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Performance, carcass characteristics and ultrasonic estimates of changes in muscle and fat of bulls, steers and heifers

John Newton Williams

To the Graduate Council:

I am submitting herewith a dissertation written by John Newton Williams entitled "Performance, carcass characteristics and ultrasonic estimates of changes in muscle and fat of bulls, steers and heifers." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

C.S. Hobbs, Major Professor

We have read this dissertation and recommend its acceptance:

O. Glen Hall, Luther Keller, J.K. Bletner

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

April 19, 1965

To the Graduate Council:

I am submitting herewith a dissertation written by John Newton Williams II entitled "Performance, Carcass Characteristics and Ultrasonic Estimates of Changes in Muscle and Fat of Bulls, Steers and Heifers." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Charles S. Hobbs
Major Professor

We have read this dissertation and recommend its acceptance:

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PERFORMANCE, CARCASS CHARACTERISTICS AND ULTRASONIC ESTIMATES OF CHANGES IN MUSCLE AND FAT OF BULLS, STEERS AND HEIFERS

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

John Newton Williams II

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CHAPTER I

INTRODUCTION

Among the major problems of beef producers for many years have been those of increasing growth rate, feed efficiency and carcass characteristics of beef animals. Much research has been directed toward the improvement of these traits. The need for more efficient beef production is impelled by the increasing costs of production and competition from other meats. The use of diethylstilbestrol (DES) has resulted in a considerable improvement in growth rate and feed efficiency. The fattening of bulls for the advantage of the naturally produced androgen is a similar practice. The main deterrent to the marketing of bulls has been the lack of consumer and packer acceptance due to the assumption that bull meat is less desirable than steer or heifer meat.

Various attempts have been made to estimate carcass merit of live animals, but thus far no highly accurate method has been developed. Ultrasonic estimates have shown the most promise. An accurate estimate of a muscle, such as the biceps femoris, with high predictive value for carcass muscling would be an invaluable advance in live animal evaluation. These estimates could provide the basis for more rapid genetic improvement in beef animals.

The objectives of the research reported herein were:

1. To determine the effect of sex on the growth rate, feed efficiency and carcass characteristics of beef animals.

2. To evaluate meat quality among sexes using as criteria mechanical shear scores for tenderness and taste panel scores for tenderness, juiciness and flavor.
3. To develop a reliable method of estimating the carcass muscle of live animals by means of ultrasonics.

CHAPTER II

REVIEW OF LITERATURE

I. PERFORMANCE AND CARCASS CHARACTERISTICS

Numerous comparisons of the performance of heifers and steers are found in the literature. Morrison (1956) and Snapp and Neumann (1960) reviewed the differences in sex of beef cattle in relation to performance and carcass traits. Heifers gained at a lower rate, fattened more quickly and were less efficient in feed conversion than steers.

Bull, Olson and Longwell (1930) fed steers and heifers in a comparison of performance and carcass characteristics to determine if the discrimination against heifer meat was justified. One group of steers was fed predominately corn silage plus some protein and hay. These steers gained 2.25, 2.18 and 2.05 pounds per head daily when on feed 140, 200 and 266 days, respectively. They weighed 873 pounds and graded choice after 266 days on feed. Other steers and heifers were fed a full feed of concentrates plus limited corn silage and hay. These animals after 140 days on feed had daily gains, weights and carcass grades, respectively: steers--2.52 and 688 pounds, good; heifers--2.56 and 712 pounds, good; after 200 days on feed, steers--2.35 and 864 pounds, choice; heifers--2.36 and 822 pounds, choice; and after 266 days on feed, steers--2.06 and 850 pounds, choice. The heifers were not fed to 266 days. Differences in rate of gain between steers and heifers were not significant.

These workers found that steers fed 266 days had a similar degree of finish to heifers fed 200 days as measured by per cent of separable fat in the 9-10-11 rib cut. Steers killed at 200 days on feed had a similar degree of finish to heifers fed 140 days. The difference in dressing per cent of heifers and steers at 140 days was not significant, but there was a slight advantage in dressing per cent in favor of the heifers at 200 days on feed. Differences in per cent rump, loin, rib or chuck due to sex, length of feeding or ration were not statistically significant. Differences in color of the meat, per cent of round or per cent of cutting fat were not significant, but longissimus dorsi (l. dorsi) areas were greater in steers. Total cooking losses were about the same for heifers and steers fed 140 days, but these losses were greater for heifers when both were fed 200 days.

Trowbridge and Moffett (1932) reported that yearling steers gained more rapidly and more economically than yearling heifers, but that the heifers attained a finished condition in a shorter feeding period. They found that heifers dressed higher and yielded carcasses with more finish when the animals were sold weighing less than 725 pounds. When comparable steers and heifers were fed until they weighed approximately 900 pounds, steers yielded a lower percentage of carcass meat, but smoother, less wasty carcasses. The 9-10-11 rib cut of heifers contained more fat than similar cuts from comparable steers. Palatability tests revealed few significant differences due to sex.

Kennedy et al. (1955) investigated performance and carcass characteristics in individually-fed steer and heifer calves. Animals were slaughtered at four times 50 days apart beginning after 121 days on feed. Heifer gains decreased after 84 days, and steers gained well to 140 days then dropped more slowly than heifers. Rate of gain, feed consumption and feed efficiency were higher in steers when comparing cattle of both sexes slaughtered at the same time, but no significant differences were found when heifers were compared with steers fed 50 days more before slaughter. Most production factors were similar at the same degrees of finish. Fatness, as measured by slaughter grade, carcass grade, carcass separable fat, and ether extract in boneless meat, was similar in the two sexes when steers were fed 50 days longer than heifers. The degree of finish had no significant effect on percentage of wholesale loin, rump, chuck or plate. Heifers had a slightly higher percentage of hindquarters and flank, and higher meat to bone ratios in the carcass both by kills and by the same finish. Steers had more forequarter, chuck, shank and carcass bone as percentages of carcass.

Other researchers have used hormones in beef cattle production to explain sex differences in performance traits. Burris _et al_. (1954) injected testosterone intramuscularly into growing beef heifers and steers at the rate of one milligram per kilogram body weight each week. The treatment resulted in increased rate of gain and increased feed efficiency in both heifers and steers, but heifers showed a more marked response. Testosterone-treated calves had more thyrotropic hormone content of pituitary glands and larger thyroid and adrenal glands than control calves. It was also found that the thyrotropic hormone content of the anterior pituitary gland of steer calves was greater than that of heifer calves. These researchers attempted to explain the action of testosterone in increasing daily gains through a possible stimulation of the pituitary gland to secrete more thyrotropic hormone which would act on the thyroid gland to secrete more thyroxine. They reasoned that an increased level of thyroxine would increase metabolic rate, resulting in decreased fat storage and might increase nitrogen retention. They also reported that meat from steers was much lower in per cent fat and higher in per cent protein than meat from heifers.

Hall and Hobbs (1962) investigated the effect of implanting thyroxine into steers and heifers on gains, feed utilization and carcass characteristics. Steers averaging 730 pounds received a total of 60 milligrams of thyroxine in a 170-day feed trial. Heifers averaging 630 pounds in a separate 70-day trial received either 100 or 200 milligrams of implanted thyroxine. All animals in both trials received 24 milligrams of implanted DES. Thyroxine did not improve feedlot gains or carcass grades of steers. Heifers treated with 200 milligrams of thyroxine gained more slowly and required more feed per 100 pounds of gain than controls or heifers treated with 100 milligrams of thyroxine. Thyroxine did not significantly affect slaughter grades, carcass grades, marbling scores or dressing percentages of heifers.

Klosterman _et al_. (1958) compared 12 heifers and 11 steers using DES, testosterone and a combination of the two. Heifers received 72 milligrams and steers received 96 milligrams of DES. Testosterone-treated animals received a total of 240 milligrams in two treatments for the 154-day feed trial. Steers gained 0.14 pound daily more than heifers.

DES increased daily gains of heifers by 0.18 pound and steers by 0.36 pound. Testosterone, however, increased daily gains of heifers 0.21 pound and steers only 0.06 pound. Results of a combination of DES and testosterone did not exceed the results of DES alone. Total feed per 100 pounds of gain was 913 pounds for all heifers and 885 pounds for all steers.

Arizona annual reports (1945, 1946) presented some of the earlier work with bulls and steers. Bulls consistently outgained steers with a substantial saving in feed per 100 pounds gained.

In a study of the effect of DES implantation on carcass composition and weight of certain endocrine glands of steers and bulls, Cahill *et al*. (1956) fed bulls and steers to 900-1000 pounds weight with and without DES. DES raised carcass grades of bulls but lowered carcass grades of steers. Implanted cattle had slightly heavier pituitary glands and significantly heavier adrenal glands. Thyroid glands of implanted bulls were significantly lighter in weight than those of untreated bulls but DES had little effect on thyroid weight of steers. DES increased fat percentage in bulls but decreased fat percentage in steers.

Extensive investigations with bulls and steers were reported by Klosterman *et al*. (1958). Bulls consistently outgained steers on less feed per 100 pounds of gain. In 1950-51 on a 252-day feed test, steers gained 2.00 pounds per head daily while bulls gained 2.23 pounds per head. In 1951-52 steers were fed longer in an attempt to reach the same final weight as bulls (848 pounds) and steers averaged 0.48 pound per head daily less than the daily gain for bulls. The appraised selling price per 100 pounds was about $4.00 more for steers than for bulls. Initial weights of animals in these experiments were about 375 pounds. In 1952-53, the differences in average daily gains between bulls and steers and between DES-treated and untreated bulls or steers were significant ($P < .01$). The implantation of DES increased daily rate of gain more in steers (0.48 pound) than in bulls (0.20 pound). In an experiment in 1954-55 DES implantation increased the average daily gains of steers by 0.52 pound and bulls by 0.11 pound. The total pounds of feed required to produce 100 pounds of gain in these experiments were as follows for bulls and steers, respectively (including concentrates, hay and hay equivalent): 1950-51, 678, 738; 1951-52, 677, 823; 1952-53, first period 595, 707, second period, 705, 769; 1953-54, 644, 788. These values were for animals not treated with DES. When animals were treated with DES, the amount of feed required per 100 pounds of gain was usually less than for those not treated. Implanted bulls required 534 and 652 pounds of feed per 100 pounds of gain in the first and second periods, respectively, of the 1952-53 experiment. Implanted bulls and steers, respectively, required 657 and 667 pounds of feed per 100 pounds of gain in the 1953-54 experiment.

In the 1950-51 and 1951-52 experiments bulls had a significantly ($P < .01$) lower dressing per cent than steers and significantly ($P < .01$) heavier hides and forequarters, lighter hindquarters, flanks and kidney knobs and lower carcass grades. The bull carcasses also had less fat trim and a greater percentage of edible portion. The differences between bulls and steers in these traits were significant ($P < .01$).

Per cent edible portions (carcass meat less fat trim and bone) of bulls and steers, respectively, in four experiments were: 77.7, 74.1; 77.5, 74.4; 77.1, 73.2; and 76.1, 69.9. The authors stated that the differences between steer and bull carcasses were undoubtedly influenced by the difference in amount of finish present on their carcasses. Due to a greater stimulus for growth, bulls were slower to fatten to the higher grades than steers.

Comparisons of performance, carcass cut-out data and eating quality of bulls and steers were made by Brown, Bartee and Lewis (1962). Eleven bulls and 11 steers representing five sires were fed the same ration consisting of a ratio of two parts of grain to one part hay for 168 days. Differences in performance between bulls and steers were not significant, but steers tended to gain more than bulls to 120 days and required more feed per pound of gain. The results of the carcass work indicated that l. dorsi areas of bulls were significantly larger than those of steers, and that bulls had significantly greater per cent chuck and greater chuck weight. Steers had significantly larger per cent trimmed loin and per cent fat trim. Steers slightly exceeded bulls in carcass grade, but the differences were not significant. There were no significant differences between bulls and steers in dressing per cent, chemical analyses (fat, moisture and protein) of 9-10-11 rib cuts or in weight of wholesale cuts.

Koger et al. (1960) fed 16 bulls and 16 steers a 60 per cent concentrate all pelleted ration from weaning to 1000 pounds weight. Bulls gained faster, more efficiently and had higher percentages of their carcass weights in trimmed retail cuts than did steers. Aitken _et al_. (1963) used 10 pairs of Friesian male twins, castrated one of each set of twins and fed them on a high barley ration. Bulls gained faster, reached slaughter weight sooner and had higher feed efficiency than steers. Bulls had less fat cover, lower dressing percentage and lower carcass grades than their steer mates. Kieffer _et al_. (1959) self-fed steers and heifers after weaning and found that steers gained more rapidly than heifers.

Thirty-eight Angus male calves, one-half of which were castrated shortly after birth, were used in a study by Field, Schoonover and Nelms (1964) to compare performance, carcass yield and consumer acceptance of retail cuts from steers and bulls. Initial weights of steers were 391 pounds while bulls weighed 422 pounds. Nine bulls and 9 steers were fed 232 days while the remainder were fed 260 days. Bulls gained 0.24 pound per day more than steers, but accurate feed consumption information was not available. Very little difference was noted in the amount of restlessness between bulls and steers in the feedlot or in handling the animals during feeding and weighing. Bulls had significantly larger _l. dorsi_ areas and larger estimated per cent yield of retail cuts than steers. Steers had greater depth of fat at the 12th rib, more estimated per cent kidney, pelvic and heart fat, and greater per cent cooler shrink than bulls. Bull meat was judged by the federal grader to be darker, softer and coarser-textured than steer meat but it was not discriminated against by the consumer at the retail counter as judged by selection of cuts. Further, consumers did not indicate significant color and texture differences on questionnaires.

Pilkington *et al.* (1959) investigated the carcass merit of bull calves slaughtered at eight to nine months of age and the effect of implanting bull calves. Thirty Hereford calves were used, one-third of which were castrated at three months of age, one-third remained as bulls without further treatment and one-third were bulls which received 12 milligrams and 24 milligrams of DES implanted at three and one-half and six and one-half months of age, respectively. All calves were on dams and were creep-fed the entire test. The steers had more external finish, firmer, finer-textured muscle in the *l. dorsi* muscle and graded one-third grade higher than bulls. Bulls had the largest *l. dorsi* areas and a significantly higher per cent moisture in the 9-10-11 rib cut. Steers had a significantly higher per cent ether extract of the same cut. Bulls had significantly more total muscle but there was little difference in per cent bone and no significant difference in carcass conformation.

Arthaud and Adams (1964) individually fed bulls, steers and heifers a pelleted concentrate ration in 210- and 259-day feeding trials beginning 30 days after weaning. Initial weights, daily gains and total digestible nutrients per pound of gain for bulls, steers and heifers, respectively, were: 458, 2.08 and 5.80 pounds; 414, 1.77 and 6.52 pounds; and 406, 1.48 and 6.86 pounds. Carcass grades were good, low choice and high good for bulls, steers and heifers, respectively. Heifers and steers were fatter than bulls as indicated by fat thickness and per cent kidney and pelvic fat. Percents yield of trimmed boneless cuts from loin, round, rib and chuck were 56.2, 52.0 and 51.0, respectively, for bulls, steers and heifers.

II. MEAT QUALITY EVALUATION

Tenderness is considered to be one of the most important traits for evaluating quality of beef. Means and King (1959) demonstrated a close relationship (r = 0.90) between family panel ratings of overall satisfaction and tenderness values by the Warner-Bratzler shear machine. Significant sire differences for tenderness also were shown by this work.

Blumer (1963) in a literature review indicated, among other factors, that tenderness differences may be due to sires within breeds, breeds and age of animals. Cover, King and Butler (1958) found a very low relationship between tenderness and degree of fatness.

Bull, Olson and Longwell (1930) found no difference in palatability of the meat from heifers and steers as evaluated by a committee. Scores were highly variable among members of the committee.

Wierbicki et al. (1953) evaluated the eating quality of meat from bulls, early and late castrated steers and bulls treated with DES in a three-year replication with age of slaughter ranging from 11 to 16 months. Bull meat was quite acceptable, but somewhat less tender than meat from steers.

Burris et al. (1954) found shear values of meat to be higher for heifers than for steers except those treated with testosterone which increased shear values of steers and had little effect on shear values of heifers.

Tenderness values were determined by taste panel in two experiments by Klosterman *et al.* (1958). There were no significant differences in tenderness ratings between the bull and steer carcasses in the 1950-51 experiment, but differences in tenderness ratings of bulls and steers were highly significant in the 1951-52 experiment. This was thought to be due to greater differences in grade between sexes in the second experiment.

Kieffer *et al.* (1959), using sire groups of steers and heifers after a 159-day feed test, found that differences in sire groups for tenderness were highly significant. The range in Warner-Bratzler shear values was 11.5 to 15.8 pounds. These values were obtained from one-inch cores of 12th rib steaks cooked to an internal temperature of 155° Fahrenheit.

Koger *et al.* (1960), using bulls and steers of comparable initial weights and fed to 1015 pounds final weight, found no unfavorable response from selected consumers to any of the meat or to tenderness, juiciness, flavor and general desirability.

Brown, Bartee and Lewis (1962) obtained trained taste panel scores for flavor, texture, aroma, tenderness, juiciness and uncooked color of 9-12 rib sections of bulls and steers and found no significant differences. Shear values were taken before and after cooking and no significant differences were found in tenderness between bull and steer meat.

Adams and Arthaud (1963) obtained Warner-Bratzler shear values on cooked samples of the *l. dorsi* muscle at the 10-11th rib of Angus bulls, steers and heifers fed alike. Carcasses graded from low good to average choice and were from animals averaging 439 and 479 days of age for Group I and Group II, respectively. Samples from Group I were significantly ($P < .05$) more tender than from Group II. Steers were significantly ($P < .01$) more tender than bulls. However, no significant difference was found in tenderness between bulls and heifers or between heifers and steers.

III. ESTIMATING MUSCLE AND FAT

Ultrasonics or high frequency sound has been used to estimate fat thickness and muscling of meat animals. Temple *et al.* (1956) reported that an ultrasonic device held promise for measuring fat thickness in live cattle.

Stouffer *et al.* (1961) developed a technique to produce cross-sectional outlines of the *l. dorsi* muscle and fat thickness at the 13th rib of cattle and hogs and recorded this outline on a photograph. Correlation coefficients between ultrasonic and carcass measurements were low but significant. However, a significant repeatability was indicated and the relationships were higher for hogs than for cattle. Possible sources of error were listed as: positional variation of instrument, variability in pressure of the transducer against the hide during probing and changes of shape and size of rib eye due to slaughtering and hanging.

Visual predictions of carcass muscling from live animals have been dependent largely on subjective appraisal of different traits, and the relationships between estimates and actual carcass values are variable. The most reliable estimates of carcass muscling have been developed from carcass measurements and have provided information for developing more accurate live animal estimates of carcass meatiness.

Cole et al. (1962) developed equations for predicting carcass muscling using different carcass measurements. The most valuable prediction equation was considered to be that which utilized only fat thickness and carcass weight. These two measurements were associated with over 70 per cent of the variation in carcass separable muscle. These values could be very useful in predicting carcass muscling in live animals if reliable estimates of the two traits could be obtained. Fat thickness could be obtained with ultrasonics, but carcass weight predictions on live animals must be obtained from live weight and estimated dressing per cent. A predictive value may not be very high from these estimates as indicated by Wilson et al. (1963). These researchers used a committee of six judges to estimate carcass traits on 135 grade Hereford steers which weighed an average of 980 pounds and graded an average of high good in the carcass. Simple correlation coefficients between the estimates and actual carcass measures were as follows: fat thickness, 0.38; per cent kidney fat, 0.32; l. dorsi area, 0.33; quality grade, 0.25; and dressing per cent, 0.12. Gregory et al. (1964) used three graders to estimate dressing per cent, fat thickness at the 12th rib, l. dorsi area, per cent cutability, per cent kidney fat and slaughter grade of 204 steers. Correlations between estimated and actual values were relatively low. Live estimates of cutability accounted for about 25 to 35 per cent of the variation in actual cutability.

Hedrick et al. (1962), using the Branson Sonoray Model 5 instrument with a one megacycle transducer and "A" scan, estimated l. dorsi area and fat thickness between the 12th and 13th rib on 203 beef cattle. The correlation coefficients between live estimated and actual l. dorsi area varied from 0.58 to 0.89. The correlation coefficients between live estimated and actual fat thickness varied from 0.11 to 0.63. Lower correlations existed between measurements in a group of cattle where the spinous processes were scribed during slaughter. A significant relationship existed between l. dorsi area estimated ultrasonically five months prior to slaughter and actual area in the carcass. The relationship between fat estimated ultrasonically five months before slaughter and actual fat thickness was not significant.

Brown et al. (1964) obtained ultrasonic estimates on young bulls with a Branson Model 52 instrument with scanning device ("B" scan). Correlation coefficients between ultrasonic and carcass measurements for 20 bulls were 0.78 and 0.46 for l. dorsi area and fat thickness, respectively. Correlations between independent interpretations of the ultrasonic scan pictures (somagrams) were 0.91 and 0.94 for l. dorsi area and fat thickness, respectively. Sumption et al. (1964) estimated fat and muscle thickness of 770 finished cattle including bulls, steers and heifers. Correlations of live estimates and l. dorsi muscle depth ranged from 0.01 to 0.72 but were generally too low to be useful as predictors. The pooled within group, sex and treatment correlation between live estimates and fat thickness, was 0.63. A Branson Sonoray Model 52 with "A" scan was used in this work.

Temple and Ramsey (1964) collected considerable data with ultrasonic estimates of _l. dorsi_ area and fat thickness at the 12th rib of cattle. Estimates on hogs have been higher than those on cattle. About 50 per cent of the variation in size of the _l. dorsi_ area and 80 to 85 per cent of the variation in fat thickness of cattle could be accounted for by ultrasonic estimates.

Ramsey _et al._ (1965) with 69 bulls, steers and heifers found that _biceps femoris_ area from carcass measurements in combination with live weight accounted for 86 per cent of the variation in trimmed round weight and 83 per cent of the variation in round muscle weight. Orme _et al._ (1960), holding slaughter weight constant, demonstrated a high correlation (0.96) between _biceps femoris_ weight and total carcass muscling. Cole, Orme and Kincaid (1960) had previously shown that _l. dorsi_ area was associated with only 4 per cent of the variation in separable carcass muscle when carcass weight was held constant.

Davis _et al._ (1964) used 60 beef steers to estimate carcass composition with high frequency sound and to test the ability of livestock judges to predict carcass muscling in beef cattle. Ultrasonic estimates of the _l. dorsi_ area and fat thickness were correlated with corresponding carcass measurements (0.87 and 0.90, respectively). Ultrasonic estimates of _biceps femoris_ thickness and forearm thickness were nonsignificantly correlated with actual carcass measurements. Results of the visual appraisal study revealed that three livestock judges successfully grouped steers by ranking them into light, medium or heavy muscling categories using *l. dorsi* area as a basis for muscling.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. FEEDING PERIODS

Thirty Angus and 15 Hereford weanling calves from three herds of the University of Tennessee were equally divided among bulls, steers and heifers in each breed. Allotment was by sire progeny trios with each of six Angus and three Hereford sires being represented by at least one bull, steer and heifer trio. Five animals of the same sex and breed were fed per lot in a barn with each lot containing about 460 square feet of space, approximately one-half of which was under shelter. All animals were moved to feeding lots at the Main Experiment Station about 10 days before the beginning of the experiment and placed on a high roughage ration containing antibiotics. After allotment to feeding groups and about one week before the experiment began, the males assigned to steer groups were castrated. An average of two weights taken on consecutive days at the beginning and end of the experiment were used as initial and final weights. Other weights were taken at 28-day intervals.

All animals were fed alike throughout the experiment. Water, salt and a mixture of equal parts salt and dicalcium phosphate were available *ad libitum*.

The first part of the experiment consisted of a 133-day high roughage feeding period from November, 1963, to March, 1964. During this time the ration consisted of a full feed of good quality corn silage plus four pounds of coarsely ground number 2 shelled yellow corn, one and one-half pounds cottonseed meal and two pounds of mixed grass and legume hay per head daily. Silage and concentrates were fed twice daily, morning and evening, while hay was fed in the morning and weighbacks were taken daily before the evening feeding.

The finishing period began in March, 1964. During this period the animals were full-fed a mixture of concentrates (ratio of eight pounds coarsely ground number 2 shelled yellow corn to one pound cottonseed meal) plus four pounds mixed grass and legume hay per head daily. At the beginning of this period, corn silage was gradually decreased for about 10 days and then discontinued while the concentrate feed was increased as rapidly as the animals would take it without digestive disturbances.

All animals were graded by three graders at the end of the wintering period and again on the day of slaughter. Immediately prior to slaughter, all feed and water were withheld overnight and animals were trucked a short distance to a packing plant.

Animals were slaughtered on May 19, June 12, and July 3, 1964, according to prior random assignment of sire progeny trios. The plan of experiment included slaughtering: (1) the first group when the heifers averaged weighing 750 pounds; (2) the second group when the remaining steers averaged weighing 875 pounds; and (3) the third group when the remaining bulls averaged weighing 1000 pounds.

II. CARCASS DATA

Data Obtained at Packing Plant

Animals were individually weighed at the packing plant and each carcass was tagged for identification before the hide was removed. Individual hot carcass weights were recorded after washing and prior to shrouding. Chilled carcass weights were calculated as 97.5 per cent of hot carcass weights. After a 48-hour chill the following data were obtained from the USDA grader: marbling score, maturity, estimated per cent kidney and pelvic fat, conformation grade and carcass grade. The fat thickness over the *l. dorsi* muscle between the 12th and 13th rib was measured to the nearest millimeter at a point three-fourths the longitudinal distance of the *l. dorsi* from the chine end. A tracing of a cross section of the *l. dorsi* muscle was taken on acetate paper at the same location and, in addition, intermuscular fat, other muscles and bone of this cross section were traced. The *l. dorsi* tracing was measured with a compensating polar planimeter and fat thickness was measured on the tracing corresponding to the measurement taken on the carcass.

Measurements to the nearest one-tenth inch were taken on the carcass to correspond to live measurements taken for ultrasonic scan locations. These measurements were: (1) from the anterior edge of the *tuber coxae* (hook) to the posterior edge of the *tuber ischii* (pin); and

(2) from the lateral malleolus (hock) to a point one-half the distance between hook and pin. In addition, the following parts were measured: (1) length of carcass--from the anterior edge of the aitch bone to the anterior edge of the first rib; (2) exterior leg length--from a point one-half the distance between hook and pin to the distal end of the tarsal bones; (3) interior leg length--from the anterior edge of the aitch bone to the lower medial end of the tarsal bones; and (4) loin length--from the anterior edge of the aitch bone to the cut made to separate the fore and hind quarters at a point seven and one-fourth lumbar vertebra anterior to the lumbo-sacral joint.

The wholesale round and 6-12 rib section from the left side of each carcass were shipped to the University of Tennessee Meat Laboratory for detailed cutting and analyses.

Data Obtained at University of Tennessee Meat Laboratory

Wholesale round. Each round was weighed, trimmed to approximately three-eighths inch of external fat, and weighed again without fat trim. It was then divided into two parts by cutting perpendicular to the outside surface of the round and at right angles to the longitudinal axis of the *biceps femoris* muscle. This cut severed the *femur* and was made at a point corresponding to the scan site on the live animal. The cross sectional area of the exposed *biceps femoris* muscle was traced. The outside fat layer, other muscles and bone of this cross section also were included on the same tracing. The *biceps femoris* area was measured from the tracing with a compensating polar planimeter, and fat thickness was measured over the center of this muscle from the tracing. The *biceps* femoris muscle was trimmed of separable fat and weighed. However, this did not include all of the muscle since part of the biceps femoris extends into the loin section. The remainder of the round was separated into fat, muscle and bone and these components were weighed.

Wholesale rib--components for analyses. The weight of the 6-12 rib section from the left side of each carcass was recorded. The 12th rib was removed (by cutting close to the 11th rib), identified, wrapped and frozen. After about one hour in a cooler, each 6-11 rib section was placed in a well-lighted area and subjective determinations were made on the 11th rib cross section by a meats researcher of the Animal Husbandry-Veterinary Science Department as follows: muscle color, muscle texture, firmness of muscle, fat color and marbling texture. The meat was given a numerical score for each trait. Highest scores represented most desirable qualities within each trait. The values for muscle color were: one = "black," seven = "very light cherry red." The values for muscle texture were: one = "very coarse," seven = "very fine." Values for firmness of muscle were: one = "extremely soft," seven = "very firm." Values for marbling texture were: one = "coarse," three = "fine." There were other values intermediate to these extremes within each trait listed.

Each 9-10-11 rib section was removed (by cutting close to the eighth rib), weighed, divided into separable muscle, fat and bone and these components were weighed. Each l. dorsi muscle of these sections, after removal of fat, was ground three times in a Hobart Model 4722 grinder, mixed thoroughly after each grinding and a representative sample was frozen for subsequent chemical analyses. Each 6-7-8 rib roast was boned out, wrapped, identified and frozen for subsequent cooking tests, shear tests and evaluation by an experienced taste panel.

Cooking losses of the 6-7-8 rib roasts. Each 6-7-8 boneless rib roast was removed from the freezer on the day before cooking, thawed for seven hours at room temperature and refrigerated overnight. The oven was preheated to 325° Fahrenheit and each roast was weighed and placed in a pan in the oven. The fat side of the roast was placed up with a thermometer in the center of the *l. dorsi* muscle. When the internal temperature of the roast reached 68° centigrade it was removed from the oven and allowed to cool ten minutes. The meat and drippings were weighed with pan weight accounted for and cooking time was recorded. Moisture loss was calculated from the weight of the uncooked roast less weights of the cooked meat, drippings and pan. Three one-inch cores of the *l. dorsi* muscle were taken for shear tests and cross sectional slices of each roast were taken for taste panel evaluation.

Chemical analyses of the 9-10-11 rib *l. dorsi* muscles. Ground meat samples were removed from the freezer, thawed, and samples were taken for analyses. The analyses of these samples were conducted in accordance with A. O. A. C. (1960) methods with the exception of nitrogen which was determined by the Kjeldahl method with slight modifications.

III. EVALUATION OF MEAT QUALITY

After each 6-7-8 rib roast was cooked, as previously described, the meat was subjected to shear tests for tenderness and to taste panel evaluation. Three cores taken from each roast were sheared three times each with a Warner-Bratzler machine. The values recorded represent average pounds of shear force required to shear the cores of each roast. The taste panel consisted of six experienced members of the Animal Husbandry-Veterinary Science and Home Economics Departments. Each roast was evaluated by the panel for tenderness, juiciness and flavor. The values assigned each roast for each of these traits were based on numerical scales of one through nine. The value of one represented "dislike extremely," and the value of nine represented "like extremely." Intermediate numbers represented intermediate values for desirability.

IV. ESTIMATING CARCASS YIELDS

The following three methods were used to estimate carcass yields:

a. Tennessee method (Cole, Ramsey and Epley, 1962). Pounds of separable muscle in one side of carcass = 39.16 - 1.40 (single fat thickness measurement over _l. dorsi_ at 12th rib, millimeters) + 0.2266 (carcass weight, pounds).

b. U.S.D.A. yield (Murphey _et al._, 1960). Per cent of boneless retail cuts = 51.34 - 5.784 (single fat thickness measurement over _l. dorsi_ at 12th rib, inches) - 0.0093 (carcass weight, pounds) - 0.462 (kidney fat, per cent of carcass) + 0.740 (area of _l dorsi_, square inches).

c. Wisconsin method (Brungardt and Bray, 1963). Per cent retail yield = 16.64 + 1.67 (per cent trimmed round) - 4.94 (single fat thickness measurement over l. dorsi at 12th rib, inches).

V. ULTRASONIC ESTIMATES OF MUSCLE AND FAT

Ultrasonic estimates were taken on the left side of each animal at the beginning of the experiment, one to five days prior to slaughter and at intervals between these times. A Teco chute with headgate was used to restrain the animals while ultrasonic estimates were made. The chute was equipped with a removable platform eight inches high to elevate animals sufficiently to scan the round in the desired location.

Estimates were made of: (1) fat thickness and area of the l. dorsi muscle between the 12th and 13th rib; and (2) fat thickness and cross sectional area of the biceps femoris muscle of the round. Procedures for making an estimate of the biceps femoris were worked out in 1963 and reported by Ramsey et al. (1965). The scan site was located as follows: first, a point was located one-half the distance from the anterior edge of the tuber coxae bone (hook) to the posterior edge of the tuber ischii bone (pin). Then the distance from this point was measured to the outer prominence of the tarsal joint (hock). This measurement is referred to as "hip to hock." The scan site was then found by measuring 37.5 per cent of the latter distance from the upper point downward and in line with the hock joint. All measurements were made to the nearest one-tenth inch.

The scanner was directed from rear to front across the scan site in a line parallel to the line of the back. Prior to scanning, the desired location was closely clipped and mineral oil applied as a couplant to provide contact between the hide and transducer. The start of the scan was from the rear edge of the biceps femoris muscle at the junction with the semitendinosus muscle. This point was located by palpation.

The ultrasonic instrument used was a Branson Sonoray Model 52 equipped with a Polaroid camera and a scanning device to which a two megacycle transducer was attached. The speed and direction of the scanner were controlled from the sonoray unit. As the scanner passed over the desired location, electrical energy was converted by the transducer into high frequency sound and directed into the animal tissue. Echoes resulting where differences in density of tissue occurred were reflected back to the transducer, converted into electrical energy, transmitted to the oscilloscope and recorded on film by the camera set for "time" exposure.

Two interpreters, using acetate paper, traced the recorded echoes judged as representing the edge of the l. dorsi and biceps femoris muscles from their respective somagrams. These outlines were measured with a compensating polar planimeter. The results were multiplied by a factor for square measure determined from calibration photographs to obtain life size of the muscle. A single fat thickness over the l. dorsi was taken in millimeters from the photograph at a point three-fourths of the length of the rib eye from the chine end. The results were multiplied by a factor for linear measure determined from the calibration photograph to obtain estimated life size of fat thickness.

Another ultrasonic instrument, the Branson Sonoray Model 12, was used several times to measure fat thickness and to check depths of muscles.

VI. METHODS OF ANALYSIS

The data were statistically analyzed using the analysis of variance procedure of Snedecor (1956). When sex effects were significant, the means were tested with Duncan's multiple range test (1955). Simple correlations on a within breed and sex basis were calculated on selected performance and carcass traits and on ultrasonic estimates. Multiple regression analyses based on the method of least squares were used to determine the relationship of selected carcass traits to three measures of round composition.

VII. PREDICTING ROUND COMPOSITION

Prediction equations for each of the measures of round composition were obtained from the multiple regression analysis using the following formula:

$$\hat{Y} = b_o + b_1 X_1 + b_2 X_2 + . . . + b_k X_k$$

where

$$b_o = \overline{Y} - b_1 \overline{X}_1 - b_2 \overline{X}_2 - . . . . - b_k \overline{X}_k$$

$b_1, b_2, . . . b_k$ are standard partial regression coefficients of the dependent variables on the independent variables.

$X_1, X_2, \ldots X_k$ are the independent variables measured on the individual animals.

$Y_1, Y_2, \ldots Y_k$ are the dependent variables.

$\hat{Y}$ is the estimated value of the dependent variable for specified values of the X's.

$\overline{Y}_i$ is the mean of the ith dependent variable.

$\overline{X}_i$ is the mean of the ith independent variable.

CHAPTER IV

RESULTS AND DISCUSSION

I. FEEDLOT PERFORMANCE

Winter Period

The animals used were uniform with respect to weights at the beginning of the experiment (Table I), but the heifers had condition grades significantly higher than steers or bulls. Differences of performance traits with significance levels attached are presented in Table IV (page 36). The average initial weight of all animals on test was 463 pounds.

The average daily gains of bulls, steers and heifers during the wintering period were 2.10, 1.84 and 1.65 pounds, respectively. Significant differences existed between bulls and heifers ($P < .01$) and between bulls and steers ($P < .05$), but the difference in the gain between steers and heifers was not significant. The average daily feed consumption was computed as animal averages by lots since the animals were fed in groups of five. Steers consumed daily 0.49 pound more feed than bulls and 1.04 pounds more feed than heifers. Most of these differences were composed of silage on the wet basis. There were no significant differences in feed consumption.

On an air-dry basis steers required 128 pounds more feed per 100 pounds of gain than bulls; heifers required 55 pounds more feed per 100

TABLE I

PERFORMANCE OF BULLS, STEERS AND HEIFERS ON A WINTERING RATION
(133 Days)

Item	Bulls	Steers	Heifers
No. of animals	14	14	14
Av. initial age, days	252	256	275
Av. wt. and gain/head, lb.			
Initial wt.	459	461	467
Final wt.	739	706	687
Total gain	280	245	220
Av. daily gain	2.10	1.84	1.65
Av. daily ration, lb.			
Corn silage[a]	23.31	23.82	22.78
Grass and legume hay	1.94	1.94	1.94
Ground shelled corn	3.99	3.98	3.98
Cottonseed meal	1.50	1.49	1.49
Total	30.74	31.23	30.19
Air-dry feed/cwt. gain, lb.			
Corn silage	347 (1089)[a]	416 (1304)[a]	434 (1361)[a]
Hay	91	106	116
Ground shelled corn	186	218	238
Cottonseed meal	70	82	89
Total	694	822	877
Grades[b]			
Weaning type	12.2	12.1	11.8
Weaning condition	8.8	9.0	9.9
Final condition	8.4	8.4	9.1

[a]Wet basis.

[b]High standard = 8; low choice = 12.

pounds of gain than steers. These differences were significant ($P < .01$) between bulls and heifers and between bulls and steers, but not significant between steers and heifers. The gains, feed consumption and feed efficiency during this period are in general agreement with other reports in the literature. The heifers graded almost one-third of a condition grade higher ($P < .05$) than either bulls or steers at the end of the wintering period, while the average grade for bulls and steers was similar.

Finishing Period

Performance during the finishing period is presented in Table II. Bulls gained 0.44 and 0.77 pound more daily than steers and heifers, respectively, and steers gained 0.33 pound more than heifers. The differences in gains among sexes were significant. Bulls ate 1.10 pounds more ($P < .05$) feed per day than heifers and 0.69 pound more feed daily than steers. Differences in average daily feed consumption between bulls and steers and between steers and heifers were not significant. The differences in the amount of air-dry feed consumed per 100 pounds of gain among sexes during the finishing period were all highly significant. Bulls required less feed per unit gain than steers or heifers and steers required less feed per unit gain than heifers.

Immediately prior to slaughter, the average condition grade of bulls was one-third of a grade lower than for steers and one-half of a grade lower than for heifers.

TABLE II

PERFORMANCE OF BULLS, STEERS AND HEIFERS ON A FINISHING RATION

Item	Bulls	Steers	Heifers
No. of animals	14	14	14
Av. no. days on feed	75	75	75
Av. wt. and gain/head, lb.			
Initial wt.	739	706	687
Final wt.	916	850	806
Total gain	177	144	119
Av. daily gain	2.35	1.91	1.58
Av. daily ration, lb.			
Corn silage[a]	1.72	1.67	1.64
Hay	3.76	3.76	3.75
Ground shelled corn	12.58	12.01	11.68
Cottonseed meal	1.57	1.50	1.46
Total	19.63	18.94	18.53
Air-dry feed/cwt. gain, lb.			
Corn silage	24	28	34
Grass and legume hay	161	199	242
Ground shelled corn	537	635	754
Cottonseed meal	67	79	94
Total	789	941	1124
Grades[b]			
Initial condition	8.4	8.4	9.1
Final condition	10.8	11.8	12.3

[a]Wet basis.

[b]High standard = 8; low choice = 12.

Performance During Wintering and Finishing Periods

A summary of performance during the entire experiment is given in Table III with differences and significance levels shown in Table IV. The sex groups began the experiment at about the same weight. Bulls gained 0.33 and 0.57 pound daily more than steers and heifers, respectively, and steers gained 0.24 pound daily more than heifers. The differences among sexes were highly significant. These gains were similar to those of the bulls, steers and heifers fed for 210 days described by Arthaud and Adams (1964) and somewhat higher than for their animals fed for 259 days.

Growth curves from the beginning of the experiment until the first animals were slaughtered (Figure 1) illustrate differences in rate of growth among sexes. These curves also show that changes in rates of gain from one weigh period to the next were generally in the same direction for animals of different sexes.

Over the entire experiment bulls required significantly less feed per 100 pounds of gain than heifers and steers, and the difference in feed efficiency between steers and heifers was also significant. These results are in agreement with those of Arthaud and Adams (1964) who worked with bulls, steers and heifers and with the results reported by Klosterman et al. (1958) and Brown, Bartee and Lewis (1962) using bulls and steers.

The cause of differences in rate of gain and feed efficiency among sexes is not evident in this experiment. Klosterman et al. (1958) suggested a possible growth stimulus in normal bulls due to the male hormones produced. Burris et al. (1954) discussed the possible action

TABLE III

PERFORMANCE OF BULLS, STEERS AND HEIFERS THROUGH WINTERING AND FINISHING PERIODS

Item	Bulls	Steers	Heifers
Av. no. days on test	208	208	208
Av. final age, days	460	464	483
Av. wt. and gain/head, lb.			
Initial wt.	459	461	467
Final wt.	916	850	806
Total gain	457	389	339
Daily gain	2.19	1.86	1.62
Air-dry feed/cwt. gain, lb.	729	865	961
Air-dry feed/animal, lb.	3332	3315	3241
Grades[a]			
Weaning type	12.2	12.1	11.8
Weaning condition	8.8	9.0	9.9
Final condition	10.8	11.8	12.3

[a]High standard = 8; low choice = 12.

TABLE IV

DIFFERENCES IN PERFORMANCE TRAITS OF BULLS, STEERS AND HEIFERS DURING WINTERING AND FINISHING PERIODS AND THROUGH BOTH PERIODS

Item	Bulls Minus Heifers	Bulls Minus Steers	Steers Minus Heifers
Wintering Period (133 Days)			
Av. daily gain, lb.	0.45**	0.26*	0.19
Av. daily ration, lb.	0.55	-0.49	1.04
Air-dry feed/cwt. gain, lb.	-183**	-128**	-55
Finishing Period (Av. 75 Days)			
Av. daily gain, lb.	0.77**	0.44**	0.33*
Av. daily ration, lb.	1.10*	0.69	0.41
Air-dry feed/cwt. gain, lb.	-335**	-152**	-183**
Performance During Wintering and Finishing Periods			
Av. initial wt., lb.	-8	-2	-6
Av. final wt., lb.	109**	66*	44
Av. daily gain, lb.	0.57**	0.33**	0.24**
Air-dry feed/cwt. gain, lb.	-232**	-138**	-96**
Grades			
Weaning type	0.4	0.1	0.3
Weaning condition	-1.1*	-0.2	-0.9*
Final condition	-1.5**	-1.0**	-0.5

*P < .05.

**P < .01.

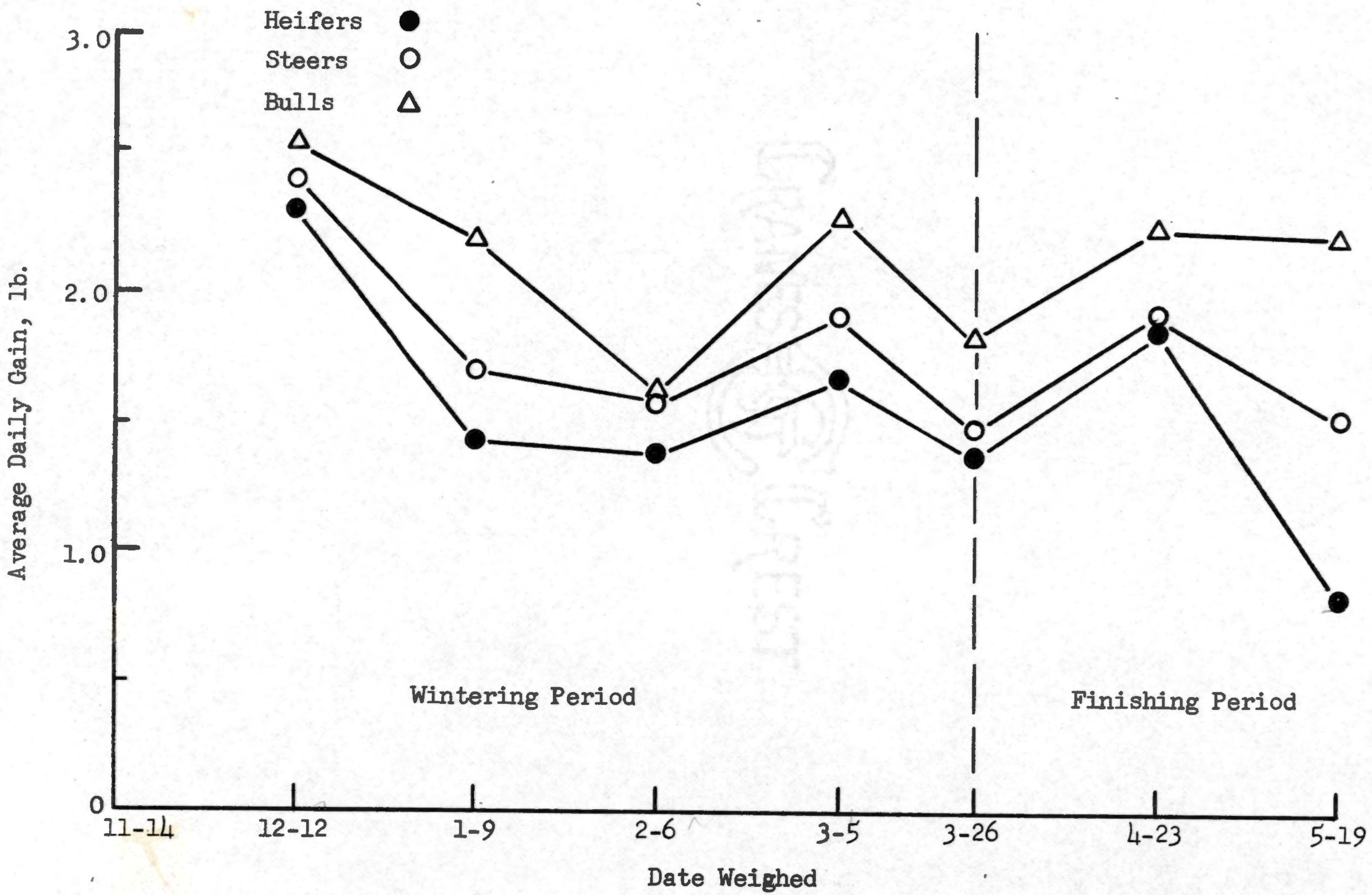

Figure 1. Gains of bulls, steers and heifers during wintering and finishing periods, 1963-64.

of male hormones on the anterior pituitary gland and a subsequent effect on the thyroid gland resulting in increased secretion of thyroxine. However, instances of significant growth responses of beef animals due to the administration of thyroxine were not found in the literature.

There appeared to be little difference in the amount of restlessness among sexes in the feedlot. These observations are similar to those of Klosterman et al. (1954) and Field, Schoonover and Nelms (1964). However, even though not a serious problem, some disturbances among the cattle were caused by certain bulls when several lots were turned together for handling or weighing.

II. CARCASS DATA

Carcass Data and Carcass Yield Estimates

In addition to estimates of carcass yields among bulls, steers and heifers, the carcass data which are normally collected on University of Tennessee experimental animals are presented in Table V, and the differences in carcass traits are given in Table VI. Bull carcasses graded significantly lower ($P < .01$) than those of heifers and steers, but the difference in carcass grades of steers and heifers was not significant. The carcasses of bulls were almost a full grade lower than those of heifers and two-thirds of a grade lower than those of steers. Steer carcasses were less than one-third of a grade lower than those of heifers.

Chilled carcasses of bulls weighed significantly ($P < .01$) more than those of steers (42.1 pounds) or heifers (57.5 pounds) but steer

TABLE V

CARCASS TRAITS OF BULLS, STEERS AND HEIFERS

Item	Bulls	Steers	Heifers
USDA carcass grade[a]	10.4	12.4	13.1
Chilled carcass wt., lb.[b]	547.9	505.8	490.4
Dressing per cent	60.4	60.3	61.6
L. dorsi area, sq. in.	11.77	10.27	9.03
L. dorsi area/cwt. carcass, sq. in.	~~2.16~~	~~2.04~~	~~1.85~~
Estimated kidney and pelvic fat, %	2.8	3.2	4.1
Marbling score	4.4	5.8	6.6
Carcass length, in.	44.2	43.3	42.7
Fat thickness, mm.	6.4	10.3	14.3
Estimated separable muscle, %	56.6	55.2	53.4
Estimated USDA yield, %	~~52.2~~	~~50.4~~	~~48.3~~
Estimated retail yield, %	53.4	51.7	48.1

[a]High standard = 8; low choice = 12.

[b]Hot carcass weight less 2.5 per cent.

TABLE VI

DIFFERENCES IN CARCASS TRAITS OF BULLS, STEERS AND HEIFERS

Item	Bulls Minus Heifers	Bulls Minus Steers	Steers Minus Heifers
USDA carcass grade	-2.7**	-2.0**	-0.7
Chilled carcass wt., lb.	57.5**	42.1**	15.4
Dressing per cent	-1.2*	0.1	-1.3*
L. dorsi area, sq. in.	2.74**	1.50**	1.24**
L. dorsi area/cwt. carcass, sq. in.	~~0.31**~~	~~0.12*~~	~~0.19**~~
Estimated kidney and pelvic fat, %	-1.3**	-0.4*	-0.9**
Marbling score	-2.2**	-1.4**	-0.8
Fat thickness, mm.	-7.9**	-3.9**	-4.0**
Carcass length, in.	1.5**	0.9	0.6
Estimated separable muscle, %	3.2**	1.4	1.8*
Estimated USDA yield, %	~~3.9**~~	~~1.8**~~	~~2.1**~~
Estimated retail yield, %	5.3**	1.7	3.6**

*P < .05.

**P < .01.

carcasses weighed only 15.4 pounds more than those of heifers and this difference was not significant. There was a significant advantage in dressing per cent of slightly over 1 per cent in favor of heifers over bulls or steers. These differences are similar to those found by Burris _et al._ (1954) between steers and heifers and Brown, Bartee and Lewis (1962) between bulls and steers. The _l._ _dorsi_ areas of bulls were larger than those of steers and heifers. Part of these differences may be due to the differences in final size among sexes. Bulls had more _l._ _dorsi_ area than steers and heifers on a 100 pounds of carcass basis. The differences in _l._ _dorsi_ areas among sexes were significant both on a per animal and on 100 pounds of carcass weight bases. Bull carcasses were significantly longer than those of steers or heifers. The greater weight of bulls may have been partially the cause of this greater body length. However, Field _et al._ (1963), with over 200 bulls and steers each, found that bulls were shorter-bodied than steers at the same weight.

All carcasses were less than 18 months of age and within the "A" maturity classification.

The estimated per cent kidney and pelvic fat was significantly ($P < .01$) greater for heifers than for bulls or steers. Steers had significantly ($P < .05$) more estimated kidney and pelvic fat than bulls. Heifers and steers had significantly ($P < .01$) more marbling than bulls, but no significant differences in marbling were detected between steers and heifers. The differences in fat thickness over the 12th rib were highly significant among sexes with outside fat for sexes as follows:

heifers > steers > bulls. These data agree with Arthaud and Adams (1964) who reported fat thicknesses and per cent kidney and pelvic fat on the same order for bulls, steers and heifers as the results reported herein.

Bull, Olson and Longwell (1930) have shown heifers to be more highly finished than steers at the same time on feed. Koger et al. (1960) reported that bulls had less marbling than steers and Klosterman et al. (1955) found that bulls graded lower than steers. It is evident from these studies that heifers fattened earlier than steers and steers fattened earlier than bulls. A greater part of the feed for the fattening animal was utilized to form fat tissues. Due to the greater energy requirement for fat formation, the feed efficiency on a weight comparative basis was less for fattening than for growing animals. Conversely it is evident that the more rapidly growing animals utilized feed energy for growth and deposited less fat tissue in the carcass which resulted in higher feed efficiency.

In comparisons of carcass yields among sexes by three different methods, significant differences were detected among all comparisons within methods except between bulls and steers in separable muscle and in retail yield. Estimated yields for carcasses were higher for bulls and steers than for heifers. None of the formulas used may give reliable estimates to compare carcasses among all sexes. The formula for per cent separable muscle (Cole, Ramsey and Epley, 1962) was developed using 132 steers treated alike and widely varying in breed and grade; the per cent retail yield formula (Brungardt and Bray, 1963) was developed from

99 steer carcasses of the U. S. Choice grade. The only formula discussed here which utilized animals of more than one sex was the per cent U.S.D.A. yield (Murphey *et al.*, 1960). This equation was developed from 162 carcasses of steers, heifers and cows of Prime through Canner grades. No estimates of yields from bulls were found. However, the order of magnitude of yields of carcasses among sexes in this study was the same as reported by other workers, but the magnitude of the differences was not the same. Using actual cut out of carcasses, Cahill *et al.* (1956) found that bulls had almost 7 per cent more edible portion than steers. Arthaud and Adams (1964) cut out carcasses of bulls, steers and heifers and reported per cent yield of trimmed boneless cuts from loin, round, rib and chuck to be about 4 per cent greater for bulls than steers and about 1 per cent greater for steers than heifers.

Physical Composition of Rounds and Rib Sections

The round was selected for use in this study because it was shown by Cole, Orme and Kincaid (1960) that round weight had a high value for predicting total carcass muscle. Further, Orme *et al.* (1960) demonstrated the very high relationship of *biceps femoris* muscle weight and total carcass muscle.

Data obtained from a detailed physical separation of each round and 9-10-11 rib section into separable muscle, fat and bone are presented in Table VII. Differences among sexes for selected components are presented in Table VIII. Bulls had significantly heavier rounds than steers or heifers and steers had significantly heavier rounds

TABLE VII

PHYSICAL ANALYSIS OF ROUND AND RIB SECTIONS
OF BULLS, STEERS AND HEIFERS

Item	Bulls	Steers	Heifers
Wholesale round wt., lb.	63.74	58.77	54.38
Separable muscle, lb.	42.25	36.82	32.03
Separable fat, lb.	12.17	13.18	14.93
Separable bone, lb.	9.13	8.71	7.41
Separable muscle, %	66.3	62.7	58.9
Separable fat, %	19.1	22.4	27.5
Separable bone, %	14.3	14.8	13.6
Trimmed round wt., lb.	61.52	55.82	50.30
Wt. of trimmed fat, lb.	2.22	2.95	4.08
B. femoris wt., lb.	9.32	8.25	7.31
Trimmed round as per cent of one-half carcass wt.	22.82	22.20	20.55
6-12 rib wt., lb.	26.11	23.67	23.02
9-10-11 rib wt., lb.	9.52	8.81	8.76
Separable muscle, lb.	5.44	4.59	3.86
Separable fat, lb.	2.60	3.01	3.74
Separable bone, lb.	1.48	1.28	1.15
Separable muscle, %	57.1	52.1	44.1
Separable fat, %	27.3	34.2	42.7
Separable bone, %	15.5	14.5	13.1

TABLE VIII

DIFFERENCES IN SELECTED COMPONENTS OF ROUND AND RIB SECTIONS OF BULLS, STEERS AND HEIFERS

Item	Bulls Minus Heifers	Bulls Minus Steers	Steers Minus Heifers
Wholesale round wt., lb.			
Untrimmed	9.36**	4.97**	4.39*
Muscle	10.22**	5.43**	4.79**
Fat	-2.76**	-1.01	-1.75*
Bone	1.72**	0.42	1.30*
Trimmed	11.22**	5.70**	5.52**
B. femoris	2.01**	1.07**	0.94**
Trimmed round as per cent of one-half carcass wt.	2.27**	0.62	1.65**
6-12 rib wt., lb.	3.09**	2.44*	0.65
9-10-11 rib wt., lb.	0.76	0.71	0.05
Muscle	1.58**	0.85**	0.73**
Fat	-1.14**	-0.41*	-0.73**
Bone	0.33**	0.20*	0.13

*$P < .05$.

**$P < .01$.

than heifers. Differences in trimmed round weights among sexes were greater than differences in untrimmed round weights because less fat was trimmed from the rounds of bulls than from those of steers or heifers, and less fat was trimmed from the rounds of steers than from those of heifers. The average weights of fat trimmed from rounds of bulls, steers and heifers, respectively, were 2.22, 2.95 and 4.08 pounds.

The differences in biceps femoris weights among sexes were highly significant in the following order: bulls > steers > heifers. Some of the differences in the round components among sexes may be due to differences in carcass weights. However, when considering the trimmed round weight as per cent of one-half the carcass weight, bulls, steers and heifers had 22.82, 22.20 and 20.55 per cent, respectively. The differences between bulls and heifers and between steers and heifers were significant but not significant between bulls and steers.

The differences among sexes in components of the round were not as great when expressed in per cent of total round weight as when expressed in pounds. However, rounds from bull carcasses had 3.6 per cent more separable muscle than steers and 7.4 per cent more separable muscle than heifers. Bulls had 3.3 per cent less separable fat than steers and 8.4 per cent less separable fat than heifers. The amount of separable bone among sexes was the most nearly alike of the three physical components. Steers had the greatest per cent bone (14.8 per cent) with bulls second (14.3 per cent) and heifers third (13.6 per cent).

The weights of the 6-12 rib sections of bulls were significantly heavier than those of steers ($P < .05$) and heifers ($P < .01$), but the difference of 6-12 rib weights between steers and heifers was not significant. There were no significant differences in weights of 9-10-11 rib sections among sexes.

Hankins and Howe (1946) reported that the physical composition of the 9-10-11 rib section was highly related to total carcass composition. In the study reported herein, the yield of separable muscle of the 9-10-11 rib section was significantly different ($P < .01$) among sexes with bulls having more separable muscle than steers (0.85 pound) and heifers (1.58 pounds). The yield of separable fat was significant in the inverse order with bulls having 0.41 pound less separable fat than steers and 1.14 pounds less than heifers. Bulls had significantly ($P < .05$) more bone (0.20 pound) in the 9-10-11 rib section than steers and significantly ($P < .01$) more bone than heifers (0.33 pound), but the difference in weight of bone between steers and heifers (0.13 pound) was not significant.

A comparison of the physical composition of the two cuts studied revealed that the rounds had a higher per cent of muscle and lower per cent of fat than the 9-10-11 rib sections. There was about the same per cent of bone in the two cuts with the exception that bulls had 1.2 per cent more bone in the 9-10-11 rib section than in the round. There were greater percentage differences among sexes within each component (muscle, fat and bone) of the 9-10-11 rib sections than in the rounds.

Considering the physical composition of rounds and rib sections, it is probable that a part of the differences are related to differences in grade. However, Brannan (1957) found that heifers had more separable fat and less separable muscle than steers within the same grade. The magnitude of differences in fat between heifers and steers in his work was greater in the Standard grade than in the Choice grade.

Chemical Analyses of Muscle Components

Chemical components of the 9-10-11 rib section of the defatted *l. dorsi* muscles of bulls, steers and heifers are presented in Table IX and differences in these components are presented in Table X. Bulls, steers and heifers had 20.67, 20.33 and 19.92 per cent crude protein, respectively. Only the differences between bulls and heifers were significant ($P < .01$).

Bulls had 4.25 per cent more moisture in the 9-10-11 rib section than heifers and 1.88 per cent more moisture than steers; steers had 2.37 per cent more moisture than heifers. These differences were all highly significant. Significant differences ($P < .01$) existed among sexes in per cent ether extract and values for bulls, steers and heifers, respectively, were 2.92, 4.74 and 7.39 per cent. The difference values for ether extract among sexes were about the same magnitude and with the same significance levels as difference values for moisture but in the inverse order. The amount of ether extract and moisture was related to the grade of the animals. Differences among sexes in this study would be expected because bulls graded lower than heifers. Backus (1958) reported that per cent moisture increased as grade decreased because muscle with the least amount of marbling yielded the highest amount of moisture. Brannan (1957) presented evidence that sex had an effect on per cent moisture

TABLE IX

CHEMICAL ANALYSIS OF L. DORSI MUSCLE OF 9-10-11 RIB SECTIONS AND COOKING LOSSES OF 6-7-8 RIB ROASTS OF BULLS, STEERS AND HEIFERS

Item	Bulls	Steers	Heifers
9-10-11 rib section			
Crude protein, %	20.67	20.33	19.92
Moisture, %	74.39	72.51	70.14
Ether extract, %	2.92	4.74	7.39
6-7-8 rib roast			
Drip loss, %	4.49	5.94	7.14
Evaporation loss, %	17.96	16.68	14.02
Total loss, %	22.45	22.61	21.16
Roast wt., lb.	6.38	5.63	5.57
Cooking time, min./lb.	36.51	37.66	35.81

TABLE X

DIFFERENCES IN CHEMICAL ANALYSIS OF *L. DORSI* MUSCLE OF 9-10-11 RIB SECTIONS AND COOKING LOSSES OF 6-7-8 RIB ROASTS OF BULLS, STEERS AND HEIFERS

Item	Bulls Minus Heifers	Bulls Minus Steers	Steers Minus Heifers
9-10-11 rib section			
Crude protein, %	0.75**	0.34	0.41
Moisture, %	4.25**	1.88**	2.37**
Ether extract, %	-4.47**	-1.82**	-2.65**
6-7-8 rib roast			
Drip loss, %	-2.65**	-1.45**	-1.20**
Evaporation loss, %	3.94**	1.28	2.66**
Total loss, %	1.29*	-0.16	1.45*
Roast wt., lb.	0.81*	0.75*	0.06
Cooking time, min./lb.	0.70	-1.15	1.85

*P < .05.

**P < .01.

and ether extract inasmuch as heifers had a greater per cent fat and lower per cent moisture within grade than did steers.

Cooking Losses of 6-7-8 Rib Roasts

The cooking losses of 6-7-8 rib roasts are presented in Table IX (page 49) and differences in these values are presented in Table X (page 50). Drip losses were lowest for bulls (4.49 per cent), intermediate for steers (5.94 per cent) and highest for heifers (7.14 per cent). Differences in drip losses among sexes were highly significant. Evaporation losses had an inverse relationship with drip losses. The highest evaporation losses occurred in bulls (17.96 per cent), next highest in steers (16.68 per cent) and lowest in heifers (14.02 per cent). Evaporation losses were significantly ($P < .01$) greater in bulls and steers than in heifers, but the difference in evaporation losses between bulls and steers was not significant. Bulls and steers had significantly ($P < .05$) more total losses than heifers, but there was no significant difference in total losses between bulls and steers.

The higher evaporation losses and lower drip losses of bulls in relation to these losses in heifers or steers indicate the relative degree of fatness among sexes, because evaporation represents mainly moisture and drip represents mainly fat. Backus (1958) reported that evaporation losses were inversely related to grade, found drip losses were higher in roasts with the greater covering of fat, and indicated that the major part of drip loss was from outside fat. His findings are in agreement with the data reported herein.

The cooking time in minutes per pound of roast was 36.51, 37.66 and 35.81 for bulls, steers and heifers, respectively, and the differences were not significant.

Selected Carcass Measurements

Certain carcass measurements were recorded (Tables XI and XII), most of which were related specifically to live animal ultrasonic estimates of the round. Fat thickness over the biceps femoris muscle was 2.4, 3.6 and 5.4 millimeters for bulls, steers and heifers, respectively. Bulls had significantly less ($P < .01$) fat than heifers and less ($P < .05$) fat than steers. Steers had significantly ($P < .01$) less fat than heifers. The cross sectional areas of biceps femoris muscles among sexes were 19.27, 16.32 and 14.03 square inches for bulls, steers, and heifers, respectively. The differences among sexes were all highly significant.

Linear measurements from hooks to pins of bulls, steers and heifers were 17.81, 16.99 and 17.29 inches, respectively. These measurements were significantly longer ($P < .01$) for bulls than for steers, but no other significant differences were detected. Distances from hock to hip were 26.19, 26.14 and 25.51 inches for bulls, steers and heifers, respectively, but differences were not significant among sexes. Interior leg measurements were almost two inches shorter than exterior leg length for each sex. Bulls and steers had the same measurement for exterior leg length (28.84 inches) which was significantly ($P < .01$) longer than that of heifers (27.81 inches). Bulls and steers also had the same

TABLE XI

SELECTED CARCASS MEASUREMENTS OF BULLS, STEERS AND HEIFERS

Item	Bulls	Steers	Heifers
B. femoris			
Fat thickness, mm.	2.4	3.6	5.4
Cross sectional area, sq. in.	19.27	16.32	14.03
Hooks to pins distance, in.	17.81	16.99	17.29
Hock to hip distance, in.	26.19	26.14	25.51
Leg length, in.			
Exterior	28.84	28.84	27.81
Interior	26.99	26.99	25.95
Loin length, in.	22.98	22.82	22.86

TABLE XII

DIFFERENCES IN SELECTED CARCASS MEASUREMENTS OF BULLS, STEERS AND HEIFERS

Item	Bulls Minus Heifers	Bulls Minus Steers	Steers Minus Heifers
B. femoris			
Fat thickness, mm.	-3.0**	-1.2*	-1.8**
Cross sectional area, sq. in.	5.24**	2.95**	2.29**
Hooks to pins distance, in.	0.52	0.82**	-0.30
Hock to hip distance, in.	0.68	0.05	0.63
Leg length, in.			
Exterior	1.03**	0.00	1.03**
Interior	1.04**	0.00	1.04**
Loin length, in.	0.12	0.16	-0.04

*$P < .05$.

**$P < .01$.

interior leg measurement (26.99 inches) which was significantly ($P < .01$) longer than that of heifers (25.95 inches). Loin lengths were not significantly different among sexes.

III. EVALUATION OF MEAT QUALITY

Shear Tests and Taste Panel Scores

Shear values and taste panel scores of meat from 6-7-8 rib roasts are presented in Table XIII and differences of these values are presented in Table XIV. The force required to shear one-inch cores of meat from bulls, steers and heifers, respectively, was 20.23, 17.63 and 16.89 pounds. The shear force required for bulls was significantly greater ($P < .01$) than the force required to shear heifer meat and significantly greater ($P < .05$) for bulls than for steers. Taste panel scores for tenderness agreed with the results of the shear machine with the exception that the significance of difference between bulls and steers was found to be at the 1 per cent level by taste panel, whereas with the shear machine, the corresponding difference was significant at the 5 per cent level. The differences in tenderness among sexes reported in the literature have been highly variable, but most of the reports have shown that bulls were less tender than steers or heifers. Arthaud and Adams (1964) reported similar results for tenderness between bulls and steers to those reported herein, but found no significant differences in tenderness between bulls and heifers or between heifers and steers.

The taste panel found no significant differences among sexes for juiciness. Bull meat was scored significantly less desirable than meat of

TABLE XIII

MEAT QUALITY EVALUATION OF BULLS, STEERS AND HEIFERS--
TENDERNESS VALUES, TASTE PANEL SCORES AND
VISUAL EVALUATION OF MUSCLE AND FAT

Item	Bulls	Steers	Heifers
Shear force, lb.	20.23	17.63	16.89
Taste panel scores			
Tenderness	6.23	7.31	7.50
Juiciness	7.16	7.19	7.32
Flavor	7.41	7.71	7.90
12th rib cross section			
Muscle			
Color	4.4	6.0	5.9
Texture	3.1	4.1	4.3
Firmness	4.0	4.3	5.3
Fat color	2.1	2.3	2.4
Marbling texture	1.9	1.8	1.9

TABLE XIV

DIFFERENCES IN VALUES FOR MEAT QUALITY EVALUATION
OF BULLS, STEERS AND HEIFERS

Item	Bulls Minus Heifers	Bulls Minus Steers	Steers Minus Heifers
Shear force, lb.	3.34**	2.60*	0.74
Taste panel scores			
Tenderness	-1.27**	-1.08**	-0.19
Juiciness	-0.16	-0.03	-0.13
Flavor	-0.49**	-0.30	-0.19
12th rib cross section			
Muscle			
Color	-1.5**	-1.6**	0.1
Texture	-1.2**	-1.0*	-0.2
Firmness	-1.3**	-0.3	-1.0**
Fat color	-0.3	-0.2	-0.1
Marbling texture	0.0	0.1	-0.1

*$P < .05$.

**$P < .01$.

heifers for flavor. The differences between flavor scores of bulls and steers and between steers and heifers were not significant.

Color and Texture of Muscle and Fat

The evaluation of muscle and fat at the 12th rib cross section is reported in Tables XIII (page 56) and XIV (page 57). The color of muscle of bulls was significantly ($P < .01$) darker than muscle of heifers or steers, but there was no significant difference in color of muscle between steers and heifers. The texture of bull muscle was significantly ($P < .01$) coarser than muscle of heifers, and significantly ($P < .05$) coarser than muscle of steers, but there was no significant difference in the texture of the muscle between steers and heifers. Muscle of bulls or steers was significantly ($P < .01$) softer than muscle of heifers, but bull and steer muscle was not significantly different in firmness. These results agree with those of Field, Schoonover and Nelms (1964) in which a federal grader judged bull meat to be darker, softer and coarser-textured than steer meat. However, bull meat in their work was not discriminated against by consumers by selection at the meat counter. Brown, Bartee and Lewis (1962) found no differences in texture or color of muscle between bulls and steers.

No significant differences were detected among sexes in fat color or marbling texture.

IV. RELATIONSHIPS AMONG TRAITS

Performance and Carcass Traits

Correlations among performance and carcass traits of bulls, steers and heifers are presented in Table XV. Among performance traits, the daily gains over the entire experiment were significantly correlated with all other period gains and with initial weight. The overall daily gains would be expected to have a high relationship with gains during individual periods. However, the relationships among gains during different periods were very low as indicated by the correlation of 0.12 between wintering gains (133 days) and finishing gains (March 26, 1964, to slaughter). These low relationships as well as the low correlations between gains during each of these periods suggest compensatory gains by individual animals between periods.

The daily gains during the different periods generally were significantly related to linear measurements (except hooks to pins), *l. dorsi* and *biceps femoris* areas and weights of almost all carcass components. Daily gains were not significantly related to fat thickness over *biceps femoris*, carcass grades or marbling scores, and with the exception of the first 56 days, were not highly correlated with per cent kidney and pelvic fat. These correlations show the low relationship between gains and fattening.

The correlations among performance and carcass traits revealed, in general, that birth weight, weaning weight and initial weight were more highly related to each other and to linear measurements than to

TABLE XV

CORRELATIONS AMONG PERFORMANCE AND CARCASS TRAITS OF BULLS, STEERS AND HEIFERS[a]

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)
(1) Birth wt.																																												
(2) Weaning wt.	0.21																																											
(3) Weaning adj. ADG	-.14	0.55																																										
(4) Weaning condition grade	0.07	-.06	0.11																																									
(5) Initial wt.	0.34	0.85	0.46	0.07																																								
(6) 56-day ADG (11-14-63 to 1-9-64)	0.28	0.07	0.03	0.16	0.37																																							
(7) 133-day ADG (11-14-63 to 3-26-64)	0.11	0.12	0.02	-.17	0.32	0.77																																						
(8) 77-day ADG (1-9-64 to 3-26-64)	-.06	0.12	0.01	-.37	0.18	0.35	0.87																																					
(9) 54-day ADG (3-26-64 to 5-19-64)	0.28	0.46	0.25	0.23	0.52	0.11	0.12	0.08																																				
(10) ADG 3-26-64 to slaughter	0.14	0.18	0.13	0.16	0.20	0.17	0.12	0.05	0.70																																			
(11) ADG 11-14-63 to slaughter	0.16	0.18	0.05	-.07	0.34	0.71	0.87	0.73	0.42	0.58																																		
(12) Final type grade	-.09	-.24	-.24	0.40	-.09	0.27	0.26	0.18	0.02	-.15	0.15																																	
(13) Final condition grade	0.02	-.14	-.13	0.32	-.02	0.42	0.39	0.25	0.13	0.31	0.50	0.56																																
(14) Sale wt.	0.29	0.46	0.17	-.03	0.66	0.62	0.64	0.46	0.55	0.63	0.84	-.05	0.42																															
(15) Chilled carcass wt.	0.31	0.38	0.12	0.02	0.64	0.68	0.65	0.43	0.49	0.55	0.80	-.01	0.44	0.98																														
(16) Dressing per cent	0.22	-.05	-.09	0.20	0.30	0.61	0.39	0.12	0.03	0.01	0.34	0.14	0.34	0.48	0.65																													
(17) L. dorsi area	0.15	0.23	0.01	0.05	0.40	0.49	0.59	0.48	0.47	0.41	0.68	0.17	0.31	0.70	0.71	0.46																												
(18) Fat over l. dorsi	-.01	-.01	-.08	0.11	0.14	0.42	0.40	0.26	0.16	0.38	0.50	0.17	0.46	0.53	0.54	0.30	0.29																											
(19) Carcass length	0.41	0.51	0.28	-.01	0.66	0.49	0.47	0.31	0.61	0.63	0.69	-.20	0.24	0.90	0.88	0.43	0.61	0.42																										
(20) Marbling score	-.10	-.05	-.21	0.11	0.05	0.27	0.25	0.16	-.06	0.05	0.22	0.38	0.53	0.24	0.27	0.27	0.11	0.38	0.09																									
(21) Conformation grade	0.18	-.03	-.16	0.36	0.21	0.43	0.30	0.11	0.12	0.18	0.34	0.37	0.56	0.44	0.51	0.55	0.35	0.52	0.27	0.54																								
(22) Estimated kidney and pelvic fat, %	-.05	0.12	-.02	0.17	0.32	0.35	0.19	0.01	0.05	-.05	0.12	0.14	0.11	0.28	0.34	0.45	0.14	0.37	0.18	0.34	0.36																							
(23) Carcass grade	0.06	-.01	-.31	0.02	0.10	0.28	0.25	0.14	-.07	0.05	0.22	0.24	0.43	0.30	0.33	0.28	0.15	0.46	0.17	0.92	0.58	0.34																						
(24) Hook to pin distance	0.21	0.41	0.15	-.07	0.52	0.30	0.24	0.11	0.19	0.21	0.29	-.35	0.01	0.53	0.56	0.44	0.28	0.16	0.60	0.17	0.11	0.18	0.25																					
(25) Hock to hip distance	0.28	0.57	0.17	-.16	0.63	0.35	0.30	0.17	0.45	0.46	0.48	-.26	0.15	0.72	0.71	0.36	0.55	0.21	0.73	0.13	0.23	0.10	0.16	0.50																				
(26) Exterior leg length	0.28	0.53	0.30	-.19	0.61	0.37	0.34	0.21	0.39	0.34	0.45	-.37	-.05	0.61	0.60	0.34	0.41	0.02	0.65	-.09	0.08	0.04	-.08	0.37	0.89																			
(27) Interior leg length	0.28	0.50	0.38	-.33	0.59	0.35	0.41	0.34	0.37	0.43	0.55	-.58	-.12	0.71	0.68	0.29	0.39	0.10	0.77	-.13	-.05	0.08	-.07	0.48	0.73	0.85																		
(28) Loin length	0.28	0.45	0.27	-.17	0.62	0.46	0.47	0.34	0.31	0.44	0.60	-.36	0.04	0.79	0.77	0.36	0.44	0.34	0.80	0.07	0.28	0.23	0.13	0.45	0.68	0.70	0.86																	
(29) Fat over b. femoris	-.05	-.06	-.23	-.05	-.01	0.19	0.20	0.14	-.01	0.04	0.18	0.07	0.08	0.09	0.07	-.03	-.14	0.31	-.01	0.24	0.09	0.23	0.29	0.23	-.05	-.11	-.05	-.06																
(30) B. femoris area	0.11	-.07	-.10	-.06	0.16	0.34	0.47	0.42	0.30	0.36	0.57	0.09	0.42	0.61	0.67	0.59	0.62	0.35	0.52	0.12	0.45	0.16	0.10	0.26	0.48	0.41	0.37	0.46	-.14															
(31) Trimmed round wt.	0.34	0.18	0.01	-.05	0.45	0.52	0.51	0.36	0.43	0.57	0.71	-.10	0.39	0.89	0.92	0.61	0.66	0.47	0.81	0.12	0.40	0.21	0.18	0.49	0.66	0.55	0.67	0.71	-.02	0.76														
(32) B. femoris wt.	0.23	0.17	0.04	-.14	0.31	0.30	0.45	0.43	0.45	0.55	0.65	-.19	0.32	0.78	0.78	0.45	0.70	0.39	0.76	0.03	0.26	0.16	0.10	0.43	0.59	0.47	0.63	0.61	0.04	0.75	0.85													
(33) Round muscle wt.	0.33	0.12	0.03	-.05	0.40	0.50	0.51	0.37	0.41	0.53	0.69	-.08	0.42	0.84	0.87	0.61	0.67	0.39	0.77	0.06	0.40	0.15	0.09	0.44	0.63	0.53	0.63	0.67	-.12	0.82	0.97	0.86												
(34) Round fat wt.	0.30	0.25	-.09	0.11	0.51	0.55	0.38	0.14	0.42	0.48	0.53	0.06	0.34	0.75	0.79	0.59	0.44	0.58	0.67	0.42	0.43	0.42	0.51	0.56	0.54	0.38	0.43	0.50	0.27	0.42	0.73	0.51	0.60											
(35) Round bone wt.	0.19	0.19	0.24	-.20	0.38	0.45	0.55	0.47	0.21	0.43	0.67	-.31	0.18	0.77	0.78	0.48	0.58	0.33	0.71	-.05	0.20	0.12	-.01	0.46	0.54	0.56	0.77	0.75	-.05	0.65	0.85	0.77	0.83	0.50										
(36) 6-12 rib wt.	0.25	0.24	-.05	0.04	0.52	0.71	0.67	0.43	0.41	0.48	0.78	0.14	0.46	0.88	0.93	0.66	0.78	0.61	0.76	0.35	0.56	0.42	0.42	0.44	0.61	0.46	0.50	0.65	0.09	0.61	0.81	0.69	0.77	0.79	0.65									
(37) 9-10-11 rib cut	0.19	0.23	-.06	-.01	0.46	0.62	0.67	0.50	0.41	0.50	0.80	0.10	0.49	0.88	0.90	0.58	0.75	0.61	0.75	0.26	0.47	0.34	0.29	0.43	0.58	0.42	0.49	0.63	0.07	0.66	0.83	0.73	0.80	0.71	0.67	0.95								
(38) 9-10-11 rib, muscle wt.	0.08	0.15	-.05	-.04	0.35	0.49	0.58	0.47	0.28	0.32	0.65	0.06	0.36	0.71	0.75	0.56	0.71	0.34	0.64	0.15	0.35	0.24	0.11	0.41	0.50	0.41	0.43	0.54	-.13	0.68	0.70	0.67	0.75	0.40	0.61	0.77	0.85							
(39) 9-10-11 rib, fat wt.	0.25	0.28	-.06	0.11	0.48	0.61	0.51	0.27	0.38	0.45	0.62	0.15	0.44	0.75	0.77	0.52	0.57	0.72	0.62	0.32	0.49	0.46	0.42	0.36	0.47	0.28	0.33	0.49	0.21	0.41	0.65	0.52	0.56	0.84	0.46	0.86	0.84	0.48						
(40) 9-10-11 rib, bone wt.	0.09	-.01	-.03	-.21	0.18	0.38	0.53	0.48	0.30	0.38	0.62	0.16	0.39	0.59	0.55	0.18	0.37	0.41	0.41	0.11	0.22	0.08	0.18	0.02	0.31	0.23	0.37	0.37	0.19	0.39	0.61	0.53	0.59	0.44	0.48	0.53	0.54	0.24	0.49					
(41) Muscle color	-.10	-.26	-.35	-.26	-.18	-.01	0.02	0.04	-.22	-.16	-.07	-.08	0.03	-.03	-.01	0.05	-.03	0.15	-.18	0.29	-.09	0.24	0.31	-.04	0.01	-.05	0.02	-.04	0.11	0.05	0.10	0.07	0.04	0.18	0.09	-.01	-.02	-.13	0.10	0.13				
(42) Muscle texture	-.18	-.23	-.22	0.10	-.23	-.23	-.09	0.05	-.08	-.01	-.10	0.17	0.19	-.11	-.13	-.14	-.20	0.38	-.11	0.46	0.18	0.19	0.45	-.01	-.22	-.38	-.30	-.17	0.16	0.05	-.06	-.08	-.12	0.12	-.10	-.11	-.11	-.22	0.01	0.05	0.34			
(43) Muscle firmness	-.16	-.06	-.26	0.05	0.04	0.05	0.13	0.14	0.01	0.03	0.09	0.27	0.17	0.07	0.10	0.17	0.23	0.15	-.04	0.47	0.41	0.38	0.49	-.01	0.06	-.06	-.13	-.06	0.31	0.16	-.05	0.10	-.08	0.22	-.08	0.26	0.14	-.02	0.29	0.03	0.16	0.20		
(44) Fat color	0.07	0.28	0.09	-.14	0.33	0.05	0.12	0.14	0.26	-.07	0.06	0.04	-.21	0.07	0.03	-.12	0.15	-.14	0.10	-.19	-.10	0.02	-.09	0.06	-.01	0.05	0.07	0.08	0.06	-.02	-.10	0.03	-.09	-.02	-.10	0.05	0.04	0.04	0.02	-.05	-.30	-.24	0.27	
(45) Marbling texture	0.07	-.22	-.06	0.17	-.18	0.08	0.09	0.08	0.03	0.02	0.11	0.05	0.25	0.02	0.07	0.22	0.15	-.05	0.02	0.01	0.25	0.13	-.04	-.23	0.02	0.14	0.07	0.03	-.20	0.25	0.08	0.19	0.15	-.11	0.10	0.10	0.08	0.20	-.06	-.05	0.12	-.16	0.09	-.31

[a]Correlation of 0.31 and 0.41 required for significance (P<.05) and (P<.01), respectively.

other traits. The relationships between sale weight and weaning weight, initial weight and daily gains during all periods were highly significant. The association between weaning condition and final condition was significant but low (r = 0.32).

The correlations between performance traits and muscle and fat color and texture were low and usually negative. Final condition grade was significantly correlated with measures of body fat as expected except with fat over the *biceps femoris*. Traits having the highest correlations with condition grade were conformation grade (0.56) and marbling score (0.53).

Dressing per cent was significantly correlated with most linear measurements, weights of carcass components and muscle areas. Its highest relationships were with *biceps femoris* area (r = 0.59) and trimmed round weight (r = 0.61). *L. dorsi* area was significantly correlated with gains during different periods and with weights of carcass components, being more highly correlated with carcass weight (0.71), with 6-12 rib weight (0.78) and 9-10-11 rib weight (0.75). It had high correlations with *biceps femoris* weight (0.70) and *biceps femoris* area (0.62).

Fat over the *l. dorsi* was significantly related to daily gains in most periods, to final condition grade, carcass weight and weights of other carcass components. Fat over the *l. dorsi* was more closely related to many of the traits which were closely related to *l. dorsi* area, but usually of a lower magnitude. There was a low but significant correlation (0.31) between fat over the *l. dorsi* and fat over the biceps femoris. Carcass length was associated with most of the measurements which indicated body size.

Marbling score was significantly related with values for fat and the correlations with this trait were as follows: condition grade (0.53), fat over l. dorsi (0.38), estimated per cent kidney and pelvic fat (0.34), carcass grade (0.92), round fat weight (0.42) and fat weight of the 9-10-11 rib section (0.32). Marbling score generally had a very low relationship to linear measurements and weights of carcasses and carcass components. This was because bulls, which were the heaviest animals, had lower marbling scores than heifers, which were the lightest animals.

Carcass grade was more highly associated with marbling score (r = 0.92) and conformation grade (r = 0.58) than any other traits. However, there was a highly significant correlation between carcass grade and final condition grade (0.43).

Fat over the biceps femoris had the highest correlation with fat over the l. dorsi (0.31) and was correlated 0.24 and 0.23, respectively, with marbling score and estimated kidney and pelvic fat. Fat over the biceps femoris was not closely associated with any other traits. The low relationship to other fat values indicates that fat deposition on the round is not identical to fat deposition over the loin.

Muscle texture and firmness were significantly correlated (0.46 and 0.47, respectively) with marbling score. Muscle texture was significantly correlated (0.38) with fat over l. dorsi and muscle firmness was significantly correlated (0.38) with estimated per cent kidney and pelvic fat. Muscle color, texture and firmness were also significantly correlated (0.31, 0.45 and 0.49, respectively) with carcass grade. These relationships indicate a significant effect of carcass fat content on these traits. There were few other significant correlations among the subjective scores of muscle and fat.

Selected Carcass Traits, Cooking Losses, Taste Panel Scores and Chemical Analyses

The relationships among selected carcass traits, meat evaluation scores and chemical analyses are presented in Table XVI. Drip loss which was expected to be primarily a function of fat was significantly correlated with fat over the *biceps femoris* (0.36), round fat weight (0.53) and 9-11 rib fat weight (0.37). Drip loss was not significantly correlated with fat over the *l. dorsi* (0.21), marbling score (0.20), tenderness (0.26), flavor (0.28) and negatively correlated with evaporation loss (-.33) and shear value (-.32).

The evaporation loss was negatively correlated with fat over the *biceps femoris* (-.32), round fat weight (-.33), 9-10-11 rib fat weight (-.29) fat over the *l. dorsi* (-.26) and was significantly negatively correlated with flavor (-.46). The correlations between evaporation losses and these traits are about the same magnitude as the same traits correlated with drip losses, but in the opposite direction. This was expected since evaporation loss represents mainly moisture and drip loss represents mainly fat.

TABLE XVI

CORRELATIONS AMONG SELECTED CARCASS TRAITS, COOKING LOSSES, TASTE PANEL SCORES AND CHEMICAL ANALYSES OF BULLS, STEERS AND HEIFERS[a]

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
(1) L. dorsi area																						
(2) Fat over l. dorsi	0.29																					
(3) Marbling score	0.11	0.38																				
(4) Fat over b. femoris	-.14	0.31	0.24																			
(5) B. femoris area	0.62	0.35	0.12	-.14																		
(6) Trimmed round wt.	0.66	0.47	0.12	-.02	0.76																	
(7) B. femoris wt.	0.70	0.39	0.03	0.04	0.74	0.85																
(8) Round muscle wt.	0.67	0.39	0.06	-.12	0.82	0.97	0.86															
(9) Round fat wt.	0.44	0.58	0.42	0.27	0.42	0.73	0.51	0.60														
(10) Round bone wt.	0.58	0.33	-.05	-.04	0.65	0.85	0.77	0.83	0.50													
(11) 9-10-11 rib, muscle wt.	0.71	0.34	0.15	-.13	0.68	0.70	0.67	0.75	0.40	0.61												
(12) 9-10-11 rib, fat wt.	0.57	0.72	0.32	0.21	0.41	0.65	0.52	0.56	0.84	0.46	0.48											
(13) 9-10-11 rib, bone wt.	0.38	0.41	0.11	0.19	0.39	0.61	0.53	0.59	0.44	0.48	0.24	0.49										
(14) Drip loss, %	0.01	0.21	0.20	0.36	-.04	0.18	0.14	0.07	0.53	0.12	-.13	0.37	0.04									
(15) Evaporation loss, %	0.07	-.26	-.23	-.32	-.04	-.02	-.04	0.02	-.33	0.10	0.05	-.29	0.04	-.33								
(16) Total loss, %	0.08	-.15	-.12	-.12	-.07	0.08	0.03	0.06	-.04	0.17	-.02	-.09	0.07	0.24	0.84							
(17) Shear value	-.23	-.14	-.16	-.08	-.35	-.43	-.37	-.42	-.32	-.30	-.20	-.23	-.18	-.32	0.16	-.02						
(18) Taste panel tenderness	0.07	-.03	0.05	-.01	0.18	0.28	0.19	0.28	0.27	0.19	0.09	0.17	0.15	0.26	-.27	-.11	-.65					
(19) Taste panel juiciness	0.03	0.17	0.33	0.06	0.18	0.19	0.12	0.17	0.16	0.11	0.11	0.12	0.25	-.01	-.09	-.10	-.08	0.11				
(20) Taste panel flavor	0.07	-.06	0.22	0.02	0.26	0.20	0.20	0.23	0.22	0.13	0.17	0.19	0.02	0.28	-.46	-.31	-.39	0.47	0.28			
(21) 9-10-11 rib, l. dorsi moisture	-.11	-.16	-.77	-.01	-.12	-.13	-.01	-.11	-.40	0.03	-.22	-.26	0.11	-.21	0.27	0.16	0.29	-.18	-.25	-.36		
(22) 9-10-11 rib, l. dorsi protein	0.16	-.01	-.23	0.10	0.22	0.19	0.10	0.19	0.08	0.25	0.27	0.07	0.16	-.11	-.02	-.08	-.02	-.09	0.09	0.02	0.20	
(23) 9-10-11 rib, l. dorsi ether extract	-.01	0.19	0.78	-.01	0.06	0.07	-.05	0.04	0.31	-.07	0.04	0.19	-.12	0.23	-.21	-.08	-.30	0.20	0.34	0.31	-.90	-.48

[a]Correlations of 0.31 and 0.41 required for significance ($P < .05$) and ($P < .01$), respectively.

Tenderness as measured by shear values was significantly negatively correlated with biceps femoris area (-.35), trimmed round weight (-.43), biceps femoris weight (-.37), round muscle weight (-.42) and round fat weight (-.32). Since these measures of composition were significantly positively associated with body weight, this indicates that heavier animals tended to be more tender. Tenderness as measured by shear values was also negatively correlated with drip loss (-.32), tenderness as scored by taste panel (-.65) and flavor (-.39). The correlation of shear value and marbling was a low negative (-.16) and with ether extract the correlation of shear value (-.30) approached significance. Tenderness as scored by the taste panel was correlated significantly with flavor (0.47) but not significantly correlated with any other trait except the negative relationship with shear value previously mentioned. Flavor had significant negative correlations with evaporation loss (-.46) and shear value (-.39).

Moisture of the 9-10-11 rib l. dorsi muscle had negative correlations with marbling (-.77), round fat weight (-.40), 9-10-11 rib fat weight (-.26), juiciness (-.25) and flavor (-.36). Moisture also had a very high significant negative correlation (-.90) with ether extract and was positively, but not significantly, correlated with evaporation loss (0.27) and shear value (0.29). The relationship of protein with other values was relatively low, but there was a highly significant negative correlation (-.48) of protein with ether extract. Ether extract was significantly correlated with marbling (0.78), round fat weight (0.31), juiciness (0.34), flavor (0.31) and negatively correlated with moisture (-.90) and protein (-.48), respectively.

Predicting Round Composition

Results of the multiple regression analyses using trimmed round weight, biceps femoris weight and round muscle weight as dependent variables and selected traits as independent variables are presented in Table XVII. The purpose of this analysis was to determine the combination of traits which have the highest value in predicting carcass composition; especially to determine those traits of high predictive value which may be readily obtained from live animals.

Live weight and biceps femoris area accounted for more of the variation in trimmed round weight (87 per cent), biceps femoris weight (73 per cent) and round muscle weight (86 per cent) than any other two traits in combination which could be obtained on live animals.

The amount of variation in trimmed round weight accounted for was not increased when live weight and biceps femoris area were used in combination with any one of the following: l. dorsi area, fat over l. dorsi, fat over biceps femoris or hock to hip measurement. When live weight and biceps femoris area were used in combination with l. dorsi area, the variation accounted for in biceps femoris weight was 74 per cent. L. dorsi area did not make a significant contribution toward increasing the variation accounted for in any of the combinations. When live weight and biceps femoris area were used in combination with either fat over l. dorsi or fat over biceps femoris, the amount of variation accounted for in round muscle weight was 88 per cent. Adding hock to hip or hooks to pins alone or in combination with live weight and biceps femoris area did not significantly increase the variation accounted for

TABLE XVII

SIMPLE CORRELATIONS (r) OF TRIMMED ROUND WEIGHT, B. FEMORIS WEIGHT AND ROUND MUSCLE WEIGHT WITH OTHER TRAITS, PARTIAL REGRESSIONS (b), STANDARD PARTIAL REGRESSIONS (b') AND SQUARED MULTIPLE CORRELATION COEFFICIENTS (R^2) OF THESE TRAITS ON OTHER TRAITS

Traits	Trimmed Round Weight			B. Femoris Weight			Round Muscle Weight		
	r	b	b'	r	b	b'	r	b	b'
Live wt.	0.89**	0.495**	0.683**	0.78**	0.059**	0.522**	0.85**	0.266**	0.556**
B. femoris area	0.76**	1.039**	0.342**	0.75**	0.203**	0.429**	0.82**	0.959**	0.478**
R^2		0.873			0.731			0.865	
Live wt.	0.89**	0.612**	0.845**	0.78**	0.066**	0.583**	0.85**	0.355**	0.741**
L. dorsi area	0.66**	0.433	0.069	0.70**	0.282*	0.291*	0.67**	0.640	0.156
R^2		0.802			0.660			0.735	
Live wt.	0.89**	0.658**	0.910**	0.78**	0.092**	0.813**	0.85**	0.433**	0.905**
Fat over l. dorsi	0.47**	-.055	-.027	0.39*	-.016	-.051	0.39*	-.135	-.102
R^2		0.800			0.618			0.730	
Live wt.	0.89**	0.654**	0.905**	0.78**	0.089**	0.788**	0.85**	0.416**	0.869**
Fat over b. femoris	-.02	-.406	-.105	0.04	-.018	-.030	-.12	-.523*	-.205*
R^2		0.810			0.617			0.764	
B. femoris area	0.76**	0.824**	0.271**	0.75**	0.195**	0.411**	0.82**	0.855**	0.426**
Hot carcass wt.	0.92**	0.076**	0.735**	0.78**	0.008**	0.505**	0.87**	0.040**	0.589**
R^2		0.881			0.703			0.865	

TABLE XVII (CONTINUED)

Traits	Trimmed Round Weight			B. Femoris Weight			Round Muscle Weight		
	r	b	b'	r	b	b'	r	b	b'
Live wt.	0.89**	0.520**	0.719**	0.79**	0.051**	0.449**	0.85**	0.273**	0.571**
B. femoris area	0.76**	1.105**	0.364**	0.75**	0.181**	0.382**	0.82**	0.978**	0.487**
L. dorsi area	0.66**	-.426	-.068	0.70**	0.141	0.145	0.67**	-.120	-.029
R^2		0.875			0.741			0.866	
Live wt.	0.89**	0.509**	0.704**	0.78**	0.063**	0.555**	0.85**	0.295**	0.617**
B. femoris area	0.76**	1.043**	0.344**	0.75**	0.204**	0.431**	0.82**	0.966**	0.482**
Fat over l. dorsi	0.46**	-.075	-.037	0.39*	-.020	-.063	0.39*	-.153	-.116
R^2		0.874			0.734			0.875	
Live wt.	0.89**	0.503**	0.695**	0.78**	0.057**	0.505**	0.85**	0.282**	0.590**
B. femoris area	0.76**	1.001**	0.330**	0.75**	0.212**	0.447**	0.82**	0.885**	0.441**
Fat over b. femoris	-.02	-.152	-.039	0.04	0.035	0.058	-.12	-.300	-.117
R^2		0.874			0.734			0.878	
Live wt.	0.89**	0.500**	0.690**	0.78**	0.058**	0.510**	0.85**	0.270**	0.564**
B. femoris area	0.76**	1.041**	0.343**	0.75**	0.203**	0.428**	0.82**	0.960**	0.479**
Hock to hip	0.66**	-.062	-.009	0.59**	0.017	0.017	0.63**	-.049	-.011
R^2		0.873			0.731			0.865	
Live wt.	0.89**	0.621**	0.859**	0.78**	0.067**	0.594**	0.85**	0.382**	0.798**
L. dorsi area	0.66**	0.413	0.066	0.70**	0.279*	0.288*	0.67**	0.583	0.142
Fat over l. dorsi	0.46**	-.040	-.019	0.39*	-.005	-.017	0.39	-.112	-.085
R^2		0.802			0.661			0.740	

TABLE XVII (CONTINUED)

Traits	Trimmed Round Weight			B. Femoris Weight			Round Muscle Weight		
	r	b	b'	r	b	b'	r	b	b'
Live wt.	0.89**	0.647**	0.895**	0.78**	0.087**	0.764**	0.85**	0.412**	0.861**
Hock to hip	0.66**	0.128	0.020	0.59**	0.054	0.054	0.63**	0.150	0.035
Hooks to pins	0.49**	-.154	-.028	0.42**	-.030	-.034	0.44**	-.242	-.066
R^2		0.800			0.618			0.726	
B. *femoris* area	0.76**	0.824**	0.271**	0.75**	0.195**	0.411**	0.82**	0.855**	0.426**
Hot carcass wt.	0.92**	0.076**	0.733**	0.78**	0.007**	0.455**	0.87**	0.040**	0.585**
Hock to hip	0.66**	0.018	0.002	0.59**	0.069	0.070	0.63**	0.025	0.006
R^2		0.881			0.706			0.865	
Live wt.	0.89**	0.540**	0.747**	0.78**	0.054**	0.478**	0.85**	0.310**	0.647**
B. *femoris* area	0.76**	1.119**	0.369**	0.75**	0.183**	0.387**	0.82**	1.001**	0.499**
L. *dorsi* area	0.66**	-.484	-.078	0.70**	0.132	0.136	0.67**	-.220	-.053
Fat over *l. dorsi*	0.46**	-.095	-.047	0.39*	-.014	-.046	0.39**	-.162	-.122
R^2		0.876			0.742			0.876	
Live wt.	0.89**	0.526**	0.726**	0.79**	0.064**	0.563**	0.85**	0.321**	0.671**
B. *femoris* area	0.76**	1.048**	0.345**	0.75**	0.204**	0.431**	0.82**	0.975**	0.486**
Fat over *l. dorsi*	0.46**	-.090	-.045	0.39*	-.021	-.066	0.39*	-.176	-.133
Hock to hip	0.66**	-.176	-.027	0.59**	-.009	-.009	0.63**	-.272	-.065
R^2		0.874			0.734			0.877	
Live wt.	0.89**	0.491**	0.678**	0.78**	0.056**	0.495**	0.85**	0.269**	0.562**
B. *femoris* area	0.76**	1.052**	0.347**	0.75**	0.205**	0.432**	0.82**	0.961**	0.479**
Hock to hip	0.66**	-.093	-.014	0.59**	0.011	0.011	0.63**	-.052	-.012
Hooks to pins	0.49**	0.128	0.023	0.42**	0.025	0.029	0.44**	0.016	0.004
R^2		0.873			0.732			0.865	

TABLE XVII (CONTINUED)

Traits	Trimmed Round Weight			B. Femoris Weight			Round Muscle Weight		
	r	b	b'	r	b	b'	r	b	b'
B. femoris area	0.76**	0.823**	0.271**	0.75**	0.195**	0.411**	0.82**	0.853**	0.425**
Fat over l. dorsi	0.46**	-.080	-.040	0.39*	-.008	-.024	0.39*	-.159	-.121
Hot carcass wt.	0.92**	0.079**	0.765**	0.78**	0.008*	0.475*	0.87**	0.047**	0.682**
Hock to hip	0.66**	-.074	-.011	0.59**	0.061	0.061	0.63**	-.158	-.037
R^2		0.882			0.706			0.874	
B. femoris area	0.76**	0.789	0.260**	0.75**	0.207**	0.437**	0.82**	0.780**	0.389**
Fat over b. femoris	-.02	-.135	-.034	0.04	0.048	0.080	-.12	-.288	-.113
Hot carcass wt.	0.92**	0.077**	0.748**	0.78**	0.007*	0.421*	0.87**	0.043**	0.633**
Hock to hip	0.66**	-.024	-.003	0.59**	0.085	0.086	0.63**	-.066	-.015
R^2		0.882			0.712			0.877	
B. femoris area	0.76**	0.889**	0.293**	0.75**	0.179**	0.378**	0.82**	0.871**	0.434**
L. dorsi area	0.66**	-.529	-.085	0.70**	0.178	0.183	0.67**	-.156	-.038
Hot carcass wt.	0.92**	0.080**	0.777**	0.78**	0.005	0.327	0.87**	0.042**	0.608**
Hock to hip	0.66**	0.070	0.011	0.59**	0.039	0.040	0.63**	0.047	0.011
Hooks to pins	0.49**	-.031	-.005	0.42**	0.062	0.072	0.44**	-.037	-.010
R^2		0.884			0.722			0.866	

*P < .05.

**P < .01.

in any of the three dependent variables. The "hock to hip" and "hooks to pins" measurements reported here were obtained on the carcass. However, these measurements also could be readily obtained on live animals.

Hot carcass weight was used in a combination with biceps femoris area and this combination accounted for only about 1 per cent more variation in trimmed round weight than did a combination of live weight and biceps femoris area, and accounted for 3 per cent less of the variation in biceps femoris weight (70 versus 73 per cent). Live weight and hot carcass weight each in combination with biceps femoris area accounted for the same amount of variation in round muscle weight (87 per cent). Thus, live weight is almost as precise as hot carcass weight in predicting round composition and has the advantage of being taken on live animals. An accurate estimate of the biceps femoris area in combination with live weight would be valuable in predicting round composition of live beef animals.

The variables and means used in computing prediction equations are presented in Table XVIII. Four prediction equations each for trimmed round weight, biceps femoris weight and round muscle weight are given in Table XIX. These are the most useful equations obtained from the multiple regression analyses presented in Table XVII (page 67), and values for making predictions may be obtained from live animals. Equations may be readily developed from other desired combinations by substituting the appropriate partial regressions (Table XVII, page 67) and mean values (Table XVIII) into the formulas given in the procedure section (page 28).

TABLE XVIII

VARIABLES AND MEAN VALUES USED IN COMPUTING PREDICTION EQUATIONS

Symbol	Variable	Mean
Y_1	Trimmed round wt., lb.	55.88
Y_2	*B. femoris* wt., lb.	8.29
Y_3	Round muscle wt., lb.	37.03
X_1	Live wt., lb.	857.3
X_2	*B. femoris* area, sq. in.	16.54
X_3	*L. dorsi* area, sq. in.	10.36
X_4	Fat thickness over *l. dorsi*, mm.	10.33
X_5	Fat thickness over *b. femoris*, mm.	3.79
X_6	Hot carcass wt., lb.	527.95
X_7	Hock to hip distance, in.	25.94
X_8	Hooks to pins distance, in.	17.36

TABLE XIX

PREDICTION EQUATIONS FOR ROUND COMPOSITION OF BULLS, STEERS AND HEIFERS

Variables[a]	Equations
	Prediction of Trimmed Round Weight
X_1 X_2	$\hat{Y}_1$ = -385.669 + 0.495 (X_1) + 1.039 (X_2)
X_1 X_2 X_3	$\hat{Y}_1$ = -403.779 + 0.520 (X_1) + 1.105 (X_2) - .426 (X_3)
X_1 X_2 X_4	$\hat{Y}_1$ = -396.962 + 0.509 (X_1) + 1.043 (X_2) - .075 (X_4)
X_1 X_2 X_5	$\hat{Y}_1$ = -391.322 + 0.503 (X_1) + 1.001 (X_2) - .152 (X_4)
	Prediction of *B. Femoris* Weight
X_1 X_2	$\hat{Y}_2$ = -45.648 + 0.059 (X_1) + 0.203 (X_2)
X_1 X_2 X_3	$\hat{Y}_2$ = -39.887 + 0.051 (X_1) + 0.181 (X_2) + 0.141 (X_3)
X_1 X_2 X_4	$\hat{Y}_2$ = -48.887 + 0.063 (X_1) + 0.204 (X_2) - .020 (X_4)
X_1 X_2 X_5	$\hat{Y}_2$ = -44.215 + 0.057 (X_1) + 0.212 (X_2) + 0.035 (X_5)
	Prediction of Round Muscle Weight
X_1 X_2	$\hat{Y}_3$ = -206.874 + 0.266 (X_1) + 0.957 (X_2)
X_1 X_2 X_3	$\hat{Y}_3$ = -211.946 + 0.273 (X_1) + 0.978 (X_2) - .120 (X_3)
X_1 X_2 X_4	$\hat{Y}_3$ = -230.271 + 0.295 (X_1) + 0.966 (X_2) - .153 (X_4)
X_1 X_2 X_5	$\hat{Y}_3$ = -218.230 + 0.282 (X_1) + 0.885 (X_2) - .300 (X_5)

[a]Refer to Table XVIII for designation of variables and means.

V. ULTRASONIC ESTIMATES OF MUSCLE AND FAT

Simple correlation coefficients between estimated and actual muscle areas and fat depths over these muscles and between interpreters for final estimates on May 14, 1964, are presented in Table XX. Interpretations for all scan dates are included for interpreter A while *biceps femoris* area, fat over *biceps femoris* and fat over *l. dorsi* in final scans are included for interpreter B. Interpreter B was the most experienced of the two and this is shown in the relative accuracy of some of the estimates, especially the estimates of final fat thickness.

With reference to animals slaughtered on May 14, 1964, interpreter A's correlations of estimated with actual final values for *biceps femoris* area, fat over *biceps femoris* and fat over *l. dorsi* were 0.42, 0.23 and 0.72, respectively. Correlations for area or fat thickness over the *l. dorsi* will be given for estimates taken between 12th and 13th ribs unless otherwise stated. Corresponding interpretations for interpreter B were 0.54, 0.86 and 0.70. Correlations between interpreters for these values were 0.27, 0.43 and 0.69 which indicated closer agreement between interpreters in fat estimates over *l. dorsi* than for other estimates. Since the correlation between estimated and actual fat over the *biceps femoris* was relatively low for interpreter A, measurements were taken again and the correlation was increased to 0.81.

The magnitude of the correlation coefficients between estimated and actual values for interpreter A varied considerably from beginning to end of the experiment. The estimates taken immediately prior to

TABLE XX

SIMPLE CORRELATION COEFFICIENTS[a] BETWEEN ESTIMATED AND ACTUAL MUSCLE AREAS AND FAT DEPTHS OF BULLS, STEERS AND HEIFERS SLAUGHTERED MAY 19, 1964

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
(1) L.D.[b] area (actual)																										
(2) L.D. fat (actual)	0.34																									
(3) B.F.[c] fat (actual)	0.04	0.38																								
(4) B.F. area (actual)	0.64	0.36	-.24																							
(5)[d] B.F. area 11-14-63	0.23	0.40	0.05	0.41																						
(6) B.F. fat 11-14-63	-.29	-.33	0.02	-.20	-.36																					
(7) B.F. area 2-13-64	-.11	0.16	0.40	0.03	0.25	0.50																				
(8) B.F. fat 2-13-64	0.05	0.13	0.45	-.09	0.35	0.42	0.31																			
(9) B.F. area 3-18-64	0.23	0.47	0.22	0.26	0.62	-.14	0.72	0.02																		
(10) B.F. fat 3-18-64	0.47	0.64	0.74	0.15	0.10	-.07	0.22	0.31	0.25																	
(11) B.F. area 5-14-64	0.60	0.60	0.13	0.42	-.09	-.20	0.16	-.30	0.39	0.59																
(12) B.F. fat 5-14-64	0.16	-.01	0.23	0.05	-.35	-.08	0.16	-.35	0.16	0.11	0.38															
(13) L.D. area 11-14-63	-.11	0.52	0.14	-.06	-.41	0.12	0.22	-.33	0.21	0.30	0.61	0.41														
(14) L.D. fat 11-14-63	-.21	-.26	-.01	-.11	0.37	0.44	0.32	0.69	-.02	-.26	-.57	-.58	-.60													
(15) L.D. area 1-24-64	0.20	0.27	-.15	0.35	0.80	-.24	0.29	0.27	0.58	-.25	-.10	-.14	-.30	0.46												
(16) L.D. fat 1-24-64	-.04	0.34	0.41	0.11	0.24	0.46	0.32	0.85	-.03	0.27	-.20	-.25	-.02	0.56	0.25											
(17) L.D. area 3-18-64	0.62	0.42	-.02	0.59	-.02	-.17	0.17	-.36	0.43	0.31	0.73	0.27	0.42	-.51	0.02	-.20										
(18) L.D. fat 3-18-64	-.20	0.44	0.74	-.10	0.10	0.40	0.57	0.62	0.20	0.60	0.07	-.12	0.27	0.24	-.11	0.72	-.02									
(19) L.D. area 4-30-64	0.58	0.21	-.24	0.78	0.33	-.20	-.07	-.02	0.10	-.09	0.16	-.07	-.25	0.20	0.53	0.18	0.40	-.26								
(20) L.D. fat 4-30-64	0.27	0.47	0.43	0.22	-.03	0.35	0.21	0.67	-.07	0.52	0.29	-.05	0.23	0.20	0.01	0.80	0.17	0.69	0.15							
(21) L.D. area (12)[e] 5-14-64	0.75	0.52	0.39	0.47	0.49	-.33	0.20	0.35	0.49	0.55	0.48	0.02	-.12	0.02	0.42	0.24	0.55	0.26	0.39	0.49						
(22) L.D. area (13)[f] 5-14-64	0.29	0.20	0.57	0.06	0.03	-.10	0.08	0.32	-.04	0.48	0.12	-.26	-.22	0.23	-.09	0.28	0.24	0.46	0.24	0.43	0.57					
(23) L.D. fat (12) 5-14-64	-.07	0.71	0.46	-.18	0.26	-.35	0.23	0.10	0.44	0.28	0.26	0.15	0.45	-.08	0.40	0.24	0.04	0.31	0.01	0.21	0.27	0.12				
(24) L.D. fat (13) 5-14-64	-.02	0.72	0.75	-.08	0.12	-.25	0.30	0.18	0.32	0.56	0.33	0.21	0.45	-.13	0.12	0.37	0.15	0.63	-.01	0.44	0.39	0.47	0.85			
(25)[g] B.F. area 5-14-64	0.79	0.16	-.05	0.54	0.40	-.23	-.05	0.01	0.36	0.27	0.27	0.19	-.20	-.25	0.25	-.13	0.45	-.31	0.39	-.09	0.48	-.11	-.20	-.27		
(26) B.F. fat 5-14-64	-.03	0.21	0.86	-.36	-.02	0.18	0.43	0.56	0.19	0.53	0.05	0.43	0.15	0.05	-.04	0.45	-.17	0.64	-.38	0.48	0.31	0.26	0.43	0.60	-.06	
(27) L.D. fat 5-14-64	0.17	0.70	0.56	-.12	0.48	-.41	0.22	0.25	0.55	0.55	0.29	-.22	0.18	-.04	0.29	0.16	0.23	0.44	-.11	0.21	0.61	0.46	0.71	0.69	0.06	0.37

[a]Values of 0.31 and 0.41 required for significance ($P < .05$) and ($P < .01$), respectively.

[b]*L. dorsi.*

[c]*B. femoris.*

[d]Items 5-24 are estimates by interpreter A.

[e]Taken over 12th rib.

[f]Taken between 12th and 13th ribs.

[g]Items 25-27 are estimates by interpreter B.

slaughter generally had the highest relationship to carcass values and the estimates taken at the first scan of the experiment generally had the lowest. This relationship indicates that all animals do not deposit tissues at the same rate. However, the estimate of biceps femoris area on November 14, 1963, was significantly correlated with actual biceps femoris area (0.41) and was close to the correlation between estimated and actual biceps femoris area on May 14, 1964 (0.42). All estimates on March 18, 1964, and April 30, 1964, were significantly correlated with corresponding values except the estimates of biceps femoris area on March 18, 1964.

Correlation coefficients for estimates made on animals slaughtered June 12, 1964, are presented in Table XXI. The correlations of actual and estimated carcass values for fat over l. dorsi, fat over biceps femoris and biceps femoris area, respectively, were 0.46, -.09 and 0.75 for interpreter A and 0.72, 0.79 and 0.33 for interpreter B. Correlations between interpreters for those values, respectively, were 0.74, 0.43 and 0.01, again indicating closer agreement between interpreters for estimates of fat over the l. dorsi than for other comparisons.

Relative to scans taken on animals slaughtered on June 12, 1964, all correlations for interpreter A between estimated and actual areas of l. dorsi and biceps femoris were significant and relatively high. However, correlation coefficients between estimates and actual fat over biceps femoris were highly variable and the relationships between actual values and estimates on February 13, 1964, and June 11, 1964, were especially low (r = 0.05 and -.09, respectively). The somagrams from

TABLE XXI

SIMPLE CORRELATION COEFFICIENTS[a] BETWEEN ESTIMATED AND ACTUAL MUSCLE AREAS AND FAT DEPTHS OF BULLS, STEERS AND HEIFERS SLAUGHTERED JUNE 12, 1964

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
(1) L.D.[b] area (actual)																												
(2) L.D. fat (actual)	0.37																											
(3) B.F.[c] fat (actual)	-.35	0.15																										
(4) B.F. area (actual)	0.72	-.06	-.30																									
(5)[d]B.F. area 11-14-63	0.34	-.30	-.31	0.79																								
(6) B.F. fat 11-14-63	0.14	0.22	0.51	0.03	0.15																							
(7) B.F. area 2-13-64	0.69	0.28	-.39	0.62	0.11	-.20																						
(8) B.F. fat 2-13-64	0.02	0.22	0.05	0.04	-.04	0.17	0.14																					
(9) B.F. area 3-18-64	0.68	0.15	-.53	0.71	0.61	-.31	0.38	-.19																				
(10) B.F. fat 3-18-64	0.23	0.35	0.30	0.38	0.34	0.55	0.16	0.78	0.02																			
(11) B.F. area 5-14-64	0.66	-.27	-.82	0.73	0.65	-.29	0.50	-.08	0.74	-.07																		
(12) B.F. fat 5-14-64	-.02	-.15	0.50	0.11	-.12	0.29	0.08	0.55	-.44	0.50	-.24																	
(13) B.F. area 6-11-64	0.79	-.16	-.25	0.75	0.40	0.15	0.68	-.01	0.41	0.17	0.67	0.24																
(14) B.F. fat 6-11-64	0.71	0.06	-.09	0.63	0.44	0.31	0.27	0.44	0.42	0.57	0.50	0.48	0.64															
(15) L.D. area 11-14-63	0.33	0.03	-.12	-.07	-.14	-.03	-.22	-.19	0.20	-.30	0.19	0.08	0.09	0.45														
(16) L.D. fat 11-14-63	0.23	0.40	-.12	-.09	-.02	0.14	-.10	-.70	0.25	-.44	0.01	-.64	-.16	-.25	0.35													
(17) L.D. area 1-24-64	0.60	0.48	-.23	0.20	-.02	-.05	0.14	0.16	0.46	0.11	0.29	0.07	0.13	0.62	0.79	0.30												
(18) L.D. fat 1-24-64	0.02	-.01	-.13	-.35	-.59	0.03	0.33	0.21	-.48	-.15	-.08	0.14	0.25	-.14	-.13	-.25	-.23											
(19) L.D. area 3-18-64	0.82	0.33	-.02	0.56	0.10	0.27	0.59	0.25	0.28	0.38	0.35	0.50	0.69	0.80	0.45	0.01	0.67	0.09										
(20) L.D. fat 3-18-64	0.17	0.31	0.16	-.22	-.64	-.30	0.30	0.08	0.01	-.14	-.19	0.07	0.16	-.02	0.08	-.20	0.12	0.50	0.18									
(21) L.D. area 4-30-64	0.80	0.53	-.13	0.71	0.49	0.26	0.44	0.32	0.66	0.62	0.43	0.12	0.43	0.78	0.24	0.13	0.69	-.39	0.73	-.08								
(22) L.D. fat 4-30-64	0.30	0.24	0.03	-.25	-.29	0.25	-.14	0.09	0.09	-.01	0.01	-.15	0.19	0.29	0.40	0.08	0.29	0.38	0.16	0.55	0.10							
(23) L.D. area (12)[e] 6-11-64	0.66	0.01	-.48	0.83	0.69	0.08	0.53	0.18	0.53	0.36	0.73	0.17	0.56	0.65	0.15	0.03	0.44	-.28	0.64	-.49	0.72	-.35						
(24) L.D. area (13)[f] 6-11-64	0.91	0.31	-.25	0.78	0.39	0.11	0.69	-.07	0.59	0.21	0.58	0.13	0.71	0.65	0.33	0.28	0.59	-.17	0.86	-.04	0.79	-.07	0.80					
(25) L.D. fat (12) 6-11-64	0.14	0.36	0.45	-.39	-.70	0.32	0.11	0.04	-.39	-.02	-.44	0.21	0.18	-.01	0.13	0.01	0.02	0.66	0.26	0.75	-.14	0.67	-.52	-.05				
(26) L.D. fat (13) 6-11-64	0.32	0.46	0.06	-.33	-.55	0.31	0.19	-.16	-.17	-.19	-.17	-.21	0.21	-.08	0.18	0.38	0.11	0.67	0.22	0.55	-.06	0.70	-.34	0.09	0.85			
(27)[g]B.F. area 6-11-64	-.06	0.21	0.09	0.33	0.21	0.03	0.48	0.35	-.07	0.50	-.09	0.18	0.01	-.17	-.82	-.30	-.40	-.05	-.02	-.19	0.15	-.66	0.27	0.10	-.27	-.34		
(28) B.F. fat 6-11-64	-.13	-.08	0.79	0.01	0.07	0.65	-.40	0.34	-.35	0.58	-.44	0.72	0.04	0.43	0.09	-.37	-.02	-.21	0.23	-.06	0.14	0.14	-.10	-.08	0.24	-.15	-.06	
(29) L.D. fat 6-11-64	0.37	0.72	0.08	-.28	-.44	0.47	0.07	0.31	-.14	0.25	-.20	0.03	0.01	0.27	0.38	0.31	0.54	0.39	0.45	0.30	0.35	0.64	-.05	0.20	0.62	0.74	-.27	0.09

[a]Values of 0.31 and 0.41 required for significance ($P < .05$) and ($P < .01$), respectively.

[b]*L. dorsi*.

[c]*B. femoris*.

[d]Items 5-26 are estimates by interpreter A.

[e]Taken over 12th rib.

[f]Taken between 12th and 13th ribs.

[g]Items 27-29 are estimates by interpreter B.

scans taken on June 11, 1964, were difficult to interpret, and this is indicated by the low relationship between actual and estimated fat over biceps femoris on that date. However, interpreter B had a corresponding correlation of 0.79 between those values, and this indicates the value of experience in interpretation of the somagrams. Interpreter A attempted to improve the estimate of fat over the l. dorsi (r = 0.46) and estimate of fat over the biceps femoris (r = -.09) by taking fat measurements again. Results were little improved over the first, however, and the corresponding values were 0.52 and 0.04, respectively.

The correlations obtained between estimated and carcass values on animals slaughtered July 3, 1964, (Table XXII) are in general agreement with those on the other two kill dates. However, the agreement between interpreters with these animals was low with reference to other kill dates. The correlations of estimates between interpreters for biceps femoris area, fat over biceps femoris and fat over l. dorsi were 0.26, 0.26 and 0.27, respectively. The estimates of interpreter A for fat over biceps femoris were variable and had low relationships to actual values. Estimates of interpreter A for biceps femoris area for this slaughter group had low correlations with carcass values except for the final scan (0.52) which was high relative to the others. The reason for the low correlation between estimated and actual fat thickness of the biceps femoris may be because of the small amount of fat over this muscle and because of the relative inexperience of the interpreter. The reason may be that fat tissue is not laid down over the biceps femoris at the same rate as it is over other muscles. However, the estimates

TABLE XXII

SIMPLE CORRELATION COEFFICIENTS[a] BETWEEN ESTIMATED AND ACTUAL MUSCLE AREAS AND FAT DEPTHS OF BULLS, STEERS AND HEIFERS SLAUGHTERED JULY 3, 1964

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
(1) L.D.[b] area (actual)																																
(2) L.D. fat (actual)	0.28																															
(3) B.F.[c] fat (actual)	-.08	0.82																														
(4) B.F. area (actual)	0.81	0.55	0.21																													
(5)[d] B.F. area 11-14-63	0.11	-.37	-.32	0.04																												
(6) B.F. fat 11-14-63	-.25	-.13	-.43	-.11	0.30																											
(7) B.F. area 2-13-64	0.15	0.58	0.71	0.34	0.18	-.46																										
(8) B.F. fat 2-13-64	0.53	0.23	0.29	0.55	0.64	-.29	0.59																									
(9) B.F. area 3-18-64	-.19	0.35	0.70	0.09	0.29	-.40	0.88	0.57																								
(10) B.F. fat 3-18-64	0.35	0.16	-.04	0.06	0.34	0.31	-.14	0.32	-.26																							
(11) B.F. area 5-14-64	0.19	0.02	0.02	0.24	0.18	-.33	0.64	0.21	0.46	-.53																						
(12) B.F. fat 5-14-64	0.50	0.15	-.11	0.02	-.15	-.10	-.14	-.04	-.48	0.69	-.19																					
(13) B.F. area 7-2-64	0.26	0.03	-.26	0.52	0.45	0.66	-.22	0.31	-.16	0.23	-.25	-.32																				
(14) B.F. fat 7-2-64	0.31	0.13	-.02	-.12	0.24	0.06	0.03	0.21	-.18	0.87	-.23	0.86	-.21																			
(15) L.D. area 11-14-63	0.53	-.15	-.48	0.31	0.33	0.08	0.16	0.13	-.17	0.02	0.69	0.33	0.04	0.24																		
(16) L.D. fat 11-14-63	0.12	0.38	0.47	0.55	0.40	0.00	0.54	0.71	0.67	-.10	0.12	-.62	0.57	-.38	-.22																	
(17) L.D. area 1-24-64	0.83	0.41	0.14	0.95	0.07	-.31	0.43	0.57	0.16	-.11	0.48	-.01	0.34	-.18	0.46	0.48																
(18) L.D. fat 1-24-64	0.53	0.87	0.66	0.53	-.13	-.19	0.53	0.45	0.23	0.55	-.06	0.52	-.02	0.55	0.01	0.24	0.41															
(19) L.D. area 3-18-64	0.73	0.72	0.39	0.70	-.43	-.24	0.13	0.22	-.20	0.38	-.19	0.55	0.09	0.31	0.02	0.06	0.58	0.81														
(20) L.D. fat 3-18-64	0.45	0.83	0.78	0.62	0.10	-.31	0.79	0.71	0.61	0.31	0.15	0.14	0.09	0.27	-.03	0.61	0.55	0.89	0.61													
(21) L.D. area 4-30-64	0.43	0.15	-.04	-.69	0.32	0.12	-.01	0.60	0.09	0.10	-.22	-.37	0.82	-.32	-.17	0.77	0.57	0.12	0.29	0.34												
(22) L.D. fat 4-30-64	-.06	0.41	0.60	0.10	0.50	0.01	0.56	0.70	0.68	0.46	-.17	-.11	0.19	0.32	-.35	0.66	-.02	0.51	0.04	0.71	0.32											
(23) L.D. area (12)[e] 6-11-64	0.76	0.21	0.07	0.77	-.18	-.59	0.26	0.39	0.04	-.30	0.42	0.03	0.05	-.28	0.34	0.24	0.89	0.21	0.54	0.32	0.43	-.28										
(24) L.D. area (13)[f] 6-11-64	0.85	0.30	0.03	0.74	0.22	-.08	0.01	0.65	-.16	0.59	-.27	0.39	0.49	0.34	0.10	0.34	0.63	0.57	0.72	0.52	0.70	0.28	0.52									
(25) L.D. fat (12) 6-11-64	0.56	0.73	0.40	0.83	-.36	0.01	0.10	0.22	-.09	0.14	-.21	0.06	0.48	-.13	-.14	0.43	0.65	0.61	0.84	0.56	0.62	0.09	0.52	0.65								
(26) L.D. fat (13) 6-11-64	0.57	0.92	0.66	0.77	-.26	-.16	0.43	0.41	0.18	0.30	-.09	0.24	0.24	0.16	-.09	0.45	0.62	0.89	0.89	0.85	0.44	0.37	0.44	0.64	0.90							
(27) L.D. area (12) 7-2-64	0.60	0.76	0.44	0.89	-.35	-.11	0.24	0.28	0.02	0.01	-.02	0.01	0.41	-.20	-.04	0.47	0.75	0.61	0.82	0.61	0.60	0.07	0.64	0.61	0.98	0.90						
(28) L.D. area (13) 7-2-64	0.33	0.71	0.44	0.76	0.03	0.29	0.28	0.39	0.20	0.15	-.12	-.24	0.71	-.19	-.14	0.74	0.55	0.53	0.52	0.64	0.72	0.41	0.24	0.51	0.85	0.79	0.83					
(29) L.D. fat (12) 7-2-64	0.28	0.06	0.25	0.34	0.73	-.20	0.49	0.95	0.62	0.27	0.09	-.23	0.34	0.11	-.06	0.75	0.35	0.24	-.03	0.57	0.61	0.77	0.18	0.50	0.05	0.21	0.08	0.31				
(30) L.D. fat (13) 7-2-64	0.52	0.61	0.37	0.64	-.70	-.36	0.01	-.02	-.21	-.09	-.14	0.20	0.04	-.18	-.16	0.08	0.57	0.48	0.86	0.36	0.32	-.24	0.67	0.48	0.86	0.74	0.86	0.48	-.22			
(31)[g] B.F. area 7-2-64	0.63	0.23	0.17	0.46	0.62	-.14	0.41	0.90	0.29	0.69	0.01	0.36	0.26	0.60	0.21	0.42	0.43	0.60	0.37	0.68	0.43	0.67	0.22	0.76	0.20	0.44	0.20	0.29	0.81	-.05		
(32) B.F. fat 7-2-64	0.35	0.86	0.81	0.57	0.10	-.19	0.74	0.67	0.60	0.35	0.04	0.08	0.16	0.26	-.14	0.65	0.45	0.87	0.57	0.99	0.36	0.77	0.19	0.49	0.58	0.85	0.61	0.70	0.55	0.33	0.64	
(33) L.D. fat 7-2-64	0.04	0.78	0.68	0.05	-.40	-.14	0.50	-.06	0.23	0.29	0.05	0.49	-.43	0.50	-.02	-.14	-.03	0.78	0.50	0.59	-.45	0.29	-.15	-.04	0.25	0.57	0.26	0.19	-.21	0.27	0.12	0.60

[a]Values of 0.31 and 0.41 required for significance ($P < .05$) and ($P < .01$), respectively.

[b]*L. dorsi.*

[c]*B. femoris.*

[d]Items 5-30 are estimates by interpreter A.

[e]Taken over 12th rib.

[f]Taken between 12th and 13th ribs.

[g]Items 31-33 are estimates by interpreter B.

for l. dorsi areas and fat over the l. dorsi were all significantly correlated with carcass values.

Some difficulty was experienced with changes in size of somagrams due to variations in voltage of the power supply on all scans through March 18, 1964. This may account for some, but not all, of the low correlations obtained between estimated and actual values for the earlier scans. After March 18, 1964, however, the power was channelled through a regulator which held the voltage constant.

Estimates of the muscle areas and fat depths over the respective muscles by interpreter A are presented in Tables XXIII (page 82) and XXIV (page 86). Some difficulty was encountered with calibrations and the final calibrations were adjusted such that the mean estimates for muscle and fat corresponded to carcass values. The final calibrations are not the same for estimates of biceps femoris muscle as for estimates of the l. dorsi. This is probably because the behavior of ultrasound is different through fat layers than it is through muscle. Muscles under thick fat layers tend to be underestimated compared to those under thin fat layers.

The calibration photographs for estimates on the March 18, 1964, scans and earlier were obtained through use of a plastic block designed for this purpose. Scans on April 30, 1964, and afterward were calibrated on the Model 12 Sonoray calibration block and this resulted in a slightly different calibration photograph from that on the plastic block.

The growth data reflect adjustments in calibration for muscle and fat to correspond to actual values on all final estimates. Calibrations prior to May 14, 1964, for fat (both over _l. dorsi_ and _biceps femoris_) are based on the value "each block depth on the Model 12 Sonoray equals 1.3 inches of fat." Calibrations which were taken from the plastic block prior to April 30, 1964, were converted to the Model 12 equivalent. To adjust calibrations for growth data for muscle areas prior to May 14, 1964, calibrations for _biceps femoris_ area were converted to an equivalent of the best final estimate on _biceps femoris_. This estimate was on May 14, 1964, and the value obtained was "one block depth on Model 12 Sonoray equals 1.58 inches of muscle." The best final estimates of the _l. dorsi_ muscle was found to be those on May 14, 1964, and the depth of each block on the Model 12 Sonoray using actual calibration was found to be 1.5 inches of beef muscle so no adjustment was needed for _l. dorsi_ area prior to May 14, 1964, except for converting plastic block calibrations to Model 12 Sonoray equivalent.

The ultrasonic estimates of _l. dorsi_ muscle area and fat thickness over this muscle for all scans throughout the experiment are presented in Table XXIII. _L. dorsi_ area appeared to be about the same among sexes on November 14, 1963, with steers having slightly more muscle area than heifers or bulls. The estimates on January 24, 1964, represented a considerable increase in muscle area for all sexes, and these estimates were slightly less for steers than for heifers or bulls. The gain from the previous scan in square inches was 2.21, 1.73 and 2.06 for bulls, steers and heifers, respectively. It is possible that the estimates on January 24, 1964, were high in comparison to those of November 14, 1963, and March 18, 1964, because the growth during the first five weeks

TABLE XXIII

ESTIMATES OF L. DORSI AREA AND FAT THICKNESS BETWEEN THE 12TH AND 13TH RIBS OF BULLS, STEERS AND HEIFERS[a]

Item	11-14-63	1-24-64	3-18-64	4-30-64	5-14-64	6-11-64	7-2-64
				Fat Thickness, mm.			
Heifers	2.82(15)	5.93(15)	7.33(15)	8.79(15)	12.18(6)	14.08(9)	18.30(4)
Steers	1.03(15)	3.64(15)	4.72(15)	6.62(15)	8.07(6)	9.52(9)	11.82(4)
Bulls	0.64(14)	2.35(14)	2.93(14)	3.98(14)	5.72(5)	6.28(9)	8.25(4)
Mean	1.52	4.01	5.04	6.52	8.83	9.96	12.79
				L. Dorsi Area, sq. in.			
Heifers	5.87(15)	7.93(15)	8.39(15)	9.03(15)	9.28(6)	10.56(9)	9.72(4)
Steers	6.15(15)	7.88(15)	8.01(15)	9.07(15)	9.72(6)	10.40(9)	10.28(4)
Bulls	6.06(14)	8.27(14)	8.88(14)	9.89(14)	10.26(5)	10.90(9)	11.55(4)
Mean	6.03	8.02	8.42	9.32	9.72	10.62	10.52

[a]Number of animals in each sex listed in parentheses.

appears to be too large in comparison to the growth during the next three and one-half weeks. On March 18, 1964, all sexes had gained in estimated muscle area from the previous scan, but the steers gained the least (0.13 square inches), while heifers gained more (0.46 square inches) and bulls gained the most (0.61 square inches). During the next six-week period, the area of the l. dorsi increased most in steers (1.06 square inches), next greatest in bulls (1.01 square inches) and least in heifers (0.64 square inches).

The estimates of l. dorsi muscle during the time that all animals were scanned (November 14, 1963, to April 30, 1964) showed the greatest gain in muscle area for bulls (3.83 square inches), the next greatest gain for heifers (3.16 square inches) and the least gain for steers (2.92 square inches). It is difficult to place any interpretation on the estimates between scans of the final three estimates, because the same animals were not included each time.

Ultrasonic estimates of fat thickness over the l. dorsi muscle are presented in Figure 2 taken from the data in Table XXIII. There appeared to be an increase in fat thickness for all sexes throughout the experiment with sexes holding their relative position at all times. Heifers had the most fat thickness with steers second and bulls third. Estimates of fat thickness at the beginning of the experiment were relatively close for bulls and steers while heifers had over twice the estimated fat of steers or bulls. There tended to be an increase of the differences among sexes throughout the experiment with the greatest increase in fat deposition in heifers and the next greatest increase

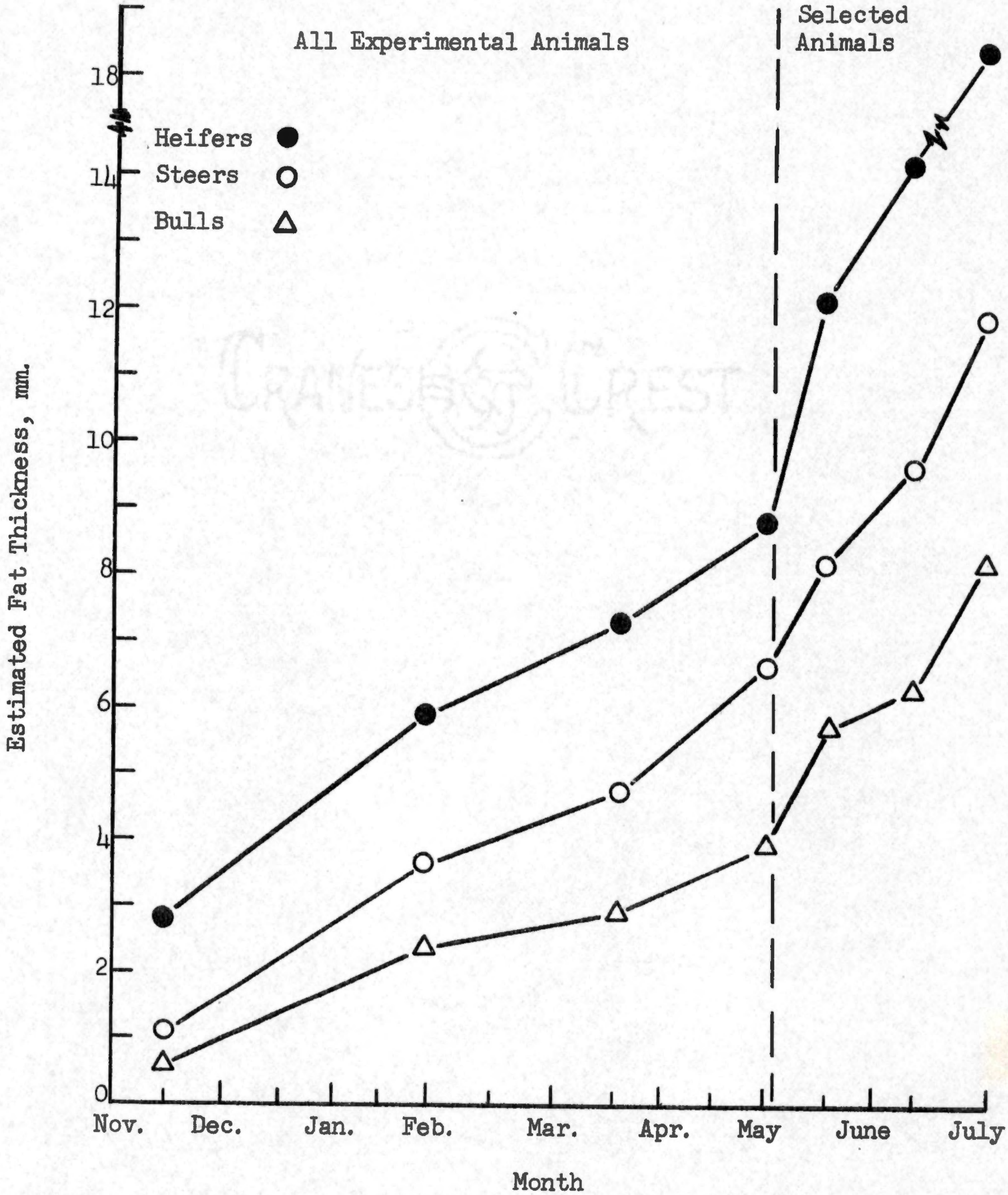

Figure 2. Estimated fat thickness over l. dorsi muscles of bulls, steers and heifers.

in steers. These positions were held even when the last three scans were used in the comparisons. Estimates of fat thickness on January 24, 1964, may have been high in relation to others. It is doubtful whether weanling animals would deposit more fat the first two months on a high roughage ration than they would the next two months.

The upturn in the curves of fat estimates from March 18, 1964, to April 30, 1964, reflects the change from a high roughage to a high concentrate ration on March 26, 1964. It is also possible that part of the influence of animals being closer to maturity is shown. Although the numbers of animals are different during the final three scans, there are indications that the differences among sexes continued to increase. There is also an indication of a more rapid deposition of fat after April 30, as compared to deposition of fat during the earlier periods.

The correlations between estimated _l. dorsi_ area on April 30, 1964, and actual values were significant ($P < .01$) for each slaughter group, and estimates of fat over the _l. dorsi_ on the same date with actual values were significantly ($P < .01$) correlated two out of three times. Thus, the estimates are believed to be reasonably indicative of actual values.

Growth data in Table XXIV show the estimates of fat over the _biceps femoris_ muscle and _biceps femoris_ area. In the first two scans of this muscle, the estimates indicated that steers had larger areas than bulls or heifers. However, on March 18, 1964, and all subsequent scans, the relationship was the same as that found in the carcasses;

TABLE XXIV

ESTIMATES OF *B. FEMORIS* AREA AND FAT THICKNESS OVER THE *B. FEMORIS* OF BULLS, STEERS AND HEIFERS[a]

Item	11-14-63	2-13-64	3-18-64	5-14-64	6-11-64	7-2-64
			Fat Thickness, mm.			
Heifers	1.78 (15)	2.62(15)	3.21(15)	4.49(15)	5.42(5)	4.48(4)
Steers	0.86(14)	1.69(14)	2.43(14)	3.81(14)	3.82(4)	3.68(4)
Bulls	0.81(14)	0.91(14)	1.63(14)	2.50(14)	3.48(5)	2.28(4)
Mean	1.16	1.76	2.44	3.62	4.27	3.48
			B. Femoris Area, sq. in.			
Heifers	9.13(~~15~~)	16.33(15)	14.66(15)	16.30(15)	16.10(5)	16.35(4)
Steers	9.31(14)	16.87(14)	15.29(14)	16.81(14)	16.90(4)	17.75(4)
Bulls	9.15(14)	16.26(14)	15.74(14)	17.98(14)	17.22(5)	20.30(4)
Mean	9.20	16.48	15.22	17.01	16.73	18.13

[a]Number of animals in each sex listed in parentheses.

that is, bulls had larger *biceps femoris* areas than steers, and steers had larger *biceps femoris* areas than heifers.

The estimates of *biceps femoris* areas on February 13, 1964, may have been in error because of the very large areas among sexes in comparison to the estimates before and after this date. In comparing the increase in *biceps femoris* areas from the first to last scans in which all animals were included (November 14, 1963 and May 14, 1964), heifers had an estimated increase of 7.17 square inches of muscle, while the corresponding values for steers and bulls were 7.50 and 8.83 square inches, respectively.

Ultrasonic estimates of fat thickness over the *biceps femoris* muscle are presented in Figure 3 taken from the data in Table XXIV. These estimates show a gradual increase in fat deposition over the *biceps femoris* for each sex from the beginning to end of the experiment. The increase in fat was relatively low up to February 13, 1964, especially for bulls and the increase was more rapid thereafter through May 14, 1964, the last time all animals were scanned. Steers and bulls started the experiment with about the same fat thickness and there was a tendency toward an increase of these differences through the last scan. The differences in fat thickness between steers and heifers remained almost the same during the experiment with a trend during the last part for steers to increase fat deposition a little more rapidly than heifers. The estimates of *biceps femoris* area and fat over the *biceps femoris* after May 14, 1964, should not be compared with previous estimates because different numbers of animals were scanned.

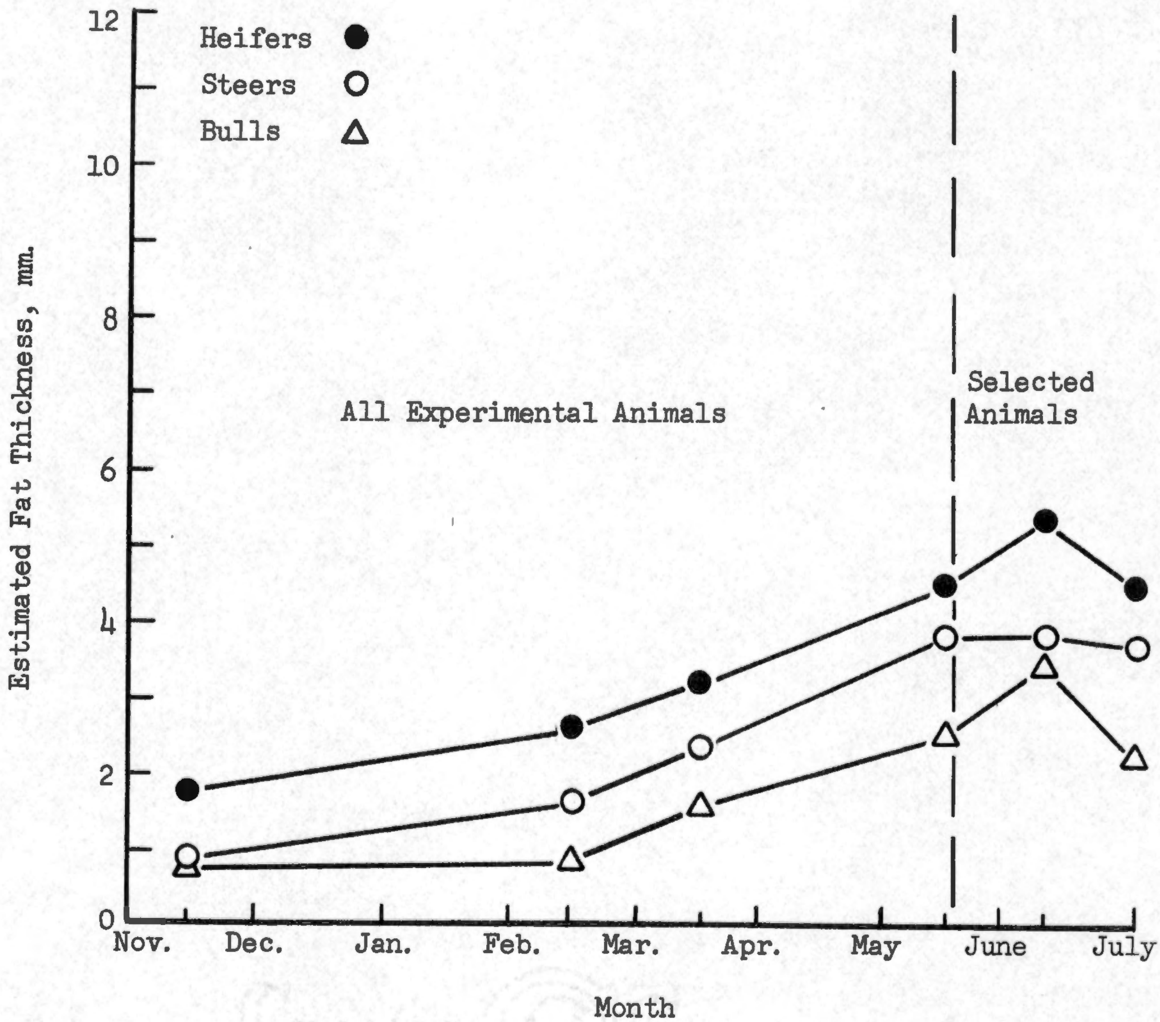

Figure 3. Estimated fat thickness over <u>biceps</u> <u>femoris</u> muscles of bulls, steers and heifers.

The correlations between estimated biceps femoris area on May 14, 1964, and actual values and between fat over biceps femoris muscle and actual values were both significant ($P < .01$) two out of three times.

In comparison with the deposition of fat over the l. dorsi muscle, the fat deposition over the biceps femoris began at a much lower level and increased at a lower rate. Estimates for heifers were 1.78 and 2.82 millimeters of fat over the biceps femoris and l. dorsi, respectively, on November 14, 1963, while on the last scan in which estimates were made on all animals (April 30, 1964, and May 14, 1964, for l. dorsi and biceps femoris, respectively) the estimates were 4.49 and 8.78 millimeters, respectively. This represents an increase in fat deposition of 2.71 and 5.97 millimeters for biceps femoris and l. dorsi, respectively. Beginning and ending estimates for steers were 0.86 and 3.81 millimeters over the biceps femoris and 1.03 and 6.62 millimeters over the l. dorsi. This was an increase of 2.95 and 5.59 millimeters, respectively, for deposition of fat over the biceps femoris and l. dorsi. Beginning and ending estimates of fat deposition over the biceps femoris in bulls were 0.81 and 2.50 millimeters, respectively, and for fat over the l. dorsi were 0.63 and 3.98 millimeters, respectively. This was an increase in fat deposition of 1.69 and 3.35 millimeters, respectively, for fat over the biceps femoris and l. dorsi.

It appeared that the fat deposition increased more rapidly after the wintering period (November 14, 1963, to March 26, 1964) both over the l. dorsi and biceps femoris. The rate of deposition of fat over the l. dorsi muscle was greater than rate of deposition of fat over the biceps femoris muscle within all sexes. The difference in increase from first to last scan in biceps femoris and l. dorsi muscles was greater for heifers, intermediate for steers and least for bulls. These values were 3.26, 2.64 and 1.66 millimeters, respectively, for heifers, steers and bulls. It must be pointed out that the final scan on all animals for these comparisons was two weeks later for the biceps femoris muscle than for the l. dorsi muscle. Therefore, the increase in fat over the l. dorsi muscle would be expected to be even greater than the figures presented if both sites had been scanned at the same time.

The results of this experiment show that the muscle areas and fat thickness of cattle were ultrasonically estimated with a reasonable degree of accuracy. Since biceps femoris area was shown to account for a high percentage of the variation in round muscle weight when live weight was held constant, an ultrasonic estimate of biceps femoris area in combination with live weight provides promise of being a very good predictor of total carcass muscling.

CHAPTER V

SUMMARY

Thirty Angus and 15 Hereford bulls, steers and heifers allotted by sire progeny trios were used in a study to investigate performance, carcass characteristics and ultrasonic estimates of muscle and fat. Feeding periods, ultrasonic estimates and carcass data were used as criteria of evaluation.

Steers were castrated after allotment and five animals of the same sex and breed were fed per lot in a 133-day wintering period followed by a 75-day finishing period. The wintering ration was a full feed of corn silage with 5.5 pounds concentrates and 2 pounds hay. The finishing ration was a full feed of a mixture of 8:1 ratio of ground shelled corn to cottonseed meal and 4 pounds of hay per head daily. Feed consumption, feed efficiency, average daily gains and condition grades were used for evaluation during the feeding periods.

Slaughter was by sire progeny trios at three times: (1) when all heifers averaged 750 pounds; (2) when the remaining steers averaged 875 pounds; and (3) when the remaining bulls averaged 1000 pounds. Carcass data routinely obtained at the packing plant by the Animal Husbandry-Veterinary Science Department and the following data were collected: physical components of wholesale rounds and 9-10-11 rib sections, cooking losses, organoleptic scores, shear values, chemical analyses and

color evaluation of muscle and fat. Carcass yields were estimated by prediction equations and equations were developed for predicting round composition.

The results of the experiment were:

1. During the wintering period, bulls gained significantly more than steers or heifers on significantly less feed per 100 pounds of gain.

2. During the finishing period, bulls gained significantly more than steers or heifers and steers gained significantly more than heifers. Differences in feed required per 100 pounds of gain were significant among sexes in the following order: bulls < steers < heifers.

3. Over both periods, gains and feed per 100 pounds of gain were significant among sexes. Condition grades of bulls were significantly less than those of heifers or steers.

4. Bull carcasses graded significantly lower than those of steers or heifers. Bulls and steers had significantly lower dressing per cents than heifers. Heifers had significantly more estimated kidney and pelvic fat and greater fat thickness than steers or bulls.

5. Weights of trimmed round, round muscle, *biceps femoris* and 9-10-11 rib cuts were significantly different among sexes as follows: bulls > steers > heifers. Bulls and steers had a significantly greater per cent trimmed round than heifers.

6. There was a significantly greater per cent protein in bull meat than in heifer meat. Per cent mositure and ether extract were significantly different among sexes with bulls > steers > heifers in moisture and bulls < steers < heifers in ether extract.

7. Total cooking losses were significantly greater for bulls and steers than for heifers. There were no differences in the length of time required to cook roasts to the same internal temperature among sexes.

8. Bull meat was significantly less tender than steer or heifer meat by shear tests and taste panel scores. Bull meat was also significantly darker and coarser textured than steer or heifer meat.

9. Prediction equations for round composition utilizing only live weight and *biceps femoris* area accounted for 87 per cent of the variation in trimmed round weight, 73 per cent of the variation in *biceps femoris* weight and 86 per cent of the variation in round muscle weight.

10. Ultrasonic estimates of *l. dorsi* and *biceps femoris* muscle areas and fat over these muscles were made with a reasonable degree of accuracy.

11. Ultrasonic estimates of *biceps femoris* areas in combination with live weights provide promise of being good predictors of total carcass composition.

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