. of 9-10-11th rib separable fat	0.490	N.S.	3 1 4 5 2
55. % 9-10-11th rib fat	1.073	N.S.	5 4 3 1 2

Table 13 (concl.).

Trait	F-test	Significance	Ordered Array of Sire Group Means
6-7-8th rib data			
56. Juiciness score	2.377	N.S.	4 3 1 2 5
57. Shear value	1.032	N.S.	1 2 5 3 4
58. Number of chews	1.197	N.S.	5 1 3 2 4
59. Cooking loss, % drippings	1.857	N.S.	3 4 5 1 2
60. Press fluid	1.438	N.S.	4 3 5 1 2

Table 14. Correlations among live grades and between live grades and carcass grades.[a]

	Weaning Grade	Yearling Grade	Slaughter Grade	Carcass Conformation	Marbling Score	Final Carcass Grade
Weaning grade		.48	.39	.17	.49	.38
Yearling grade	.46		.40	.20	.21	.03
Slaughter grade	.43	.48		.51	.46	.31
Carcass conformation	.33	.17	.52		.48	.33
Marbling score	-.29	-.18	-.07	-.15		.84
Final carcass grade	-.26	-.21	-.13	-.14	.96	

[a] 1962 Correlations are above the diagonal.
Levels of significance, 68 degrees of freedom
$P < .01$ 0.306
$P < .05$ 0.235

1963 Correlations are below the diagonal.
Levels of significance, 49 degrees of freedom
$P < .01$ 0.358
$P < .05$ 0.276

on whether or not the steer happens to possess the degree of marbling needed for the particular conformation grade.

Relationships Between Live Grades and Scores at Slaughter

The correlations between the subjective weaning, yearling and slaughter grades and the live classification scores placed on the steers prior to slaughter were positive (range .38 to .81, Table 15). As would be expected, the slaughter grades showed the highest relationship of the three grades to the classification score (.80 and .81).

In addition to slaughter grade and classification scores, each steer was scored at slaughter for width and muscling through the loin, rump and round region. The sum of these scores for each steer is referred to as a combined muscle score. There was a positive relationship between the subjective live grades and combined muscle score (range .26 to .82, Table 15). Slaughter grade showed the highest relationship both years (.74 and .82). This would indicate that heavier muscled steers through the loin, rump and round grade higher, as would be expected.

Relationship Between Weaning Weight Measures and Weight Per Day of Age

Adjustment of weaning weights consists of converting the weights of calves to a standard age in days (210 days in this study), making allowances for expected differences in maternal environment due to differences in the age of dam and converting all calves to an equal sex basis. The weaning weights are adjusted to a standard age of calf, etc.

Table 15. Correlations between live grades and slaughter scores.[a]

	Live Classification Score at Slaughter		Combined Muscle Score	
	1962	1963	1962	1963
Weaning grade	.38	.49	.26	.55
Yearling grade	.50	.50	.32	.49
Slaughter grade	.81	.79	.74	.82

[a] 1962 levels of significance, 68 degrees of freedom
$P < .01$ 0.306
$P < .05$ 0.235

1963 levels of significance, 49 degrees of freedom
$P < .01$ 0.358
$P < .05$ 0.276

in order to more accurately evaluate the production ability of dams and the bred in performance ability of calves.

In this study, the correlations between adjusted weaning weight and weight per day of age (.52 and .58, Table 16) were significantly higher than the correlations between actual weaning weight and weight per day of age (.42 and .19). This indicates that adjusting the weaning weight not only gives a better prediction of a cow's mothering ability and performance ability of the calf up to weaning, but also means that the adjusted weights also gave a more accurate prediction of total performance in this study.

Relationships Between Grades and Gain on Feed

Many researchers have reported little or no connection between gains and grades. In this study, weight gains were measured during the wintering phase, during the full feeding phase and the total gain on feed, i.e., the sum of the gain made for the two phases (gain from weaning to slaughter). The live grades obtained were weaning, yearling and slaughter grades.

The only positive correlations obtained between grades and gains were between slaughter grade and full feed gain (.14 and .28, Table 17) and slaughter grade and total gain on feed (.42 and .13). The comparison of weaning grade and gains consistently gave the most negative correlations (range -.20 to -.35). This might lead one to suspect that selecting for higher grading calves at weaning would decrease performance in the feedlot. However, it is possible that calves in higher condition at weaning graded higher while the lower conditioned calves graded lower.

Table 16. Correlations between weaning weight measures and weight per day of age.[a]

	Weight Per Day of Age	
	1962	1963
Adjusted weaning weight	.52	.58
Actual weaning weight	.42	.19

[a] 1962 levels of significance, 68 degrees of freedom
$P < .01$ 0.306
$P < .05$ 0.235

1963 levels of significance, 49 degrees of freedom
$P < .01$ 0.358
$P < .05$ 0.276

Table 17. Correlations between grades and gain on feed and daily gain.[a]

	Weaning Grade		Yearling Grade		Slaughter Grade		Carcass Conformation		Marbling Score		Final Carcass Score	
	1962	1963	1962	1963	1962	1963	1962	1963	1962	1963	1962	1963
Wintering gain	-.35	-.20	-.06	-.02	-.06	-.15	.03	.08	-.14	.01	-.37	.03
Full feeding gain	-.24	-.25	-.25	-.13	.14	.28	.22	.29	-.03	.24	-.17	.18
Total gain on feed	-.24	-.25	-.03	-.12	.42	.13	.45	.27	.32	.19	.10	.16
Weight per day of age	.11	-.14	.01	.05	.41	.25	.41	.31	.29	.30	.06	.24
A.D.G. birth to weaning	.34	.23	.13	.30	.16	.15	.11	.26	.08	.04	-.03	-.02

[a] 1962 levels of significance, 68 degrees of freedom
$P < .01$ 0.306
$P < .05$ 0.235

1963 levels of significance, 49 degrees of freedom
$P < .01$ 0.358
$P < .05$ 0.276

If indeed the higher condition and grading calves gained slower in the feedlot and/or the lower condition and grading steers gained faster, this would result in a negative weaning grade and subsequent gain correlation. Therefore, we may be studying condition and gain as well as grade and gain. At any rate, the relatively low magnitude of the negative weaning grade and gain correlations is not grounds for alarm.

The yearling grade and gain correlations were of a low magnitude and ranged from -.02 to -.25.

Relationship Between Grades and Weight Per Day of Age

Correlations between average daily gain from birth to weaning and live grades ranged from .15 to .34 (Table 17). The highest correlations occurred between weaning grade and daily gain to weaning while the lowest relationships were between slaughter grade and daily gain prior to weaning. Thus, average daily gain to weaning had its greatest effect on weaning grades, as would be expected.

The correlations between grades and weight per day of age to slaughter ranged from -.15 to .41. The correlations between total average daily gain and weaning and yearling grades were low (range -.14 to .10). The correlations between total daily gain and slaughter grade for the two years were .41 and .25. These results indicate that steers with the ability to make greater daily gains did not necessarily grade higher at weaning or yearling time, but did tend to grade higher at slaughter.

Relationships Between Gain and Carcass Grades and Marbling

A study of correlations found between carcass conformation grade and the different methods of measuring daily gain shows that these correlations closely parallel those found between slaughter grade and daily gains for the various periods. The lowest correlations were found between carcass conformation and daily gains during the earlier part of the calves' lives. Correlations between carcass conformation grade and daily gain to weaning and wintering daily gain ranged from .03 to .26 (Table 17). The correlations between carcass conformation grade and daily gain on feed and full feeding daily gain ranged from .22 to .45 for the two years. The relationship between carcass conformation and weight per day of age was .41 and .31 for the two years. It can be concluded that gains made during the feeding phases prior to slaughter and greater weight per day of age had the most effect on carcass conformation.

The correlations between marbling score and daily gain to weaning and wintering daily gain were quite low (range -.14 to .08). Marbling score and daily gain on full feed were related at a magnitude of -.03 and .24 for the two years. Total daily gain on feed (weaning to slaughter) and weight per day of age were correlated to marbling score at a higher magnitude (range .19 to .33). This indicates that by selecting cattle for increased weight for age and greater gains on feed, we are not inadvertently selecting cattle that have less marbling.

The correlations between final carcass grade and various gains generally paralleled the marbling-gain relationships, but at a lower magnitude. Gains at the various periods had little or no effect on final carcass grade.

In studying all the gain-grade combinations, it seems that gains made during a particular period have the greatest effect on grades at the end of the gain period, i.e., birth to weaning gains positively correlated to weaning grade and full feed gain and weight per day of age positively correlated to slaughter grade. However, steers that grade higher at the end of a particular period tend to gain less in subsequent periods, i.e., weaning grade negatively related to wintering gain and full feed gain, yearling grade negatively related to full feeding gain and total gain on feed.

Relationships Between Gains at Various Periods and Weight Per Day of Age

The correlations between average daily gain from birth to weaning and feedlot performance during various phases after weaning were low (range -.08 to .16, Table 18). This indicates that calves that had higher weight per day of age at weaning did not consistently gain the fastest after weaning. However, a comparison of birth to weaning daily gains with weight per day of age reveals highly positive correlations of .58 and .56, indicating that steers that made the greatest average daily gains to slaughter usually exhibited their potential growing ability by weaning time.

Correlations between wintering daily gain and full feeding daily gain were .62 in 1962 and .08 for 1963. The correlations between wintering gain and total gain on feed were more consistent (.45 and .64)

Table 18. Correlations between gains at various periods and weight per day of age.[a]

	Wintering Gain	Full Feeding Gain	Total Gain on Feed	Weight per Day of Age	A.D.G. Birth to Weaning
Wintering gain		.62	.45	.33	-.08
Full feeding gain	.08		.67	.55	.05
Total gain on feed	.64	.82		.89	.16
Weight per day of age	.29	.72	.72		.58
A.D.G. birth to weaning	-.04	-.01	.02	.56	

[a] 1962 Correlations are above the diagonal.
Levels of significance, 68 degrees of freedom
$P < .01$ 0.306
$P < .05$ 0.235

1963 Correlations are below the diagonal.
Levels of significance, 49 degrees of freedom
$P < .01$ 0.358
$P < .05$ 0.276

for the two years. Wintering daily gain showed a rather low relationship to weight per day of age (r = .33 and .29).

Full feeding daily gains were highly positive when correlated to total gain on feed (.67 and .82) and weight per day of age (.55 and .72). Total daily gain on feed showed the highest relationships to weight per day of age (r = .89 and .73). Since total daily gain on feed measures performance of the steer from weaning to slaughter, one might expect it to have the highest relationship to total weight per day of age.

Relationship of Carcass Fat Measures to Slaughter and Carcass Grades and Marbling

The four measures of carcass fat (fat thickness, fat thickness per 100 pounds, weight of 9-10-11th rib separable fat and per cent 9-10-11th rib fat) showed a higher relationship to both slaughter grade and carcass conformation grade in 1962 than in 1963. The correlations between slaughter grade and the carcass fat measures ranged from .24 to .45 (Table 19) in 1962. The relationship of fat to carcass conformation ranged from .21 to .34 the first year.

The 1963 correlations obtained between fat measures and slaughter grade ranged from -.14 to .26 while the correlations between fat measures and carcass conformation grade were quite consistent, range .13 to .21.

The correlations between fat estimations and marbling ranged between .32 and .46 for 1962 while the 1963 correlations fell between .25 and .38. Fat measures and final carcass grade correlations where higher in 1963 than for the 1962 calves (1962 r = .14 to .26; 1963 r = .26 to .35).

Table 19. Correlations between carcass fat and carcass and growth traits.

Trait	Fat Thickness		Fat Thickness Per Cwt.		9-10-11th Rib Separable Fat		% 9-10-11th Rib Separable Fat	
	1962[a]	1963	1962	1963	1962*	1963*	1962*	1963*
Slaughter grade	.45	-.03	.40	-.14	.24	.26	.32	.18
Carcass conformation	.34	.20	.26	.13	.23	.21	.21	.14
Marbling score	.37	.31	.32	.25	.37	.37	.46	.38
Final carcass grade	.14	.35	.15	.31	.18	.28	.26	.26
Loin eye area	.25	-.29	.11	-.41	.34	.15	.14	-.11
Loin eye area per cwt.	-.52	-.49	-.40	-.34	-.47	-.54	-.47	-.52
Primal cut weight	.44	.24	.16	-.15	.64	.65	.42	.35
% Primal cuts	-.50	-.50	-.44	-.31	-.59	-.66	-.63	-.67
9-10-11th Rib lean*	-.03	.07	-.25	-.17	.38	.25	.03	.25
% 9-10-11th Rib lean*	-.74	-.48	-.67	-.35	-.87	-.79	-.98	-.90
Slaughter weight	.60	.21	.38	-.07	.70	.68	.52	.42
Weight per day of age	.58	.24	.40	.02	.64	.60	.47	.42
Chilled carcass weight	.65	.27	.43	-.02	.75	.74	.55	.47
Wintering gain	.27	.14	.15	.09	.47	.11	.39	.01
Full feeding gain	.20	.22	.09	.09	.37	.43	.26	.34
Total gain on feed	.54	.25	.38	.12	.60	.40	.45	.27

[a] 1962 Levels of significance
68 degrees of freedom
P < .01 0.306
P < .05 0.235

1963 Levels of significance
49 degrees of freedom
P < .01 0.358
P < .05 0.276

*38 degrees of freedom
P < .01 0.403
P < .05 0.312

*34 degrees of freedom
P < .01 0.424
P < .05 0.329

It can be concluded that there is a positive relation between carcass finish or fat and the above traits. Marbling score was consistently the most positively correlated to fat, approximately .35. Fat seemed to be related to slaughter grade, carcass conformation and final carcass grade in the neighborhood of .25.

Relationships Between Fat Measures and Slaughter Weight and Weight Per Day of Age

Slaughter weight tended to be positively related to the various measures of carcass fat. This would be expected, since heavier cattle usually carry more condition.

Weight per day of age was positively correlated to both fat thickness and fat per cwt. at the 12th rib. However, the 1962 relationships (r = .58 and .40, Table 19) were higher than those for 1963 (r = .24 and .02). Thus, faster gaining cattle tended to be fatter in 1962 than in 1963. Here again the shorter feeding period and somewhat lighter market weight for the 1963 calves may have effected the correlations. Weight per day of age was significantly correlated to both weight and per cent fat in the 9-10-11th rib (range .42 to .64).

Relationship Between Gain on Feed and Carcass Fat

A study of the correlations between the various fat measures of the carcass and gains on feed reveals a positive trend in relationship between fat and gain (Table 19). The correlations between gains on feed and absolute fat measures (fat thickness at the 12th rib and grams of fat in 9-10-11th rib) ranged from .20 to .60 in 1962. The 1963 correlations between the same traits ranged from .11 to .43.

When the carcass fat was expressed on a percentage basis (fat thickness per 100 pounds carcass weight and percent 9-10-11th rib fat) the relationships to gain were lower (1962 r = .09 to .39; 1963 r = .01 to .34).

Thus, faster gaining cattle tended to have more fat; however, the relationship was not strongly significant.

Relationships Between Carcass Fat Measures and Carcass Lean Measurement

Loin eye area at the 12th rib was positively related at a low magnitude to fat thickness at the same point in 1962 (r = .25). However, the correlation between the two traits was negative at nearly the same magnitude (-.29) in 1963 (Table 19). The correlations between loin eye area and 9-10-11th rib separable fat was .34 and .15 for the two years. One explanation of the wide difference in loin eye area-fat relationships for the two years might be that the 1962 steers were on full feed longer, and marketed at a heavier weight than the 1963 steers.

When the carcass fat measures were expressed on a percentage basis, the correlations between the fat measures and loin eye area were considerably lower. The correlations between loin eye area and fat thickness per 100 pounds carcass weight were .11 and -.41 for the two years while percent 9-10-11th rib fat and loin eye area were related at the level of .14 and -.11.

Loin eye area per hundredweight was consistently negatively correlated to the fat measures for the two years (range -.34 to -.54). Thus, steers with more loin eye area per cwt. tended to be trimmer.

This writer offers this explanation of the negative relationship: steers that are lighter in weight and heavier muscled tend to excel in loin eye per cwt. measurement. Also, these cattle tend to have less fat cover, while heavier weight cattle often carry more fat and have a lower loin eye area, carcass weight ratio, thus creating the negative correlations.

Correlations between weight of 9-10-11th rib lean and loin eye area were essentially zero for the two years (-.03 and .07) while the relationship between 9-10-11th lean weight and weight of 9-10-11th rib fat was .38 and .25 for the two years. Weight of rib lean was negatively correlated to fat thickness per cwt. (-.25 and -.17) and related to percent 9-10-11th separable fat at the level of .03 and .25 for the two years.

Percent 9-10-11th rib separable lean was negatively correlated to the fat measures (range -.35 to -.98) for the two years.

Relationships Between Lean Measures and Carcass Traits

The absolute measures of carcass lean, i.e., loin eye area and grams of 9-10-11th rib separable lean, were generally positively related to slaughter grade. With the exception of the 1962 relationship between slaughter grade and 9-10-11th rib lean (r = .16) the correlations between lean measures and slaughter grade ranged from .15 to .32 (Table 20). The correlations between carcass conformation grade and the absolute measures of carcass lean followed the same general trend (range .14 to .38) while the relationship between lean and marbling score and final carcass grade were lower and essentially zero (Table 20).

These results indicate that steers with a higher slaughter and/or carcass conformation grade tended to have more carcass lean mass.

Table 20. Correlations of lean and primal cuts to grades and weights.[a]

	Loin Eye Area		9-10-11th Rib Lean		Primal Cut Weight		Trimmed Round Weight		Loin Eye Area Per Cwt.		% 9-10-11th Rib Lean		% Primal Cuts		% Trimmed Round	
	1962	1963	1962*	1963*	1962	1963	1962	1963	1962	1963	1962*	1963*	1962	1963	1962	1963
Slaughter grade	.32	.32	-.16	.15	.23	.33	.28	.40	-.27	-.04	-.36	-.18	-.13	-.18	.03	-.02
Carcass conformation	.38	.31	.14	.20	.22	.26	.16	.32	-.21	-.01	-.19	-.10	-.23	-.05	-.18	.04
Marbling score	.12	.08	-.07	.15	.15	.23	.06	.01	-.29	-.31	-.44	-.10	-.41	-.54	-.33	-.63
Final carcass grade	-.09	-.08	-.12	.18	-.02	.18	-.08	-.02	-.19	-.24	.25	-.09	-.22	-.42	.20	-.53
Slaughter weight	.58	.30	.59	.60	.92	.94	.77	.79	-.57	-.56	-.48	-.32	-.31	-.51	-.30	-.56
Carcass weight	.58	.32	.62	.61	.96	.97	.80	.85	-.60	-.58	-.51	-.39	-.39	-.56	-.35	-.54
Weight per day of age	.44	.32	.52	.46	.73	.79	.52	.62	-.60	-.38	-.44	-.28	-.42	-.41	-.45	-.54
Wintering gain	.27	.11	.33	.28	.59	.29	.41	.28	-.30	.07	.36	.05	-.22	-.08	-.21	-.02
Full feed gain	.31	.20	.33	.32	.43	.49	.30	.27	-.32	-.22	-.15	-.25	-.11	-.34	-.22	-.53
Total gain on feed	.52	.22	.48	.42	.72	.54	.54	.37	-.54	-.21	-.43	-.09	-.22	-.22	-.31	-.42

[a] 1962 Levels of significance
68 degrees of freedom
$P < .01$ 0.306
$P < .05$ 0.235

*38 degrees of freedom
$P < .01$ 0.403
$P < .05$ 0.312

1963 Levels of significance
49 degrees of freedom
$P < .01$ 0.358
$P < .05$ 0.276

*34 degrees of freedom
$P < .01$ 0.424
$P < .05$ 0.329

However, the only correlations that were significant at the $P < .01$ level were the 1962 relationships between loin eye area and slaughter and carcass conformation grade.

The measures of carcass lean were also calculated on the basis of loin eye area per 100 pounds carcass and percent lean of the 9-10-11th rib cut. Loin eye area per cwt. was negatively related at a generally low magnitude to slaughter grade, conformation of carcass, marbling and final carcass grade (range -.01 to -.29). Percentage lean of the 9-10-11th rib section was likewise negatively correlated, but at a slightly higher level, to the slaughter and carcass grades and marbling (range -.09 to -.44, Table 20).

These correlations indicate that while lean mass increases slightly with higher slaughter and carcass grades, when figured on a percentage basis, there is a negative trend between slaughter and carcass conformation and lean percentage.

Relationship Between Carcass Lean and Weights

There was a strong positive relationship between the absolute lean measures and both slaughter and carcass weight. In 1962, loin eye area was related to slaughter weight and carcass weight at the level of .58 for the two traits (Table 20). The 1963 correlations between loin eye area and slaughter and carcass weight were .30 and .32.

The correlations between grams of 9-10-11th rib lean and slaughter and carcass weight were quite similar for the two years (range of .59 to .62, Table 20).

There also was a positive correlation between weight per day of age and carcass lean (range .32 to .52 for the two years).

Loin eye area per cwt. was highly negatively correlated to slaughter weight and carcass weight (range -.56 to -.60, Table 20). Thus, measurement of loin eye area per hundred pounds of carcass weight favors lighter weight steers. Percent 9-10-11th rib lean was similarly related to slaughter and carcass weight (-.32 to -.51).

The correlations between weight per day of age and loin eye area per cwt. were -.60 and -.38 and between weight per day and percent rib lean, -.44 and -.28.

Relationship Between Lean and Gains on Feed

There was a positive relationship between loin eye area and gains made during the wintering phase, full feeding phase and total gain for the two phases (referred to a total gain on feed). The correlations between loin eye area and winter and full feeding gain were .27 and .31 for 1962 and .11 and .20 for 1963. Loin eye area and total gain on feed were related at the level of .52 and .22 for the two years (Table 20).

Weight of 9-10-11th rib lean and winter and full feeding gain correlations ranged between .28 and .33 for both years. Total gain on feed and 9-10-11th rib lean were related at the level of .48 and .42.

Loin eye area per cwt. and winter and full feeding gain correlations ranged from -.32 to .07 (Table 20). Loin eye area per cwt. and total gain on feed were related at the level of -.54 and -.21 for the two years. The correlations between percent separable lean of the 9-10-11th rib and winter gain were positive (.36 and .05), while full feed gains and total gain on feed were negatively related to separable lean (range -.09 to -.43).

Relationship Between Primal Cuts and Carcass Traits

The weight of the primal cuts (trimmed round, loin, rib and chuck) was related to slaughter grade and carcass conformation grade in a positive manner (range .22 to .33, Table 20). The correlations between primal cuts and marbling score were .15 and .23 for the two years, while final carcass grade and primal cuts were related at the level of -.02 and .18.

Weight of trimmed round was positively correlated to slaughter grade and carcass conformation grade (range .16 to .40). The correlations of trimmed round to marbling and final carcass grade were essentially zero (range -.08 to .01).

Primal cuts based on side weight were negatively correlated to slaughter and carcass grade (range -.05 to -.23, Table 20). The relationship between percent primal cuts and marbling score and final carcass grade ranged from -.22 to -.54. The correlations between percent trimmed round of side weight and slaughter and carcass conformation grades ranged from -.20 to -.63.

Relationship Between Primal Cuts and Weight

Primal cut weights were highly correlated to slaughter and carcass weights, as would be expected. Primal cut weight and slaughter weight were related at the level of .92 and .94 for the two years, while the primal cut-carcass weight relationship was .96 and .97 (Table 20).

The correlations between trimmed round weight and slaughter weight were .77 and .79 and between round weight and carcass weight, .80 and .85. From these results it is safe to conclude that weight of primal cuts is dependent more on slaughter weight of the steer, rather than slaughter grade.

Weight per day of age was correlated to primal cut weight at .73 and .79 and to trimmed round weight at .52 and .62.

Percent primal cuts and percent trimmed round were both negatively correlated to slaughter weight and carcass weight. The correlations ranged between -.30 and -.56 (Table 20). Percent primal cuts and percent trimmed round were also negatively related to weight per day of age for both years (range -.41 to -.54). In this study, primal cuts and trimmed round based on a percentage tended to favor lighter weight and slower gaining cattle.

Relationships Between Primal Cuts and Gains

Both primal cut weight and trimmed round weight were positively correlated to gains in the feedlot. The correlations between primal cut and trimmed round weight and winter gain ranged from .28 to .59 (Table 20). Full feed gain was positively related to primal cuts and trimmed round weight, range .27 to .49. The correlations between primal cuts and total gain on feed were .72 and .54 for the two years, while trimmed round and gain on feed were related at the level of .54 and .37.

Primal cuts based on a percent of side weight were negatively related at a low magnitude in most cases in feedlot gains. The correlations between percent primal cuts and gains ranged from -.08 to -.34. Percent trimmed round and feedlot gains were related between -.02 and -.54 (Table 20).

Relationships Between Measures of Carcass Fatness

Carcass finish was analyzed by five methods in this study: Fat thickness at the twelfth rib; fat thickness per hundredweight of carcass; weight of fat trim from the primal cuts; 9-10-11th rib separable fat and percent 9-10-11th rib separable fat. Correlations of each fat measure to the other fat measures were positive and ranged from .34 to .96 for both years (Table 21). Fat thickness at the twelfth rib correlated to the remaining fat measures ranged from .60 to .96 and averaged .74 for the two years. This was the highest range and average correlations of individual fat measures and the other fat indications. Thus, twelfth rib fat thickness, which was the easiest fat indicator to obtain, was the most consistent indicator of carcass fatness of the five methods studied.

Table 21. Correlations among measures of carcass fatness.[a]

	Fat Thickness	Fat Thickness Per Cwt.	Pounds Fat Trim	9-10-11th Rib Fat*	% 9-10-11th Rib Fat*
Fat thickness		.96	.75	.66	.73
Fat thickness per cwt.	.96		.64	.49	.65
Pounds fat trim	.65	.42		.70	.73
9-10-11th Rib fat*	.61	.34	.81		.93
% 9-10-11th Rib fat*	.60	.44	.73	.91	

[a] 1962 correlations are above the diagonal. Levels of significance:

68 degrees of freedom		*38 degrees of freedom	
$P < .01$	0.306	$P < .01$	0.403
$P < .05$	0.235	$P < .05$	0.312

1963 correlations are below the diagonal. Levels of significance:

49 degrees of freedom		*34 degrees of freedom	
$P < .01$	0.358	$P < .01$	0.424
$P < .05$	0.276	$P < .05$	0.329

Relationships Between Carcass Lean Measures

Carcass lean mass was studied by loin eye area measurement, primal cut weight, trimmed round weight, 9-10-11th rib separable lean and the expression of each of these measures as a ratio or a percentage--loin eye area per hundredweight of chilled carcass, trimmed primal cut weight of side weight, trimmed round of side weight and percent lean of 9-10-11th rib. The lean mass correlations were not as consistent with each other as were the carcass fat correlations presented above. In general, the actual lean measures (unadjusted for carcass or side weight) were positively correlated at significant levels to each other--primarily in a range of .35 to .65 (Table 22). Also, LEA per hundredweight and the lean measures expressed as a percent were positively correlated to each other in a general range of .35 to .62.

The correlations between the actual lean measurements and lean measures as a ratio or percent of carcass weight were of a low to negative magnitude (general range of zero to -.45) with the exception of loin eye area and LEA per hundredweight (.58 for 1963 and .26 for 1962).

SUMMARY AND CONCLUSIONS

Data from two successive calf crops born the spring of 1962 and the spring of 1963 at the Jim and Clifford Houghton Stock Farm, Tipton, Kansas, were used in this study. The calves were the progeny of four bulls and 70 cows in 1962 and five bulls and 51 cows in 1963. The dams were good, commercial Hereford cows. The sires used in this

Table 22. Correlations among various carcass lean measurements.[a]

	Loin Eye Area	Loin Eye Area Per Cwt.	9-10-11th Rib Lean*	% 9-10-11th Rib Lean*	Primal Cut Weight	% Primal Cut	Trimmed Round Weight	% Trimmed Round
Loin eye area		.26	.55	.07	.54	-.08	.08	-.08
Loin eye area per cwt.	.58		-.07	.52	-.45	.35	-.34	.31
9-10-11th Rib lean*	.60	-.04		.10	.65	-.02	.48	-.23
% 9-10-11th Rib lean*	.20	.53	.34		-.38	.62	-.22	.48
Primal cut weight	.42	-.52	.63	-.31		-.13	.89	-.15
% Primal cuts	-.03	.50	-.16	.51	-.36		.09	.78
Trimmed round weight	.48	-.36	.64	-.11	.91	-.18		.28
% Trimmed round	.04	.52	-.13	.58	-.40	.81	-.03	

[a] 1962 correlations are above the diagonal. Levels of significance:

68 degrees of freedom		*38 degrees of freedom	
$P < .01$	0.306	$P < .01$	0.403
$P < .05$	0.235	$P < .05$	0.312

1963 correlations are below the diagonal. Levels of significance:

49 degrees of freedom		*34 degrees of freedom	
$P < .01$	0.358	$P < .01$	0.424
$P < .05$	0.276	$P < .05$	0.329

study were registered Hereford bulls of superior type. The calves were identified as to sire and dam at birth. The calves were weighed and graded at weaning time, then went through a wintering or limited energy intake period. At the end of this phase, the cattle were again weighed and graded and then placed on full feed until reaching slaughter condition and weight. No attempt was made to hold weaning or slaughter weight constant. Gross carcass data were collected on all steers. Carcasses representing each sire group were randomly selected for further study. The right side of each selected carcass was broken down into the four primal cuts and trimmed to 0.25 inch outside fat cover. The 9-10-11th rib cut was physically separated into fat, lean and bone. The 6-7-8th rib cut was used for cooking, tenderness and sensory tests.

Effects of sires within year for all traits were studied by analysis of variance according to Snedecor. Simple phenotypic correlations were computed for all traits.

From the results of this study, the following conclusions appear justified:

1. Sire had a non-significant effect on most production traits both years including adjusted weaning weight, total gain on feed, weight per day of age, and slaughter grade.

2. Sire effect was nonsignificant for the carcass traits of final carcass grade, fat thickness at the twelfth rib, pounds of fat trim, percent primal cuts of chilled side weight and percent round of chilled side weight.

3. Sires had a significant effect one year but not both on weaning grade, yearling grade, yearling gain, marbling score, loin eye area, loin eye area per hundredweight of chilled carcass and primal cut weight.

4. Fat thickness at the twelfth rib, which was the easiest fat indicator to obtain, was the most consistent indicator of carcass fatness of the five methods studied.

5. Cattle with higher weight per day of age had more pounds of trimmed wholesale cuts but a lower percentage of trimmed cut when expressed on a trimmed cut weight:carcass weight basis.

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APPENDIX

Table 1. Additive corrective factors for adjusting the weaning weight of a calf to 210 days.

	Correction factor (pounds)
Age of dam	
2	+60
3	+49
4	+31
5	+23
6	0
7	0
8	0
9 and older	+20
Sex of calf	
steer	0
heifer	+20

Table 2. Numerical values for live animal grades, carcass conformation, and carcass quality scores.

Grade	Minus	Average	Plus
Prime	14	15	16
Choice	11	12	13
Good	8	9	10
Standard	5	6	7
Commercial	2	3	4

Table 3. Score card for grading cattle at slaughter.[a]

General appearance			30
	type	14	
	size	10	
	quality	6	
Beef character			50
	shoulder and chest	8	
	rib and back	10	
	loin	10	
	rump	10	
	thighs and round	12	
Breed qualities			20
	feet and legs	12	
	head and neck	8	
Total points			100

[a] American Angus Association Herd Classification Report.

Table 4. Numerical values of visual scores for forearm muscling, over the top muscling, and muscling through the round.

Visual score	Value
Very heavy muscle	6
Heavy muscle	5
Moderately heavy muscle	4
Medium muscle	3
Slightly light muscle	2
Light muscle	1

Table 5. Numerical values for marbling scores.

	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 6. Numerical values for maturity scores.

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

Table 7. Numerical values for juiciness scores.

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

Table 8. Numerical values for tenderness scores.

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

A SIRE EVALUATION STUDY IN BEEF CATTLE WITH EMPHASIS ON RELATIONSHIPS BETWEEN PROGENY PERFORMANCE, CONFORMATION AND CARCASS CHARACTERISTICS

by

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Data from two successive calf crops born the spring of 1962 and the spring of 1963 at the Jim and Clifford Houghton Stock Farm, Tipton, Kansas, were used in this study. The calves were the progeny of four bulls and 70 cows in 1962 and five bulls and 51 cows in 1963. The dams were good, commercial Hereford cows. The sires used in this study were registered Hereford bulls of superior type. The calves were identified as to sire and dam at birth. The calves were weighed and graded at weaning time, then went through a wintering or limited energy intake period. At the end of this phase, the cattle were again weighed and graded and then placed on full feed until reaching slaughter condition and weight. No attempt was made to hold weaning or slaughter weight constant. Gross carcass data were collected on all steers. Carcasses representing each sire group were randomly selected for further study. The right side of each selected carcass was broken down into the four primal cuts and trimmed to 0.25 inch outside fat cover. The 9-10-11th rib cut was physically separated into fat, lean and bone. The 6-7-8th rib cut was used for cooking, tenderness and sensory tests.

Effects of sires within year for all traits were studied by analysis of variance according to Snedecor. Simple phenotypic correlations were computed for all traits.

From the results of this study, the following conclusions appear justified:

1. Sire had a non-significant effect on most production traits both years including adjusted weaning weight, total gain on feed, weight per day of age, and slaughter grade.

2. Sire effect was nonsignificant for the carcass traits of final carcass grade, fat thickness at the twelfth rib, pounds of fat trim, percent primal cuts of chilled side weight and percent round of chilled side weight.

3. Sires had a significant effect one year but not both on weaning grade, yearling grade, yearling gain, marbling score, loin eye area, loin eye area per hundredweight of chilled carcass and primal cut weight.

4. Fat thickness at the twelfth rib, which was the easiest fat indicator to obtain, was the most consistent indicator of carcass fatness of the five methods studied.

5. Cattle with higher weight per day of age had more pounds of trimmed wholesale cuts but a lower percentage of trimmed cut when expressed on a trimmed cut weight:carcass weight basis.