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METHODS FOR ESTIMATING CARCASS
CHARACTERISTICS IN BEEF

presented by

Leon Edwin Orme

has been accepted towards fulfillment
of the requirements for

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A. M. Pearson
Major professor

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METHODS FOR ESTIMATING CARCASS CHARACTERISTICS IN BEEF

By

LEON EDWIN ORME

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Animal Husbandry

1958

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ABSTRACT

One of the handicaps in improvement of beef cattle is the lack of an accurate method of measuring carcass traits in breeding stock. In the past, most improvement has been made through visual evaluation, but accuracy in prediction of carcass traits by visual methods is at best limited. The objectives of this study were first to correlate objective and subjective live animal measurements with carcass attributes, and secondly, working with certain cuts of meat, to evaluate and develop objective measures of muscling, marbling and tenderness.

High repeatability estimates were obtained between both the various live animal and carcass measurements studied, while good agreement was found between the two subjective methods of live animal evaluation. Certain subjective and objective measurements were highly associated with various carcass measurements studied and also with carcass grade. However, the objective live animal measurements were found to be more highly related in most instances. The relationship between objective and subjective live animal scores was found to be quite low in most cases.

Live animal circumference measurements of hind and fore flanks and circumference of middle were most highly related to rib-eye area, and with the effects of live weight removed circumference of fore flank accounted for 81 percent of the variation in rib-eye area. Rib-eye area was also found to be highly related

to such carcass measurements as width of shoulders, width of rump and width of round. The width and circumference measurements of the fore and hind cannons were associated with 15 to 25 percent of the variation in rib-eye area when the effects of live weight were eliminated. Radiographic measurements of the dorsal and lateral view of the lumbar vertebrae disclosed that the width of the body of the lumbar vertebrae and width of the vertical processes, accounted for 22 to 20 percent of the variation in rib-eye area. When live weight was held constant, the width of the transverse processes and height of the anterior articular processes were equally as good.

Specific gravity of the Longissimus dorsi muscle of the 9-10-11 rib section was determined in order to test the usefulness of specific gravity as an objective measure of marbling. A correlation coefficient of -.81 and a regression equation of -413.30 with a standard error of 1.20 was obtained with percent fat in the rib-eye on specific gravity. No definite relationship was evident between blood fat levels and measures of degree of finish or amount of muscling. Using the Longissimus dorsi muscle and comparing the various measures of tenderness, good agreement was obtained between hot and cold shear values and chew count, while muscle fiber extensibility seemed to be more highly influenced by the amount of intramuscular fat.

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INTRODUCTION

One of the handicaps in improvement of beef cattle is the lack of an accurate method of measuring carcass traits in breeding stock. In the past, most improvement has been made through visual evaluation, but accuracy in prediction of carcass traits by visual methods is at best limited. Progeny testing and evaluation of parents and sibs by the carcasses of related animals is necessarily slow and does not always give a true evaluation of each animal, since inheritance is variable, even when the same mating is repeated. With changes in market demands, there has been more and more emphasis placed on inherent muscling and freedom from excessive fatness. This same problem has been of great concern to the swine producer with efforts being directed toward production of a meat type hog. However, the problem is equally acute in the production of superior beef cattle.

In the past, major emphasis has been placed on either the use of visual estimates in evaluation of cattle from birth to slaughter, or solely on the evaluation of the carcass with no particular attempt to relate carcass traits to those of the live animal. Without a combination of these two aspects, it is impossible to relate one to the other or to be able to ascertain which traits are accurately appraised in the live animal and which in turn are carried over to the carcass. Clark (1954) presented the following estimates of heritability which pertain to beef cattle production for such important items as birth weight - 71.6, gain in the feed lot - 60.4, final feed lot weight - 84.0, dressing percentage - 72.7 and area of the eye muscle - 67.0. Such heritability estimates of these important traits indicate that greater progress could be made towards producing the type of cattle which are produced most economically and yet hang up a heavier, more desirable carcass, if such traits could be accurately identified and measured in the live animal.

Another perplexing problem in evaluation of the beef carcass is a definition and measure of quality. Quality includes such items as marbling; color, texture, and firmness of lean; color and porosity of bone; and color and firmness of fat. In many cases, marbling is used synonymously with quality in beef. The ultimate grade of the carcass usually will be determined by the amount of marbling when conformation and finish are adequate with other factors remaining constant. Many of the desirable characteristics in meat have been attributed to this quality factor. Therefore, with so much emphasis being placed on this trait, it would be extremely useful to have simple accurate measures of marbling.

Tenderness of meat has received considerable emphasis, and this will probably be true until carcasses can be tenderized by chemical or physical methods or until improvement in all carcasses can be achieved through breeding. The achievement of increased tenderness through breeding would be greatly facilitated if live animal measurements could be used for prediction.

The objectives of this study were, first, to correlate objective and subjective live animal measurements with carcass attributes, and second, working with certain cuts of meat, to evaluate and develop certain objective measures of marbling and tenderness.

REVIEW OF LITERATURE

GROWTH AND BODY MEASUREMENTS

Many workers have studied growth in farm animals using external body measurements and live weight changes as a criterion on which to base their judgement. These workers include Meek (1901), Brody and Ragsdale (1924), and Lush(1928), who found that during the post-natal stage of growth, live weight increased at a much faster rate than any body measurement. Measurements of the skull, followed by height over the shoulders and rump, increased at a much slower rate than the various measurements affected by an increase in muscle and fat mass, which would include circumference and width of heart girth. Furthermore, the head, the limbs and fore quarters are relatively better developed at birth than the hind quarters, after birth a gradient of increasing growth rate passes from the head backwards to the pelvic region, thus, the length and width measurements of the hind quarters, such as, the length and width of the pelvis increases proportionately faster than the measurements about the head and fore quarters. It was deducted from the above facts that the skeleton was relatively better developed at birth than muscle or fat, which in the full grown animal make up the greatest proportion of weight.

Hammond (1932a), who dissected complete bodies of sheep from birth to four years old, confirmed the work of the earlier workers and also outlined in some detail the fundamental principles underlying developmental changes occurring in various anatomical regions and within the major tissues and organs of the body from birth to maturity. He showed that the developmental changes in the animal are caused by a primary growth wave from the cranium down to the facial parts of the head and posteriorally to the lumbar region. A secondary growth rate also was found to begin at the lower parts of the limbs (metacarpals and metatarsals) and continues down to the digits and upwards along the limbs and trunk to the lumbar region. The lumbar region was the last part of the body to attain its maximum growth and consequently, was the latest maturing part of the animal. These findings were later confirmed by McMeekan (1940, 1941) working with pigs, Pálsson and Vergés (1952) and Wallace (1948) working with sheep, who employed the technique of Hammond using relatively large numbers of animals. Dissection of cattle from birth to maturity is lacking, but the above workers feel that cattle follow growth changes similar to sheep.

LIVE ANIMAL MEASUREMENTS

Scoring live beef cattle subjectively, when small differences are present in the population being studied, has been reported by Knapp et al. (1939) to be of doubtful value. Repeatedly, slaughter tests of progeny of two different sires proved to show differences, whereas, the visual appraisal of the same animals by judges previous to slaughter had shown no significant differences.

Live animal measurements have been used extensively with beef cattle to evaluate individual performance and production. Such factors as birth weight, weaning weight and grade, rate and efficiency of gain, weight at the close of the feeding period, and slaughter weight and grade have been found important items in performance studies (Black _et al_. 1936, Black 1938, Knapp _et al_. 1941, Knapp _et al_. 1942, Knapp and Clark 1950). Also, certain linear body measurements have been taken as an index to the growth and fattening process of the beef animals while few other studies have been carried to the post slaughter stage and correlated with certain carcass characteristics and cutting tests. With the exception of the last phase, namely the relating of the live animal to the carcass, the available literature is voluminous.

The literature reviewed here will include only that which is related to live animal measurements and evaluation of the carcass. Lush (1928, 1929) who has studied and applied live animal measurements extensively, realized the limitations of such appraisal. He was only able to obtain maximum duplication of measurements on the live animal when measuring the rigid skeletal structures. However, from a standpoint of meat production, the conformation of the rest of the body and of the soft tissues are of greatest importance. This, he found was impossible to "describe in a mathematical sense with anything like completeness" and suggested that possibly photographs or some other media would add more than linear measurements. Lush (1928) and Tallis _et al_. (1957) listed, in common, the following live animal measurements which possessed a high degree of repeatability: heart girth, paunch girth, depth of chest, and height at withers and rump. Lush also listed cannon bone circumference, width at hooks and pelvic width to be quite highly repeatable while chest width, loin width, body length and width of pins were quite poor.

Smith et al. (1950) reported high repeatability for the four measurements studied, namely, length of body, height at withers, depth of chest and from "patella to patella". Estimates of repeatability in this study, which included three age groups, varied from .546 to .898. The same measurements of the same animals were taken from photographs, where the repeatability ranged from .726 to .844.

Heart girth has been found to be highly correlated with live weight in both dairy and beef cattle (Johnson, 1940; Lush, 1928, 1929; Barton, 1938; Wanderstock and Salsbury, 1946; and Kidwell, 1955).

Severson and Gerlaugh (1917), Lush (1932), Hankins and Beard (1944) and Yao, Dawson and Cook (1953) have reported that width, depth and circumference measurements are mainly fleshing measurements, which reflect quite highly the amount of finish which a particular steer or sheep possesses. These measures should then indicate to some extent the ultimate grade of the animal. Large fleshy measurements but small bony measurements indicate a steer which is fatter and more heavily muscled than other steers of the same skeletal dimensions according to the findings of Lush (1932). He stated that between these measurements, width at hooks was the best estimate of degree of finish. It was stated by Knapp et al. (1946) that weight of the live animal accounts for a large amount of the variation in live animal scores and ultimately the grade of the carcass. Severson and Gerlaugh (1917) stated that the hind quarters are more indicative than the fore quarters when determining the gaining capacity of an animal.

The relationship of various live animal measurements in beef cattle and lambs to their subsequent slaughter grade and dressing percentage has been studied by a great many investigators (Lush, 1932; Hankins and Beard, 1944; Cook, Kohli and Dawson, 1951; Yao, Dawson and Cook, 1953; Green, 1954). Lush (1932), Cook _et al_. (1951), Yao _et al_.(1953), Green (1954) and Kidwell (1955) stated that a positive relationship exists between carcass grade and dressing percentage with the so called "fleshing" measurements which include primarily body width and depth measurements. However, most of the correlations obtained were quite low as far as predictive value was concerned, but high enough to be of selective value in a long time breeding program. Lush (1932) stated that the steers possessing the smallest bone measurements and having the greatest thickness had the highest yield. Cook _et al_. (1951) found steers with shortest legs and bodies and having less height at withers and chest tended to have the highest dressing percent.

Cook, Kohli and Dawson (1951), White and Green (1952), Green _et al_.(1955), Dawson _et al_.(1955) and Tallis _et al_. (1957) have studied the relationship between body measurements of the live beef animal and carcass traits. Branaman (1940), Henneman (1942) and Ljungdahl (1942) have made similar studies in lamb and mutton.

Live animal weight was the best single measurement of the subsequent weight of the wholesale cut, (Ljungdahl, 1942; Green and White, 1951; Green, 1954; Green, Jessup and White, 1955) while various width and depth measurements of the live animal were also quite highly associated with the weight of the wholesale cut. Body length measurements were not as high in predictive value.

Correlation coefficients calculated between size of rib-eye and the ratio of weight to height or weight to length were found by Tallis _et al_. (1957) to be highly significant. The relationship between these two ratios and the edible portion were each significantly but negatively correlated. Ljungdahl (1942) found a direct relationship between size of eye muscle with growth rate and average width over the rack and loin in the live lamb, while circumference at the twist was the best indication of rib-eye size in the carcass. He also measured the spinous processes of the shoulder, rack and loin and found that the lengths were not closely related to the weights of the respective wholesale cuts. Hankins _et al_. (1943) and Yao _et al_. (1954) studied the relationship of various live animal measurements with the muscle-bone ratios of the 9-10-11 rib section in beef cattle. It was generally concluded that the relationships found were relatively low and of little value for predictive purposes.

GRADE

McMeekan and Walker (1950) outlined a score card, including such items as marbling, color, texture of muscle, color and texture of fat, and fat covering over rib for the visual appraisal of carcass beef. Woodward *et al.* (1954) found that a higher correlation existed between grade and fat covering than between grade and rib-eye size. Cook *et al.* (1951) working with beef cattle, and Ljungdahl (1942) working with lambs, found the shorter legged and shorter bodied animals tended to grade higher than the more rangy ones.

9-10-11 RIB ANALYSIS

The 9-10-11 rib section of the wholesale rib in beef has been used extensively in estimating the total amount of fat, lean and bone in the carcass. This was based on the early findings of Lush *et al.*(1929), which was later verified by Hopper *et al.* (1944), that the percentage of fat in the wholesale rib was an accurate indication of the total fat percent in the carcass. Hankins and Howe (1946) correlated the separable fat, lean and bone from the 9-10-11 rib section to the same components of the whole carcass. The correlation coefficients were sufficiently high that they calculated regression equations from their data, which have been used extensively by other workers.

SPECIFIC GRAVITY

Working with 50 guinea pigs of both sexes, Rathbun and Pace (1945) found that the relationship between the actual and theoretical values of carcass specific gravity and body fat were high ($r = .972$). They expressed the relationship in the following formula:

$$\%\ \text{Fat} = 100 \left(\frac{5.362}{\text{Sp. Gr.}} - 4.88 \right)$$

Using the previous equation, they derived a second equation to correct the specific gravity of the eviscerated carcass to that of the whole animal. This equation follows:

$$\% \text{ Fat} = \left(\frac{5.501}{\text{Sp. Gr.}} - 5.031 \right)$$

Specific gravity has been used quite extensively with pork and has proven itself as a reliable measure of carcass fatness. Brown *et al.*(1951), Whiteman *et al.* (1953), Pearson *et al.* (1956) and Price *et al.* (1957) have reported the use and validity of specific gravity as a measure of leanness of pork carcasses and various wholesale cuts. Its use with beef has been more restricted. Breidenstein *et al.* (1955), working with beef ribs, that varied from high Good to low Prime in grade, used specific gravity as an objective measure of marbling in the rib-eye. They stated that little relationship existed between subjectively evaluated marbling and ether extract of the rib-eye. Cole *et al.* (1957) also worked with the 9-10-11 rib section from 50 beef ribs ranging in grade from Prime to Commercial cow. They reported that percent chemically determined fat and specific gravity are inversely related, while percent protein was directly related to specific gravity. They stated that a correlation between specific gravity and beef quality was indicated from their results, although the relationship was not reported.

BLOOD FAT

Allen (1938) described a simple, accurate, volumetric method for the determination of fat in blood plasma. When he related this determination to the plasma of dairy cattle, he reported that the fat content of the plasma was not highly related to the productive ability of the cow nor to the fat content of milk. Morrow et al. (1956) have studied the relationship of blood fat content as a possible method for determining body composition in the market hog. They reported that a significant negative correlation existed between plasma fat content and area of the rib-eye as measured at the 10th rib. They also stated that factors, such as temperature and time of day, may influence the results obtained.

CANNON BONES

Bone growth in length takes place earlier in the life of an individual than does growth in thickness. Hammond (1932a) and Pálsson (1939, 1940) reported that increased thickness in bone is directly associated with breed improvement for increased meat production and early maturity. Pálsson (1939, 1940) further observed that short fore cannons having a thick shaft and fine extremities are associated with early maturity, whereas cannons with long slender shafts and coarse ends indicate later development and inferior carcass quality. He also found the fore cannons to be the best index of weight of bone and shape of bone in the carcass. Hirzel (1939) reported that shortening and thickening of the cannon is associated with a thickening and shortening of muscle covering in sheep. Ljungdahl (1942) stated that, although the short legged compact animal was most desired and graded higher than the longer legged lamb, the lamb with the longest legs had the highest percent of leg.

TENDERNESS

Tenderness is probably the characteristic most desired in meat. Various subjective measurements have been suggested and used. Today, additional emphasis is being placed on the heredity, environment and nutrition of the animal in order to find possible relationships existing between these items and tenderness.

There seems to be at present some question as to the possible factors which may affect tenderness. Lehmann (1907), Mitchell, Hamilton and Haines (1928), Mackintosk, Hall and Vail (1936) and Cover (1937) have all reported a possible relationship existing between tenderness and the amount of connective tissue which is found in meat. Lehmann (1907) further postulated the use and disuse theory of muscle tissue as directly related to the amount of connective tissue present in a given muscle. Mitchell _et al_.(1928) however, observed that age of the animal did not appear to cause a significant increase in the amount of connective tissue. If tenderness of meat was wholly determined by the amount of connective tissue present then it would seem reasonable that cooked meat would be more tender, since Bell _et al_. (1941) reported that cooked meat in nearly all cases studied, contained less connective tissue than raw meat. However, this relationship does not appear to exist since Warner (1929) and Ramsbottom _et al_. (1945) and other workers have found raw meat to be more tender than similar samples which have been cooked. Winegarden _et al_. (1952), working with connective tissue samples which contained collagen, elastin, and a mixture of the two types, found the critical softening temperature for connective tissue was near the temperature of 65°C, and that the tenderness of meat was influenced more by the collagen present than by the elastin present.

The muscle fiber itself has also been investigated as a possible index to tenderness of meat. Moran and Smith (1929) observed that the diameter of the individual muscle fiber and the area of the primary and secondary bundles increased in the following order: tenderloin, the eye muscle, outside round, and finally the inside round, which had muscle fibers of the greatest diameter. Hiner _et al_.(1953) studied the relationship of tenderness to fiber diameter of nine different muscles taken from ten-week old calves to nine year old cows. They reported a consistent average fiber diameter increase with age for all samples studied and a general trend for the muscle fiber diameter to decrease with increased muscle activity. The results as reported by Brady (1937) are somewhat contradictory, insomuch as he found that fineness of muscle texture indicated tenderness and that the larger the muscle bundle was, the finer the texture.

Ramsbottom _et al_. (1945) and Winegarden _et al_. (1952) attributed the decrease in muscle tenderness upon cooking to denaturation and coagulation of the muscle fiber proteins. Ramsbottom _et al_. (1945) further concluded that the shrinking and the hardening of the muscle fibers also contributed to cooked meat being less tender than the uncooked raw meat sample.

Wang _et al_. (1956) also studied the muscle fiber in relation to its possible influence upon tenderness of meat. They correlated the degree of muscle fiber extensibility of the Longissimus dorsi and Semitendinosis muscles with the degree of tenderness. Correlation coefficients of -.36 (P = .05) and -.45 were obtained between muscle fiber extensibility and shear strength for the Longissimus dorsi and Semitendinosis muscles, respectively. However, the muscles used came from beef graded Prime through Commercial.

In order to integrate the dual effect which connective tissue and the muscle fiber might have upon meat tenderness, Wang, Rasch, and Bates (1954) postulated that an inverse tendering action exists between connective tissue and the muscle fiber in meat upon cooking, and that the net tenderness of cooked meat at any point would be due to the combined effect of these two components. Upon cooking, the connective tissue content in meat decreases while the muscle fiber becomes less tender due to the coagulation of the protein in the fiber. Therefore, the most tender cooked meat would be at a point where the sum of the shear force of each component would be at minimum.

The influence of the fat content in meat upon its ultimate degree of tenderness has been investigated by several workers although its total effect is not clearly understood due to the somewhat contradictory reports of various workers. Helser, Nelson and Lowe (1930) reported that the meat from feeder cattle was less tender than the meat from the same kind of cattle after fattening.

Since the fat content in meat increases markedly when fattening is accomplished, this would indicate that the difference in tenderness existing between the feeder steer and the fattened steer was due to the difference in content of fat.

Hankins and Ellis (1939) correlated five different indexes of fatness to tenderness of beef including percent caul fat, percent kidney fat, percent ether extract of the rib-eye, percent fat of 9-10-11 rib-eye, and ether extract of rib-eye from 69 grain fat steers. None of the correlation coefficients was significant, therefore, they concluded that meat tenderness is due to factors other than amount of finish. Butler et al. (1956) reported that juiciness scores in broiled loin steaks were more highly related to measurements of fatness than to tenderness, while with broiled and braised bottom round steaks the correlations between measures of degree of finish and tenderness were the highest.

Other factors have been reported by numerous workers, which include age of animal and aging of meat. Working with 52 beef animals, varying in age, Hiner and Hankins (1950) reported that with increased age there was a tendency for tenderness to decrease. Paul et al. (1944) reported that the physical properties of the muscle fiber change during aging or refrigerated storage. The fibers are changed from well defined, undulating structures after one days storage, to structures which are fractured at many locations after nine days.

Significant correlation coefficients have been reported between tenderness of meat as measured by the Warner-Bratzler shear with tenderness as measured by organoleptic methods. Brady (1937) and Yao and Hiner (1953) have all reported that such a relationship exists.

EXPERIMENTAL PROCEDURES

SOURCE OF MATERIAL

Thirty-one steers from the performance testing program of the Animal Husbandry Department at Michigan State University were slaughtered in two different years and provided the bulk of the data for this dissertation. The steers were sired by eight bulls, two Angus and six Herefords, with each sire being represented by four steers with exception of one Hereford, which had only three offspring in the group, as the fourth died after being placed on test. The group was measured and slaughtered when the average grade of each group was estimated to be low Choice. At the time of slaughter, the range in age was from 12 to 16 months.

In addition to the 31 steers, 20 wholesale beef ribs were purchased to increase the scope of the specific gravity study.

SUBJECTIVE LIVE ANIMAL EVALUATION

The first year five judges assisted in evaluation, while the second year seven judges participated with three of them participating both years. Steers not included in this study were used to acquaint the judges with the rating system involved. After this brief session, each judge worked independently.

Two subjective live animal evaluation procedures were used. The first was called the adjusted, which was designed to disregard the effects of leg length in the evaluation of the live steer; and the second procedure was termed unadjusted, which followed the common practice of steer evaluation. These methods of steer evaluation were carried out independent of one another over a period of two days. Care was taken to keep the identity of the steers unknown from the judges insofar as possible, in order to keep the influence of previous appraisals at a minimum.

Adjusted Live Animal Evaluation

The word adjusted was used to denote that the feet and legs of the steers below the knees and hocks were not visible to the judges. This was accomplished by the use of a solid floor 16 ft. long and 9 ft. wide between the steer and the judges. The end nearest the steers was raised or lowered by use of pulleys and ropes. This end of the floor was in a raised position when each steer was led onto a level platform with an attached backstop just beyond and perpendicular to the platform. The steer was allowed time to become acquainted with the new surroundings and an attempt was made to get him to stand squarely on his legs. Then the raised end of the movable floor was lowered to the knees and hocks and secured until the judgement of each steer was complete. Thus, the steer was visible only above the knees and hocks while being scored. The floor was constructed so that the gradient of the floor from the immovable end (resting on ground) to the end nearest the knees and hocks of the steers would eliminate any height perspective which might otherwise be present. Canvas lined either side of a nine foot wide view-way where the judges were located, and the backstop behind the steer was painted a solid grey, eliminating any height perspective or reference point which otherwise might be present. In this phase, the steer was presented only from the side view while the judges stood 20 feet or more back and from this point evaluated the steer for all points listed in Figure 1. The ratings were made on 1 - 21 scale of excellence, with a score of 21 representing the ideal.

Each steer was graded for type and slaughter grade on a 1 - 12 scoring system, with 1 representing high Prime type or grade and 12 representing low Standard type or grade. The carcass estimations were made for thickness of fat and area of rib-eye.

Unadjusted Live Animal Evaluation

The steers were evaluated by each judge from all views and handled for degree of covering and firmness of fleshing, if desired. Each steer was rated for the same characteristics with the same numerical values and designations as used in the adjusted live animal evaluation, where the effect of length of leg was removed. In addition, several estimates of thickness were also made, since in this case the steers were viewed from all possible angles, thus thickness of topline and fullness of round could be observed. Such measures included thickness and fullness of round, loin, rib, chuck, brisket and cod, and with the exception of the fullness of the cod, the 1 - 21 rating system was used as previously described. Although the 1 - 21 scale was used for rating fullness of cod, the rating was reversed with the least development of cod fat being rated the highest. Figure 2 shows the points upon which each steer was evaluated.

FIGURE 1

Name of Panel Member ____________________ Steer No. ________ Date ______

Live Animal Evaluation:

I. Adjusted - legs to hocks and knees not showing.

A. Body Rating from Side View - (Degree of excellence based upon score of 1-21 points - with 21 being the highest).

	Point Score
1. Round	
a. depth	________
b. plumpness	________
2. Length of Rump	________
3. Length of Back	
a. loin (last rib to anterior edge of hip)	________
b. rib (6th rib to last rib)	________
4. Body Depth	
a. Rear Flank	________
b. Fore Flank at heart girth	________
5. Length of Neck	________
6. Fullness of Brisket	________

B. Type and grade ratings (degree of excellence based upon 1-24 - with 1 being comparable to high prime and 24 low canner).

Grade	Rating Score* High	Average	Low
Prime	1	2	3
Choice	4	5	6
Good	7	8	9
Standard	10	11	12

1. Type ________
2. Grade ________

C. Carcass Estimations

1. Dressing percent ________
2. Thickness of fat over 12th rib (nearest 0.1 inch) ________
3. Eye muscle size for weight (sq. in.) ________
   (1955 steers averaged:
   weight 888 pounds
   eye muscle 9.4 sq. in.)

COMMENTS:

*Rating Scores were coded for statistical analysis as follows:

High	Average	Low	
24	23	22	(Prime)
21	20	19	(Choice)
18	17	16	(Good)

FIGURE 2

Name of Panel Member ________________ Steer No.________ Date_______

Live Animal Evaluation

II. Unadjusted - legs to hocks and knees showing.

A. Body rating from side view (degree of excellence based upon score of 1-21 points).

	Point Score
1. Round	
a. depth	________
b. plumpness	________
2. Length of rump	________
3. Length of back	________
a. loin (last rib to anterior edge of hip)	________
b. rib (6th rib to last rib)	________
4. Body depth	
a. rear flank	________
b. fore flank at heart girth	________
5. Length of neck	________
6. Fullness of brisket	________
7. Length of front legs	________
8. Length of hind legs	________

B. Type and grade ratings (degree of excellence based upon 1-24 points)

Grade	Score for places within grade* High	Average	Low
Prime	1	2	3
Choice	4	5	6
Good	7	8	9
Standard	10	11	12

1. Type ________
2. Grade ________

C. Body rating - front, rear and over the top view (degree of excellence bases upon 1-21 points - 21 being excellent and 1 being the lowest)

1. Thickness and fullness of the following
   - a. Round ________
   - b. Loin ________
   - c. Rib ________
   - d. Chuck ________
   - e. Brisket ________
   - f. Cod ________
2. Color of eye ________

D. Carcass estimations

1. Dressing percent ________
2. Thickness of fat over 12th rib (nearest o.1 in.) ________
3. Eye muscle size for weight (sq.in.) ________
   (1955 steers averaged: weight 888 lbs. eye muscle 9.4 sq. inc)

COMMENTS:

* See footnote Figure 1.

OBJECTIVE LIVE ANIMAL EVALUATION

The day prior to slaughter, each steer was weighed and measured.

Weighing

Each steer was weighed on livestock scales in order to obtain an off feed weight. After this weight was obtained, the fore and hind weights were taken following the procedure of Dawson *et al*. (1955) except that the fore and hind weights were not taken simultaneously, but by the steers having their front feet or the hind feet on the scale while the opposite end was level to the scale floor. The level of the head was kept as nearly constant as possible between and within steers, and the steers were forced to stand squarely on their feet. Front and hind weights were repeated until a combined fore and hind weight was within ± ten pounds of the total live weight. All weights were taken to the nearest pound.

Measurements

All 32 live animal measures were taken by the author as the steers stood naturally on level cement flooring. All linear measurements were obtained by the use of metal calipers which had been made by the Bio Metric Instrument Inc. of Berkley, California. The height and total body length measurements were taken using the 180 centimeter bar to the nearest 0.25 centimeter while the width measurements and various portions of body length were taken to the nearest 0.25 centimeter using the 100 centimeter bar. Length of legs, length of cannon bones and all body and leg circumference measurements were taken using a 200 centimeter steel tape. The spring of fore ribs was measured by a special device with which an angle measurement was obtained, traced on a piece of paper and later measured with a protractor. The measuring devices are shown in Figure 3. The first year each measurement was taken once. Independent duplicate measurements were made and repeatability estimates were calculated for the second year's data.

Width Measurements - Width measurements were obtained as follows:

Width of Neck: Width of neck was taken just anterior to the point where the shoulder blends into the neck. The same amount of pressure was exerted upon the caliper arms in each width measurement and locked in position, then the reading was made and recorded.

Width of Shoulder: Width of shoulder was taken as shown in Figure 4 at the widest point of the shoulders.

Width of Rump: This measurement was taken on the topline at the widest point of the rump.

Width of Round: This measurement was taken from directly behind the steer, holding the caliper arms parallel to the floor at the widest point.

Width of Pins: Width of pins was measured at the pin bones holding the calipers parallel to the floor.

The arms of the caliper used in the width measurements were 15.5 inches long. Thus, it was necessary to cut down the arm length so the width of topline might be obtained without being

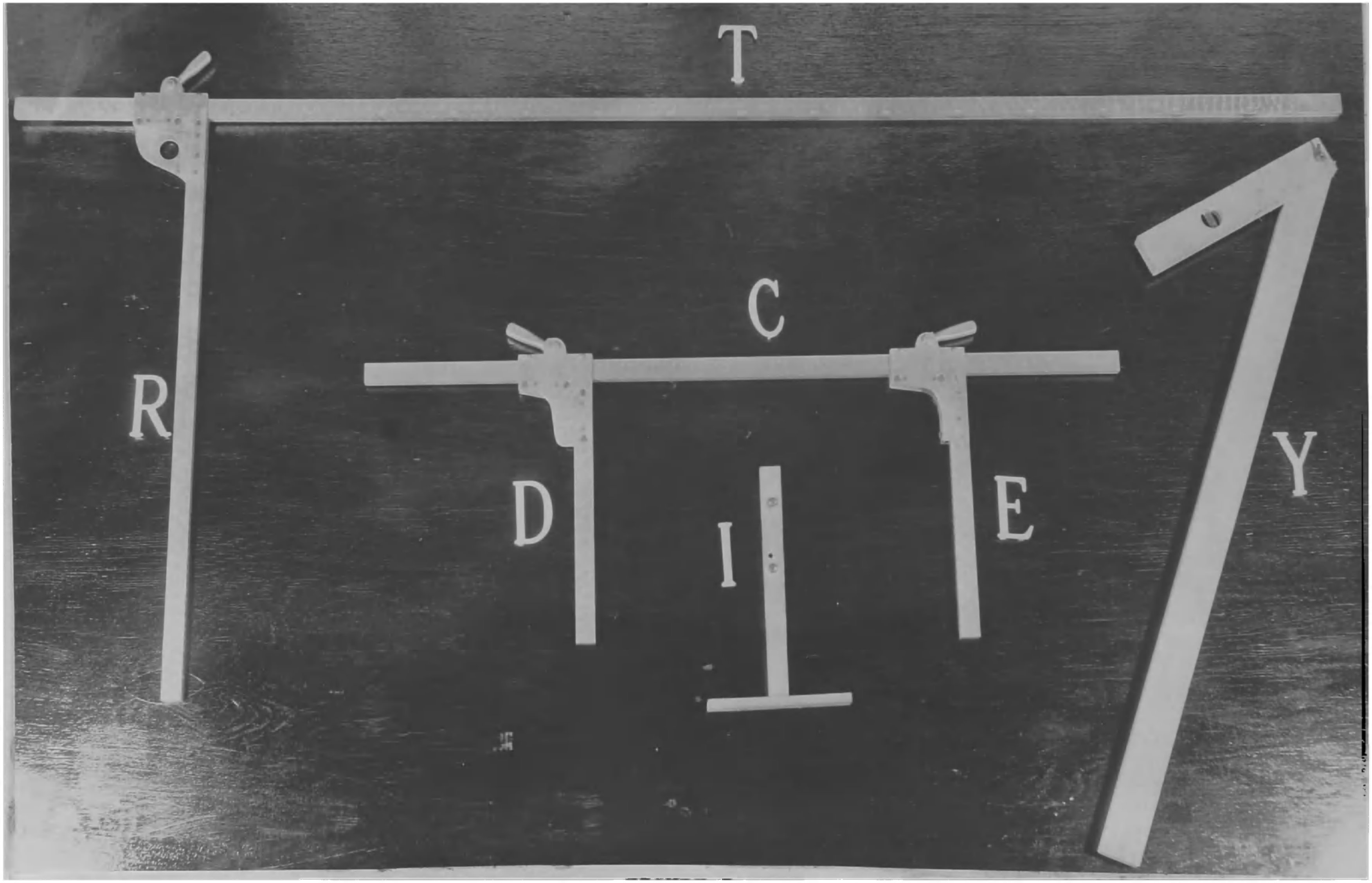


FIGURE 3

T: 180 Centimeter bar calibrated in .25 centimeters.

C: 100 Centimeter bar calibrated in .25 centimeters.

D, R and E: Caliper arms.

I: Wooden "T" used for rib and loin width.

Y: "V" shaped tool used to measure spring of rib.

FIGURE 4

WIDTH OF SHOULDER

influenced by differences in spring of ribs or thickness of paunch between steers. In order to standarize the length of arm to five inches, a wooden "T" 12.5 inches long was slipped on the caliper. Thus, all subsequent width of topline measurements were taken at the same place for all steers, alleviating most of the effects of spring of ribs and paunchiness between steers.

Width of Rib: Three measures of width were taken over the rib area at the following points; over the crops, half way between the crops and 13th rib and over the 13th rib. In order to be able to get half the distance between the crops and 13th rib, the site of measurement at crop and at the 13th rib were marked with a livestock marking crayon. See Figure 5.

Width of Loin: Measurements of loin width were made between 13th rib and hooks, and at the hooks. The first site of measurement was a point half way between the 13th rib and the point of the hooks. The second was measured at the anterior edge of the hooks.

Body Length Measurements - Total body length of each steer was obtained by measuring the distance from the first thoracic vertebra to the pins (Figure 6). The point on the live animal taken to be the location of the first thoracic vertebra was the point of the shoulder. Other linear body measurements included the distance from the first thoracic vertebra to the 13th rib and length of the rump taken from the anterior edge of the hooks

FIGURE 5

WIDTH OF RIB OVER CROPS

FIGURE 6

BODY LENGTH

to the pins. The distance from 13th rib to the hooks was obtained by substracting the sum length from first thoracic vertebra to the 13th rib and length of rump from the total body length.

Depth and Height Measurements

Depth of Chest: This measurement was the distance from the floor of the chest to the top of the crops.

Height at Withers: This was the distance from the floor to the highest point of the withers.

Height at Rump: This measurement was taken from the floor to the highest point of the rump with the steer standing normally. See Figure 7.

Twist to Floor: This measurement was made using the steel centimeter tape and measuring the distance from the floor to the bottom of the twist.

Twist to Hocks: This measurement was taken also by using the steel tape and measuring the distance from the bottom of the twist to the point of the hocks.

Rump to Hocks: This measurement was taken as shown in Figure 8 with the small calipers held vertically and measuring the distance from the top of the rump to the inside of the hocks.

Length of Legs: This measurement was taken on the fore leg by measuring the distance from the floor to the smooth joint or at a point one-half inch above where the metacarpal begins to enlarge. The length of the hind leg was the distance from the floor to the break joint or one-half inch above the point where

FIGURE 7

HEIGHT AT RUMP

FIGURE 8

RUMP TO HOCKS

the metatarsus begins to enlarge. These distances were measured with the steel tape to the nearest 0.1 centimeter (Figure 9).

Length of the Cannon Bones: The length of the metacarpal or fore cannon was measured from the break joint to a point parallel to the proximal edge of the dew claw or proximal edge of the first phalanx, while the length of metatarsus (hind cannon) was measured in centimeters from the break joint to the point parallel to the proximal edge of the dew claw on the hind leg.

Circumference Measurements

Heart Girth: This circumference was measured by encircling the steel tape about the steer at a point behind the fore legs.

Circumference of Middle: This was the distance around the barrel of the steer at a point two inches anterior to the pizzle.

Flank Circumference: The distance encircling the body of the steer at the highest point of the flank.

Circumference of Fore Leg above Elbow: This measurement as shown in Figure 10 was made by encircling the steel centimeter tape about the fore arm as close to the body as possible and parallel to the floor.

Circumference of Hind Leg above Hock: The tape was placed around the hind leg at a point approximately one-third the distance from the hock to the twist and parallel to the floor.

Circumference of Fore Leg below Knee: This measurement was taken by encircling the fore leg at a point half the distance

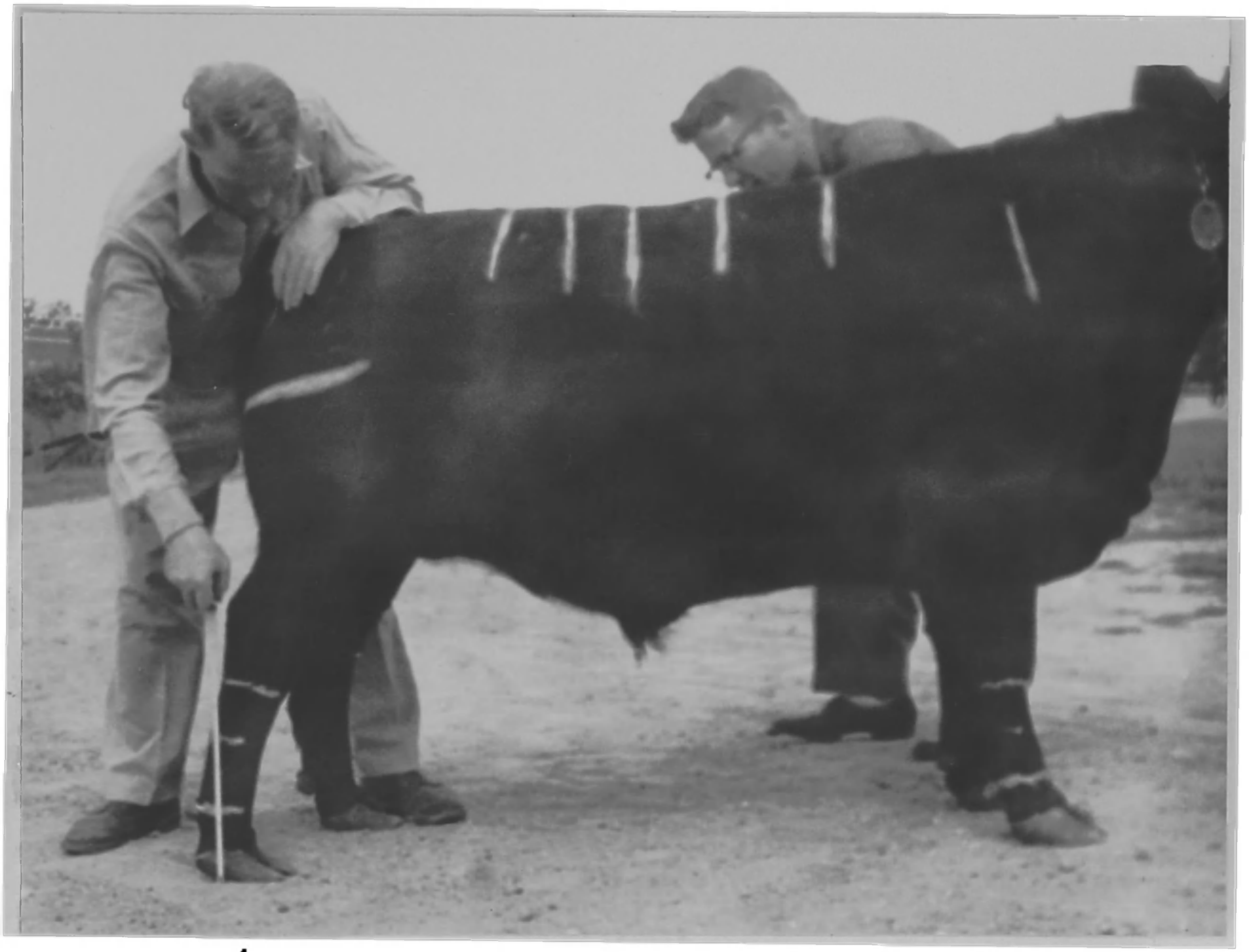


FIGURE 9

LENGTH OF HIND LEG

FIGURE 10

CIRCUMFERENCE OF FORE LEG ABOVE ELBOW

from the smooth joint to the dew claws.

Circumference of Hind Leg below Hocks: The tape was placed around the metatarsus at a point previously marked, which was half the distance between the break joint and dew claw.

Spring of Rib - was measured as shown in Figure 11. This value was obtained by the use of a "V" shaped tool having movable ends and a protractor. The angle was obtained by placing the shorter of the two arms of this "V" shaped tool vertical (as determined by a leveling bulb) at the crops; whereas the other arm was moved towards the shorter arm until contact with the rib or side of the steer was made. At this point the tool was locked into position and laid on a sheet of paper and the angle traced. Later the angle thus obtained was measured by using a protractor.

Live Animal Photographs - Photographs were taken of all steers as they stood behind and parallel to a wire grid divided into six inch squares. (Figure 12) From the photographs the following height, depth and length measurements were taken: height at withers and rump; depth of chest; depth of body (just anterior to pizzle); depth of flank; and total body length.

SLAUGHTER AND CARCASS DATA

Slaughtering

The steers were given water but deprived of feed for 24 hours prior to slaughter and killed at a rate of four per day. The slaughter procedure recommended by Deans (1951) was followed with

FIGURE 11

SPRING OF RIB

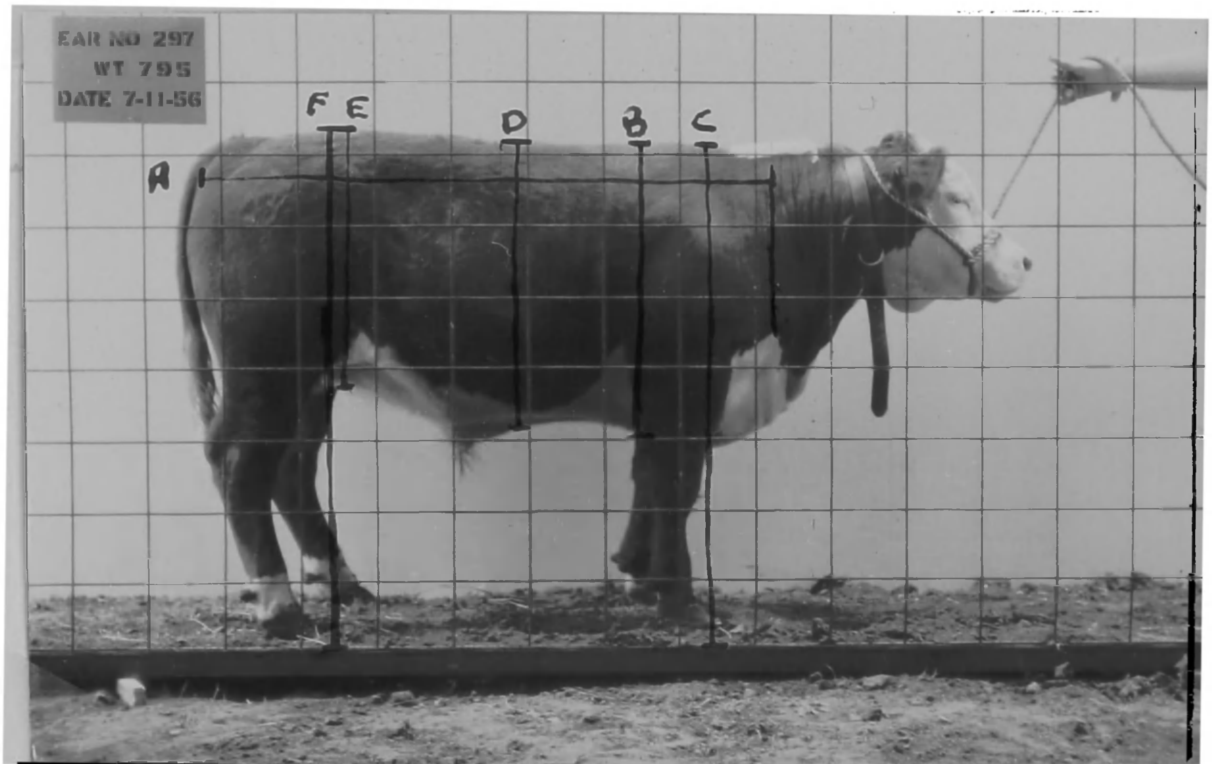


FIGURE 12

PHOTOGRAPHIC MEASUREMENTS

A: Length of body
B: Depth of chest
C: Height at withers
D: Depth of body (anterior to pizzle).
E: Depth of flank
F: Height of rump

the exception of one deviation, namely, the skinned eviscerated carcass was not split in order to keep the vertebrae intact for X-ray studies. Slaughter weights, weights of various body parts which were removed, organs, viscera, and killing fat were recorded for all steers. The carcasses were not split at the end of the slaughter process as usually practiced, but hoisted and hung by using a beef trolley for each hind leg. A 2 X 4 X 32 inch spreader which had previously been notched at the ends was inserted between the two trolleys to hold the two joined sides apart and thus facilitate chilling. All carcasses were shrouded, after which the carcasses were chilled at - 1 to 0°C for 24-36 hours. The carcasses were weighed 48 hours after slaughter to obtain a chilled carcass weight. They were then transferred to 0.6 to 2.2°C aging cooler where they were held until subsequent cutting tests were made.

Carcass Photographs

Photographs were made of two carcass views, namely, the side (Figure 13) and the back (Figure 14) as it hung on the rail. To facilitate measuring, the carcasses were photographed with the same wire grid used in photographing the live animals. Each photo was taken at the same distance from the carcass. From the pictures depicting the side view, the following depth measurements were taken: depth of chest at approximately the fifth rib and parallel to the grid, depth of flank as measured from the line of back to the line of the flank at a point just anterior to the tip of the pin bone and parallel to the grid, and depth of round as measured

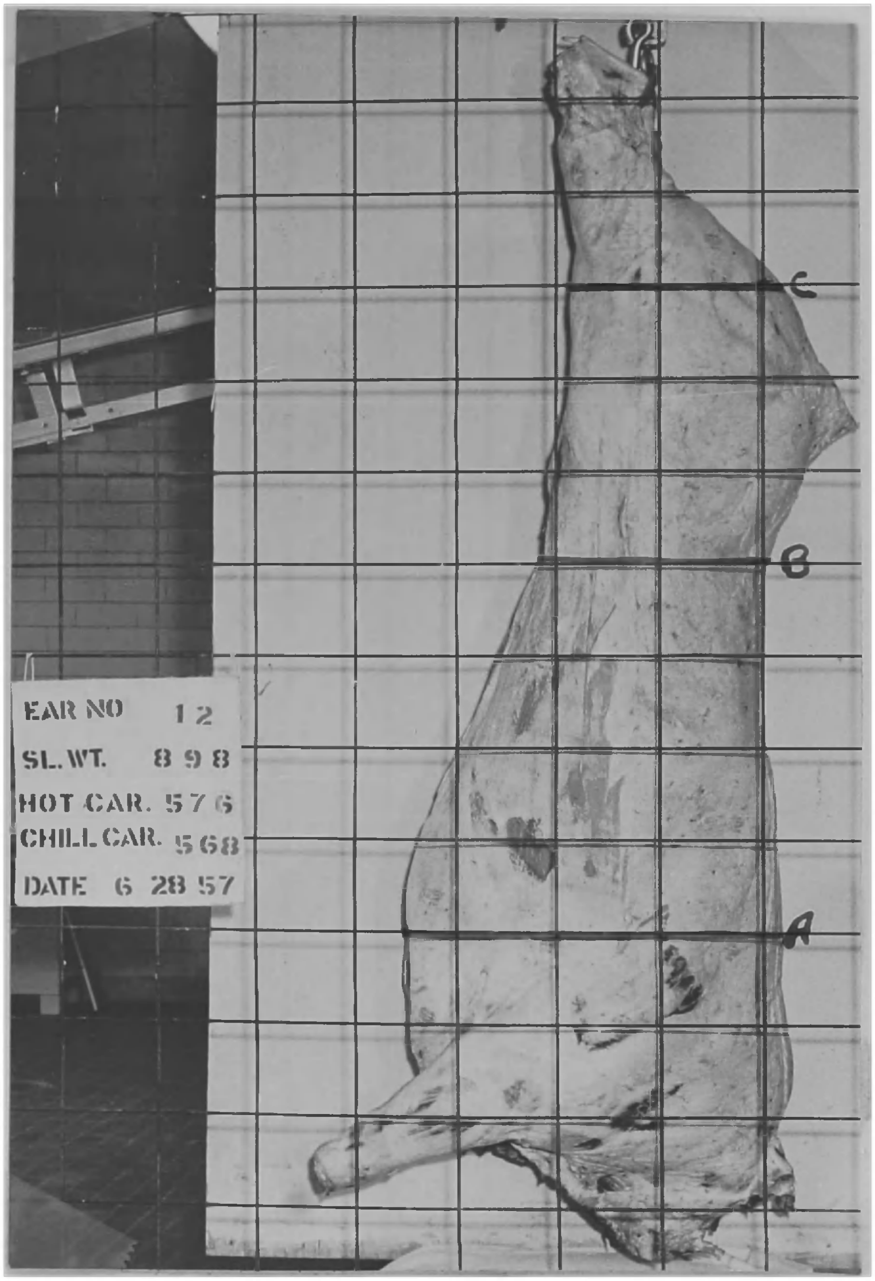


FIGURE 13

SIDE VIEW OF CARCASS

A: Depth of chest
B: Depth of flank
C: Depth of round

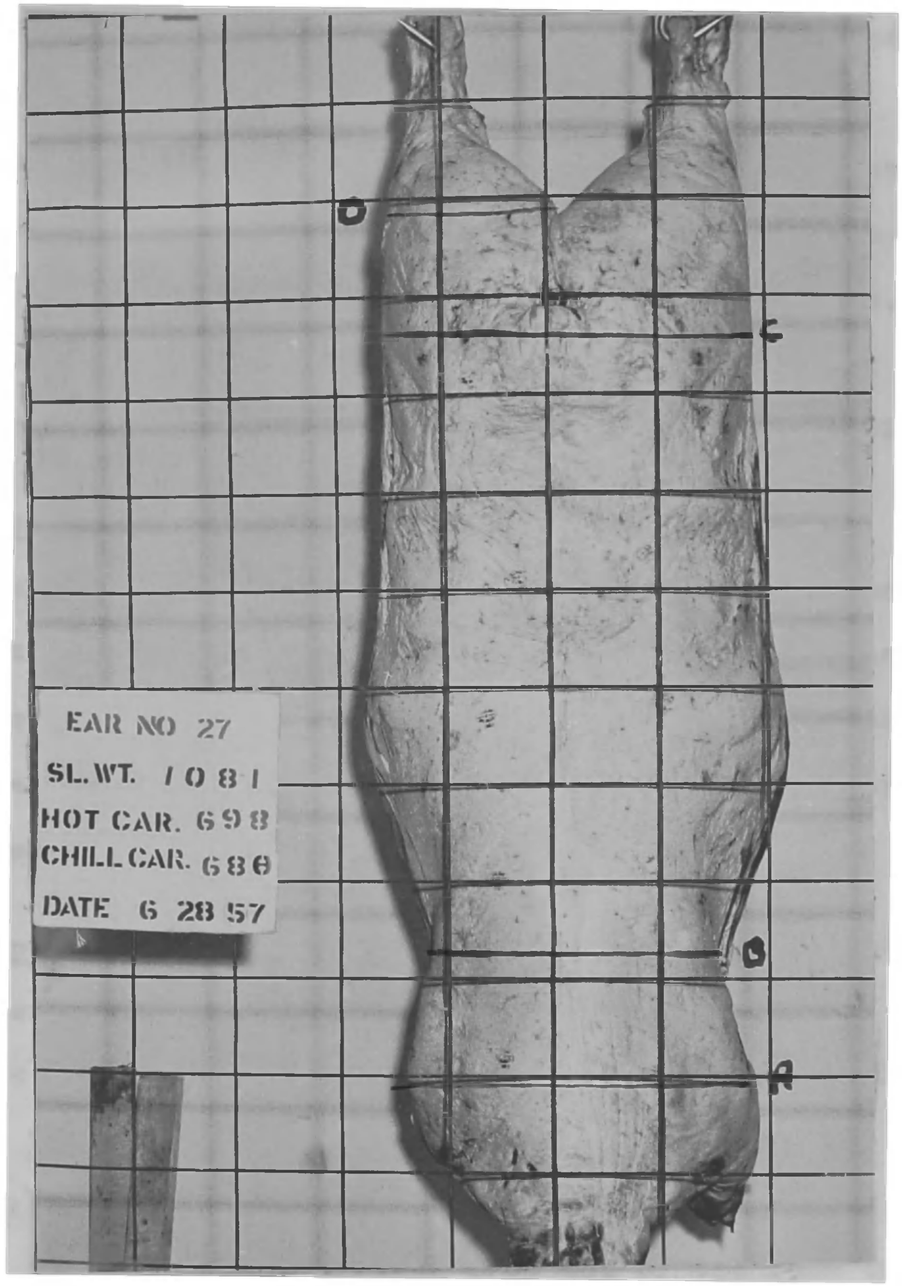


FIGURE 14

BACK VIEW OF CARCASS

A: Width of shoulders
B: Narrowest width just behind shoulders
C: Width of rump
D: Thickness of round

at a point which was 70 percent of the distance between the hind shank and the point where the tail had been removed and parallel to the grid.

From the back view, the following width measurements were taken: width of shoulders, rump, and round at the widest point, width at the narrowest point just behind the shoulders, and the width from the twist to the outside of the round. All linear measurements were taken parallel to the grid at the point indicated.

Carcass Measurements

Linear measurements were taken of all carcasses prior to the time that they were graded. Six and eight carcass measurements were taken the first and second year, respectively, while duplicate independent measurements were made and estimates of repeatability calculated for the second year's data.

Depth and Width Measurements - The following depth and width measurements were made on each carcass with the use of the calipers described previously for determining the width of the live animal:

Depth at Brisket: taken parallel to the line of the ribs at the fifth rib from top of the back to the bottom of the brisket.

Depth of Flank: taken from top of the loin to the flank at a point anterior to the point of the hip bone.

Width of Shoulder, Rump and Round: were taken at the widest point over each respective area.

Width of Crops: narrowest point just behind the shoulders. The above measurements were made both years on all carcasses.

In addition to these measurements, two additional circumference measurements were taken the second year.

<u>Circumference of Round</u>: was measured by encircling the round with the tape in such a manner that it passed over the anterior portion of the stifle joint and was held as close in the twist as possible.

<u>Circumference of Fore Shank</u>: was taken by holding the tape as close to the brisket as possible while encircling the fore arm.

Grading and Estimated Marbling

All carcasses were ribbed 72 to 96 hours after slaughter and graded to one-third of a grade immediately after ribbing by a U.S. D.A. grader. In addition, three judges estimated the percentage of marbling in the ribbed carcass of each steer, using a maximum range of 1 - 21 percent. Each judge worked independently. All three scores were averaged to get an estimated marbling score for each steer.

Cutting Tests

Each carcass was aged for eight days. The carcasses were divided into front and hind halves between the 12th and 13th rib, since they were still unsplit. The front half was split down the backbone, after which the left side was cut into wholesale cuts, following closely the standard cutting procedure recommended by Hankins and Howe (1946) and which was adopted by the Reciprocal

Meat Conference as explained by Wellington (1953). The small end of the standing rib was squared off using an electric saw, after which a tracing was taken of this cut surface, which included eye muscle, bone, outside fat covering and miscellaneous lean. The area of the rib-eye was later determined by the use of a planimeter; while the thickness of fat over the 12th rib was determined by the procedure described by Naumann (1951). The rib was identified and used in subsequent specific gravity determinations. A cross sectional area tracing of lean, fat and bone was taken of the fore shank by cutting at right angles to the humerus just above the projection of the lateral condyle of the humerus.

The flanks and kidney knobs were removed as outlined by Wellington (1953) and those cuts coming from the left side were weighed. The full tenderloin was removed from the left side and weighed. Since the double shortloin was needed for subsequent X-ray work, this was identified and removed by cutting across the lumbar vertebra at the anterior tips of ilium on each side. The rounds with sirloins attached were split and the round with sirloin attached from the left side weighed. The <u>Semitendinosis</u> muscle was then excised from the round. This muscle was wrapped and frozen for subsequent tenderness studies.

<u>Bone Studies</u>

<u>Measurements</u> - The fore and hind shanks from each steer were taken at the time of slaughter from which the metacarpals and metatarsals were removed and cleaned of all extraneous material. When

this had been accomplished the following weights and measures were taken of each individual cannon bone: weight to the nearest gram, length as measured from the articular surface of the medial portion of the proximal end to a point medial of the sagittal ridge of the third condyle. Width, thickness, and circumference of the cannon was measured at a point one-half the distance of the length. The cannon bones were then identified and frozen until breaking strength determinations were made.

Breaking Strength - A breaking strength value for each cannon bone was achieved by using the middle load range of 1,000 - 12,000 pounds of a Super L Hydraulic Tinus Olsen Universal Testing Machine. The weights were loaded at a rate of 15 - 20 units as shown on the loading knob. To obtain breaking strength, the cannon bones were placed on a device which supported the bones at both extremities. The two fulcrums were attached to a base allowing rotation, thus, the bones were maintained in a level position throughout the entire time the load was being applied. The distance between the two fulcrums was six inches the first year and five and one-half inches the second year. Attached to the machine was a wedge shaped device which made contact across the cannon at a point equi-distant between the two fulcrums when the load was applied. The edges of the fulcrum and this wedge shaped device which came into contact with the bone were rounded so to eliminate breaking of bone due to a cutting or a splitting action. The breaking strength for all cannon bones was converted to the breaking moment by the following formula:

Breaking moment = one-half the distance between the two points of the fulcrum X one-half the highest load reached in breaking the bone.

X-rays - Radiographs of the dorsal view of the unsplit or double shortloin and the lateral view of the shortloin from the left side were taken. The dorsal view showing the length of the transverse processes, length and thickness of the body of the vertebrae were taken by using a setting of 74 KV for a time of 3/20 second and at a distance of 40 inches. When this was accomplished the double shortloin was split in half, after which a lateral view of the shortloin of the left side showing the length of the vertical processes, canal, length and depth of the body of the vertebrae were taken from the same distance and using a setting of 90 KV for one-half second.

The following measurements were taken (Figure 15) from the X-rays of the dorsal view of the double shortloin.

Total Length of Transverse Processes: included the first four lumbar vertebrae and was the distance from the lateral tip of the left transverse process to the lateral tip of the right transverse process recorded in millimeters. Thus, this measurement included the length of both lateral transverse processes and the width of the vertebra body.

Width of Transverse Processes: was taken at a point which was 20 percent of the total length of the transverse processes and on a line which was parallel to a line drawn along the lateral

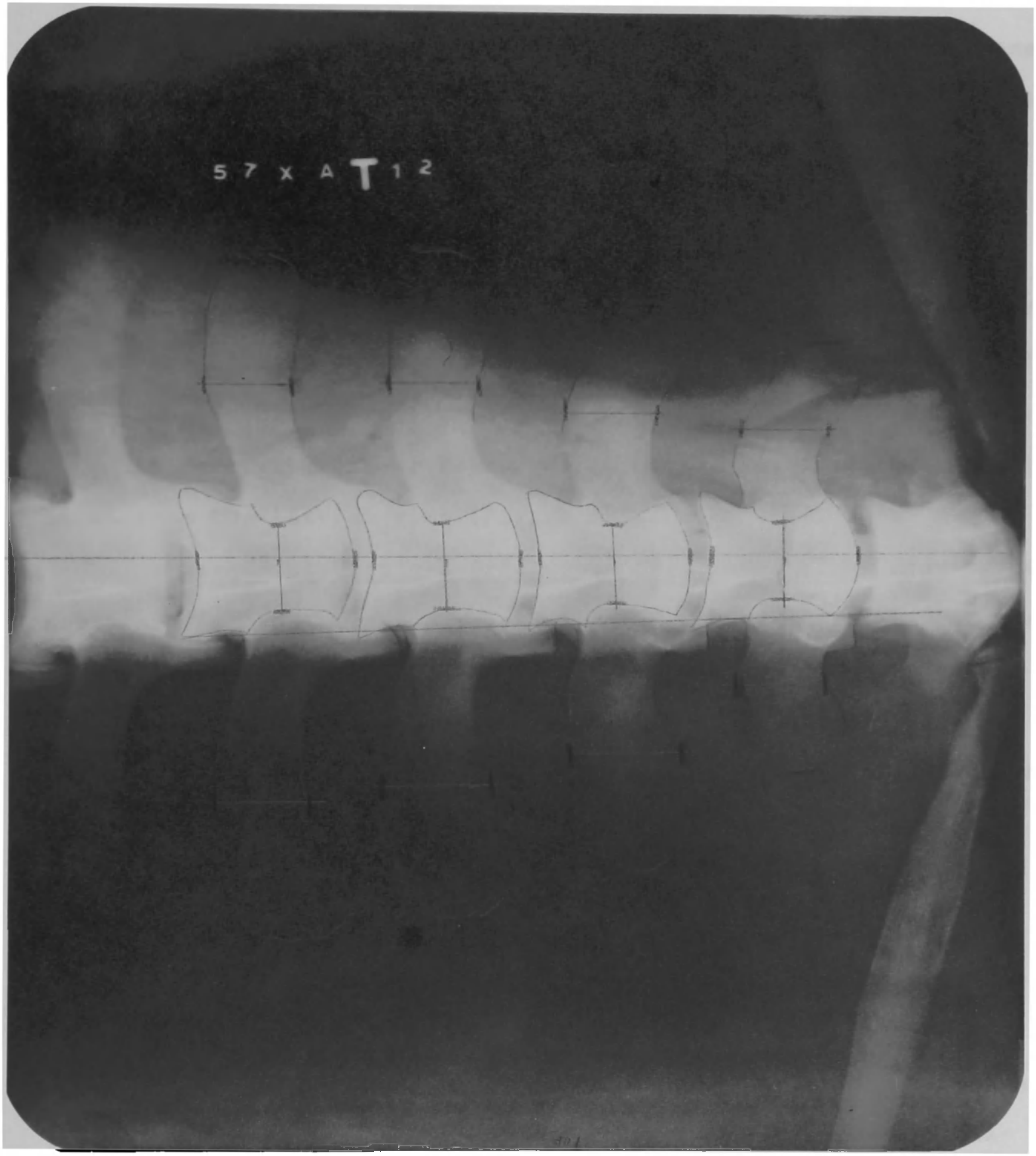


FIGURE 15

DORSAL VIEW LUMBAR VERTEBRAE

tips of the body of the vertebra.

Total Area of Transverse Processes: was taken by the use of the planimeter and measured the area within the margin of right transverse processes.

Width of the Lumbar Vertebra: was taken at the point where the body of the vertebra is the narrowest.

Length of Lumbar Vertebra: was taken from the most anterior portion of the convex surface to the most anterior concave surface of the vertebra body.

The following linear measurements of the lumbar vertebrae were taken from the lateral view (Figure 16).

Length of Vertical Processes: was obtained by drawing an arbitrary line between two points located at the dorsal tip of the body of the vertebrae. The length of the vertical process was taken from the tip of the spinous process to the arbitrary line.

Height of Anterior Articular Processes: was the distance from the arbitrary line to the most dorsal point of the anterior articular process.

Width of Vertical Processes: was taken at a point 60 percent of the distance from the arbitrary line to the tip of the spinous process and on a line parallel to the arbitrary line.

All linear measurements of the X-rays of the lumbar vertebrae were taken on the first four lumbar vertebrae recorded in millimeters. Seven X-rays of the lateral view were so poorly differentiated the second year that they could not be measured.

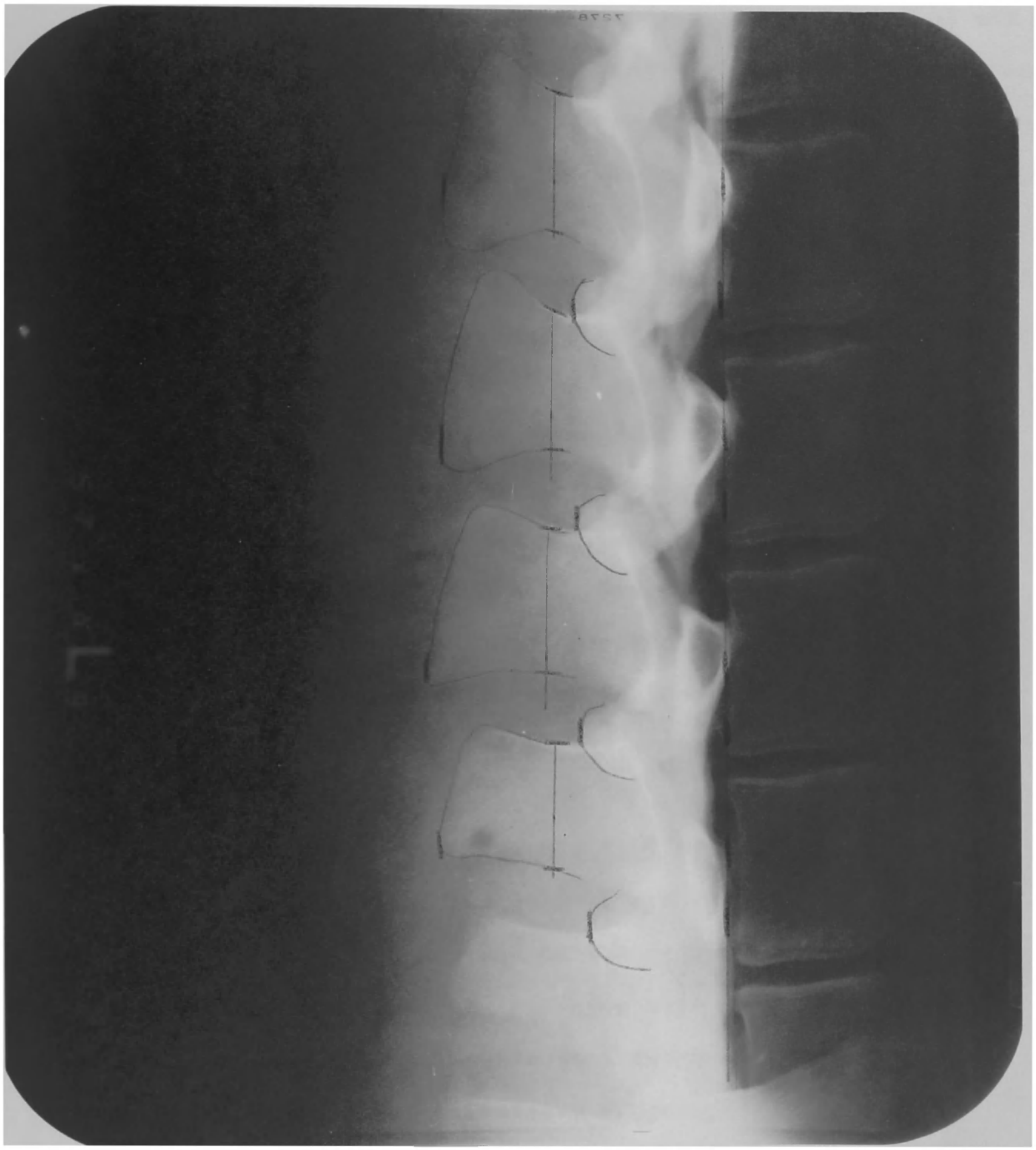


FIGURE 16

LATERAL VIEW LUMBAR VERTEBRAE

Specific Gravity

Experimental Ribs - Fifty-one wholesale beef ribs were used with 31 ribs coming from the steers previously described and the additional 20 ribs being purchased to add numbers to the study. Following ribbing, the carcasses were graded as two Prime, twenty-five Choice and four Good. The average weight of the ribs from this group of steers was 25.0 pounds. The 9-10-11 rib sections were removed from the wholesale rib as described by Hankins and Howe (1946). The *Longissimus dorsi* muscle was excised from the 9-10-11 rib and all external fat removed.

The remaining 20 ribs were obtained from two large packers and came from carcasses that were U.S.D.A. graded without ribbing. Half of the ribs were Prime and half Good. The ribs were selected to represent the entire grade. Average weights were 31.1 and 24.3 pounds for the Prime and Good grades, respectively. A portion of the aging period was spent enroute from the slaughterer, but otherwise the ribs were handled in the same manner as described previously.

Specific Gravity Determination - The excised rib-eye (*Longissimus dorsi*) portion of the 9-10-11 rib section was weighed to the nearest 0.1 gram in air and to the nearest 0.01 gram in distilled water. The first year 16 rib-eyes were weighed in water at room temperature, while all subsequent weighing was at 6°C $\pm$ 1°. Specific gravity was calculated according to the formula given by Brown *et al*. (1951).

Grinding and Chemical Analysis - After weighing in water, the *Longissimus dorsi* muscle was blotted dry and immediately ground five times through a 5/64 inch grinder plate. The ground sample was placed in a glass jar, sealed and frozen for subsequent analysis. Percent water and protein were determined according to the procedure of Benne *et al.* (1956). Ether extract was determined on the moisture-free sample, which was dried in a disposable aluminum weighing dish. Each dried sample was folded in the weighing dish and inserted into an alundum cup, which was placed in a metal sample container and extracted with anhydrous ethyl ether for four hours with a Goldfisch Fat Extractor. The excess ether was evaporated, after which the beaker and other soluble residue was dried to a constant weight at 100°C.

Blood Fat Determination

Forty milliliters of whole blood were collected at the time of slaughter from each steer. The blood fat was determined by the procedure of Morrow (1956) which was a modification of the method of Allen (1938).

Tenderness

Preparation - The frozen anterior halves of the boneless shortloins and the whole *Semitendinosis* muscles were removed from the freezer after eight to ten months in storage and the anterior end was squared by the use of an electric meat saw. The first steak removed from each of the two cuts was made 1.75 inches thick to be used later for the muscle extensibility determination. Two adjacent steaks one and one-half inches thick were then removed and used in the hot and cold shear value determinations. Each steak was carefully labeled as to position and steer and rewrapped individually, using freezer paper. These individually wrapped steaks were thawed for 24 hours at 2.7° to 4.0°C.

The posterior end of the boneless shortloin was taken from freezer storage, and the anterior end squared off and two adjacent one and one-half inch steaks were cut, identified as to location and steer, individually wrapped, and thawed as mentioned previously. These steaks were used by the chew panel for determination of tenderness.

After thawing, each of the above steaks was unwrapped, blotted dry and weighed to the nearest 0.1 gram. The mercury bulb of a thermometer was positioned in the center of each steak, and it was cooked to an internal temperature of 63°C (145.4°F). The steaks were cooked in deep fat at a temperature of 147° $\pm$ 2°C (296.6°F). When the internal temperature was reached the steak was removed from the deep fat, the thermometer removed, and the steak immediately weighed to the nearest 0.1 gram. After weighing, the steaks used for cold shear values and muscle extensibility studies were allowed to cool and were placed in air tight containers or wrappers and refrigerated at 2.7° to 4.4°C for 24 hours, while the steaks which were used for hot shear determination and panel testing for tenderness were used directly following cooking.

<u>Mechanical Shear Values</u> - Eight one-half inch cores and

seven one-half inch cores were taken from each boneless shortloin and *Semitendinosis* steak, respectively. Each core was cut parallel to the direction of the muscle fibers using a circular motion while exerting little pressure. A shear value was obtained for each core by using the Warner-Bratzler Shear Apparatus. A mean was obtained from each steak derived from these individual shear values.

Hot shear values were obtained by removing the cores quickly after obtaining the cooked steak weight. Cold shear values were obtained on cores removed after the steak had been refrigerated for 24 hours. With the cold steaks, it was necessary to use a lubricating compound to eliminate the tendency of the core to fracture. Water was used on the borer the first year, while corn oil was found to be much superior the second year.

Muscle Extensibility - The procedure outlined and described by Wang *et al*. (1956) for determining the extensibility of the single muscle fiber of beef was followed. The brown surface of the refrigerated cooked meat sample was trimmed off and discarded. Several slices approximately 2 X 3 X 0.5 centimeters in size were placed in a Waring Blendor, the knife of which had been dulled previously by filing, with sufficient distilled water to cover the blades of the knife. For blending the cooked meat, a rheostat, type 116, was used with a setting on the indicator dial of 30 - 35. The meat samples were blended at this speed until small bundles of muscle fibers were evident in the supernatant liquid. The time required was about 15 - 20 seconds.

Individual fibers and small bundles of muscle fibers were transferred to a petri dish containing distilled water. This petri dish was in turn placed upon a transparent plastic ruler calibrated in centimeters which in turn rested upon a light source. The light source was a wooden box with a frosted glass top containing a 150 watt light bulb. Single muscle fibers longer than five millimeters, which were without apparent injury and free from all endomysial tissues were used for the muscle extensibility determinations. Generally, these fibers had to be teased out of the small bundles, in which case, precaution was taken not to stretch the fiber nor handle the fibers, except at the ends. The individual fibers were placed directly over and parallel to the ruler and gripped firmly exactly five millimeters between the forceps, which were used to stretch the fibers. The muscle fiber was then extended by holding one forcep stationary and moving the other one slowly and steadily until the fiber broke. Five millimeters were subtracted from the number of millimeters observed at the time the fiber broke and this value recorded. Twenty such readings were taken; the mean of which was taken as the extensibility index for each sample. If the fiber broke within one millimeter of either forcep, the extensibility value was not used; or if a single fiber broke as soon as it was stretched, this reading was likewise discarded unless other fibers of the same sample gave the same results or a very low extensibility value.

The stretching of all fibers was observed using a magnifying glass having a total magnification of ten times.

Number of Chews - The boneless shortloin steaks cooked as previously mentioned were allowed to stand at room temperature for several minutes after which five one-inch cores were removed from each steak. The browned ends of each bore was trimmed off and the remaining part cut in half. The two pieces were placed on a lettered plate, coded and allowed to stand 30 minutes at room temperature before panel testing. Ten panel members were used and each panel member was given a sample taken from the same location between steers and the same position within steaks. In the test for the first year, steaks from four steers were tested per chew session while for the second year, only three steers per session were tested. Each judge was given two cores from the same steak, since each core was cut in half.

The end point was determined by counting the number of chews required to masticate each sample to the same consistency. No attempt was taken to standardize the end point between judges, since each judge was instructed to chew each sample to the same end point.

STATISTICAL ANALYSIS

Single and multiple correlation coefficients, regression and partial regression coefficients and analysis of variance were employed as given by Snedecor (1946) in order to analyze the data. Data were analyzed on a within year basis to eliminate any effect of years.

RESULTS AND DISCUSSION

SUBJECTIVE LIVE ANIMAL EVALUATION

Comparison of Subjective Scores

When correlation coefficients were calculated between the two subjective methods of live animal evaluation, highly significant positive relationships were obtained for all measurements except length of rib which was significant (P = .05) (Table 1). The relationships between the two methods of evaluation were lowest with the several body length scores and depth of round. The low relationships could possibly be attributed to the fact that these length measurements and depth of round may not be as easily defined as the other measurements, or may vary with the position of the animal.

On the other hand, scores for various items, such as, depth of fore flank, type and estimated grade, dressing percentage, fat covering at the 12th rib and rib-eye area were highly related between the adjusted and unadjusted live animal scores. The high correlations obtained for these several items between evaluation methods may possibly be due to one or more of the following explanations: first, these items may be better defined than others, giving higher repeatability between steers; second, these various points may be stressed more in the evaluation of fat steers, thus the judges may have been better trained in observing differences, and third, possibly the judges remembered the steers from one method of evaluation to the other. An attempt was made to minimize

TABLE 1 Simple Correlation Coefficients Between Adjusted and Unadjusted Scores for the Same Subjective Live Animal Measurement[a]

X	r
Depth of Round	.665
Plumpness of Round	.718
Length of Rump	.618
Length of Loin	.526
Length of Rib	.356
Depth at Rear Flank	.739
Depth at Fore Flank	.848
Length of Neck	.750
Fullness of Brisket	.766
Type	.840
Estimated Grade	.868
Estimated Dressing Percentage	.898
Estimated Fat over 12th Rib	.787
Estimated Rib-eye Area	.889

[a].349 Required for significance at P.05.
.449 Required for significance at P.01.

the effect of association due to recollection of the animals, since ear tag numbers were used to identify each steer and the scoring cards were collected after each animal was evaluated.

The adjusted method of evaluating the live steer was employed in this part of the experiment to find what effect length of legs might have on the evaluation. The correlation coefficients obtained between the adjusted and unadjusted methods (Table 1) indicated that the length of legs had little effect on the scoring. This was indicated by the fact that the higher correlations between the two methods of evaluation were obtained for such points as type, grade, dressing percentage and depth of rear and fore flanks which might be expected to be influenced greater by the length of legs. However, if greater differences in animal type had been present between steers, the influence of leg length may have been more evident. It was evident from the group of steers studied that close agreement existed between the two subjective methods of live animal evaluation. As was discussed previously, however, some points were much better than others.

Comparison of Unadjusted Scores and Live Animal Measurements

Table 2 lists the correlation coefficients obtained between the unadjusted live animal evaluation scores and various objective live animal measurements. In order to illustrate this, length of rump as appraised by the judges was correlated with the length of rump as measured with the use of calipers. This same procedure was followed in all cases when there was a direct counter part.

TABLE 2 Simple Correlation Coefficients of Various Live Animal Measures and Actual Dressing Percentage, Rib-eye Area and Fat over 12th Rib with Appraisal of the Live Animal by the Unadjusted Method

Live Animal Appraisal		Live Animal Measurement	r
Depth of Round	-	Distance from Twist to Floor	-.295
Plumpness of Round	-	Circumference of Round above Hock	.110
Length of Rump	-	Length of Rump	.039
Length of Loin	-	Length from 13th Rib to Hooks	-.102
Length of Rib	-	Length from 1st Thoracic to 13th Rib	.430
Length of Neck	-	Length from 1st Thoracic to Pins	-.326
Length of Fore Legs	-	Length from Smooth Joint to Floor	-.116
Length of Hind Legs	-	Length from Break Joint to Floor	-.219
Depth of Rear Flank	-	Circumference of Rear Flank	..646
Depth at Heart Girth	-	Depth at Heart Girth	.059
Thickness of Round	-	Width of Round	.685
Thickness of Loin	-	Width between 13th Rib and Hooks	.458
Thickness of Rib	-	Width between Crops and 13th Rib	.287
Thickness of Chuck	-	Width of Shoulder	-.726
Estimated Dressing Percentage	-	Actual Dressing Percentage	.588
Estimated Thickness of Fat at 12th Rib	-	Actual Thickness of Fat at 12th Rib	.489
Estimated Area of Rib-eye muscle	-	Actual Area of Rib-eye muscle	.573
Estimated grade	-	Actual Carcass grade	.682
Type grade	-	Actual Carcass grade	.492

[a].349 Required for significance at P.05.
.449 Required for significance at P.01.

In the cases where a parallel measurement was not available, then a measurement was chosen which most nearly represented the point.

The correlation coefficients between the subjective and objective methods of live animal evaluation in most cases were quite low (Table 2). Fairly high relationships were found between the two evaluation methods for most of the various width and thickness values. The correlations obtained between the estimated dressing percentage, thickness of fat at 12th rib, area of rib-eye and grade were equally as high or higher than the correlations with the body width and thickness measure.

Comparison of Unadjusted Scores and Carcass Measurements

Correlation coefficients were calculated between carcass measurements and unadjusted live animal scores in order to test the usefulness of visual appraisal of the live animals to estimate various carcass measurements. These are listed in Table 3. Subjective live animal scores were correlated with the carcass measurement which best represented or illustrated a particular subjective live score. From the correlation coefficients obtained it was quite evident that the carcass width measurements were more highly estimated from the live steer than were other carcass measurements. The four live animal scores for width were associated with 28 to 50 percent of the variation existing between a particular live animal score and a certain carcass width measure. Another relationship which was also highly significant was length of rib with carcass length.

TABLE 3 Simple Correlation Coefficients Between Linear Carcass Measurements and Unadjusted Live Animal Scores

Carcass Measurement		Unadjusted Live Animal Score	r
Width of Shoulder	-	Width of Chuck	.637**
Width at Crops	-	Width of Rib	.705**
Width at Crops	-	Width of Loin	.680**
Width of Round	-	Width of Round	.533**
Depth of Chest at 5th Rib	-	Depth of Fore Flank	.275
Depth of Flank	-	Depth of Rear Flank	.285
[1]Circumference of Round	-	Depth of Round	.292
[1]Circumference of Round	-	Plumpness of Round	.536*
Length of Carcass	-	Length of Rump	.033
Length of Carcass	-	Length of Loin	.441*
Length of Carcass	-	Length of Rib	.520**
Length of Carcass	-	Length of Neck	-.192
Length of Carcass	-	Length of Fore Leg	-.322
Length of Carcass	-	Length of Hind Leg	-.322

[1]Only 15 steers included.
*Denotes significance at P.05.
**Denotes significance at P.01.

The plumpness of round score in the live animal with the circumference of the round measurement in the carcass were significantly related (P = .05). The loin length scores with carcass length were also significant at the five percent level. Carcass depth measurements, at the fifth rib or flank were not highly correlated with the subjective scores for depth of rear or fore flank in the live animal. Carcass length seemed to be inversely related to such subjective scores as length of fore and hind legs and length of neck. Although the relationships are low they were unexpected since it is commonly thought that the longer legged and longer necked animals are associated with the less compact and longer carcasses.

Comparison of Adjusted and Unadjusted Scores to Carcass Grade

Table 4 lists the correlation coefficients obtained between carcass grade and either the adjusted (legs not showing) or the unadjusted (legs showing) live animal scores and estimates. Comparison of these correlation coefficients, when both the adjusted and unadjusted were given, reveals in all cases except one, namely, plumpness of round, that the adjusted scores were more highly or equally related to carcass grade. It was recognized, however, that in most comparisons the two correlations between either adjusted or unadjusted evaluation and carcass grade were nearly equal in magnitude. Since carcass grade was constant, this indicates that a high relationship existed between the scores given with the adjusted method and those obtained with the unadjusted

TABLE 4 Simple Correlation Coefficients Between Carcass Grades and Adjusted and Unadjusted Live Animal Evaluation[a]

X	r adjusted scores with	r unadjusted scores with
Depth at Round	.610	.606
Plumpness of Round	.600	.696
Length of Rump	.584	.536
Length of Loin	-.112	-.030
Length of Rib	-.203	-.077
Depth at Rear Flank	.634	.508
Depth at Fore Flank	.693	.568
Length of Neck	.607	.588
Fullness of Brisket	.762	.668
Length of Fore Legs	--	.415
Length of Hind Legs	--	.417
Type	.628	.492
Estimated Grade	.756	.682
Thickness of Round	--	.600
Thickness of Loin	--	.698
Thickness of Rib	--	.626
Thickness of Chuck	--	.552
Thickness of Brisket	--	.676
Fullness of Cod	--	.617
Estimated Dressing Percent	.724	.641
Estimated Fat Thickness over 12th Rib	.812	.627
Estimated Rib-eye Area	.765	.744

[a].349 Required for significance at P.05.
.449 Required for significance at P.01.

method. Thus, in the group of steers studied, the duplication of scores given under each method of evaluation appeared to be quite high.

All correlation coefficients obtained between carcass grade and the adjusted live animal scores were highly significant and directly related, except length of loin and rib, which were not significant, but inversely related to carcass grade (Table 4). The remaining correlation coefficients accounted for 34 to 66 percent of the variation existing between carcass grade and adjusted live animal scores. The highest relationships were obtained between carcass grade and the following items: depth at fore flank, fullness of brisket, and the various estimates of grade, dressing percentage, fat thickness at 12th rib, and rib-eye area. These were associated with 48 to 66 percent of the variation existing between carcass grade and the various adjusted scores.

The relationships existing between carcass grade and the unadjusted live animal scores were quite similar to those reported on between carcass grade and the adjusted scores. All correlations were related in a positive manner to grade, except loin and rib length, which again showed an inverse relationship which lacked significance. All other correlation coefficients between carcass grade and unadjusted scores were found to be highly significant, except for length of fore and hind legs, which were only significant at the five percent level. All other correlations accounted for 24 to 55 percent of the variation existing between the various unadjusted measures and carcass grade. The various adjusted scores accounted for 40 percent or more of the variation in carcass grade and included the following: plumpness of round, fullness of brisket, estimated grade, thickness of loin, estimated dressing percentage and estimated area of rib-eye.

Several points were evident from the correlations presented, first, with the group of steers evaluated and with several judges participating, good agreement in scores for the items studied was found to exist between the two methods of subjective live aniaml evaluation, and secondly, many of subjectively evaluated live animal traits were found to be highly related to the ultimate carcass grade.

OBJECTIVE LIVE ANIMAL EVALUATION

Repeatability Estimates for Live Animal Measurements

Independent duplicate live animal and carcass measurements were obtained the second year, in order to acquire an estimate of repeatability. The repeatability estimates are listed in Table 5. The range of repeatability estimates was from .428 for angle or spring of ribs to .995 for circumference of middle. All estimates of repeatability were significant except for spring of ribs, while all other repeatability estimates were highly significant with the exception of those for width at pins and length from 13th rib to hooks, which were significant only at the five percent level. The best repeatability estimates were obtained for the various height measurements (wither, rump and legs), circumference measure-

TABLE 5 Repeatability Estimates for Live Steer Measurements[a]

Measurements	Repeatability Estimate
Width	
Neck	.904
Shoulder	.884
Rump	.837
Round	.882
at Pins	.502
at Hooks	.828
Between 13th Rib & Hooks	.841
at 13th Rib	.733
Between 13th Rib and Crops	.823
at Crops	.716
Length	
1st Thoracic to Pins	.818
1st Thoracic to 13th Rib	.862
13th Rib to Hooks	.525
Rump	.858
Height	
Brisket to Crops	.859
at Withers	.965
at Rump	.965
Smooth joint to Dew Claws	.955
Smooth joint to Floor	.728
Break joint to Dew Claws	.879
Break joint to Floor	.945
Twist to Floor	.901
Twist to Hocks	.733
Rump to Hocks	.740
Circumference	
Fore Flank	.981
Hind Flank	.941
Middle	.995
Fore Legs above Knee	.703
Fore Legs below Knee	.800
Hind Leg above Hock	.834
Hind Leg below Hock	.958
Spring of Ribs	.428

[a] .497 Required for significance at P .05.
.623 Required for significance at P .01.

ments (fore and hind flanks and middle), and various width measurements (round, rump and shoulder). Lush (1928) used some of the above measurements and reported that they were easily duplicated.

In order for a given measurement to be useful, it must be one in which duplication of results is at a maximum. With the exception of a few measurements, repeatability was sufficiently high to be useful. However, the position in which the steer is standing, the temperament of the animal, the location of the measurement on the animal and the technique of the operator are all probable sources of error. All factors can and will affect the ultimate measurement. Several steers each year tended to be excitable. The measurements taken on these steers, especially those involving the hind legs, were more difficult to obtain. It is also recognized that it is difficult, if not impossible, to measure a rounded object with straight measuring devices and relate the various linear measures back to the original object with great precision.

Comparison of Live Animal and Photographic Measurements

The photographs of each live steer were measured at seven locations. The values thus obtained were correlated with comparable measurements taken with the live animal. The correlation coefficients are listed in Table 6. All relationships were found to be highly significant with the exception of body length, which was significant at the five percent level. Length of body was measured from the point of the shoulder to the pins on the live animal. However, while from the photographs it was taken using the same

TABLE 6 Simple Correlation Coefficients Between Various Live Animal Measurements and Measurements Taken from Live Animal Photographs[a]

Live Animal Measurement		Photograph Measurement	r
Circumference of Fore Flank	-	Depth of Chest	.626
Circumference of Middle	-	Depth of Middle	.544
Circumference of Hind Flank	-	Depth of Flank	.770
Height at Withers	-	Height at Withers	.723
Height at Rump	-	Height at Rump	.928
Depth of Chest	-	Depth of Chest	.632
Length of Body	-	Length of Body	.400

[a].349 required for significance at P.05.
.449 required for significance at P.01.

points of reference, it was impossible to accurately define the point of the shoulder.

Circumferences could not be obtained from the photograph of the live animal. However, body depth measurements were taken from the photographs at the same points at which live animal circumference had been taken previously and the depth and circumference measurements were correlated. Since only one dimension, namely depth could be measured, as compared to circumference, the correlation coefficients obtained were not unusually high. Photographic measurements of height at withers and rump were correlated with the same live animal measurements. The correlation between the two methods of measuring height at rump showed then to be in good agreement with an association accounting for 86 percent of the variation, while height at withers accounted for 50 percent of the variation occuring between the two measurements. Since the live animal and photographic measurements of height at rump were highly associated with each other, the lower relationship existing between the two measures of height at withers can best be explained as a result of position of the fore legs. The depth of chest measurements taken on the live and photographed animal were significantly correlated. However, this correlation was not as high as would be expected.

These correlations indicated that it is possible to obtain certain estimates of body measurements by the use of photographs. Body height measurements taken from the photographs were the measurements most highly correlated with those of the live animal. However, results show that care must be taken to get each animal to stand in the same relative position.

Comparison of Objective Live Animal and Carcass Measurements

In order to test the validity of using various live animal measurements to estimate a particular carcass measurement, correlation coefficients were calculated. These are listed in Table 7. Comparable live animal and carcass measurements were correlated when available, while in all other instances, the correlations between the measurements of the live animal and carcass were chosen for best fit. A good correlation was shown to exist between the carcass measurements and some of the objective live animal measurements. All carcass width measurements were highly correlated with the same live animal measurements. The correlation coefficients were .770 for width of shoulder, .635 for width at crops, .755 for width at rump, and .661 for width of round and all were highly significant. Since these estimates are all higher than similar estimates made between subjective live animal scores and carcass measurements (Table 3), it is evident that width of carcass could be more accurately predicted from live animal measurements than from subjective scoring. Carcass depth taken at the fifth rib and flank were significantly related to the live animal measurements, brisket to crops and circumference of rear flank, which most closely approximated these measurements. It was obvious that the depth measurements on the live animal predicted carcass

TABLE 7 Simple Correlation Coefficients Between Linear Carcass and Live Animal Measurements

Carcass Measurement		Live Animal Measurement	r
Width of Shoulder	-	Width of Shoulder	.770**
Width at Crops	-	Width at Crops	.635**
Width of Rump	-	Width of Rump	.755**
Width of Round	-	Width of Round	.661**
Depth of Chest at 5th Rib	-	Depth from Brisket to Crops	.584**
Depth at Flank	-	Circumference of Middle	.419*
Depth at Flank	-	Circumference of Hind Flank	.428*
[1]Circumference of Round	-	Circumference of Leg above Hock	.512*
[1]Circumference of Round	-	Depth from Twist to Hocks	.162
[1]Circumference of Round	-	Circumference of Hind Flank	-.148
[1]Circumference of Round	-	Height from Rump to Hocks	.032
[1]Circumference of Round	-	Depth from Twist to Floor	.123
[1]Circumference of Foreshank	-	Circumference of Leg above Knee	.389
Length of Carcass	-	Height at Withers	.331
Length of Carcass	-	Height at Rump	.804**
Length of Carcass	-	Length from 1st Thoracic to Pins	.008
Weight of Fore Quarter	-	Weight of Fore	.904**
Weight of Hind Quarter	-	Weight of Hind	.865**

[1]Only 15 steers included.
*Denotes significance at P.05.
**Denotes significance at P.01.

depth more accuately than the subjective scores for depth (Table 3). Either of these correlations did not account for as much of the variation as the width measurements.

Circumference of the round of the carcass was only obtained for second year. Circumference of the hind leg above the hock was found to be the live animal measurement most highly related to the circumference of the round (r = .512). Circumference of fore shank on the carcass, also was only obtained for the steers the second year, but when correlated with the circumference of fore leg above the knee on the live animal, the relationship, although not significant due to the small numbers studied, did show a definite relationship. The length of the carcass was most highly related with the height of the rump on the live animal. A correlation coefficient of .804 was obtained.

The fore and hind quarter weights of the carcass were correlated with the fore and hind weight taken on the live animal. Correlation coefficients of .904 was obtained between the fore weight of the carcass and the fore weight of the live animal. Dawson et al. (1955) weighing both ends of the live animal simultaneously reported that on the average 43.55 percent of the weight of the live animal was carried on the hind legs. They also found a correlation coefficient of .66 existing between the percent of hind weight of the live animal and the percent of hind quarters in the carcass. It was necessary, in this study however, to have each animal stand in the same relative position when the weights of the hind and fore halves of the live animal were obtained. Raising or lowering of the head or a shifting of body weight would radically increase or decrease the weights.

Comparison of Objective Live Animal Measurements to Carcass Grade

Correlation coefficients were calculated between carcass grade and objective live animal measurements. These are given in Table 8. The live animal measurements which were found to give the best estimate of carcass grade include in order of importance the following: circumference of middle, width at rump, circumference of hind and fore flank, width of round, total live weight, hind and fore weight of the live animal, and width between 13th rib and hooks. The above correlation coefficients accounted for 61 to 22 percent of the variation in carcass grade. Each was positively correlated with grade, indicating that the larger body measurements and heavier weights were associated with the higher grading steers. All were high enough for significance at the one percent level.

In addition, height at withers, width of shoulder and at hooks were positively and significantly related to grade (P = .05) and were associated with 15 to 17 percent of the variation in grade. Circumference of the hind cannon was also found to be significantly (P = .05) associated with carcass grade, but showed an inverse relationship. Thus, results indicate that the cannon bones with the smaller circumferences were associated with the higher grading steers.

TABLE 8 Correlation Coefficients Between Carcass Grade and Various Live Animal Measurements[a]

X	r Carcass Grade with
Live Animal Weight	
Hind	.492
Fore	.490
Total	.534
Live Animal Width Measurements	
over Crops	.304
between Crops and 13th Rib	.006
at 13th Rib	.343
between 13th Rib and Hooks	.472
Pins	.266
Round	.650
Rump	.738
Hooks	.387
Shoulder	.408
Neck	.302
Live Animal Length Measurements	
1st Thoracic to Pins	.016
1st Thoracic to 13th Rib	.230
13th Rib to Hooks	-.287
Rump	-.157
Live Animal Height Measurements	
Withers	.416
Rump	.150
Rump to Hocks	.238
Twist to Floor	-.110
Twist to Hocks	-.038
Brisket to Crops	.318
Smooth Joint to Dew Claws	-.050
Smooth Joint to Floor	.055
Break Joint to Dew Claws	.162
Break Joint to Floor	.066
Live Animal Circumference Measurements	
Fore Flank	.652
Middle	.782
Hind Flank	.692
Fore Leg above Elbow	.294
Fore Leg below Elbow	-.166
Hind Leg above Hock	.068
Hind Leg below Hock	-.350
Angle of Ribs	.228

[a].349 required for significance at P.05.

The data support the findings of Lush (1932) that such measures as the circumferences of barrel, and various width measurements have a direct relationship to grade. However, width at hooks which Lush considered as the best index to grade was not as highly associated with grade as some other live animal measurements in this study. The best single estimate of carcass grade was circumference of barrel just anterior to the pizzle.

<u>Relationship of Live Animal Measurements to Rib-eye Area and Live Animal Weight</u>

Rib-eye area and live weights were correlated with objective live animal measurements to determine the relationship existing between these items (Table 9). Correlation coefficients of .510, .520 and .530 were obtained between rib-eye area and circumference of fore flank, circumference of hind flank and circumference of middle, respectively. All were highly significant and showed a direct relationship to rib-eye area. Thus, the steers with the larger body circumference tended to have the larger rib-eyes. Other relationships between various live animal measurements and rib-eye area were significant at the five percent level. The significant correlation coefficients for rib-eye area were .350 for width of rump, -.360 for circumference of hind leg above hock, and .380 for live weight. Width of rump and live weight were shown to be directly related to rib-eye size while circumference of the hind leg above the hock showed an inverse relationship. Thus, there was a tendency for the heavier steers and those with

TABLE 9 Simple and Multiple Correlation Coefficients of Rib-eye Area With Live Weight and Various Live Animal Measurements, and Standard Partial Regression Coefficients with Weight Constant

X	r Rib-eye Area with	r Live Weight with	b^1(a)	R Rib-eye Area With Live Weight and
Width Measurements				
Over Crops	.200	.444*	.039	.382
Between Crops and 13th Rib	-.050	.222	-.142	.404
At 13th Rib	.120	.608**	-.176	.405
Between 13th Rib and Hooks	.150	.592**	-.115	.391
Pins	.180	.294	.074	.386
Round	.300	.677**	.078	.384
Rump	.350*	.680**	.170	.400
Hooks	.230	.538**	.036	.381
Shoulder	.220	.792**	-.218	.402
Neck	-.050	.476**	-.298	.462*
Length Measurements				
1st Thoracic to Pins	.070	.564**	-.212	.418
1st Thoracic to 13th Rib	.140	.578**	-.120	.392
13th Rib to Hooks	.120	-.328	-.274	.382
Rump	.040	.333	-.097	.390
Height Measurements				
Withers	.112	.780**	-.472	.481*
Rump	.036	.698**	-.447	.496*
Rump to Hocks	.340	.500**	.200	.418
Twist to Floor	.120	.276	-.244	.446*
Twist to Hocks	-.050	-.102	-.011	.380
Brisket to Crops	.258	.630**	.030	.380
Circumference Measurements				
Fore Flank	.510**	.901**	.891	.542**
Rear Flank	.520**	.784**	.576	.522**
Middle	.530**	.759**	.570	.531**
Fore Leg above Knee	.040	.352*	-.106	.393
Hind Leg above Hock	-.360*	.361*	-.572	.654**
Fore Cannon	-.230	.492**	-.550	.612**
Hind Cannon	-.300	.304	-.458	.578**
Live Weight	.380*	--	--	--

(a)b^1 Standard partial regression of rib-eye area on X with weight held constant.
*Denotes significance at P.05.
**Denotes significance at P.01.

the wider rumps to have larger rib-eyes, while the steers having the larger leg circumferences above hock tended to have the smaller rib-eyes. The negative relationship between circumference of the leg above the hock and rib-eye area was not expected since many livestock judges use size of round on the live animal as an indicator of rib-eye size. In any case, only 12 to 14 percent of the variation existing in rib-eye area, was associated with either width of rump, circumference of leg above hock or live weight. All other relationships studied between rib-eye size and the various live animal measurements were not significant and in some instances approached zero.

Correlation coefficients between objective live animal measurements and live weight were calculated (Table 9). In each case, the relationship was found to be higher between the live animal measurements and live weight than with rib-eye area. This would indicate that the several body measurements were more dependent upon the effects of weight than upon the effect of rib-eye muscle area. As reported by Johnson (1940), Lush (1928), Barton (1938), Kidwell (1955) and other workers, circumference of fore flank was the best single estimate of body weight. The correlation coefficient obtained was .901 which accounted for better than 81 percent of the variation in weight. Other measurements which gave high relationships to body weight included shoulder width, circumference of rear flank, height at withers, circumference of middle, height at rump, width of rump, width at round and width at 13th rib with correlation coefficients of .792, .784, .780, .759, .680, .677 and .608, respectively. Thus, each of the above listed correlation coefficients accounted for at least 36 percent of the variation existing between a particular live measurement and live weight.

It is evident from the correlation coefficients discussed above and from others listed in Table 9, that rib-eye area had a low relationship to objective live animal measurements, while on the other hand, several of the measurements studied seemed to be a direct function of weight. This would be expected since the magnitude of such measurements would be dependent upon body mass.

Standard partial regression equations were calculated in order to study the relationship of various subjective live animal measurements and live animal weight with rib-eye area. Table 9 lists the relationships between rib-eye area and various live animal measures with the effects of live weight eliminated. With weight held constant, circumference of fore flank accounted for 80 percent of the variation in rib-eye area. This was by far the best relationship found between the various live animal measures. Other live animal measurements, which were associated with 20 to 33 perdent of the variation in rib-eye area, included circumference of middle and circumference of rear flank. Similar to the fore flank, they were directly related, while other measurements such as height at withers, height at rump, circumference of hind leg above hock and below the hock or circumference of hind and fore cannons, all showed an inverse relationship to area of rib-eye. The standard partial regression equations for all the live animal measurements with rib-eye area were increased over the simple correlation coefficients obtained previously between the same dependent and independent variable.

Table 9 lists the multiple correlation coefficients obtained when rib-eye area was correlated with live animal weight and the various live animal measurements. These values account for the variation in rib-eye area which was due to the combined effects and possible interactions of live animal weight and a particular live animal measurement. The relationships of rib-eye area to the various circumference measurements were studied. The circumferences included the following: fore flank, rear flank, middle, hind leg above hock, fore cannon and hind cannon. The variation associated with rib-eye area between each of these various circumference measures and live animal weight was from 27 to 43 percent. The total range of variation in rib-eye area associated with live weight and the measurements studied was from 14 to 43 percent.

Relationship of Live Animal Measurements with Primal Cuts

Table 10 lists the correlation coefficients obtained between the various objective live animal measurements and percent primal cuts. Only two correlations between live animal measurements and percent primal cuts were significant at the one percent level. These included the circumference of fore flank and circumference of middle, with correlation coefficients of -.462 and -.534, respectively. Other measurements which accounted for 12 to 19

TABLE 10 Correlation Coefficients Between Various Live Animal Measurements and Percent Primal Cuts[a]

X	r Primal Cuts with
Weight	
Hind	-.092
Fore	-.324
Total	-.240
Circumference	
Fore Flank	-.462
Middle	-.534
Hind Flank	-.424
Leg below Knee	.352
Leg above Knee	.072
Leg below Hock	.412
Leg above Hock	.042
Width	
Neck	-.257
Shoulder	-.276
Crops	-.113
Between Crops and 13th Rib	-.131
13th Rib	-.122
Between 13th Rib and Hooks	-.129
Hooks	-.137
Rump	-.398
Round	-.322
Pins	-.436
Length	
1st Thoracic to Pins	.314
1st Thoracic to 13th Rib	.102
13th Rib to Hooks	.151
Length of Rump	.321
Height	
Rump to Hocks	-.062
Twist to Hocks	.151
Twist to Floor	.299
at Rump	.311
at Withers	-.039
Brisket to Crops	-.016
Smooth joint to Dew Claws	.263
Smooth joint to Floor	.147
Break joint to Dew Claws	.427
Break joint to Floor	-.021
Spring of Ribs	-.315

[a].349 Required for significance at P.05.
.449 Required for significance at P.01.

percent of the variation between live animal measurements and percent primal cuts were circumference of hind flank (r = -.424); circumference of hind leg below hock (r = .412); width of rump (r = -.398); width at pins (r =.436); and the distance between break joint and dew claws (r =.427). It is evident from the correlation coefficients presented in Table 10 that most of the relationships were negative. Thus there was a slight tendency for the steers having the larger live animal measurements to have a lower percent of primal cuts. This was contrary to the relationships between the various live animal measurements and wholesale cuts on a weight basis, which tended to show high positive relationships. Since converting actual weights of wholesale cuts into a percent basis markedly reduces most relationships existing between live animal measurements and percent primal cuts, it is obvious that smaller differences existed in the yield of primal cuts between steers when placed on a percentage basis. This supports the view of Butler (1957) who stated that conformation of the live beef animal could vary quite widely and still not change the proportion of wholesale cuts.

Relationship Between Various Live Animal Measurements and Weights of Various Wholesale Cuts

The relationship of various objective live animal measurements to individual wholesale cuts were investigated. In each case, the weight of a particular wholesale cut was correlated with the actual objective live animal measurement, which would seem most likely to affect its weight.

The weight of the wholesale beef rib was correlated with the various live animal measurements and correlation coefficients are listed in Table 11. All correlation coefficients except two, namely, length from first thoracic vertebra to the 13th rib and length from first thoracic vertebra to the pins, were found to show a highly significant positive relationship to the weight of the wholesale beef rib. The three highest relationships were with circumference of fore flank, circumference of middle and live weight with correlations of .880, .709 and .824, respectively. The two circumference measurements were previously shown to have correlation coefficients of .901 and .759, respectively, with live animal weight. This indicates that the ultimate weight of the wholesale beef rib will depend largely upon the weight of the animal.

Although length from the first thoracic vertebra to the 13th rib and the length from the first thoracic vertebra to the pins were shown to have correlation coefficients with live animal weight of .578 and .564, respectively, they failed to show an appreciable effect on the weight of the wholesale rib. The first mentioned length correlation coefficient, however, was high enough for significance at the five percent level. These results agree with the report of White and Green (1952) who stated that the various body depth and width measurements furnished a higher predictive value for weights of the several wholesale cuts than did

TABLE 11 Simple and Multiple Correlation Coefficients of the Weight of the Wholesale Rib with Live Weight and Various Live Animal Measurements, and Standard Partial Regression Coefficients with Weight Constant

X	r Rib Weight with	r Live Weight with	b^1(a)	R Rib-eye Area with Live Weight and
Width at 13th Rib	.648**	.608**	.232	.844**
Width between 13th Rib and Crops	.453**	.222	.284	.869**
Width at Crops	.520**	.444*	.192	.842**
Circumference of Fore Flank	.880**	.901**	.729	.882**
Cirsumference of Belly	.709**	.759**	.179	.834**
Spring of Ribs	.605**	.407*	.323	.875**
Length 1st Thoracic to 13th Rib	.359*	.578**	-.177	.836**
Length 1st Thoracic to Pins	.229	.564**	-.347	.872**
Live Weight	.824**	---	---	---

(a)b^1 = Standard partial regression of rib-eye area on X with weight held constant.
*Denotes significance at P.05.
**Denotes significance at P.01.

various body length measurements.

When comparing the correlation coefficients obtained between body measurements and rib weight with those obtained between the same body measurements and live animal weight, it is evident that the differences are small. This would further indicate the high relationship existing between live animal weight and the ultimate weight of the wholesale rib.

When the effect of live weight was eliminated by use of standard partial regression equations, only circumference of the fore flank accounted for a large amount of the variation in the weight of the wholesale rib (Table 11). In this case, 53 percent of the variation in rib weight was associated with circumference of fore flank when live weight was held constant. All other body measurements except length from first thoracic vertebra to pins were reduced markedly from the simple correlations between rib weight and various live animal measures. Both body length measurements were changed from positive values in the simple correlations with rib weight to negative values when live weight was held constant. This would indicate a tendency for the longer bodied steers to be associated with the lighter wholesale ribs when the weight was the same. However, either of the regressions obtained for these length measurements did not account for more than 12 percent of the variation in rib weight.

The combined effect of the various live animal measurements studied and live weight were associated with 70 to 78 percent of the variation existing in weight of the wholesale rib cut. Thus, all live animal measurements were about equally good in accounting variation in the weight of the rib.

The weights of the sirloin plus round were also correlated with the particular live animal measurements which would logically be expected to affect the weights of these cuts. These correlation coefficients are listed in Table 12. With the exception of the height from the twist to the hocks and width of pins, all other correlations between the various live animal measurements and the combined weight of the round plus sirloin were significant. The correlations between the combined weight of round plus sirloin with either live animal weight or height at the rump had correlation coefficients of .877 and .860, respectively, and afforded the best predictive value for the weights of this cut. Other live animal measures which indicated a high relationship to the weight of round plus sirloin included height from the rump to the hocks (r =.528), height from the twist to the floor (r =.502), circumference of hind flank and middle (r =.676 and .510), length of rump (r =.588 and .591).

Observation of the correlation coefficients between live animal weight and the various live measurements (Table 12) indicates, as was the case with the wholesale rib, that the correlations which were the highest between a particular measurement and weight of the corresponding wholesale cut, were also in most cases highest with the same measurement and live animal weight. Since live animal weight affords the best single estimate of the ultimate

TABLE 12 Simple and Multiple Correlation Coefficients of the Weight of the Wholesale Sirloin plus Round with Live Weight and Various Live Animal Measurements, and Standard Partial Regression Coefficients with Live Weight Constant

	r Sirloin plus Round Weight with	r live Weight with	b^1(a)	R Sirloin + Round Weight and Live Weight and
Height from Rump to Hocks	.528**	.500**	.119	.883**
Height from Twist to Hock	.048	-.102	.140	.888**
Height from Twist to Floor	.502**	.276	.281	.918**
Circumference of Hind Cannon	.436*	.304	.187	.895**
Circumference of Leg above Hock	.362*	.361	.052	.878**
Circumference of Hind Flank	.676**	.784**	-.004	.890**
Circumference of Belly	.510**	.759**	-.368	.909**
Height at Rump	.860**	.698**	.484	.943**
Length of Rump	.518**	.333	.254	.909**
Width at Hooks	.452**	.538**	-.027	.877**
Width at Pins	.040	.294	-.238	.906**
Width of Round	.588**	.677**	-.010	.877**
Width of Rump	.591**	.680**	-.010	.877**
Live Weight	.877**	---	---	---

(a)b^1 = Standard partial regression of rib-eye area on X with weight held constant.
*Denotes significance at P.05.
**Denotes significance at P.01.

weight of a wholesale cut, it is again evident that the final weight of a cut is a function of the live animal weight.

When the effect of live weight was held constant, most of the values obtained for the standard partial regression equations were greatly reduced from the simple correlations obtained between the various live animal measurements and the sirloin plus round weight. As is in the case with the wholesale rib, the influence of live weight is indicated upon the weight of the wholesale cut. Height at rump in animals of the same weight accounted for the largest amount of variation (23 percent) in weight of the sirloin plus round. The multilinear correlation coefficients of the various live animal measurements plus live weight accounted for 77 to 89 percent of the variation existing in the weight of the sirloin plus round.

In the case of the shortloin, the best estimates of the ultimate weight of this cut were either the width of the live animal taken between the 13th rib and hooks or the width at hooks or the live weight of the animal, which gave correlation coefficients of .698, .610 and .648, respectively (Table 13). Similar to the two previous wholesale cuts, the live animal measurements which were found to be most highly related to the weight of the shortloin were likewise highly related to the weight of the live animal. Width at pins, length from first thoracic vertebra to pins and the length from the 13th ribs to hooks showed positive relationships to the weight of the shortloin, but the correlations were not high

TABLE 13 Simple and Multiple Correlation Coefficients of the Weight of the Wholesale Shortloin with Live Weight and Various Live Animal Measurements, and Standard Partial Regression Coefficients with Live Weight held Constant

X	r Shortloin Weight with	r Live Weight with	b^1(a)	R Shortloin Weight with Live Weight and
Width at 13th Rib	.374*	.608**	-.003	.656**
Width between 12th Rib and Hooks	.698**	.592**	.484	.838**
Width at Hooks	.610**	.538**	.368	.718**
Width at Pins	.172	.294	-.002	.650**
Length at 1st Thoracic to Pins	.300	.564**	-.096	.652**
Length at 13th Rib to Hooks	.291	-.328	.564	.756**
Live Weight	.648**	--	--	--

a) b^1 = Standard partial regression of rib-eye area on X with live weight held constant.
*Denotes significance at P.05.
**Denotes significance at P.01.

enough for significance.

When the effect of live weight was eliminated, length from the 13th rib to the hooks was associated with 32 percent of variation in the weight of the shortloin. All the other direct effects (weight constant) of the various live animal measurements upon the weight of the shortloin were lower than the values obtained with the simple correlations between these measurements and the weight of shortloin.

Multiple correlation coefficients of the various live animal measurements and live animal weight accounted for 42 to 70 percent of the variation in shortloin weight. The combination of live weight and width between 13th rib and hooks, was the best relationship, accounting for 70 percent of the variation in weight of the shortloin.

Table 14 lists the correlation coefficients obtained between the weight of the wholesale chuck with various live animal measurements. All live animal measurements correlated with the weight of the chuck were highly significant except for width of neck. Again, as with the other wholesale cuts studied, all correlations were positive, indicating that an increase in a certain measurement would result in more pounds of chuck from the same animal. Each of three live animal measurements accounted for 64 to 80 percent of the variation which existed between chuck weight and the corresponding live animal measure. These included circumference of middle and fore flank, and live animal weight with correlations

TABLE 14 Simple and Multiple Correlation Coefficients of the Weight of the Wholesale Chuck with Live Weight and Various Live Animal Measurements, and Standard Partial Regression Coefficients with Live Weight held Constant

X	r Chuck Weight with	r Live Weight with	b^{1}(a)	R Chuck Weight with Live Weight and
Width of Neck	.277	.476**	-.174	.879**
Width of Shoulder	.688**	.792**	.005	.866**
Width over Crops	.483**	.444*	.123	.872**
Circumference of Fore Flank	.800**	.901**	.102	.867**
Circumference of Middle	.895**	.759**	.561	.940**
Length from 1st Thoracic to 13th Rib	.586**	.578**	.128	.872**
Height from Brisket to Crops	.578**	.630**	.054	.866**
Height at Shoulders	.712**	.780**	.092	.868**
Live Weight	.866**	---	---	---

(a)b^{1} = Standard partial regression of rib-eye area on X with live weight held constant.
*Denotes significance at P.05
**Denotes significance at P.01

of .895, .800 and .866, respectively. As was the case for the previous wholesale cuts studied, the weight of chuck was a direct function of animal weight. However, width of neck was more highly related to the live weight of the animal than to the weight of the wholesale chuck.

Standard partial regression equations between the various live animal measurements and weight of chuck are listed in Table 14. With the effects of weight eliminated, all values were lower than those obtained in the simple correlation coefficients between weight of chuck and the various live animal measurements tested. When the effect of weight was eliminated, circumference of middle (accounting for 31 percent of the variation in the weight of chuck) was the only live measurement showing a high relationship to weight of the wholesale chuck.

CARCASS EVALUATION

Repeatability Estimates for Carcass Measurements

All carcass measurements taken were highly repeatable (Table 15). Length of body was the measurement with the highest repeatability. This measurement was taken by using definite reference points which accounts for the high estimate obtained. The body depth measurements were the poorest as far as the ability for duplication was concerned, probably because the points of reference were least defined.

Examination of carcass repeatability estimates shows that these measurements can be taken with a high degree of accuracy.

TABLE 15 Repeatability Estimates for Carcass Measurements[a]

	Repeatability Estimate
Depth of Body at 5th Rib	.869
Depth of Body at Flank	.776
Width at Shoulder	.985
Width at Crops	.973
Width at Rump	.921
Width at Round	.979
Circumference of Round	.978
Circumference of Fore Shank	.953
Length of Body	.991

[a].497 Required for Significance at P.05.
.623 Required for Significance at P.01.

The variation existing between duplicate carcass measurements appears to be largely due to the lack of definite reference points. The variation accounted for between all duplicate measurements ranged from 60.2 to 98.2 percent, while with removal of the two body depth measurements, the range was from only 84.8 to 98.2 percent.

Comparison of Carcass and Carcass Photographic Measurements

Various carcass measurements were taken so that the association between carcass photographic measures and actual carcass measurements could be made (Table 16) . With the exception of the correlation obtained between circumference of round in the carcass with width plus depth of round from the photograph, all correlation coefficients obtained between the two methods were significant. Body depth at fifth rib, and width of shoulder, crops and rump were shown to be the measurements most highly duplicative.

Depth at flank and width of round measurements taken from the carcass photographs were significantly correlated ($P = .05$) with the same measurements of the carcass. The circumference of round on the carcass was not duplicated with the measurements taken from the photographs, because of inability to obtain a measure of all dimensions of the round. If the carcasses had been split, as is the common procedure in slaughtering beef, the repeatability of the photographic measurements and the carcass measurements would have been lower.

TABLE 16 Simple Correlations Coefficients Between Actual Carcass Measurements and Measurements Taken from Carcass Photographs[a]

X		r
Depth at 5th Rib	-	.704
Depth at Flank	-	.398
Width of Round	-	.427
Width of Rump	-	.658
Width of Shoulder	-	.868
Width of Crops	-	.724
Circumference	w/width + depth of Round from photographs	.047

[a].349 required for significance at P.05.
.449 required for significance at P.01.

Relationship between Carcass Measurements and Rib-eye Area, Live Weight and Percent Primal Cuts

Table 17 lists the correlation coefficients between various carcass measurements and rib-eye area, live weight and percent primal cuts. Width of shoulder ($r = .539$), width of rump ($r = .464$) and width of round ($r = .480$) showed highly significantly relationships to rib-eye area. In addition, depth of flank, depth at fifth rib and width of crops were significantly related to area of rib-eye ($P = .05$). These above correlations were directly associated with area of rib-eye. Thus, it would be expected that those steers having the larger carcass measurements tended to have the larger area of rib-eye. Such carcass measures as carcass length, circumference of round and circumference of fore shank showed very little relationship to rib-eye area. Circumference of fore shank showed a low negative relationship to the area of rib-eye.

The correlation coefficients obtained between live weight and the various carcass measurements were all significant (Table 17). With the exception of depth and circumference at the flank, all relationships between the various carcass measurements and live weight were highly significant, accounting for 39 to 64 percent of the variation.

Correlation coefficients calculated between percent primal cuts and various carcass measurements are also found in Table 17. All, except the correlation between body length, showed an inverse relationship to percent primal cuts. Thus, with the one exception,

TABLE 17 Correlation Coefficients Between Various Carcass Measurements and Rib-eye Area, Live Weight and Percent Primal Cuts

X	r Rib-eye Area with	r Live Weight with	r Percent Primal Cuts with
Carcass Length	.017	.664**	.221
Depth at 5th Rib	.369	.672**	-.320
Depth at Flank	.405*	.356*	-.153
Width of Shoulder	.539**	.788**	-.499**
Width of Crops	.414*	.622**	-.403*
Width of Rump	.464**	.656**	-.457**
Width of Round	.480**	.802**	-.436*
[1]Circumference of Round	.094	.436*	-.158
[1]Circumference of Foreshank	-.197	.794**	-.052

[1] 15 steers only.
*Denotes significance at P.05.
**Denotes significance at P.01.

the larger carcass measurements tended to be associated with a lower yield of primal cuts. However, except for width of shoulder and width of rump (P =.01) and width of crops and width of round (P =.05) all relationships were low.

Relationship of Rib-eye Area to Percent of Various Carcass Parts

Table 18 lists the simple correlation coefficients of the percent of the fore and hind quarters, percent of various wholesale cuts and Psoas major and Semitendinosis muscles with the area of rib-eye. Certain of these items, namely: hind quarter, primal cuts, sirloin plus round, shortloin, fore shank, chuck and Psoas major showed an inverse relationship to the area of the rib-eye muscle. This would indicate that as the eye muscle increased in size, the percentage of these various items tended to decrease. The highest relationship between the various percentages of the carcass and rib-eye area were found to exist between percent primal cuts, percent sirloin plus round and percent fore shank, which all showed a highly significant negative relationship to the size of rib-eye. On the other hand, percent kidney knob and shortplate showed positive relationships to area of rib-eye (P =.01).

These correlation coefficients seem somewhat spurious upon first observation. However, when the rib-eye area for each steer was plotted against either percent primal cuts, percent fore shank or percent kidney knob, the cause for these particular correlations was evident. Negative correlations were obtained between rib-eye

TABLE 18 Simple Correlation Coefficients of Rib-eye Area with Percent of Hind and Fore Quarters, Percent Primal Cuts, Percent Wholesale Cuts and Percent *Semitendinosis* and *Psoas Major* Muscles

X	r Rib-eye Area with
Hind Quarter	-.231
Fore Quarter	.230
Primal Cuts	-.507**
Sirloin + Round	-.512**
Rib	.181
Shortloin	-.167
Shortplate	.479**
Fore Shank	-.519**
Brisket	.140
Chuck	-.078
Kidney Knob	.587**
Flank	.345
Psoas Major	-.314
[1]*Semitendinosis*	.405

[1]Only 15 steers included.
**Denotes significance at P.01.

area with percent primal cuts and percent fore shank. This was largely the result of the Angus steers which had large rib-eyes but quite low percentages of primal cuts and percentages of fore shank. While the positive relationship existing between percent kidney knob and rib-eye area was largely attributed to the Angus steers as a group which had in addition to large rib-eyes, a higher percent of kidney knob.

Relationship of Animal Weight with Weights of Carcass Parts

Table 19 lists the simple correlation coefficients of the weights of the wholesale cuts, weight of *Psoas major* and *Semitendinosis* muscles with live animal weight. All existing relationships between the wholesale cuts and muscle weights and live animal weights were highly significant except for the kidney knob and the *Psoas major*. The highest relationships were found with weight of round plus sirloin and chuck, which were associated with 77 and 75 percent of the variation existing between the weight of these particular wholesale cuts and live weight, respectively. The high relationships to live weight would be expected since the round plus the sirloin accounts for approximately 33 percent of the total carcass weight, while approximately 26 percent of the carcass is composed of the chuck. The total range of variation associated with the various weights of the wholesale cuts, which were significantly related, and live weight was 37 to 77 percent.

TABLE 19 Correlation Coefficients of Live Animal Weight with Weights of Wholesale Cuts and *Psoas* Major and *Semitendinosis* Muscle

X	r - Live animal weight with
Chuck	.866**
Rib	.824**
Shortplate	.798**
Brisket	.673**
Foreshank	.664**
Shortloin	.648**
Round + Sirloin	.877**
Kidney Knob	.324
Flank	.612**
Psoas Major	.262
[1]*Semitendinosis*	.690**

[1]Only 15 steers included.
**Denotes significance at P.01.

CANNON BONES

Degree of Muscling

Hammond (1932a) Pálsson (1939, 1940) and Hirzel (1939) reported a tendency towards earlier maturity and a shortening and thickening of the muscling in sheep as the cannon bones decreased in length and increased in thickness. If such a relationship were relatively high in predictive value, it would be an easy and inexpensive measurement to obtain, since cannon bones are removed at slaughter and could be easily cleaned and measured. Thus, correlation coefficients were calculated (Table 20) between the various cannon bone measurements with the weight and percent of primal cuts. The rib, shortloin, sirloin and round were included as primal cuts.

As shown in Table 20, all correlation coefficients between the weight of primal cuts and various weight and linear measures of the fore and hind cannons were significant at the one percent level except for thickness of the fore cannon. The weight and lengths of both the fore and hind cannon bones appeared to give the best estimate of the weights of the primal cuts. All correlations were positive. In other words, the larger the various measurements of the cannons, the higher the yield of primal cuts. The weight and length of fore and hind cannons accounted for 37 to 47 percent of the weight in primal cuts.

The same measurements of fore and hind cannons were correlated with the percent of primal cuts (Table 20). It will be noticed

TABLE 20 Simple Correlation Coefficients of Various Cannon Bone Measurements with Primal Cut Weights, Percent Primal Cuts and Estimated Percent of Carcass Lean[a]

X	"r" Primal Cuts Weight with	"r" % Primal Cuts with	"r" Estimated % Carcass Lean with
Fore Cannon			
Weight	.624	.188	-.004
Length	.683	.368	.009
Width	.525	.292	.004
Thickness	.170	-.046	.025
Circumference	.501	.533	.019
Hind Cannon			
Weight	.651	.156	-.005
Length	.607	.349	.007
Width	.488	.237	.012
Thickness	.515	.044	.001
Circumference	.475	.147	-.002

[a] .349 Required for significance at P .05.
.449 Required for significance at P .01.

that only the length of the fore and hind cannons were found to be significantly related to percent primal cuts. The relationship was positive, or in other words, the longest cannons tended to be associated with the carcasses having the highest percentage of primal cuts. Ljungdahl's (1942) data also supported this conclusion, as he found that the longer legged lambs tended to have a higher percent of leg, even though the carcasses from such lambs were usually graded lower.

Since higher correlation coefficients were obtained when cannon bone measurements were correlated directly with weight of the primal cuts, it would seem that the weight and shape of the cannons were directly related to body mass or weight. Differences in primal cuts between steers were markedly reduced when converted to a percentage basis.

Estimated percent lean on a carcass basis was calculated using the data obtained from the 9-10-11 rib section and applying the regression equation $Y = 15.56 + .81\ X$ derived by Hankins and Howe (1946). The estimate of percent lean was correlated with the various cannon bone measures and the correlation coefficients appear in Table 20. All correlation coefficients obtained were zero for all practical purposes. Thus, there was no relationship manifested between the several measures of the cannon bones and the estimated percent lean in the carcass.

Correlation coefficients between rib-eye area and the various cannon bone measurements are listed in Table 21. All correlations obtained between these two items were quite low and not statistic-

TABLE 21 Simple and Multiple Correlation Coefficients of Ribeye Area with Live Weight and Various Measurements of the Fore and Hind Cannon Bones, and Standard Partial Regression Coefficients with Live Weight Constant

X	r Ribeye area with	r Live weight with	b1[a]	R Ribeye with Live weight and
Fore Cannon				
Weight	.069	.670**	-.336	.454*
Length	-.113	.245	-.219	.435*
Width	-.106	.583**	-.497	.554**
Thickness	.140	.208	.064	.385
Circumference	-.199	.361*	-.387	.524**
Hind Cannon				
Weight	.161	.682**	-.183	.403
Length	-.054	.546**	-.372	.492*
Width	-.177	.512**	-.504	.576**
Thickness	.234	.660**	-.030	.381
Circumference	-.041	.588**	-.404	.501*
Combined weight of Fore and Hind Cannon	.120	.682**	-.260	.425
Live weight	.380*	---	---	---

[a]b1 = Standard partial regression of ribeye area on X with weight held constant.
*Denotes significance at P .05.
**Denotes significance at P .01.

ally significant. Although the values were low, there seemed to be a trend, inasmuch as there was an inverse relationship between rib-eye area with length, width, and circumference of fore and hind cannons. Thus, for any increase in any of the cannon measurements there was a tendency for a decrease in rib-eye area. However, weight and thickness of the fore cannon were positively correlated with rib-eye area.

Insomuch as there was no significant relationship between measures of the cannons with rib-eye area, the cannon bone measurements were correlated with live animal weight (Table 21). In all cases, a positive correlation coefficient was obtained. Thus, it was shown that increased measurements of the cannon bones were related to increased body size. The weights of either the hind or fore cannons were the best single estimates to the weight of the live animal, with correlation coefficients of .682 and .670, respectively. Also equally as good, was thickness of the hind cannon with a correlation of .660. Width of either the fore or hind cannon along with length and circumference of the hind cannons accounted for at least 30 percent of the variation existing between the various measurements of the cannon bones and live animal weight. Thus, it would be possible to use various measurements of the cannons to estimate live animal weight. In most cases, better estimates of live animal weight exist. Unfortunately, the cannon weights which afford the best estimate of all cannon bone measures are not obtainable on the live animal. These data show, however, that there is a direct relationship between weight of the animal and a number of the cannon bone measurements.

Standard partial regression coefficients were calculated to eliminate the effect of live animal weight on the relationship between rib-eye size and cannon bone measurements. With live weight held constant, the width and circumference measurements of the fore and hind cannons gave the best estimates of rib-eye size of all cannon measurements studied accounting for 15 to 25 percent of the variation in rib-eye area (Table 21). The relationships except for thickness of fore cannon were negative, thus, indicating a tendency for the larger rib-eye areas to be associated with shorter, finer and lighter cannons. This tendency may have been due to the inclusion of eight Angus steers which for the most part had cannon bones with smaller measurements than the Herefords but had larger rib-eye areas than the average.

Multilinear correlation coefficients were obtained for rib-eye area combined with live weight and the various measures of the cannons. These are listed in Table 21. The highest multiple correlations were found to exist with live animal weight and the width or circumference measurement of the hind or fore cannons. These were associated with 25 to 33 percent of the variation in rib-eye area. All remaining multiple correlations obtained accounted for 11 to 24 percent of the variation in rib-eye area with the various cannon bone measurements and animal live weight.

Breaking Moments

Correlation coefficients were calculated between the breaking moments obtained for fore and hind cannon bones and the various measures of the cannon bones and hot and cold shear values. These are shown in Table 22. The correlation coefficients between the breaking moments and the various measures of the fore and hind cannons were all highly significant with the exception of circumference of fore cannon, which was slightly lower than the value needed for significance at the five percent level.

Considerable emphasis is placed upon the character and hardness of bone in deriving packer and federal grades for beef carcasses. This particular index gives an estimate as to the relative age of the animal, and to a lesser degree, some indication of tenderness of meat since some workers (Hiner and Hankins, 1950) have found tenderness to decrease with age. Breaking strengths were obtained for each cannon as a possible index of meat tenderness. Correlation coefficients between the hot and cold shear values obtained by use of the Warner-Bratzler shear and breaking moments are listed in Table 22. Hot or cold shear values of either the *Longissimus dorsi* or *Semitendinosis* muscles correlated with the breaking moments of fore or hind cannons were not significant. The highest variation accounted for between these two items was three percent. Therefore, the breaking moments did not seem to show any association with tenderness. Results showed that the breaking moments were directly and highly related to the size, shape and weight of the cannon bones, but there was little if any relationship between breaking moments and tenderness.

TABLE 22 Simple Correlation Coefficients Between Breaking Moments of Fore and Hind Cannons and Shear Values[a]

X	Breaking Moments of Fore Cannon	Breaking Moments of Hind Cannon
Cannon Measurements		
Weight	.563	.600
Length	.473	.481
Width	.511	.460
Thickness	.634	.537
Circumference	.332	.539
Warner-Bratzler Shear Values		
Hot - *Longissimus dorsi*	-.030	-.145
Hot - *Semitendinosis*	.183	.041
Cold - *Longissimus dorsi*	.117	-.124
Cold - *Semitendinosis*	.029	.092

[a] .349 Required for significance at P .05.
.449 Required for significance at P .01.

X-RAYS

Considerable emphasis is being placed on the amount of muscling in the beef carcass today. Therefore, a reliable objective measure of the amount of muscling in the live animal would be an extremely valuable tool in the selection of breeding stock. This part of the investigation was devoted to determining the relationship existing between linear and area measurements of the lumbar vertebrae and eye muscle size. If such a relationship exists, it could be measured directly on the live animals by the use of radiography, and in turn, this information could be used in selection of cattle for breeding purposes.

For some unknown reason, difficulty was encountered in obtaining clear distinct X-rays of the lateral view the second year. Therefore, in most cases only 24 animals are represented in the data included under measurements of the vertical processes, while the measurement of the height of anterior articular processes includes all animals.

The correlations between the various measurements taken from the X-rays with rib-eye size are given in Table 23. These correlations show that little, if any, relationship existed between the measurements of lumbar vertebrae and rib-eye muscle area. The width of vertebrae and width of vertical processes showed the greatest relationship having correlations of .473 and .449, respectively. However, the association accounted for only 22 and 20 percent of the variation existing between rib-eye size and width

TABLE 23 Simple and Multiple Correlation Coefficients of Ribeye Area With Live Weight and Various Average Lumbar Vertebrae Measurements. Also Standard Partial Regression Coefficients With Live Weight Constant

X	r ribeye Area with	r Live Weight with	b1[a]	R Ribeye Area with Live Weight and
Dorsal View				
Length of Transverse processes	-.065	.438*	-.286	.459*
Width of Transverse processes	-.323	.255	-.449	.577**
Area of Transverse processes	-.028	.164	-.094	.391
Vertebrae Length	.000	.469**	-.228	.430
Vertebrae Width	.473**	.102	.439	.579**
Lateral View				
Length of Vertical processes	.224	.234	.143	.405
Width of Vertical processes	.449*	.043	-.466	.601*
Length of Anterior Articular processes	-.239	.398*	-.463	.570**
Length of Transverse Processes				
Length of Vertical processes	.103	.345	-.032	.381
Live Weight	.380	---	---	---

a b1 = standard partial regression of ribeye area on X with weight held constant.
*Denotes significance at P .05.
**Denotes significance at P .01.

of vertebrae and width of vertical process, respectively. Width of vertebrae and the width of the vertical processes were directly related to size of eye.

Inasmuch as size of eye muscle showed little relationship to the dimensions of the lumbar vertebrae, the question arose as to the effect of live animal weight. Correlation coefficients between lumbar vertebral measurements and live weight are listed in Table 23. The relationships were found to be of about the same magnitude or slightly higher than they were with area of rib-eye. The correlations between length of the transverse process, vertebrae length and height of the anterior articular processes with live animal weight were the highest, all of which were significant and positively associated with live animal weight. Each of these accounted for approximately 20 percent of the variation between live weight and these three measurements of the vertebrae. They indicated that as a steer increases in weight, there is also a tendency for the length of the vertebrae and length of transverse processes to increase.

Standard partial regression equations were calculated in order to remove the effect of weight. This would tend to eliminate any effect which live weight might have on the relationship of rib-eye size to the various measures of the lumbar vertebrae. With live weight constant, the width of the body of the lumbar vertebrae, the width of the verticle processes, the width of transverse processes and the height of anterior articular processes were all equally good in estimating rib-eye area, accounting for 18 to 21 percent of the variation in rib-eye area. These standard partial regression equations showed an inverse relationship to rib-eye area with the exception of width of lumbar vertebrae. In other words, the larger vertebrae measurements tended to be associated with the smaller rib-eye areas.

Multiple correlations of rib-eye size with live weight and the various lumbar measurements are also listed in Table 23. The best combinations for predicting rib-eye size were obtained by combining live weight with width of transverse processes, vertebrae width, width of vertical processes and height of anterior articular processes. These various relationships accounted for 32 to 36 percent of the variation in size of rib-eye.

Since the various measurements taken from the X-rays were not highly related to rib-eye size, the relationship of these various measurements to several indexes of bone were determined. Therefore, correlation coefficients between the various measurements taken of the dorsal view of the double shortloin were obtained between the combined weight of the fore and hind cannons and weight and percent bone in the 9-10-11 rib section. The correlation coefficients are presented in Table 24.

Pálsson (1939, 1940) found the fore cannons to be the best index of the weight of bone in the carcass. In view of this, correlations were calculated between weight of cannons and the various linear measurements taken from X-rays of the lumbar vertebrae. The correlation coefficients were all highly significant

TABLE 24 Simple Correlation Coefficients Between Various Measurements of the Transverse Processes of the Lumbar Vertebrae with Cannon Bone Weight and Weight of Bone and Percent Bone in 9-10-11 Rib Section[a]

X	Weight of Cannon Bones with	Weight of Bone in 9-10-11 Rib Section with	Percent Bone in 9-10-11 Rib Section with
Length of transverse processes	.808	.337	.249
Width of transverse processes	.658	.372	.434
Area of transverse processes	.665	.268	.126
Vertebrae length	.535	.345	.321
Vertebrae width	.044	.096	.068

[a] .349 Required for significance at P .05.
.449 Required for significance at P .01.

between the various measurements of the transverse processes and weight of cannon bones, except width of vertebrae which was associated with less than two percent of the variation. The length of the transverse processes, on the other hand, accounted for 65 percent of the variation in cannon bone weights. Therefore, it appears that the relationship between the various measurements of the lumbar vertebrae was more highly associated with total weight of the cannons than with area of rib-eye.

Table 24 also gives the correlation coefficients existing between weight of bone and also percent of bone in 9-10-11 rib section with the various measurements of the dorsal view of the lumbar vertebrae. These correlations were of about the same magnitude as area of rib-eye with the same measurements.

Thus, it appears that the measurements taken of the lumbar vertebrae were much more closely related to the weight of the cannon bones than to the weight of bone or to the percent of bone found in the 9-10-11 rib section.

SPECIFIC GRAVITY

Specific gravity and percent water of the Longissimus dorsi muscle were inversely related to grade (Table 25). Conversely, percent fat increased as grade increased. Percent protein showed no definite pattern, as the mean values for all groups were almost equal. The range for specific gravity, irrespective of grade, was from 1.051 to 1.071 or a range of only two hundredths of a unit. This indicates the necessity of minimizing the variance due to ex-

TABLE 25 Mean and Range for Various Measures By Grades

	Prime		Choice		Good	
	Mean	Range	Mean	Range	Mean	Range
Specific gravity	1.059	1.051--1.065	1.064	1.057--1.069	1.065	1.060--1.071
Percent fat	8.59	6.67--11.21	5.62	3.49-- 7.84	4.25	1.90 --7.18
Percent water	69.65	67.57--71.13	72.40	70.21--74.14	73.57	71.14--75.05
Percent protein	21.49	19.85--22.37	21.18	20.31--21.92	21.59	20.87--22.38
51 steers						

perimental methods and procedures and the need of using a balance which will weigh to the required sensitivity. When grouped according to grade, there was a tendency for specific gravity ranges to overlap somewhat from one grade to another. This would be expected since factors other than marbling are considered in determining a grade for a particular carcass. However, the 31 ribs from the University cattle were graded in a ribbed condition, where marbling could be visually appraised. Since these cattle were uniform in conformation and age, it is probable that marbling was the major factor in determination of grade.

Percent fat from the 51 ribs ranged from 1.90 to 11.21 percent, or a difference of 9.31 percent. The range was from 67.57 to 75.05 for percent water, and from 19.85 to 22.38 for percent protein. Thus, the maximum variation was 7.48 percent for water and 2.53 for percent protein. Observation of Table 25 shows overlapping of these measures between grades as was shown with specific gravity, but in each of these three items the degree of overlapping was more pronounced between the Choice and Good grades than between the Prime and Choice grades.

The correlation coefficients for specific gravity with percent fat, water, protein and grade to the nearest one-third are listed in Table 26. All correlations were highly significant. The highest relationship existed between specific gravity and percent fat with a correlation coefficient of -.81. The correlation between percent water and specific gravity was .74. These

TABLE 26 Correlation Coefficients of Specific Gravity with Chemical Analysis and Grade

	Specific Gravity
Percent Fat	-.81
Percent Water	.74
Percent Protein	.68
Grade to 1/3	-.68
31 steers	

correlations indicate the validity of specific gravity as an objective measure of total marbling. Percent protein and grade were related to specific gravity with correlations of .68 and -.68, respectively. Thus, the variation in specific gravity was associated with 46 percent of the variation in either percent protein or grade, 50 percent with percentage water and 66 percent with percentage fat. As expected, both percent fat and grade (to the nearest one-third) showed an inverse relationship to specific gravity.

Data from all 51 ribs were used to plot regression lines. Figure 17 shows the relationship between specific gravity and percent fat. The regression equation was $Y = 445.24 - 413.30\ X$, with a standard error of the estimate of 1.20 percent. Each .001 increase in specific gravity resulted in a .41 decrease in fat.

Figure 18 presents the relationship between specific gravity and percent water. The estimate of the regression equation was $Y = (-273.66) + 325.28\ X$, while the standard error of the estimate was 1.21 percent. For every .001 change in specific gravity, there was a .33 percent change in water content.

The relationship between specific gravity and percent protein is depicted in Figure 19. The regression equation was $Y = (-65.38) + 81.61\ X$, and the standard error of the estimate was .46 percent protein. For every .001 change in specific gravity, there was a change of .082 percent in protein.

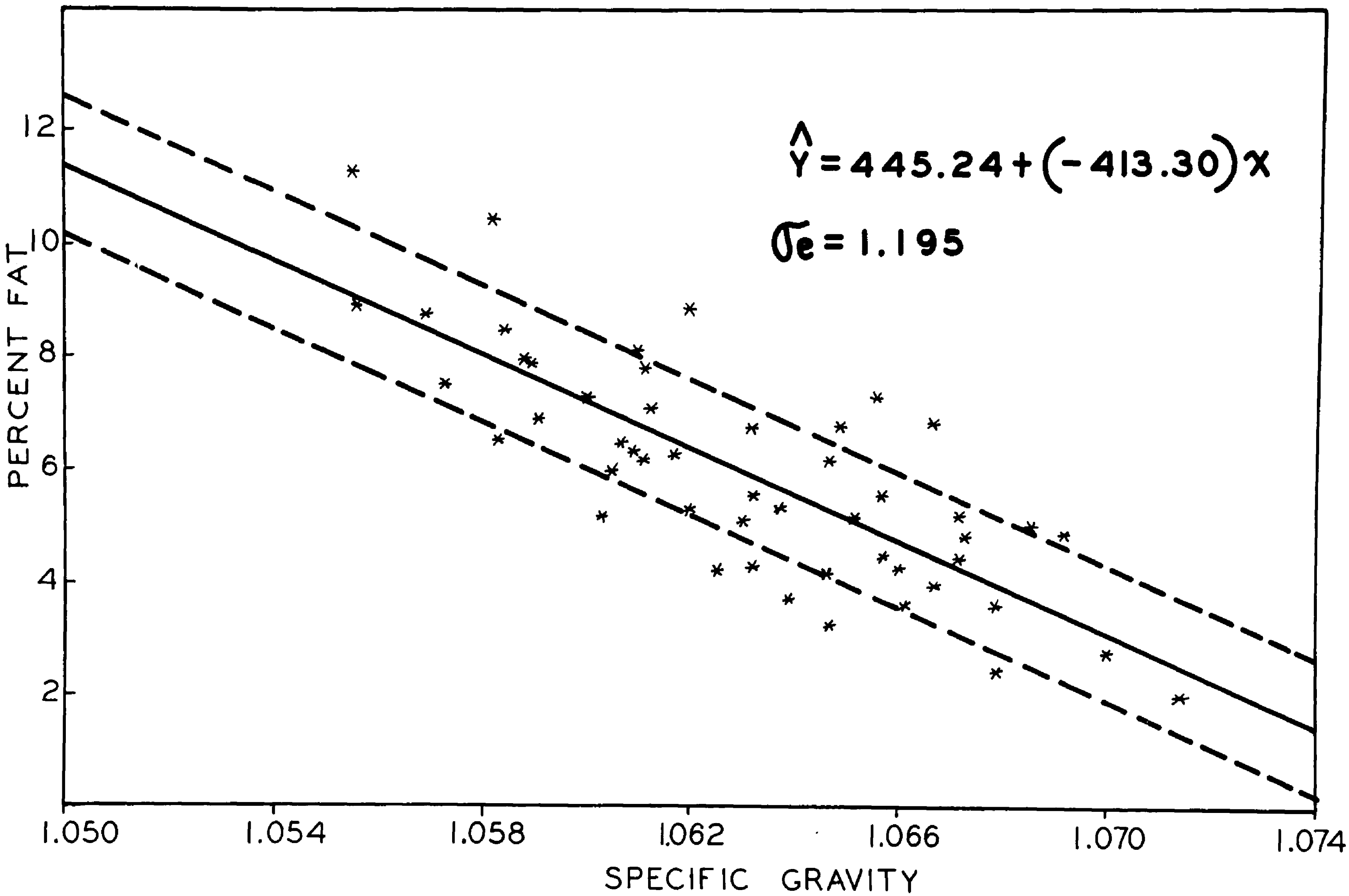
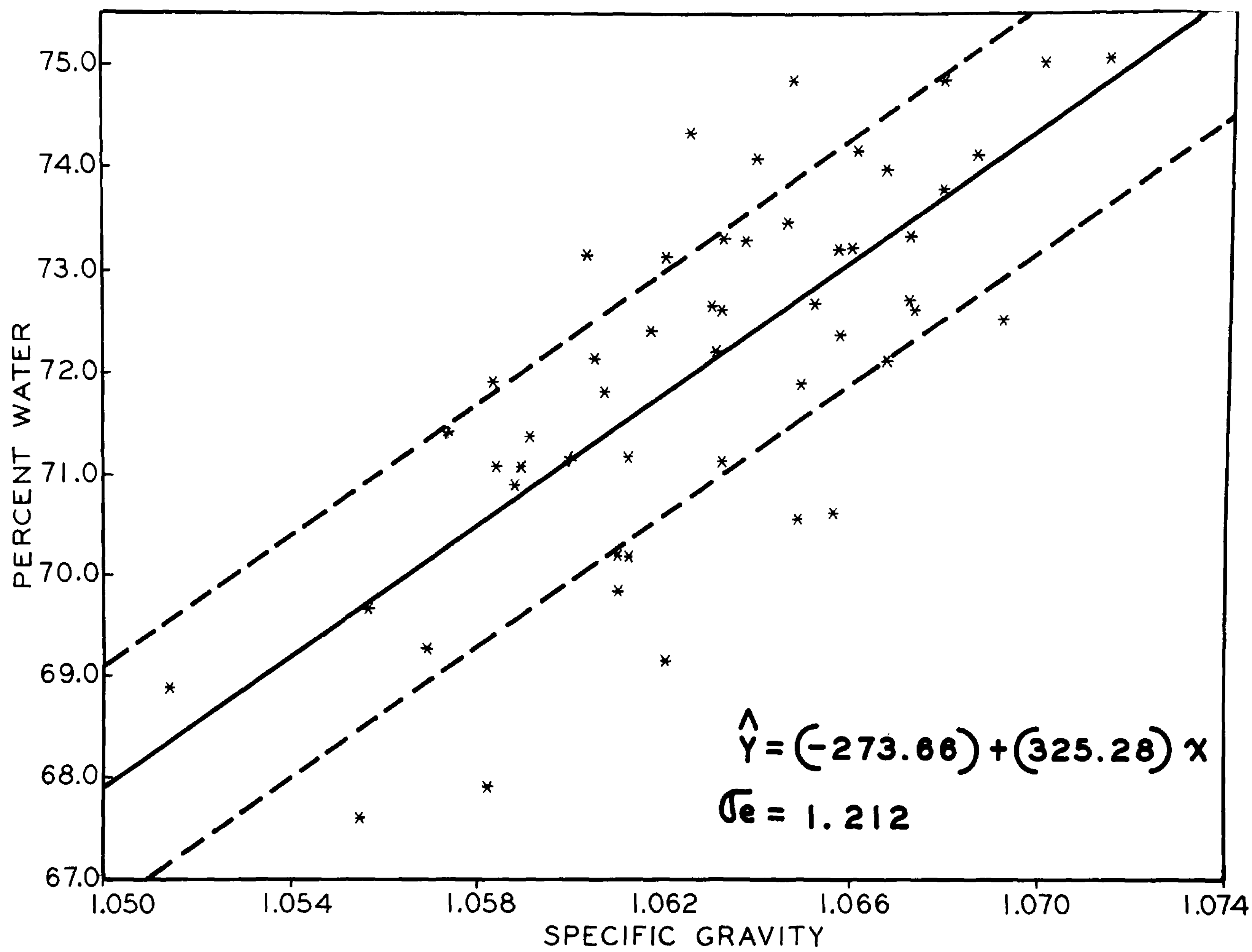

$\hat{Y} = 445.24 + (-413.30)X$
$\sigma_e = 1.195$
PERCENT FAT
12
10
8
6
4
2
1.050
1.054
1.058
1.062
1.066
1.070
1.074
SPECIFIC GRAVITY

FIGURE 17



75.0
74.0
73.0
72.0
71.0
70.0
69.0
68.0
67.0
PERCENT WATER
1.050
1.054
1.058
1.062
1.066
1.070
1.074
SPECIFIC GRAVITY
$\hat{Y} = (-273.86) + (325.28)\,X$
$\sigma_e = 1.212$

FIGURE 18

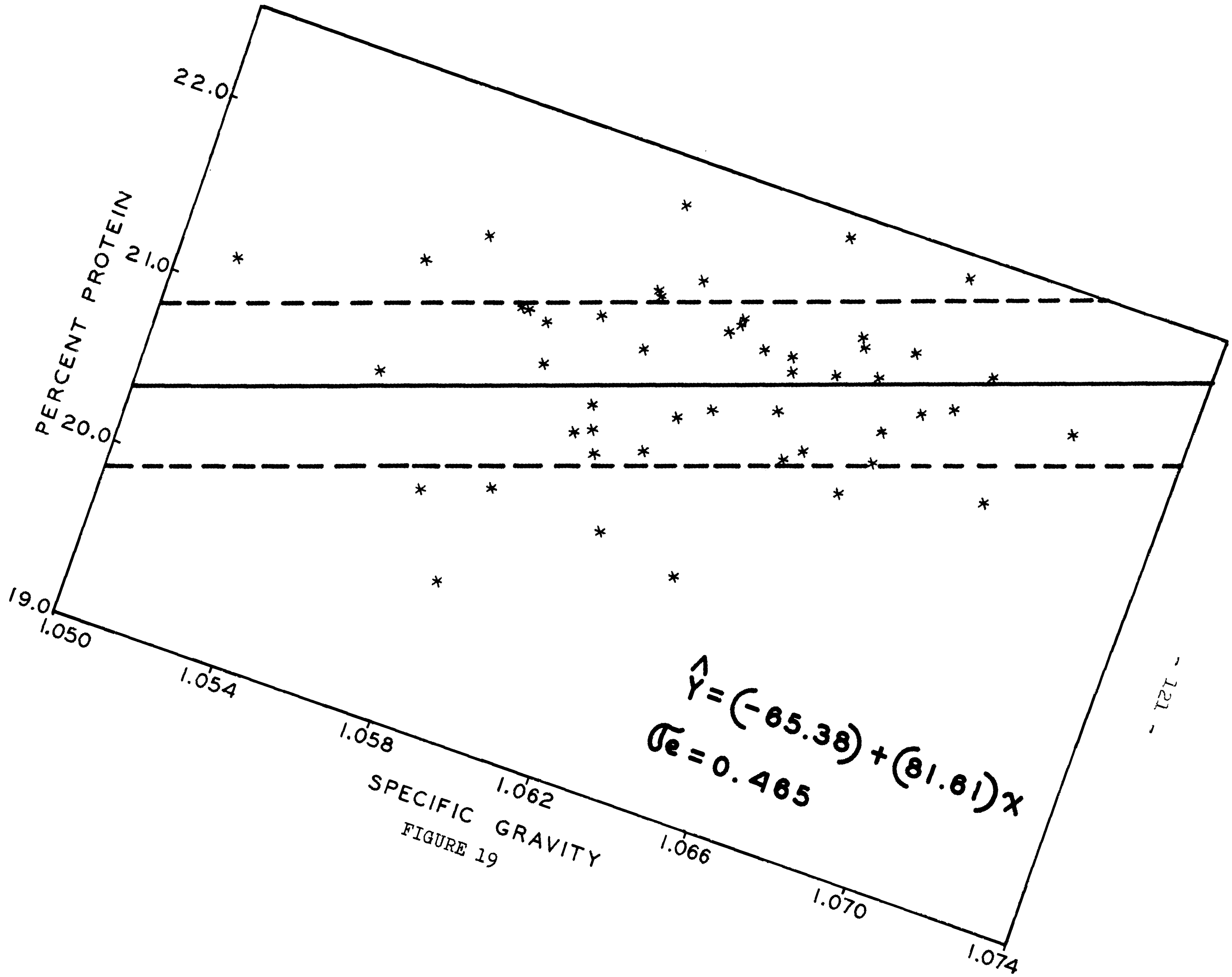

22.0
21.0
20.0
19.0
PERCENT PROTEIN
1.050
1.054
1.058
1.062
1.066
1.070
1.074
SPECIFIC GRAVITY
$\hat{Y} = (-65.38) + (81.61)X$
$\sigma_e = 0.465$

FIGURE 19

BLOOD FAT

Blood fat levels have recently been investigated as a possible means of determining the body composition of the live animal. Allen (1938) observed that a close relationship existed between dietary fat and plasma fat, while Morrow *et al*. (1956) found a significant relationship between eye muscle size and blood fat level in hogs.

The values obtained for blood fat were correlated with several measures of the degree of finish and with the amount of muscling or lean. The correlation coefficients are listed in Table 27. None of the values was high enough to show significance. However, of all the different items correlated with blood fat, the area of rib-eye, with a correlation coefficient of .252, was the highest and showed some indication of a relationship between blood fat and area of rib-eye. Morrow *et al*. (1956) have reported that numerous factors may affect the level of blood fat. The low correlation obtained in this study may have been due in part to failure to standardize the causes of variation in fat levels.

TABLE 27 Simple Correlation Coefficients of Blood Fat with Various Measures of Finish and Muscling[a]

Measure	Correlation
Grade to the nearest one third	.099
Estimated marbling	.081
Thickness of fat over 12th rib	.100
Specific gravity	.078
Percent fat of ribeye	-.078
Eye muscle size	.252
Percent primal cuts	.128
Percent lean of 9-10-11 rib cut	.001

a .349 Required for significance at P .05.
.449 Required for significance at P .01.

TENDERNESS

Longissimus dorsi Muscle

Analysis of variance was calculated for the various measures of tenderness using the *Longissimus dorsi* muscle. The "F" values are listed in Table 28. The correlations obtained for the same muscle, which were found to exist between the several measures of tenderness and specific gravity, estimated marbling, grade to the nearest one-third, percent cooking loss, breaking moments of cannons, percent fat, percent water and percent protein are listed in Table 29.

Shear Values - A highly significant difference was found to exist in tenderness between steers as measured by hot and cold shear values. In addition, the difference in the hot shear values within the same steak were highly significant.

A correlation coefficient (.74) between hot and cold shears was highly significant. This correlation may have been different had the cores for the first year's steaks been more uniform. Mechanical difficulty occurred when extracting cores from the cold steaks the first year, resulting in tearing and fracturing of the cores. This was overcome the second year by the use of corn oil which was placed on the borer before each core was taken. Correlation coefficients of hot shear and cold shear values with the measures of intramuscular fat or marbling, which included specific gravity, estimated marbling, grade to the nearest one-third, percent cooking loss and percent fat were not significant. Signifi-

TABLE 28 Analysis of Variance for Various Measures of Tenderness Using *Longissimus dorsi* Muscle

Method	Source	DF	Sum of Squares	Mean Square	"F"
Hot Shear	Steers	29	396.85	13.68	7.16**
	Replications	14	53.87	3.85	2.02**
	Error	203	386.95	1.91	
	Total	246	837.67		
Cold Shear	Steers	29	282.97	9.76	7.39**
	Replications	14	16.55	1.18	0.89
	Error	203	267.00	1.32	
	Total	246	566.52		
Number of Chews	Steers	29	4547.73	156.82	2.84**
	Judges	16	39653.31	247.83	4.49**
	Steers x Judges	231	12758.14	55.23	2.96**
	Error	278	5194.50	18.69	
	Total	554	62153.68		
Extensibility	Steers	29	974.92	33.62	1.13
	Replications	38	171.48	45.13	1.52*
	Error	551	1633.27	29.64	
	Total	618	2779.67		

*Denotes Significance at P .05.
**Denotes Significance at P .01.

TABLE 29 Correlation Coefficients Between Measures of Tenderness of <u>Longissimus dorsi</u> Muscle, Chemical Analysis, Subjective Quality Evaluation, Cooking Losses & Breaking Moments of Cannon Bones

Measure	Hot Shear	Cold Shear	Number of Chews	Muscle Fiber Extensibility
Hot Shear	---	.74	.58	.41
Cold Shear	---	---	.65	.30
Specific Gravity	.13	.21	.17	.44
Estimated Marbling	-.24	-.27	-.02	-.39
Grade 1/3	-.16	-.28	-.07	-.42
% Cooking Loss	.20	-.07	.01	.30
Breaking Moment (Metacarpals)	-.03	.12	-.23	.27
Breaking Moment (Metatarsals)	-.15	-.12	-.30	.23
% Fat	.26	.32	-.17	-.43
% Water	.16	.24	.09	.45
% Protein	.46	.45	.28	.43

.349 Required for Significance at P .05.
.449 Required for Significance at P .01.

cance was approached in several cases but the predictive value was quite low. Thus, intramuscular fat or marbling was not found to be highly associated with tenderness as determined by mechanical shear. Percent water was also not accociated with mechanical shear. This would bexpected, since percent fat shows little relationship to tenderness, but percent fat and water are inversely related. Correlation coefficients of .46 and .45 were obtained between percent protein and hot shear and cold shear values, respectively. These were sufficiently high to be significant at the one percent level.

A great deal of emphasis placed on bone hardness in the grading and evaluation of carcasses under commercial conditions, since less tender meat is believed to be associated with hard, flinty bone. The breaking moments were in turn correlated with several measures of tenderness in the carcass. Correlation coefficients between hot and cold shear values and breaking moments of fore and hind cannons were not significant. It is not only possible but probable that breaking strength of bone is not a measure of bone hardness. Although differences in tenderness existed between steers, it is obvious that breaking moment was not related to tenderness. This does not preclude, however, the possibility that tenderness and breaking moment may be related when considering a more variable population.

<u>Chew Count</u> - Table 28 shows that significant differences (P =.01) existed between steers, judges and steers X judges when analysis of variance was calculated for the number of chews

required to masticate a standard sized cooked meat sample by panel members. A larger "F" value existed between judges than between steers on the chew panel test for tenderness. This would be expected, since each judge was instructed to take each sample to the same point, but no attempt was made to standardize between judges. It was also shown that significant difference existed between the scores given the two samples from the same steak by the same judge. In some cases this may have been due to extensive connective tissue existing in one of the samples while the other sample from the same steak was relatively free from this constituent.

Correlations of .58 and .65 were obtained between the chew count method measuring tenderness and hot and cold shear values, respectively. These were significant at the one percent level, and in the case of the cold shear, it approached the magnitude of the correlation which was obtained between hot and cold shear values. The relationship of number of chews to the other items listed in Table 29 were not significant. Thus, the same relationships were evident as for hot and cold shear values, except that percent protein was not significantly related.

<u>Muscle Fiber Extensibility</u> - No significant difference was found to exist between tenderness of steers and muscle fiber extensibility. However, extensibility values within steers were significantly different at the five percent level (Table 28). This would indicate a greater difference occured within a given

steak from the same steer than between steaks coming from different steers.

Correlation coefficients for muscle fiber extensibility with other measures of tenderness, specific gravity, estimated marbling, grade to the nearest one-third, percent cooking loss, breaking moments of cannon bones, and percent water, fat and protein are listed in Table 29. Significant positive correlations existed between extensibility and hot shear, specific gravity, percent water and percent protein; while significant negative correlations existed with estimated marbling, grade to the nearest one-third and percent fat. Thus, it appears from the data that muscle fiber extensibility is influenced more by the amount of intramuscular fat than was hot or cold shear values or chew count. Conversely, muscle fiber extensibility was found to have significant positive relationships to percent protein and moisture. Similarly, hot and cold shear values showed about the same relationships with these two items.

The relationship between muscle fiber extensibility and percent cooking loss approached significance, while the correlations between fiber extensibility and breaking strength of bone were not significant.

Semitendinosis Muscle

Analysis of variance was obtained for several methods of determining meat tenderness using the *Semitendinosis* muscle. The "F" values are listed in Table 30.

TABLE 30 Analysis of Variance for Various Measures of Tenderness Using the Semitendinosis Muscle

Method	Source	DF	Sum of Squares	Mean Square	"F"
Hot Shear	Steers	29	104.81	3.61	3.09**
	Replications	12	9.38	0.78	0.67
	Error	174	204.05	1.17	
	Total	215	318.24		
Cold Shear	Steers	29	140.53	4.85	3.59**
	Replications	12	34.36	2.86	2.12**
	Error	174	235.74	1.35	
	Total	215	410.63		
Muscle Fiber Extensivility	Steers	28	1077.61	38.49	11.77**
	Replications	38	94.69	2.49	0.76
	Error	532	1738.16	3.27	
	Total	598	2910.46		

**Denotes significance at P .01.

Shear Values - The "F" value between steers, using the hot and cold shear method for determining tenderness of the _Semitendinosis_ was highly significant as was true for the _Longissimus dorsi_ muscle. Significance was also obtained between shear values within steaks for the cold shear values.

The correlation between hot and cold shear values was only .35 (Table 31). All other correlations obtained, except the relationship between cold shear and percent cooking loss, were not significant. The low correlation between hot and cold shear can probably be explained in part by the fact that the hot shear required the greatest number of pounds to shear a standard one-half inch core the first year, while the second year the cold shear required the greater pressure to shear the core. This particular trend might have been different had a lubricant been used on the core borer the first year.

Muscle Fiber Extensibility - A highly significant difference in muscle fiber extensibility existed between the tenderness of steaks from different steers (Table 30). However, no significant difference was found in extensibility values within a steak when using the _Semitendinosis_ muscle. This may be explained in part by the difference in the amount of marbling existing between the _Longissimus dorsi_ muscle and the _Semitendinosis_ muscle, since fiber extensibility seemed to be quite markedly related to percent fat in the case of the _Longissimus dorsi_ muscle. Thus, in the _Semitendinosis_ muscle, which appeared to contain less total marbl-

TABLE 31 Correlation Coefficients With Various Measures of Tenderness for *Semitendinosis* Muscle, Grade, Percent Cooking Loss and Breaking Moments of the Cannon Bones

Measure	Hot Shear	Cold Shear	Muscle Fiber Extensivility
Hot Shear	---	.35	.14
Cold Shear	---	---	.14
Grade to 1/3	-.11	-.13	.11
% Cooking Loss	.17	.35	.12
Breaking Moment Metacarpals	.18	.03	-.07
Breaking Moment Metatarsals	.04	.09	-.08

.355 Required for significance at P .05.

ing, more consistent readings within steaks were obtained.

No significant relationship existed between muscle fiber extensibility and either hot or cold shear or of the other items such as grade to the nearest one-third, percent cooking loss and breaking moments of the fore and hind cannons for the *Semitendinosis* muscle.

SUMMARY AND CONCLUSIONS

Analytical data on 31 steers were treated statistically in order to correlate objective and subjective live animal measurements with carcass attributes, and to evaluate and develop certain objective measures of marbling and tenderness. In addition to the steers, 20 wholesale beef ribs were used to increase the scope of the specific gravity study.

High relationships existed between the two methods of subjective live animal evaluation for most of the traits and characters studied, and it appeared that length of leg did not affect the scores. The correlations between the subjective live animal scores and comparable live animal measurements were in most cases found to be quite low. However, the relationships between subjective live animal estimates and actual values for such items as dressing percentage, fat thickness over 12th rib, area of rib-eye and grade were quite high. Some of the subjective live animal evaluation scores, namely, width and thickness, were quite highly related to various carcass measurements. Most of the traits studied subjectively were found to be highly related to the ultimate carcass grade.

Repeatability estimates for the various live animal measurements were .703 to .995 with the exception of the spring of ribs, the width at pins and the length from 13th rib to hooks measurements. Various objective measurements showed a high relationship to the carcass measurements and with the exception of width at crops, the relationships were higher between the carcass measurements and objective measurements than they were between carcass measurements and the subjective live animal scores. Live weights taken of the fore and hind halves of the animal were found to have correlation coefficients of .904 and .865 with the weights of the fore and hind quarter of the carcass, respectively.

Circumference of hind and fore flanks and circumference of middle were most highly related to rib-eye area. Width of rump, circumference of hind leg above the hock and live weight were also significantly related to rib-eye area. The correlation coefficients were all positive with the exception of circumference of hind leg above the hock, which showed an inverse relationship to rib-eye area. Circumference of fore and hind flank and middle, width of round, total live weight, hind and fore weight of the live animal and width between the 13th rib and hooks were associated with 22 to 61 percent of the variation existing in carcass grade. Live animal measurements showed high relationships to such wholesale cuts as chuck, rib, shortloin and sirloin plus round.

The carcass measurements used, were all highly repeatable. Rib-eye area was found to be highly related to such carcass measurements as width of shoulder, width of rump and width of round. However, placing the wholesale cuts on a percentage basis resulted in an inverse relationship to rib-eye area. High positive relationships were found to exist between live weight and the weight of the wholesale cut.

Weight and various linear measurements of the fore and hind cannons were found to have a high relationship to body weight, to weights of primal cuts and several linear measurements which were taken of the lumbar vertebrae. Rib-eye area was found to be positively related to the weight and thickness of fore cannon. When the effects of weight were eliminated, width and circumference measurements of fore and hind cannons accounted for 15 to 25 percent of the area of rib-eye. Little if any relationship existed between these various measurements and percent calculated lean in the carcass. Likewise, the association between primal cuts and the various cannon bone measurements were greatly reduced when primal cuts were expressed on a percentile basis. Thus, these measurements taken of the fore and hind cannons seemed to be a function of weight.

The breaking moments of the fore and hind cannons were found to be more directly related to size, shape and weight of the cannon bones than to tenderness of meat.

Radiographic measurements of the dorsal and lateral view of the lumbar vertebrae disclosed that the width of the body of the lumbar vertebrae and width of the vertical processes were the best single estimate of rib-eye area accounting for 22 and 20 percent of the variation in rib-eye area, respectively. With the effects of live weight eliminated, width of the transverse processes and the height of the anterior articular processes were equally as good as the two previous measurements. Multilinear correlations of live weight and each of these four measurements of the lumbar vertebrae with rib-eye area accounted for 32 to 36 percent of the variation existing in rib-eye area.

Specific gravity of the Longissimus dorsi muscle of the 9-10-11 rib section was determined in order to test the usefulness of specific gravity as an objective measure of marbling. Correlation coefficients between specific gravity and percent fat, water, protein and grade to the nearest one-third were -.81, .74, .68 and -.68, respectively. All were highly significant. The regression of percent fat in the rib-eye on specific gravity was found to be - 413.30, with a standard error of the estimate of 1.20 percent fat. The high relationship that existed between specific gravity and fat indicates the usefulness of specific gravity as an objective measure of marbling.

No definite relationship was evident between blood fat levels and the various measures of degree of finish nor the amount of muscling.

Various methods of measuring tenderness in meat were investigated and compared. Using the Longissimus dorsi muscle, the following correlations were obtained between the various measures of tenderness: between hot and cold shear values (r = .74), hot or cold shear values with number of chews (r = .58 and .65, respectively) and hot or cold shear values with muscle fiber extensibility (r = .41 and .30, respectively). Muscle fiber extensibility seemed to be more highly influenced by the amount of intramuscular fat present than the other three measures of tenderness studied.

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APPENDIX I A

LIVE ANIMAL EVALUATION - ADJUSTED

Steer No.	Round Depth	Round Plumpness	Length of Back Rump	Length of Back Loin	Length of Back Rib	Body Depth R.Flank	Body Depth L.Flank	Length of Neck	Fullness of Brisket	Type	Grade	Dressing Percent	Thickness of Fat 12th Rib	Eye Muscle Size Wt.
1956														
1	13.4	12.8	14.2	12.6	13.8	14.0	15.40	13.00	13.0	20.8	20.0	60.60	.58	10.14
2	12.8	11.0	14.8	15.0	15.4	12.0	14.20	11.00	10.6	19.8	18.0	58.56	.32	8.70
3	11.6	13.0	13.4	16.4	14.2	12.4	14.60	14.40	13.4	19.2	19.8	60.20	.50	10.02
4	12.2	12.2	14.8	12.2	13.2	12.8	15.00	12.60	14.0	20.6	19.2	60.28	.48	9.36
5	12.2	10.8	12.8	13.4	12.6	10.6	12.60	11.00	11.2	19.2	17.6	58.44	.30	8.30
6	11.2	10.8	12.8	16.6	14.4	11.0	13.20	11.00	13.2	18.4	18.4	59.30	.40	9.16
7	13.6	13.0	13.9	13.0	12.6	14.4	14.80	13.00	12.5	20.8	19.4	60.14	.55	9.56
8	9.8	8.8	11.4	13.9	14.4	9.8	10.80	11.40	9.4	17.2	16.0	57.00	.20	7.90
9	12.2	15.4	14.0	14.8	13.0	15.0	16.20	14.00	13.6	21.2	20.0	60.76	.56	9.86
10	13.4	15.2	16.4	14.4	12.8	15.0	17.20	16.00	15.0	21.8	20.4	60.60	.58	10.12
11	14.2	16.8	15.8	14.4	12.6	16.4	17.60	16.20	14.8	22.8	20.6	61.30	.62	9.82
12	14.6	14.8	16.4	16.6	13.2	15.2	16.40	13.60	14.2	21.2	19.4	60.40	.54	9.92
13	11.6	10.6	14.4	12.8	13.8	13.4	14.80	13.40	13.0	20.2	18.4	61.40	.38	8.96
14	14.0	14.0	16.4	13.2	12.4	14.6	15.60	12.00	14.2	21.2	19.6	60.30	.52	9.92
15	14.6	14.4	15.4	13.2	14.2	15.2	17.60	16.20	15.4	22.4	21.0	61.26	.52	10.22
16	14.2	12.8	15.8	15.6	14.0	13.9	15.00	12.40	12.9	19.8	19.0	59.70	.48	9.58
Mean	12.85	12.9	14.54	14.26	13.54	13.48	15.06	13.20	13.14	20.41	19.18	60.02	.47	9.47
1957														
1	15.43	17.57	15.57	17.29	17.14	15.57	17.57	17.86	16.29	20.00	20.00	62.50	.63	9.63
2	16.14	15.57	18.29	17.71	18.00	17.57	17.71	17.57	17.00	20.43	20.57	62.21	.74	10.13
3	14.14	12.43	15.14	16.43	15.71	14.43	14.14	13.57	18.29	17.29	18.00	58.07	.39	8.71
4	16.29	15.43	16.86	17.00	17.14	17.00	17.71	16.14	17.14	19.43	20.71	62.06	.71	9.84
5	16.14	16.86	14.86	16.00	17.29	15.86	17.00	18.00	15.57	19.71	19.14	61.16	.56	9.36
6	16.43	17.86	18.14	17.00	16.86	16.43	18.43	18.43	17.14	20.71	20.86	62.76	.80	10.20
7	15.14	16.43	16.14	15.29	15.86	15.71	16.71	17.29	15.57	19.57	19.43	60.47	.53	9.29
8	15.29	16.00	15.83	17.29	16.71	16.00	16.71	17.29	16.14	19.43	19.43	60.43	.53	9.26
9	16.86	17.29	17.00	16.57	17.14	16.57	18.29	18.00	17.43	20.86	20.86	62.14	.73	9.96
10	15.86	16.14	16.86	16.57	17.14	16.79	17.00	17.00	16.57	19.14	19.29	60.69	.56	9.41
12	16.43	18.29	16.00	15.86	16.86	17.57	18.43	19.57	16.29	21.29	21.00	62.76	.69	10.01
13	16.43	16.43	16.86	16.71	18.00	17.00	18.29	16.57	15.57	20.29	20.14	60.94	.61	9.64
14	14.57	14.57	15.14	16.29	16.57	14.86	15.14	15.29	14.43	19.14	18.43	59.01	.39	8.69
15	14.71	15.00	15.43	16.71	16.71	15.00	15.29	16.00	14.43	18.57	18.86	59.96	.53	8.94
16	16.00	16.43	16.00	16.86	17.14	16.57	18.86	18.43	17.00	20.57	20.43	62.49	.67	9.91
Mean	15.72	16.15	16.27	16.64	16.95	16.16	17.15	17.00	15.99	19.76	19.81	61.18	.60	9.53

APPENDIX I B

LIVE ANIMAL EVALUATION - UNADJUSTED

1956

Steer	Round		Length of Back			Body Depth		Length	Fullness	Length of	Length of
No.	Depth	Plumpness	Rump	Loin	Rib	R.Flank	L.Flank	of Neck	of Brisket	Fore Legs	Hind Legs
1	15.0	16.0	16.4	15.4	15.8	13.8	15.4	14.6	15.2	15.0	14.0
2	13.4	14.0	15.8	15.0	15.8	12.8	14.4	12.6	11.6	13.8	13.0
3	13.0	13.0	13.8	17.8	16.4	13.2	15.4	12.0	14.8	14.2	12.4
4	14.4	14.2	15.0	12.6	14.0	14.6	15.2	15.4	13.8	14.2	13.8
5	12.4	13.0	13.0	13.8	15.0	13.0	14.0	12.8	11.8	12.4	11.8
6	11.8	11.6	15.2	15.8	16.2	11.2	13.4	12.4	12.4	12.8	10.2
7	14.6	12.0	14.8	15.0	14.0	12.6	13.2	13.2	12.0	11.8	10.4
8	9.6	9.0	11.4	14.0	14.4	10.8	11.2	9.4	9.2	11.4	9.8
9	15.6	15.2	15.4	15.6	13.6	16.0	16.8	16.8	13.8	16.8	16.2
10	13.8	16.2	16.0	13.0	14.6	14.4	16.2	16.2	14.6	15.8	14.8
11	16.0	16.8	18.0	13.6	12.4	15.4	17.0	16.8	17.6	18.2	17.2
12	14.0	13.8	13.8	15.0	16.0	13.6	14.4	14.0	12.4	12.0	10.8
13	13.8	13.0	13.4	13.0	13.4	13.0	14.4	15.2	14.6	15.0	14.2
14	13.2	12.4	16.4	16.4	15.8	12.8	14.0	11.8	12.6	11.6	10.6
15	15.4	15.4	15.8	13.2	12.4	14.0	16.6	16.8	16.0	17.0	16.1
16	12.8	12.8	13.8	16.4	16.8	13.4	13.6	12.2	14.2	12.4	11.4
Mean	13.68	13.65	14.88	14.72	14.79	13.41	14.70	13.89	13.54	14.02	12.94
					1957						
1	17.71	18.86	17.00	17.29	16.86	17.00	18.86	19.14	18.00	20.43	19.86
2	18.43	18.57	18.71	18.00	18.29	18.57	19.14	18.29	18.29	18.43	17.57
3	15.29	14.43	16.29	16.57	16.29	15.29	15.57	15.29	13.71	15.72	15.14
4	17.14	16.86	17.86	17.57	17.86	17.29	18.00	17.00	16.29	18.00	16.71
5	17.29	17.57	15.14	17.14	17.57	17.00	17.71	17.71	16.57	18.14	17.14
6	17.14	18.57	16.71	16.86	17.57	17.71	18.29	17.86	17.43	17.71	17.00
7	18.00	17.43	18.00	17.57	17.43	18.14	18.43	18.43	16.29	18.43	17.86
8	16.43	16.29	16.57	17.43	17.86	16.86	17.71	17.14	15.86	17.71	16.43
9	17.43	17.57	17.86	17.71	18.00	17.29	18.00	17.29	16.71	17.43	16.86
10	17.00	16.86	17.57	18.14	18.00	17.00	17.14	17.29	16.67	17.29	16.29
12	18.14	15.71	16.71	16.86	17.29	18.14	19.14	18.29	17.71	19.29	18.57
13	17.14	16.71	18.00	17.00	17.71	18.48	19.14	17.71	17.14	18.71	17.43
14	15.00	14.57	15.86	16.00	16.71	15.14	15.71	15.71	14.43	17.00	15.57
15	15.14	16.14	16.86	16.57	17.14	15.14	15.71	16.57	14.71	16.57	14.86
16	16.29	16.86	17.57	16.86	17.29	16.29	18.14	18.00	16.29	19.14	18.00
Mean	16.90	16.87	17.11	17.17	17.46	17.02	17.78	17.45	16.41	18.00	17.02

APPENDIX I B (Continued)

1956

Steer No.	Type	Grade	Thickness and Fullness: Round	Loin	Rib	Chuck	Brisket	Cod	Dressing Percent	Thickness of Fat 12th Rib	Eye Muscle Size Wt.
1	20.8	20.2	14.4	16.2	15.2	13.8	15.0	7.0	60.24	.54	10.58
2	20.2	19.0	12.8	12.2	12.4	14.0	11.6	3.0	58.60	.30	8.30
3	20.2	19.4	14.0	15.2	14.0	13.8	14.8	4.0	60.70	.54	9.84
4	21.0	19.0	14.4	14.2	14.0	13.6	12.6	3.0	59.86	.44	9.14
5	20.0	18.2	13.4	13.2	13.4	13.4	11.6	3.6	59.24	.38	8.78
6	18.8	17.6	11.0	11.4	11.6	13.2	11.8	3.2	59.40	.34	9.06
7	19.6	18.8	11.8	13.2	13.6	15.2	12.0	2.6	59.60	.40	9.30
8	18.0	15.6	10.0	10.0	10.4	11.6	9.0	1.6	57.50	.23	7.48
9	21.8	20.0	14.8	15.2	15.8	15.2	14.2	3.0	60.50	.50	9.36
10	21.8	20.0	15.2	14.8	13.8	15.0	14.2	8.8	60.20	.44	10.14
11	22.75	21.5	16.4	16.4	16.6	17.2	17.4	10.4	61.50	.60	10.02
12	19.8	18.4	12.2	13.2	13.6	15.0	12.4	4.2	59.90	.44	9.12
13	21.2	20.0	12.8	14.2	14.2	14.0	13.8	3.8	60.30	.42	8.70
14	20.0	18.4	13.6	13.0	13.6	14.6	12.2	2.4	59.30	.40	9.72
15	22.6	20.8	14.2	15.0	15.2	17.8	16.4	13.4	60.90	.58	10.28
16	19.6	19.0	12.0	13.2	13.0	14.0	13.8	3.8	60.40	.46	9.58
Mean	20.51	19.06	13.31	13.79	13.78	14.46	13.30	4.86	59.88	.44	9.34

1957

Steer No.	Type	Grade	Round	Loin	Rib	Chuck	Brisket	Cod	Dressing Percent	Thickness of Fat 12th Rib	Eye Muscle Size Wt.
1	22.14	21.29	18.14	17.71	18.00	18.14	18.29	17.43	63.21	.66	9.94
2	21.29	21.00	18.71	18.86	18.43	18.57	18.14	16.29	63.00	.89	10.14
3	18.57	17.71	14.86	15.43	15.57	15.57	13.86	13.14	58.39	.40	8.63
4	19.86	20.14	16.57	17.57	17.43	17.43	16.86	16.29	62.43	.74	9.51
5	20.43	19.86	17.86	17.43	17.14	18.00	16.71	16.00	61.79	.57	9.74
6	20.71	20.71	17.86	18.14	17.29	17.71	17.57	17.14	62.98	.67	9.83
7	21.14	20.00	17.43	17.86	17.43	17.86	16.14	13.83	62.11	.63	9.47
8	19.57	19.29	16.71	17.14	16.86	16.71	15.50	14.86	60.79	.67	9.53
9	21.71	20.71	17.86	18.29	17.86	17.86	17.00	15.57	62.58	.73	9.96
10	19.43	19.57	17.14	17.29	17.57	17.29	16.43	15.00	60.86	.63	9.59
12	21.43	21.29	17.71	17.71	18.14	18.29	17.67	17.71	63.29	.74	9.94
13	21.57	20.71	16.57	17.14	18.14	18.00	16.71	16.43	62.30	.76	9.81
14	19.14	17.50	14.57	14.71	14.86	15.59	14.14	14.29	58.43	.39	9.03
15	19.29	18.43	14.86	14.86	15.14	15.00	15.00	13.86	59.83	.46	8.83
16	21.14	20.00	16.29	16.86	16.43	16.86	16.00	15.71	61.79	.57	9.54
Mean	20.49	19.88	16.88	17.13	17.09	17.26	16.40	15.57	61.58	.63	9.57

APPENDIX I C

LIVE ANIMAL EVALUATION - BODY MEASUREMENTS

Steer No.	Weight: Hind	Weight: Fore	Weight: Total	Width: Neck	Width: Shoulder	Width: Rump	Width: Round	Width: Pins	Width: At 13th Rib	Width: Between 13th Rib & Hooks	Width: At Hooks	Width: At Crops	Width: Between Crops & 13th Rib
1956													
1	417	488	926	18.5	47.0	49.25	48.5	23.75	37.5	33.75	41.75	34.75	35.5
2	350	460	815	18.25	42.25	37.25	44.25	26.5	31.0	28.0	34.25	27.5	35.25
3	408	536	929	20.0	50.25	47.25	48.25	24.5	32.75	32.0	37.75	34.75	36.0
4	340	500	843	19.25	44.75	47.0	46.25	29.25	34.25	31.0	37.5	30.0	34.25
5	388	437	821	21.0	45.0	46.25	48.5	19.0	37.75	37.25	40.25	33.25	38.25
6	394	503	893	20.25	44.75	48.5	48.25	19.0	33.75	32.0	40.75	31.0	31.75
7	378	490	880	18.0	46.75	48.25	46.0	25.5	32.5	31.75	40.75	31.75	32.75
8	300	377	698	17.75	39.5	39.25	43.5	20.75	29.5	30.0	36.0	31.0	35.0
9	420	512	927	21.75	47.5	47.25	46.25	28.25	36.25	32.25	40.75	30.25	33.0
10	378	500	890	26.0	46.0	51.25	51.5	28.75	34.50	33.0	42.25	30.0	34.25
11	366	470	820	19.5	43.75	46.5	47.75	25.75	33.25	31.75	38.75	33.25	33.25
12	370	510	873	16.25	48.5	46.25	46.5	27.50	33.75	31.5	36.0	32.75	32.5
13	332	462	794	17.5	46.25	45.5	46.5	24.5	40.5	35.25	40.75	34.5	41.0
14	426	492	925	17.75	48.5	45.75	47.5	26.75	34.25	31.75	38.5	28.5	30.0
15	363	490	853	19.25	45.75	48.0	48.0	27.5	33.0	35.0	41.75	32.5	33.0
16	402	494	908	19.0	47.75	48.0	49.25	23.0	40.25	37.25	44.5	33.5	34.25
Mean	377.0	482.56	862.19	19.38	45.89	46.34	47.30	25.02	34.67	32.72	39.52	31.83	34.38
1957													
1	364	462	840	19.63	46.00	46.68	47.75	24.13	36.25	35.13	39.13	29.75	34.88
2	469	648	1120	25.25	53.00	51.88	51.00	26.25	42.38	40.38	45.75	37.13	41.63
3	360	480	843	15.00	43.38	45.50	42.25	25.00	35.25	31.38	43.00	32.25	31.75
4	424	570	1001	19.25	46.88	50.38	49.13	27.50	40.50	39.88	46.00	33.38	39.75
5	360	448	813	19.25	46.38	47.25	47.63	24.00	33.75	34.00	39.38	32.38	34.25
6	428	530	955	19.25	47.25	50.88	49.88	24.50	34.13	36.63	43.38	32.25	33.63
7	400	500	902	17.63	46.50	46.25	45.75	24.75	34.25	32.38	41.13	30.63	34.38
8	428	516	933	20.38	44.75	45.88	47.25	28.13	36.38	32.13	42.75	28.38	34.50
9	428	488	935	21.75	49.13	50.00	48.00	27.38	39.38	37.38	42.88	34.63	37.13
10	402	520	925	18.13	45.50	46.38	44.38	25.13	35.75	34.00	42.63	33.13	37.00
12	346	462	823	18.63	45.63	46.13	45.63	25.88	34.88	31.88	42.25	30.88	37.88
13	404	510	911	19.25	47.63	47.88	47.75	25.75	34.25	34.50	44.63	31.25	41.75
14	330	430	750	16.38	43.75	44.00	41.88	25.00	29.75	30.75	42.25	30.00	33.75
15	362	448	808	21.13	44.50	46.50	46.00	25.25	33.00	31.25	42.00	28.00	34.00
16	402	464	865	21.38	43.13	45.00	44.50	24.13	34.50	31.88	40.00	28.88	35.75
Mean	393.80	498.4	894.93	19.42	46.23	47.37	46.58	25.52	35.63	34.24	42.48	31.53	36.14

APPENDIX I C (continued)
LIVE ANIMAL EVALUATION - BODY MEASUREMENTS

Steer No.	Length: 1st Thoracic to Pins	Length: 1st Thoracic to 13th Rib	Length: 13th Rib to Hooks	Length: Rump	Height: Brisket to Crops	Height: At Withers	Height: At Rump
1956							
1	116.5	55.5	17.25	43.75	64.0	111.75	117.0
2	121.5	53.5	18.25	49.75	63.25	106.75	113.25
3	123.75	64.25	14.00	45.5	58.0	112.25	119.25
4	117.25	56.0	14.25	47.0	62.75	110.0	114.25
5	112.5	52.25	17.00	43.25	62.5	109.25	116.5
6	125.25	62.5	16.00	46.75	67.0	115.0	118.75
7	120.75	58.5	17.50	44.75	65.0	110.5	117.5
8	125.0	60.0	23.50	41.5	61.75	104.0	114.0
9	127.25	65.75	16.00	45.5	62.0	108.25	115.25
10	124.0	65.25	13.25	45.5	64.5	113.0	116.25
11	119.0	58.5	19.50	41.0	62.75	106.75	108.5
12	124.0	66.0	12.75	45.25	64.0	110.75	120.5
13	113.75	55.75	13.75	44.25	63.75	109.25	114.25
14	130.0	66.25	17.50	46.25	65.0	111.25	118.5
15	116.5	54.5	19.00	43.0	62.75	107.25	111.75
16	130.0	71.25	12.25	46.5	69.5	110.0	122.5
Mean	121.69	60.36	16.36	44.97	63.66	109.75	116.12
1957							
1	114.75	62.50	16.50	35.75	63.75	105.38	109.5
2	129.75	68.13	16.25	45.38	73.38	117.13	123.50
3	127.00	57.88	19.13	50.00	64.63	111.25	119.50
4	131.00	72.00	15.88	43.13	66.00	115.63	122.00
5	118.25	61.63	12.75	43.88	62.63	104.38	113.50
6	127.50	73.00	9.50	45.00	67.25	112.88	119.13
7	123.88	66.38	15.13	42.38	63.25	109.88	116.25
8	127.75	69.13	14.88	43.75	63.25	113.00	118.38
9	122.38	63.75	15.13	43.50	66.88	111.75	120.50
10	122.50	61.25	21.25	40.00	64.13	111.50	117.38
12	110.63	53.75	17.75	39.13	63.25	105.75	111.13
13	118.63	65.38	16.13	42.13	64.38	108.63	115.13
14	119.63	61.63	17.38	40.63	60.00	107.38	111.13
15	118.63	60.63	15.25	42.75	63.13	110.38	117.13
16	117.88	55.75	19.25	42.88	64.13	112.38	114.88
Mean	122.01	63.52	16.14	42.68	64.67	110.48	116.60

APPENDIX I C (continued)
LIVE ANIMAL EVALUATION - BODY MEASUREMENTS

	Length of Legs							Circumference							
											Fore legs		Hind legs		
Steer No.	Smooth joint to Metacarpal	Smooth joint to floor	Break joint to Metatarsal	Break joint to floor	Twist to floor	Twist to Hocks	Rump to Hocks	Fore Flank	Rear Flank	Belly	Above elbow	Below elbow	Above hocks	Below hocks	Angle of Rib
1956															
1	18.0	31.0	22.5	34.5	67.5	24.0	82.75	183	180	209	45	18.5	63	21	31.5
2	19.0	31.0	22.5	34.0	69.0	25.8	78.75	169	165	192	49	20	60	27	27.0
3	17.5	31.0	23.0	35.0	69.3	23.6	75.75	185	179	201	43	20	83	23	32.0
4	17.5	27.5	22.0	35.0	69.2	26.0	79.25	175	171	195	46	20	76	23	27.5
5	18.0	30.0	22.5	37.0	68.8	28.0	70.5	174	173	199	45	19	73	23	28.5
6	19.0	30.0	22.5	35.0	68.5	26.3	74.0	178	164	198	43.2	21	68	23	28.0
7	19.5	30.5	23.5	30.5	70.0	26.3	82.75	178	170	203	48	19	64	21.5	28.0
8	19.0	31.0	23.0	35.0	69.2	28.4	70.0	160	154	179	43	18	70	21	26.5
9	21.0	32.0	22.0	31.5	66.5	23.6	74.25	178	170	205	44	20	78	22.5	32.5
10	19.0	30.5	21.5	32.0	69.2	26.0	73.5	181	181	217	54	19	77	21	25.5
11	17.5	29.0	20.5	31.5	60.7	25.0	72.0	175	174	206	47	18	67	20	28.0
12	19.5	32.5	23.0	35.5	69.4	25.5	76.5	176	172	200	43	19.5	74	23	27.0
13	19.5	30.5	22.5	33.5	70.0	22.0	75.25	174	170	198	50	19	73	21	32.0
14	19.0	30.5	23.5	36.5	71.3	24.0	78.5	174	168	199	55	21	76	24.5	26.5
15	18.0	32.0	22.0	34.0	68.0	30.0	74.0	179	174	217	39	17	60	19	30.0
16	20.0	31.0	24.0	38.0	72.2	27.2	78.0	181	176	199	47	20	64	22	29.0
Mean	18.81	30.62	22.53	34.28	68.68	25.73	75.98	176.25	171.31	201.06	46.32	19.31	70.38	22.22	28.72
1957															
1	17.4	27.50	21.6	32.6	60.70	28.25	73.00	176.50	170.25	199.25	49.50	18.05	54.25	19.25	28.50
2	18.35	31.5	23.75	36.55	67.70	25.50	79.63	196.25	188.00	220.25	54.50	20.90	72.00	22.95	30.50
3	19.75	29.75	25.25	26.00	70.50	27.00	79.75	170.50	171.00	194.00	49.00	19.00	55.00	20.50	26.50
4	20.5	32.00	24.00	36.75	69.75	26.75	80.00	186.00	180.50	215.50	54.50	19.75	64.00	21.70	30.25
5	16.4	28.05	22.25	34.50	63.95	27.00	72.63	172.45	167.90	197.45	54.00	20.55	69.00	22.00	27.75
6	19.75	30.60	23.00	34.30	69.00	27.85	76.00	183.00	182.00	210.00	55.50	19.10	63.50	20.75	29.50
7	20.05	32.35	24.05	35.55	68.15	27.95	77.00	177.00	172.50	199.50	53.00	19.95	66.00	22.00	30.75
8	18.00	30.5	22.9	35.25	67.50	29.00	78.25	174.50	170.00	205.50	52.50	19.60	62.00	21.30	27.25
9	18.00	31.40	21.1	32.2	65.55	27.00	76.50	181.00	176.75	204.00	52.50	20.00	72.70	22.00	28.25
10	17.65	29.15	23.10	34.80	63.50	24.50	82.50	178.50	171.00	204.00	53.50	20.00	62.50	22.00	31.00
12	17.75	29.50	21.50	32.25	63.20	23.00	72.13	177.00	171.00	203.00	48.75	17.75	59.00	19.50	30.50
13	18.5	29.75	23.00	35.00	59.50	21.50	75.63	181.00	177.50	207.00	46.50	19.50	53.75	21.00	31.50
14	18.2	28.75	22.50	34.25	67.25	27.75	75.38	163.50	160.50	184.50	47.25	19.00	59.50	20.75	27.00
15	16.5	29.25	22.60	33.75	61.75	22.50	77.25	169.00	168.50	193.75	47.75	19.50	58.75	21.00	26.75
16	16.5	28.0	22.50	33.25	63.00	24.25	75.25	178.75	168.50	204.50	53.50	18.25	64.00	19.50	26.75
Mean	18.22	29.87	22.87	33.80	65.40	25.99	76.73	177.66	173.06	202.81	51.48	19.39	62.40	21.08	28.85

APPENDIX I D

LIVE ANIMAL EVALUATION - REPEATABILITY OF BODY MEASUREMENTS

Steer No.	Width: Neck		Shoulder		Rump		Round		Pins		At 13th Rib		Between 13th Rib & Hooks		At Hooks		At Crops		Between Crops & 13th Rib	
1957																				
1	20.75	18.5	46.0	46.0	46.5	46.75	48.75	46.75	24.5	23.75	36.75	35.75	36.25	34.0	40.5	37.75	31.75	27.75	36.25	33.5
2	25.75	24.75	53.25	52.75	51.75	52.00	51.25	50.75	26.25	26.25	42.5	42.25	41.75	39.00	46.25	45.25	36.5	37.75	42.0	41.25
3	14.5	15.5	43.75	43.00	45.00	46.00	41.00	43.5	25.5	24.5	36.0	34.50	31.0	31.75	42.75	43.25	33.25	31.25	30.00	33.50
4	18.5	20.00	46.00	47.75	49.75	51.00	49.00	49.25	27.00	28.00	38.25	42.75	38.50	41.25	46.00	46.00	32.75	34.00	41.50	38.00
5	18.00	18.5	47.25	45.5	47.50	47.00	48.00	47.25	22.5	25.5	32.00	35.5	32.5	35.5	40.75	39.00	30.50	34.25	33.25	35.25
6	20.00	18.5	47.50	47.00	51.75	50.00	50.5	49.25	24.75	24.25	35.5	32.75	37.75	35.5	43.25	43.5	32.25	32.25	33.25	34.00
7	17.25	18.00	48.00	45.00	47.50	45.00	46.00	45.50	25.5	24.00	32.25	36.25	32.25	32.50	40.75	41.50	30.50	30.75	34.5	34.25
8	21.25	19.5	45.0	44.5	46.00	45.75	48.25	46.25	28.75	27.50	35.25	37.50	31.75	32.50	41.75	43.75	29.25	27.50	34.75	34.25
9	28.00	20.5	49.75	48.5	49.5	50.50	48.25	47.75	26.75	28.00	40.75	38.0	37.00	37.75	42.75	43.00	33.75	35.5	37.5	36.75
10	18.0	18.25	45.5	45.5	46.5	46.25	44.75	44.00	26.00	24.25	36.25	35.25	33.50	34.50	42.00	43.25	32.5	33.75	36.5	37.5
12	18.5	18.75	44.75	46.50	46.00	46.25	44.75	46.50	24.75	27.00	36.00	33.75	33.00	30.75	42.5	42.00	30.5	31.25	38.25	37.5
13	19.0	19.5	47.75	47.50	49.50	46.25	49.00	46.50	26.00	25.5	34.00	34.5	33.5	35.5	44.25	45.00	31.00	31.50	40.25	43.25
14	16.25	16.5	44.75	42.75	45.00	43.00	42.50	41.25	25.00	25.00	30.00	29.5	30.75	30.75	42.00	42.50	29.00	31.00	34.25	33.25
15	22.25	20.00	44.75	44.25	47.50	45.50	47.00	45.00	26.25	24.25	31.75	34.25	30.75	31.75	41.00	43.00	28.00	28.00	33.75	34.25
16	21.75	21.00	43.75	42.50	44.75	45.25	44.50	44.50	23.50	24.75	35.00	34.00	32.00	31.75	40.25	39.75	27.00	30.75	35.25	36.25
Mean	19.65	19.18	46.52	45.93	47.63	47.10	46.90	46.27	25.53	25.50	35.48	35.77	34.15	34.32	42.45	42.57	31.23	31.82	36.08	36.18

APPENDIX I D (Continued)
LIVE ANIMAL EVALUATION - REPEATABILITY OF BODY MEASUREMENTS

Steer No.	Length								Height					
	1st Thoracic to Pins		1st Thoracic to 13th Rib		13th Rib to Hooks		Rump		Brisket at Crops		At Withers		At Rump	
1957														
1	112.00	117.50	62.75	62.25	13.25	19.75	36.00	35.5	63.75	63.75	105.5	105.25	109.50	109.50
2	130.25	129.25	70.0	66.25	15.00	17.50	45.25	45.5	73.5	73.25	117.25	117.00	122.25	124.75
3	125.0	129.0	55.75	60.00	19.25	19.00	50.00	50.00	64.25	65.00	110.50	112.00	118.75	120.25
4	131.75	130.25	70.5	73.5	19.25	12.50	42.00	44.25	67.00	65.00	115.25	116.00	122.25	120.75
5	121.25	115.25	62.00	61.25	13.50	12.00	45.75	42.00	63.75	61.50	104.00	104.75	113.50	113.50
6	125.00	130.00	72.00	74.00	8.00	11.00	45.00	45.0	67.75	66.75	114.00	111.75	119.50	118.75
7	122.25	125.50	65.25	67.5	14.50	15.75	42.50	42.25	65.00	61.50	109.75	110.00	117.00	115.50
8	128.50	127.00	69.00	69.25	15.75	14.00	43.75	43.75	62.25	64.25	113.00	113.00	118.75	118.00
9	122.50	122.25	65.00	62.5	16.00	14.25	41.5	45.5	66.25	67.5	111.75	111.75	120.00	121.00
10	124.00	121.00	64.50	58.00	20.50	22.00	39.00	41.00	63.75	64.5	111.50	111.50	116.75	118.00
12	107.75	113.50	52.50	55.00	16.00	19.50	39.25	39.00	62.50	64.00	106.50	105.00	111.25	111.00
13	116.25	121.00	68.75	62.00	15.75	16.50	41.75	42.50	63.25	65.50	109.00	108.25	115.00	115.25
14	119.25	120.00	62.50	60.75	15.75	19.00	41.00	40.25	60.00	60.00	107.25	107.50	110.00	111.75
15	116.75	120.50	59.25	62.00	15.75	14.75	41.75	43.75	63.25	63.00	109.75	111.00	117.75	116.5
16	119.75	116.00	56.75	54.75	19.75	18.75	43.25	42.5	63.50	64.75	112.75	112.00	114.75	115.00
Mean	121.48	122.53	63.77	63.27	15.87	16.42	42.52	42.85	64.65	64.68	110.52	110.45	116.50	116.70

APPENDIX I D (Continued)
LIVE ANIMAL EVALUATION - REPEATABILITY OF BODY MEASUREMENTS

Steer No.	Length of Legs													
	Smooth joint at Metacarpal		Smooth joint to floor		Break joint to Metatarsal		Break joint to floor		Twist to floor		Twist to Hocks		Rump to Hocks	
1957														
1	17.3	17.5	28.5	26.5	21.7	21.5	32.7	32.5	61.0	60.4	30.0	26.5	73.25	72.75
2	18.5	18.2	31.5	31.5	24.0	23.5	36.1	37.0	67.4	68.0	24.0	27.0	80.75	78.5
3	19.5	20.0	29.5	30.0	25.2	25.3	26.0	26.0	72.0	69.0	27.0	27.0	80.00	79.5
4	20.5	20.5	32.5	31.5	23.0	25.0	36.5	37.0	70.5	69.0	28.5	25.0	80.75	79.25
5	16.3	16.5	29.3	26.8	22.5	22.0	35.2	33.8	64.2	63.7	27.5	26.5	71.5	73.75
6	19.5	20.0	30.0	31.2	23.0	23.0	34.5	34.1	69.0	69.0	28.2	27.5	73.25	78.75
7	20.1	20.0	32.8	31.9	23.8	24.3	35.6	35.5	68.3	68.0	28.3	27.6	74.75	79.25
8	18.5	17.5	31.0	30.0	22.8	23.0	36.0	34.5	67.5	67.5	29.0	29.0	77.75	78.75
9	18.2	17.8	32.3	30.5	21.1	21.1	33.1	31.3	65.6	65.5	28.0	26.0	76.25	76.75
10	17.5	17.8	29.0	29.3	23.2	23.0	34.6	35.0	65.0	62.0	26.0	23.0	83.0	82.0
12	18.0	17.5	29.0	30.0	21.5	21.5	32.0	32.5	61.4	65.0	23.0	23.0	71.0	73.25
13	18.5	18.5	29.5	30.5	23.0	23.0	34.5	35.5	59.0	60.0	21.0	22.0	76.5	74.75
14	18.4	18.0	29.5	28.0	22.5	22.5	34.0	34.5	68.5	66.0	29.5	26.0	75.25	75.5
15	16.5	16.5	29.0	29.5	22.7	22.5	33.5	34.0	62.0	61.5	23.0	22.0	78.75	75.75
16	16.5	16.5	28.0	28.0	22.5	22.5	33.5	33.0	63.0	63.0	25.5	23.0	75.50	75.00
Mean	18.25	18.19	30.09	29.68	22.83	22.91	33.85	33.75	65.63	65.17	26.57	25.41	76.55	76.90

APPENDIX I D (Continued)
LIVE ANIMAL EVALUATION - REPEATABILITY OF BODY MEASUREMENTS

Steer No.	Circumference																Angles of Rib	
							Fore legs				Hind legs							
	Fore Flank		Rear Flank		Belly		Above elbow		Below elbow		Above Hocks		Below Hocks					
1957																		
1	175.0	178.0	170.5	170.0	199.0	199.5	49.00	50.00	17.7	18.4	54.5	54.0	19.4	19.1			28.5	28.5
2	197.5	195.0	187.0	189.0	220.0	220.5	52.00	57.00	20.8	21.0	71.0	73.0	22.5	23.4			30.5	30.5
3	172.0	169.0	171.0	171.0	193.0	195.0	49.0	49.0	19.0	19.0	54.0	56.0	20.5	20.5			28.0	25.0
4	186.0	186.0	182.0	179.0	216.0	215.0	56.0	53.0	19.5	20.0	64.0	64.0	22.0	21.4			30.0	30.5
5	172.9	172.0	167.0	168.8	197.9	197.0	55.0	53.0	19.8	21.3	67.0	71.0	22.0	22.0			30.5	25.0
6	183.0	183.0	183.0	181.0	210.0	210.0	58.0	53.0	18.7	19.5	66.0	61.0	21.0	20.5			29.0	30.0
7	177.0	177.0	174.0	171.0	199.0	200.0	52.0	54.0	19.9	20.0	68.0	64.0	22.0	22.0			31.5	30.0
8	175.0	174.0	168.0	172.0	205.0	206.0	52.0	53.0	19.5	19.7	64.0	60.0	21.3	21.3			27.0	27.5
9	181.0	181.0	177.0	176.5	204.0	204.0	53.0	52.0	20.2	19.8	69.4	76.0	22.0	22.0			26.5	30.0
10	178.0	179.0	171.0	171.0	204.0	204.0	53.0	54.0	20.0	20.0	64.0	61.0	22.0	22.0			30.5	31.5
12	176.0	178.0	173.0	169.0	203.0	203.0	48.5	49.0	17.5	18.0	57.0	61.0	19.5	19.5			29.5	31.5
13	181.0	181.0	178.0	177.0	207.0	207.0	48.0	45.0	19.5	19.5	55.0	52.5	21.0	21.0			32.0	31.0
14	164.0	163.0	163.0	158.0	185.0	184.0	46.5	48.0	19.0	19.0	58.0	61.0	21.0	20.5			25.5	28.5
15	169.0	169.0	169.0	168.0	194.0	193.5	49.0	46.5	20.0	19.0	60.5	57.0	21.0	21.0			26.0	27.5
16	178.5	179.0	168.0	169.0	205.0	204.0	53.0	54.0	18.5	18.0	66.0	62.0	19.5	19.5			26.5	27.0
Mean	177.73	177.60	173.43	172.69	202.79	202.83	51.60	51.37	19.31	19.48	62.56	62.23	21.11	21.05			28.77	28.93

APPENDIX I E
LIVE ANIMAL EVALUATION - PHOTOGRAPH MEASUREMENTS

Steer No.	Body Length	Height at Withers	Height at Rump	Depth at Chest	Depth at Belly	Depth at Flank
1956						
1	48	44	45.5	27	25.5	22
2	45	43	45	27	24.5	20
3	44	44	47	27.5	26.0	23
4	43	42	45	27	26.5	22
5	45	42	47	27	25.0	22.5
6	51	46	47	28	25.5	21.5
7	45.5	43	46.5	28	26.5	22.5
8	44.5	42.5	44	26	24.0	19
9	47.5	42.5	44	26.5	25.5	23
10	45	44	44.5	26	26	23
11	42.5	45	42	25	24	20.5
12	46	42.5	46	27	24.5	21
13	44.5	43	44	25	24	21.5
14	49	42.5	45.5	27	25	20.5
15	47.5	43	43	26	26	21.5
16	46.5	43	48.5	29	28	24
Mean	45.91	43.25	45.28	26.81	25.41	21.72
1957						
1	48	40.5	40.5	25.5	24.5	21.5
2	50.5	44.5	46	29	26.5	23.5
3	45	42	45.5	26	24	22.5
4	49.5	43.5	45	27.5	26.5	23.5
5	47	40.5	42.5	26	22.5	21
6	49	42.5	44.5	28	27	23
7	45.5	42	43.5	26.5	24	21.5
8	46.5	42	44	26	23.5	21
9	44.5	43.5	44.5	26.5	24	22
10	47.5	42	44.5	27	24.5	22.5
12	43.5	40.5	41	25.5	24.5	22
13	47.5	40.5	43	28.5	28	23
14	46.5	40	41	25	22.5	19
15	48	42	44	26	24.5	22
16	48.5	42.5	42.5	27	25	22
Mean	47.13	41.9	43.47	26.67	24.77	22.0

APPENDIX II A

SLAUGHTER DATA

Steer No.	Weight in Pounds										
	Slaughter	Head	Tail	Liver	Heart	Pluck	Hide	Stomach	Intestine	Caul and ruffle fat	Warm carcass
1956											
1	915	26.2	1.3	10.7	3.3	13.4	73.0	90.8	51.4	10.0	576.5
2	790	23.6	1.4	7.7	3.3	10.8	73.0	78.3	40.0	13.6	477.0
3	920	29.1	1.7	9.8	3.3	12.4	75.1	85.0	48.7	11.9	582.0
4	825	24.8	1.6	8.1	2.9	11.0	74.5	79.0	44.0	13.1	506.0
5	798	26.4	1.2	8.6	3.5	12.6	65.0	64.2	44.4	11.0	503.5
6	868	28.5	1.7	8.9	3.4	13.0	85.0	72.8	41.8	16.6	532.0
7	851	26.0	1.6	8.6	3.5	11.0	64.0	86.0	44.5	13.6	538.5
8	692	22.6	1.4	7.3	3.2	11.2	58.8	71.2	36.0	7.8	416.5
9	875	24.5	1.7	10.0	3.3	11.0	80.0	84.3	52.3	17.8	529.5
10	852	26.8	1.2	8.9	3.2	10.7	61.0	97.6	47.5	11.3	533.5
11	808	22.8	2.0	9.3	3.4	12.4	55.0	82.2	43.7	14.5	515.5
12	864	27.1	1.4	8.4	3.2	11.0	78.0	55.2	48.0	20.0	550.0
13	783	22.8	0.7	7.8	3.1	10.6	63.5	68.8	42.0	11.5	498.5
14	910	28.8	2.3	9.8	3.7	9.3	81.0	98.5	47.2	13.6	550.5
15	855	24.4	1.0	8.8	3.2	9.5	63.5	95.2	49.5	18.3	539.5
16	875	28.2	1.4	8.1	3.8	12.4	74.5	64.0	38.4	17.4	570.5
Mean	842.56	25.79	1.48	8.80	3.33	11.39	70.31	79.57	44.96	13.88	526.22
1957											
1	808.0	23.6	1.3	10.7	3.0	8.9	63.6	66.5	38.0	17.0	522.0
2	1081.0	32.5	0.9	11.7	3.6	12.2	98.0	80.0	49.5	20.0	698.0
3	821.0	23.5	1.7	9.2	3.0	14.7	63.0	59.0	40.0	15.0	519.0
4	953.0	28.5	1.3	11.5	3.7	14.9	77.5	73.5	46.0	24.5	606.0
5	789.0	26.0	1.1	7.5	2.7	8.6	66.5	81.0	38.0	11.5	492.5
6	949.0	28.0	1.3	11.6	3.7	12.7	69.5	82.0	45.0	17.0	612.0
7	888.0	29.5	---	9.5	3.5	11.5	70.0	77.5	43.0	17.8	560.5
8	886.0	28.5	1.6	9.6	3.3	12.3	72.0	85.5	42.0	16.5	545.5
9	898.0	26.0	1.3	8.8	3.3	9.5	79.5	80.5	41.0	14.5	576.0
10	896.0	26.5	1.6	9.2	4.2	12.8	73.0	59.0	52.5	20.5	561.5
12	806.0	25.0	1.4	9.1	3.4	12.5	59.0	----	44.5	21.0	515.0
13	892.0	27.5	1.5	8.6	3.3	11.6	79.0	73.8	54.5	13.7	559.0
14	715.0	23.0	1.3	8.0	3.4	10.7	65.0	65.0	31.0	10.0	452.5
15	805.0	24.5	1.4	8.7	3.1	13.1	67.5	87.0	41.0	11.0	491.0
16	852.0	27.5	1.4	9.3	3.1	13.4	62.0	71.5	45.5	16.1	540.5
Mean	869.26	26.67	1.27	9.53	3.35	11.96	71.01	69.45	43.43	16.41	550.07

APPENDIX II B

CARCASS DATA

Steer No.	Chilled Carcass	Dressing Percent	Grade	Est. Marbling	Carcass Measurements: Carcass Length	Depth at 5th Rib	Depth at Flank	Width of Rump	Width of Shoulder	Width of Crops	Width of Round	Circum. of Round	Circum. of Fore Shank
1956													
1	567.0	61.97	22.	14.3	112.6	61.5	34.0	54.5	49.25	36.0	54.75		
2	466.0	58.99	17.	5.2	111.5	61.25	33.0	50.0	45.75	32.25	52.25		
3	572.0	62.17	19.	6.3	113.7	64.0	34.25	53.0	50.0	35.75	54.25		
4	495.0	60.00	20.	10.7	109.8	64.25	32.75	51.75	46.5	34.75	52.0		
5	493.0	61.78	19.	7.3	112.2	60.0	31.75	52.0	46.0	33.25	51.25		Only
6	521.5	60.08	19.	8.7	117.9	66.0	30.0	52.5	45.5	32.0	53.0		
7	528.0	62.04	20.0	11.3	111.4	64.5	37.0	51.25	48.0	35.5	52.5		
8	407.0	58.82	17.	4.0	110.2	60.25	32.75	47.25	41.0	30.5	47.75	2nd	year
9	521.0	59.54	19.	11.0	114.4	62.0	35.25	52.0	47.5	34.5	52.5		
10	524.0	61.50	21.	13.0	112.5	63.0	33.25	54.25	48.25	32.5	54.0		
11	508.0	62.87	21.	12.3	106.5	62.0	33.5	51.75	47.5	34.5	52.5		
12	539.0	62.38	20.	10.0	114.0	63.0	32.25	52.75	50.25	35.25	53.75		
13	488.5	62.39	19.	9.3	117.5	62.5	35.75	50.0	46.25	35.75	50.5		
14	541.0	59.45	20.	8.3	115.5	64.0	33.5	52.0	48.5	33.25	53.25		
15	531.0	62.10	21.	14.0	110.1	65.25	37.5	54.5	50.25	35.75	55.0		
16	560.0	64.00	19.	8.6	117.3	65.0	37.25	51.5	47.75	33.5	51.25		
Mean	516.38	61.25	19.56	9.64	112.94	63.03	33.98	51.97	47.39	34.06	52.53		
1957													
1	516.5	63.92	20.	10.67	108.25	58.75	34.00	52.38	47.50	35.00	51.88	101.50	55.75
2	688.5	63.69	20.	11.67	119.0	65.25	35.13	52.13	52.13	38.00	55.13	103.00	64.25
3	510.5	62.18	18.	7.00	113.25	58.75	33.88	51.00	44.38	34.63	51.88	94.50	56.75
4	599.0	62.85	21.	12.00	114.0	63.13	34.75	55.00	50.00	37.00	55.25	104.25	59.75
5	485.0	61.47	19.	6.00	107.5	59.13	30.38	51.38	45.50	33.00	51.88	97.00	56.00
6	603.0	63.54	22.	15.00	115.5	64.25	37.25	54.00	49.00	33.88	55.25	112.00	59.50
7	552.5	62.22	19.	7.00	112.25	61.88	33.75	51.75	49.75	36.13	52.38	103.75	58.00
8	538.0	60.72	19.	8.67	113.0	60.75	34.75	53.25	47.88	34.38	53.75	105.00	58.50
9	568.5	63.31	19.	9.67	114.0	61.75	35.75	53.50	48.88	36.75	54.50	113.00	54.75
10	553.5	61.77	20.	12.33	112.25	62.50	36.00	51.63	48.63	37.75	52.38	101.00	58.25
12	508.0	63.03	19.	9.00	108.75	61.13	33.50	51.13	47.75	34.75	51.63	101.25	55.00
13	550.5	61.72	19.	10.00	112.0	62.00	35.63	52.63	50.50	36.25	53.00	98.50	57.75
14	444.0	62.10	17.	5.00	109.5	58.50	32.50	49.88	43.13	32.63	50.50	97.00	55.50
15	483.0	60.00	19.	9.00	110.25	60.88	35.25	51.25	47.13	33.13	51.25	103.25	58.25
16	532.5	62.50	20.	10.67	111.5	64.38	33.50	52.00	48.75	34.25	52.50	107.00	54.25
Mean	542.20	62.33	19.40	9.58	112.07	61.54	34.40	52.19	48.06	35.17	52.88	102.80	57.48

APPENDIX II B (Continued

CARCASS DATA

Steer No.	Photograph Measurements						
	Depth at 7th Rib	Depth at Flank	Width of Round	Width at Rump	Width of Shoulder	Width of Crops	Circum. of Round
1956							
1	23.0	13.0	11.0	20.5	19.5	14.5	120.75
2	21.5	12.5	10.5	19.0	17.0	13.0	112.12
3	22.5	13.0	10.0	20.5	17.5	14.5	117.00
4	22.5	12.5	10.5	19.5	17.0	14.0	112.75
5	21.5	12.5	10.0	19.5	16.5	13.0	115.00
6	23.0	13.0	10.0	20.0	16.5	14.0	97.50
7	22.5	13.0	9.5	20.0	17.5	14.0	117.88
8	21.0	12.0	9.5	18.5	15.5	12.5	99.00
9	21.5	12.5	11.0	21.5	17.5	13.5	134.38
10	23.0	13.5	11.5	21.5	18.0	14.0	129.00
11	21.5	12.5	10.0	20.0	18.0	13.5	120.00
12	22.0	12.5	10.0	20.0	18.5	14.0	112.12
13	23.0	13.0	10.0	19.5	16.5	14.0	112.12
14	22.0	12.5	10.5	20.5	18.0	13.5	123.00
15	22.5	13.0	10.0	19.5	18.0	13.5	109.25
16	22.5	13.0	9.5	19.5	17.0	14.0	114.00
Mean	22.22	12.75	10.22	20.00	17.41	13.72	115.37
1957							
1	21.5	12.0	9.0	20.0	18.0	15.5	109.25
2	24.0	14.0	10.0	21.0	20.0	16.5	125.00
3	22.5	14.0	9.0	20.0	16.0	13.5	126.00
4	23.5	13.0	10.0	22.0	18.5	16.0	132.00
5	21.5	12.5	9.5	20.5	17.5	14.5	121.88
6	23.5	13.0	10.0	21.5	18.5	14.5	110.00
7	22.0	13.0	9.5	20.0	19.0	15.0	107.25
8	22.5	13.5	10.0	21.0	18.0	15.0	128.12
9	22.0	13.0	9.5	21.0	18.0	15.5	125.00
10	22.0	13.5	9.0	20.0	18.0	15.5	107.25
12	22.5	12.5	9.5	21.0	18.0	14.5	115.0
13	23.0	13.5	9.5	21.5	19.0	16.0	120.75
14	21.5	12.0	9.5	20.0	16.5	14.0	110.00
15	22.0	13.5	10.5	20.5	16.5	14.5	131.25
16	22.5	12.5	10.0	21.5	18.5	15.0	120.75
Mean	22.43	13.03	9.63	20.77	18.0	15.03	119.30

APPENDIX II C

CARCASS DATA REPEATABILITY OF MEASUREMENTS

Steer No.	Measurements in Centimeters																	
	Carcass Length		Depth at 5th Rib		Depth at Flank		Width of Rump		Width of Shoulder		With of Crops		Width of Round		Circumference of Round		Circumference of Fore Shank	
1957																		
1	108.	108.5	58.0	59.5	34.75	33.25	53.0	51.75	47.0	48.0	34.75	35.25	52.0	51.75	100.0	103.0	56.00	55.50
2	119.	119.	64.0	66.5	36.25	34.00	52.50	51.75	52.0	52.25	38.0	38.0	55.25	55.0	102.5	103.5	65.00	63.50
3	113.	113.5	59.25	58.25	33.00	34.75	50.75	51.25	44.50	44.25	34.50	34.75	51.75	52.0	94.0	95.0	56.50	57.00
4	114.	114.	64.75	62.50	35.50	34.0	55.00	55.00	50.00	50.00	37.00	37.00	55.25	55.25	104.0	104.5	60.50	59.00
5	107.5	107.5	59.50	58.75	30.00	30.75	51.25	51.50	45.50	45.50	32.75	33.25	52.00	51.75	97.0	97.0	56.00	56.00
6	115.5	115.5	64.00	64.50	37.00	37.50	54.00	54.00	49.00	49.00	33.75	34.00	55.50	55.00	113.0	111.0	59.00	60.00
7	112.0	112.5	62.00	61.75	34.00	33.50	51.75	51.75	49.75	49.75	36.25	36.00	52.25	52.50	104.0	103.5	57.50	58.50
8	113.0	113.0	60.75	60.75	35.50	34.00	53.50	53.50	47.75	48.00	34.50	34.25	54.00	53.5	104.5	105.5	58.50	58.50
9	114.0	114.0	62.00	61.50	35.50	36.00	53.25	53.75	49.00	48.75	37.00	36.50	54.50	54.50	113.0	113.0	54.50	55.00
10	112.0	112.5	62.50	62.50	35.50	36.50	51.75	51.50	49.00	48.25	37.75	37.75	52.75	52.00	100.5	101.5	58.00	58.50
12	108.5	109.0	61.50	60.75	34.00	33.00	51.25	51.00	47.50	48.00	34.50	35.00	51.50	51.75	101.5	101.0	55.00	55.00
13	112.0	112.0	62.00	62.00	35.25	36.00	52.75	52.50	50.50	50.50	36.00	36.50	53.00	53.00	98.5	98.5	58.00	57.50
14	109.5	109.5	58.50	58.50	32.25	32.75	49.75	50.00	43.00	43.25	32.75	32.50	50.25	50.75	97.0	97.0	54.50	56.50
15	110.0	110.5	61.00	60.75	35.00	35.50	50.75	51.75	47.25	47.00	33.25	33.00	51.00	51.50	104.0	102.5	58.50	58.00
16	112.0	111.0	65.25	63.50	33.75	33.25	52.00	52.00	48.50	49.00	33.75	34.75	52.50	52.50	107.0	107.0	54.00	54.50
Mean	112.0	112.13	61.66	61.47	34.48	34.32	52.22	52.17	48.02	48.10	35.10	35.23	52.90	52.85	102.70	102.90	57.43	57.53

APPENDIX II D

CARCASS DATA - CUTTING TESTS

Steer No.	Wholesale Cuts in Pounds: Rib	Short Plate	Fore Shank	Brisket	Chuck	Kidney Fat	Flank	Short Loin	Sirloin & Round	Hanging Tender	Fore Quarter	Hind Quarter	Primal Cuts	Psoas Major	Semi tendenosi
1956															
1	26.00	27.10	9.80	17.20	76.50	10.80	16.80	15.50	85.00	1.80	156.60	132.14	128.74	2.24	
2	19.30	17.60	10.50	13.00	58.60	4.70	10.80	13.80	77.70	1.40	119.00	110.43	112.83	2.03	
3	27.10	22.50	10.90	18.50	73.50	5.80	15.20	15.80	88.10	1.90	152.00	129.11	133.31	2.31	
4	22.50	20.00	11.10	18.20	68.50	3.90	14.70	13.60	77.80	1.60	140.30	113.91	116.21	2.31	
5	22.30	19.50	9.50	14.00	59.20	4.90	12.20	15.70	82.80	1.30	124.50	119.52	123.42	2.62	
6	25.50	20.60	9.60	15.20	68.50	5.40	12.90	14.00	85.60	1.60	139.40	122.59	128.19	3.09	None
7	22.90	21.00	10.90	18.90	62.20	5.50	16.50	16.40	85.10	1.60	135.90	127.53	126.83	2.43	first
8	16.80	14.50	8.40	8.50	54.70	2.70	8.30	12.60	69.80	0.90	102.90	96.48	139.28	2.18	year
9	22.10	22.80	10.30	14.10	64.50	4.80	16.00	16.70	80.50	1.80	133.80	122.05	121.55	2.25	
10	23.30	24.00	10.60	14.70	66.00	5.90	15.10	15.40	80.50	2.10	138.60	121.14	121.34	2.14	
11	22.90	21.20	9.60	15.70	60.70	8.40	17.30	14.70	75.90	1.70	130.10	119.83	115.33	1.83	
12	23.20	23.30	10.40	12.50	67.60	6.90	13.90	17.00	82.60	1.20	137.00	121.60	122.80	--	
13	23.10	19.90	10.10	15.00	57.50	5.20	16.20	15.70	74.10	1.30	125.60	114.37	114.77	1.87	
14	22.80	22.80	11.90	13.10	69.50	3.30	13.40	16.20	88.80	2.00	140.10	126.01	130.11	2.31	
15	22.70	25.80	9.10	17.40	66.60	8.40	17.20	19.50	74.70	1.80	141.60	123.47	118.77	1.87	
16	24.80	22.10	9.50	14.10	74.40	5.60	15.00	18.60	89.00	1.90	144.90	132.63	134.93	2.53	
Mean	22.96	21.54	10.14	15.01	65.53	5.76	14.47	15.70	81.12	1.62	135.18	120.80	124.28	2.26	
1957															
1	26.1	19.4	7.5	12.2	67.3	11.6	21.6	15.4	74.5	1.3	132.50	130.14	121.74	2.31	3.43
2	33.6	27.8	12.9	22.3	84.6	8.6	27.4	21.3	100.4	2.3	181.20	166.21	161.51	2.58	3.63
3	24.4	16.9	10.0	10.1	68.1	5.9	13.1	16.4	85.3	1.4	129.50	127.91	131.91	2.62	3.19
4	30.8	23.0	11.9	14.2	75.9	11.2	21.9	17.7	91.6	1.7	155.80	149.59	145.59	2.34	3.15
5	22.5	17.8	8.7	11.6	64.2	5.5	15.3	13.9	78.5	1.9	124.80	119.82	119.62	2.15	2.57
6	27.2	23.4	10.7	13.4	81.3	9.9	21.1	19.2	95.3	2.2	156.00	154.23	148.23	2.46	4.07
7	27.6	20.6	10.6	13.6	70.7	7.9	18.1	16.3	86.1	1.9	143.10	136.01	135.71	2.51	3.20
8	26.6	18.9	10.3	10.8	70.3	7.4	18.0	14.5	84.3	1.6	136.90	131.16	130.76	2.26	3.10
9	28.2	19.2	9.3	15.9	70.4	7.1	19.5	20.3	87.7	2.0	143.00	142.21	141.81	2.33	3.28
10	30.2	19.9	10.1	15.9	71.5	10.5	10.7	15.8	85.4	1.7	147.60	129.60	136.90	2.22	3.28
12	28.7	22.2	9.9	13.8	62.0	11.1	20.8	14.1	70.3	2.2	136.60	122.91	117.51	1.60	2.81
13	29.7	22.6	10.1	14.5	63.6	9.3	20.9	19.5	79.5	1.9	140.50	136.30	133.90	2.26	2.94
14	18.2	15.3	9.6	10.3	59.2	6.0	13.7	15.8	68.5	1.7	112.60	110.11	106.91	2.62	1.79
15	23.4	17.7	10.6	13.0	61.7	6.4	13.5	14.8	78.5	1.5	126.40	119.41	121.41	1.90	2.80
16	22.9	20.3	9.4	13.7	65.2	11.3	20.4	15.1	76.7	1.9	136.50	130.60	124.90	2.06	3.14
Mean	26.67	20.33	10.11	13.69	69.07	8.64	18.40	16.67	82.84	1.81	140.20	133.75	131.89	2.28	3.09

APPENDIX II E

CARCASS DATA - PERCENT WHOLESALE CUTS

Steer No.	Wholesale Cuts In Percent														
	Rib	Short Plate	Fore Shank	Brisket	Chuck	Kidney Fat	Flank	Short Loin	Sirloin & Round	Hanging Tender	Fore Quarter	Hind Quarter	Primal Cuts	Psoas Major	Semi tendenosis
1956															
1	9.01	9.39	3.39	5.96	26.49	3.74	5.82	5.37	29.44	.623	54.24	45.77	44.59	.776	
2	8.41	7.67	4.58	5.67	25.54	2.05	4.71	6.02	33.87	.610	51.87	48.13	49.18	.885	
3	9.62	7.99	3.87	6.57	26.10	2.06	5.40	5.61	31.28	.675	54.15	45.85	47.34	.820	
4	8.85	7.87	4.37	7.28	26.95	1.53	5.78	5.35	30.61	.629	55.19	44.81	44.71	.909	
5	9.14	7.99	3.89	5.74	24.26	2.01	5.00	6.43	33.93	.533	51.02	48.98	50.58	1.074	
6	9.73	7.86	3.66	5.80	26.15	2.06	4.92	5.34	32.67	.611	53.21	46.79	48.93	1.179	
7	8.69	7.97	4.14	7.17	23.61	2.09	6.26	6.23	32.31	.607	51.59	48.41	48.15	.922	None
8	8.43	7.27	4.21	4.26	27.43	1.35	4.16	6.32	35.01	.451	51.61	48.39	50.85	1.093	first
9	8.64	8.91	4.03	5.51	25.21	1.88	6.25	6.53	31.46	.704	52.30	47.70	47.51	.879	year
10	8.97	9.24	4.08	5.66	25.41	2.27	5.81	5.93	30.99	.809	53.36	46.55	46.72	.824	
11	9.16	8.48	3.84	6.28	24.29	3.36	6.92	5.88	30.37	.680	52.05	47.94	46.15	.732	
12	8.97	9.01	4.02	4.83	26.14	2.67	5.38	6.57	31.94	.464	52.98	47.02	47.49	--	
13	9.63	8.29	4.21	6.25	23.96	2.17	6.75	6.54	30.88	.542	52.34	47.66	47.83	.779	
14	8.57	8.57	4.47	4.92	26.12	1.24	5.04	6.09	33.37	.752	52.65	47.35	48.89	.868	
15	8.56	9.73	3.43	6.56	25.13	3.17	6.49	7.36	28.18	.679	53.42	45.58	44.81	.705	
16	8.94	7.96	3.42	5.08	26.81	2.02	5.41	6.70	32.07	.685	52.21	47.79	48.62	.912	
Mean	8.96	8.39	3.98	5.85	25.60	2.23	5.63	6.14	31.77	0.628	52.76	47.23	47.65	.835	
1957															
1	9.94	7.39	2.86	4.64	25.62	4.42	8.22	5.86	28.37	.495	50.45	49.55	46.35	.879	1.31
2	9.67	8.00	3.71	6.42	24.35	2.48	7.89	6.13	28.90	.662	52.16	47.85	46.50	.743	1.05
3	9.48	6.56	3.88	3.92	26.46	2.29	5.09	6.37	33.14	.544	50.31	49.69	51.25	1.018	1.24
4	10.08	7.53	3.90	4.65	24.85	3.67	7.17	5.80	29.99	.557	51.02	48.98	47.67	.766	1.03
5	9.20	7.28	3.56	4.74	26.25	2.25	6.26	5.68	32.10	.777	51.03	48.99	48.91	.879	1.05
6	8.77	7.54	3.45	4.32	26.21	3.19	6.80	6.19	30.72	.709	50.29	49.72	47.79	.793	1.31
7	9.89	7.38	3.80	4.87	25.33	2.83	6.48	5.84	30.85	.681	51.27	48.73	48.62	.899	1.15
8	9.91	7.04	3.84	4.02	26.20	2.76	6.71	5.40	31.42	.596	51.02	48.88	48.73	.842	1.15
9	9.89	6.73	3.26	5.57	24.68	2.49	6.84	7.12	30.75	.701	50.14	49.86	49.72	.817	1.15
10	10.90	7.18	3.64	5.74	25.80	3.79	3.87	5.70	30.81	.613	53.25	46.76	49.40	.801	1.18
12	11.06	8.55	3.81	5.32	23.89	4.28	8.01	5.43	27.09	.848	52.64	47.36	45.28	.616	1.08
13	10.73	8.16	3.65	5.24	22.98	3.36	7.55	7.04	28.72	.686	50.76	49.24	48.37	.816	1.06
14	8.17	6.87	4.31	4.62	26.58	2.69	6.15	7.09	30.76	.763	50.56	49.44	48.00	1.176	.80
15	9.52	7.20	4.31	5.29	25.10	2.60	5.49	6.02	31.94	.610	51.42	48.57	49.39	.773	1.14
16	10.45	7.60	3.52	5.13	24.41	4.23	7.64	5.65	28.72	.711	51.10	48.89	46.76	.771	1.17
Mean	9.84	7.40	3.70	4.97	25.25	3.16	6.68	6.09	30.28	0.664	51.16	48.83	48.18	0.839	1.12

APPENDIX III A

CHEMICAL & PHYSICAL ANALYSIS

						Rib-eye 9-10-11 Rib Section			Compositive 9-10-11 Rib Section		
Steer No.	Rib-eye area	Est. marbling	Specific gravity	Blood fat mg. percent	Fat at 13th rib	% water	% fat	% protein	% water	% fat	% protein
1956											
1	10.84	14.3	1.0588	217.25	.67	70.58	7.93	21.39	35.53	53.69	10.94
2	8.98	5.2	1.0714	245.59	.70	75.05	1.90	21.76	47.95	36.83	14.56
3	9.07	6.3	1.0646	182.16	.76	73.48	4.10	21.66	41.85	45.28	12.89
4	8.89	10.7	1.0667	166.53	.64	72.12	6.77	20.69	38.87	48.82	12.25
5	7.26	7.3	1.0679	222.89	.77	73.79	3.49	21.59	46.55	38.90	13.07
6	8.52	8.7	1.0667	163.91	.81	73.99	3.86	21.04	46.82	39.15	13.96
7	9.64	11.3	1.0672	213.62	.91	72.67	5.08	21.25	37.37	51.28	11.17
8	7.94	4.0	1.0700	197.00	.58	75.04	2.66	21.26	56.09	26.43	17.01
9	8.82	11.0	1.0692	206.77	.93	72.54	4.78	21.91	40.17	47.46	11.96
10	9.09	13.0	1.0656	189.50	.70	70.62	7.21	21.20	36.76	51.52	11.38
11	9.82	12.3	1.0609	226.99	.96	70.21	6.29	20.81	39.54	48.09	11.73
12	9.02	10.0	1.0652	207.78	.91	72.67	5.09	21.12	39.54	48.09	11.73
13	8.25	9.3	1.0617	197.26	1.06	72.41	6.22	20.42	35.65	53.76	10.57
14	8.38	8.3	1.0637	184.63	.60	73.30	5.26	20.31	43.38	43.71	12.55
15	9.96	14.0	1.0573	180.01	1.09	71.45	7.49	20.31	32.11	57.71	9.54
16	9.95	8.6	1.0686	186.34	1.15	74.14	4.93	21.67	44.76	41.35	13.76
Mean	9.03	9.64	1.0653	199.26	0.83	72.75	5.19	21.15	41.43	45.75	12.44
1957											
1	9.07	10.67	1.0583	204.30	.88	71.80	6.50	21.44	34.25	54.82	10.41
2	8.53	11.67	1.0591	177.25	1.58	71.35	6.83	21.18	29.85	61.09	8.98
3	8.92	7.00	1.0647	172.51	.80	74.86	3.13	21.58	38.76	49.81	11.75
4	8.78	12.00	1.0657	187.72	1.22	72.37	5.49	21.65	33.14	56.55	10.18
5	8.41	6.00	1.0660	167.64	1.22	73.23	4.15	21.89	33.79	55.67	10.18
6	9.64	15.00	1.0584	198.87	.84	71.08	8.42	19.85	38.32	50.20	11.39
7	9.17	7.00	1.0672	202.16	1.00	73.33	4.33	21.44	33.35	56.60	10.32
8	8.01	8.67	1.0673	190.19	.95	72.62	4.71	21.92	35.98	54.16	10.83
9	7.57	9.67	1.0605	177.37	1.00	72.14	5.95	21.06	33.83	55.59	10.44
10	8.57	12.33	1.0589	161.54	.92	71.06	7.84	20.44	38.02	50.33	11.21
12	8.50	9.00	1.0620	153.96	1.23	73.13	5.24	20.92	32.23	58.41	8.98
13	9.42	10.00	1.0612	183.56	1.11	71.17	7.04	21.44	31.86	58.19	10.04
14	6.73	5.00	1.0661	152.78	1.18	74.17	3.51	21.84	38.04	50.54	11.49
15	7.50	9.00	1.0632	168.03	.95	72.62	5.46	21.24	35.28	53.73	11.12
16	9.07	10.67	1.0607	160.93	.85	71.82	6.41	20.93	33.71	55.80	10.56
Mean	8.53	9.58	1.0626	177.25	1.05	72.45	5.67	21.25	34.69	54.77	10.52

APPENDIX III A (continued)

CHEMICAL & PHYSICAL ANALYSIS

Steer No.	Separable lean, fat & bone 9-10-11 rib: Rib-eye weight	Other lean	Total lean	Total fat	Total bone	Total weight	Percent of total weight: Lean	Fat	Bone	Y=15.56 +.81X	Total area of fore shank: Total lean	Total Bone	Total fat	Total area
1956														
1	943	1297	2240	1709	504	4453	50.3	38.4	11.3	56.303	15.26	3.58		24.34
2	725	1262	1987	868	607	3463	57.4	25.1	17.5	62.054	16.52	3.61		22.64
3	927	1562	2489	1589	738	4821	51.6	33.0	15.3	57.356	16.71	2.98		23.03
4	1012	1336	2348	1369	579	4306	54.5	31.8	13.5	59.705	14.37	2.96		21.08
5	772	1299	2071	947	667	3685	56.2	25.7	18.1	61.082	15.69	3.64		22.61
6	722	1139	1861	1460	725	4055	45.9	36.0	17.9	52.739	15.05	3.34		21.75
7	841	1388	2229	1627	766	4615	48.3	35.3	16.6	54.683	13.76	3.29	None	22.26
8	720	1136	1856	488	484	2825	65.7	17.3	17.1	68.777	14.57	3.31	first	20.22
9	906	1368	2274	1362	645	4285	53.1	31.8	15.1	58.571	15.34	2.80	year	21.64
10	933	1255	2188	1375	698	4261	51.4	32.3	16.4	57.194	15.88	3.64		24.00
11	771	1223	1994	1675	519	4201	47.5	39.9	12.4	54.035	16.00	2.71		22.69
12	868	1415	2283	1505	569	4360	52.4	34.5	13.1	58.004	16.42	3.61		24.59
13	900	1255	2155	1652	585	4394	49.0	37.6	13.3	55.250	12.37	2.60		19.66
14	860	1284	2144	1191	644	3988	53.8	29.7	16.2	59.138	15.77	5.05		26.22
15	846	1010	1856	1685	496	4037	46.0	41.7	12.3	52.820	13.11	1.91		20.37
16	894	1575	2469	1205	788	4462	55.3	27.0	17.7	60.353	---	5.67		27.76
Mean	852.5	1300.25	2152.75	1356.68	625.87	4138.18	52.40	32.32	15.24	58.00	15.12	3.42		22.80
1957														
1	779	1226	2005	1813	616	4434	45.2	40.9	13.9	52.172	16.63	2.93	7.82	27.38
2	929	1612	2541	3272	784	6597	38.5	49.6	11.9	46.745	14.79	8.96	--	33.75
3	809	1229	2038	1568	518	4124	49.4	38.0	12.6	55.574	14.40	4.81	6.09	25.30
4	832	1574	2406	2365	856	5624	42.8	42.1	15.2	50.228	12.48	5.49	7.27	25.24
5	728	1106	1834	1651	559	4044	45.4	40.9	13.8	52.334	16.79	5.78	8.42	30.99
6	872	1384	2256	1573	616	4445	50.8	35.4	13.9	56.708	16.96	5.80	6.73	29.49
7	872	1399	2271	2199	598	5068	44.8	43.4	11.8	51.848	16.04	3.71	6.69	26.44
8	826	1369	2195	1750	784	4729	46.4	37.0	16.6	53.144	15.43	6.37	7.91	29.71
9	716	1522	2238	2455	720	5413	41.4	45.4	13.3	49.094	14.40	3.37	8.01	25.78
10	744	1602	2346	1867	793	5006	46.9	37.3	15.8	53.549	17.97	5.92	9.48	33.37
12	722	1192	1914	2076	641	4631	41.3	44.8	13.8	49.013	12.81	5.50	6.46	24.77
13	783	1337	2120	2130	696	4946	42.9	43.1	14.1	50.309	14.62	6.29	8.85	29.76
14	589	1170	1759	1362	524	3645	48.3	37.4	14.4	54.683	13.73	5.50	5.61	24.84
15	779	1180	1959	1635	707	4301	45.6	38.0	16.4	52.496	15.91	5.42	7.98	29.31
16	804	1245	2049	1819	542	4410	46.5	41.3	12.3	53.225	13.82	4.67	7.33	25.82
Mean	785.60	1343.13	1995.68	1969.00	663.60	4761.13	45.08	40.97	13.99	52.07	15.12	6.03	7.48	28.13

APPENDIX III B
CHEMICAL ANALYSIS

		Rib eye		
Rib No.	Specific Gravity	% H_2O	% Fat	% Protein
21	1.0514	68.87	9.51	21.17
22	1.0582	67.89	10.37	21.44
23	1.0569	69.26	8.72	21.73
24	1.0649	70.55	6.73	22.37
25	1.0555	67.57	11.21	20.86
26	1.0620	69.14	8.80	21.89
27	1.0632	71.13	6.67	21.72
28	1.0610	69.84	8.04	22.23
29	1.0556	69.69	8.88	21.50
30	1.0612	70.17	7.77	21.73
41	1.0679	74.85	2.35	22.38
42	1.0600	71.14	7.18	21.54
43	1.0603	73.15	5.16	20.87
44	1.0639	74.10	3.61	21.65
45	1.0657	73.22	4.39	21.63
46	1.0647	71.89	6.12	21.36
47	1.0611	72.21	6.15	21.77
48	1.0632	73.33	4.22	21.76
49	1.0625	74.34	4.16	21.14
50	1.0630	72.64	5.01	21.68
Mean	1.0611	71.25	6.75	21.62

APPENDIX III C
BONE STUDIES

Steer No.	Fore Cannon Average weight	Fore Cannon Average length	Fore Cannon Average circum.	Fore Cannon Average width	Fore Cannon Average thickness	Hind Cannon Average weight	Hind Cannon Average length	Hind Cannon Average circum.	Hind Cannon Average width	Hind Cannon Average thickness
1956										
1	353.5	189.0	107.0	36.5	23.0	418.5	221.0	108.0	32.5	29.0
2	392.5	191.5	118.0	40.5	25.0	439.0	218.5	113.0	33.0	29.0
3	426.5	195.0	120.0	42.0	26.0	491.5	218.5	116.5	31.0	31.0
4	365.5	192.0	113.0	40.0	23.5	437.0	221.5	115.0	34.0	28.5
5	335.5	192.5	107.0	39.0	24.0	385.0	222.5	112.0	33.5	28.5
6	427.0	196.5	117.0	41.0	24.5	476.0	228.5	113.5	34.0	29.0
7	356.0	196.0	110.5	38.0	22.0	434.5	223.0	110.5	34.0	27.5
8	334.5	188.0	116.0	37.0	23.0	389.5	214.5	102.5	30.5	26.0
9	359.5	190.5	110.5	38.5	24.0	410.5	214.0	108.0	31.5	29.0
10	351.0	186.0	108.5	37.0	24.0	401.0	216.5	108.5	31.5	27.5
11	293.0	169.0	99.0	35.5	21.0	343.5	197.0	105.0	30.5	26.0
12	407.0	194.0	120.0	42.5	25.0	472.0	224.5	118.0	35.0	31.5
13	310.5	184.0	114.0	35.5	22.0	355.0	211.5	111.5	29.0	26.0
14	410.0	196.0	117.0	41.5	23.0	496.0	223.5	117.0	35.0	29.5
15	359.0	183.5	105.0	36.0	23.0	450.0	209.0	102.0	30.0	27.0
16	447.5	199.5	111.5	40.5	26.0	534.0	230.0	112.0	34.5	31.0
Mean	370.53	190.19	112.12	38.81	23.69	433.31	218.38	110.81	32.47	28.50
1957										
1	296.5	171.5	109.0	39.0	23.0	345.0	198.5	108.0	32.5	29.0
2	420.0	198.0	116.5	44.0	24.0	489.0	223.5	116.5	36.0	30.0
3	357.5	191.0	111.5	40.5	24.0	430.5	222.0	110.5	36.0	29.0
4	414.5	196.0	116.0	41.0	26.0	476.5	227.5	117.0	36.0	30.0
5	335.5	178.0	108.5	38.5	23.5	396.0	208.0	108.0	34.0	27.0
6	386.5	192.0	114.0	39.5	26.0	445.0	216.0	116.0	37.0	29.0
7	346.0	183.5	112.0	40.5	24.0	418.5	209.5	111.0	35.0	28.5
8	380.0	188.5	112.5	42.0	24.0	443.0	214.0	109.0	35.0	28.0
9	360.0	194.0	113.0	40.0	23.0	424.5	216.0	113.0	36.0	28.0
10	367.5	192.0	113.0	41.0	24.0	435.0	214.0	116.0	38.0	29.0
12	307.5	176.5	106.0	36.5	23.0	340.0	203.0	103.0	33.5	26.5
13	334.0	180.5	107.0	39.5	23.0	373.5	208.0	104.0	33.5	27.0
14	328.0	181.5	108.5	38.0	23.0	367.5	206.5	108.0	35.0	26.5
15	337.5	182.5	104.0	38.5	22.0	379.0	212.0	101.0	31.0	26.5
16	293.5	177.0	101.0	36.0	23.0	347.0	206.5	104.5	33.0	27.0
Mean	350.97	185.5	110.17	39.63	23.70	407.37	212.33	109.70	34.77	28.07

APPENDIX III C (continued)

BONE STUDIES

Steer	Average X-ray measurements of lumbar vertebrae									Breaking strength of		Breaking	
	Transverse process			Vertebrae		Length of Mamillary	Vertical process		Length of transverse process X length	Cannon bones		Moments	
No.	Length	Area	Width	Length	Width	process	Length	Width	of Vertical process	Fore	Hind	Fore	Hind
1956													
1	20.45	4.70	2.78	5.39	2.99	3.60	7.40	3.37	169.13	31.75	24.00	47.63	36.00
2	21.21	4.20	3.08	5.64	3.23	3.79	6.94	3.78	146.92	34.35	26.60	51.53	39.90
3	23.10	4.70	3.27	5.59	2.77	3.89	6.96	3.77	160.40	41.90	27.50	62.85	41.25
4	22.14	4.42	2.97	5.32	2.56	3.41	6.74	3.66	148.87	36.50	27.70	54.75	41.55
5	24.14	4.79	3.13	5.36	2.61	3.95	7.57	3.76	182.62	36.55	25.50	54.83	38.25
6	23.98	5.60	3.55	5.70	2.88	4.09	7.58	4.01	182.99	35.65	27.30	53.48	40.95
7	23.10	4.63	2.99	5.35	3.04	3.90	7.16	3.66	165.02	31.50	22.35	47.25	33.53
8	23.09	4.88	3.40	5.43	2.67	3.91	7.16	3.82	164.41	24.85	19.20	37.28	28.80
9	22.89	4.64	3.02	5.43	2.84	3.85	7.20	3.62	164.10	34.00	23.45	51.00	35.18
10	23.59	4.53	2.89	5.18	2.92	3.89	7.32	3.56	172.92	30.65	24.65	45.98	36.98
11	22.04	4.11	2.72	5.13	2.85	3.66	7.22	3.20	158.89	29.55	25.00	44.33	37.50
12	22.27	4.69	3.25	5.50	2.64	3.78	7.19	3.91	159.07	36.20	27.60	54.30	41.40
13	21.09	3.74	2.76	4.99	2.70	3.70	7.02	3.36	148.01	29.10	24.60	43.65	36.90
14	23.28	5.00	3.29	5.62	2.58	4.01	7.22	4.00	168.30	35.30	25.60	52.95	38.40
15	23.53	4.42	2.74	5.26	2.92	3.54	6.96	3.43	162.91	27.25	22.80	40.88	34.20
16	23.60	4.83	3.33	5.67	2.85	4.00	7.44	4.03	175.14	45.45	31.90	61.18	47.85
Mean	22.72	4.62	3.07	5.41	2.82	3.81	7.19	3.68	164.36	33.72	25.36	50.24	38.04
1957													
1	21.68	3.83	2.80	5.27	3.01	3.60	7.22	2.66	156.44	24.75	34.45	30.94	43.06
2	24.79	5.68	3.49	5.98	2.89	4.00	--	--	--	28.10	39.20	35.13	49.00
3	23.49	5.10	3.34	5.86	2.76	3.84	--	--	--	33.60	39.40	42.00	49.25
4	24.51	5.16	3.23	5.71	2.86	4.02	--	--	--	32.20	36.95	40.25	46.19
5	20.62	3.77	2.95	5.38	2.75	3.58	--	--	--	30.35	41.25	37.94	51.56
6	25.20	4.94	2.97	5.89	2.95	3.82	8.04	3.76	202.29	32.70	37.00	40.88	46.25
7	22.88	4.65	2.99	5.62	2.73	3.65	7.00	2.66	159.89	24.65	37.70	30.81	47.13
8	23.64	4.59	3.01	5.85	2.75	3.91	--	--	--	30.05	42.10	37.50	52.63
9	21.84	4.20	3.07	5.50	2.56	3.56	6.96	3.84	151.57	26.15	38.65	32.69	48.31
10	21.80	4.26	3.19	--	--	3.98	--	--	--	30.95	42.50	38.69	53.13
12	20.17	3.89	2.93	5.12	2.84	3.50	7.59	3.30	157.78	31.10	32.15	38.88	40.19
13	22.16	4.18	3.10	5.59	2.58	3.45	6.89	3.68	152.75	26.60	32.60	33.25	40.75
14	23.46	4.87	3.17	5.64	2.70	3.71	7.08	3.84	165.43	36.40	36.20	45.50	45.25
15	21.34	4.02	3.04	5.72	2.83	3.72	6.68	4.07	142.19	27.20	40.60	34.00	50.75
16	---	--	--	--	--	3.59	7.76	3.11	--	28.60	33.45	35.75	41.81
Mean	22.68	4.51	3.09	5.62	2.78	3.73	7.25	3.44	160.42	29.56	37.61	36.95	47.02

APPENDIX IV A
TENDERNESS STUDIES

Steer No.	Longissimus dorsi muscle % Cooking Loss	Longissimus dorsi muscle Hot Shear	Longissimus dorsi muscle Cold Shear	Longissimus dorsi muscle Muscle Extensibility	Longissimus dorsi muscle No. of Chews	Semitendenosis muscle % Cooking Loss	Semitendenosis muscle Hot Shear	Semitendenosis muscle Cold Shear	Semitendenosis muscle Muscle Extensibility
1956									
1	26.75	6.53	3.99	4.80	20.56	28.24	7.78	6.76	7.35
2	21.49	5.63	5.34	5.40	20.12	26.05	7.22	5.11	1.25
3	22.83	6.00	4.21	3.60	22.38	30.87	8.04	5.24	6.00
4	21.83	4.85	3.66	4.25	23.69	31.85	7.68	5.39	4.45
5	24.84	5.69	5.01	5.70	26.06	30.37	7.68	5.39	4.45
6	15.81	5.53	4.13	3.65	22.00	29.17	7.88	5.18	4.50
7	21.40	6.84	4.99	3.90	29.38	27.33	9.24	5.33	6.65
8	28.45	7.85	4.79	6.65	28.81	29.86	7.44	5.73	7.35
9	30.87	5.60	3.78	5.85	24.06	31.10	6.60	6.29	5.65
10	24.42	6.69	5.44	4.00	25.18	28.60	6.71	4.39	6.55
11	33.65	7.57	4.51	4.70	24.38	31.34	6.74	5.84	4.40
12	24.51	6.85	5.24	5.90	25.12	30.76	8.54	4.76	6.05
13	24.26	4.66	4.50	3.15	23.00	34.68	8.58	7.00	7.45
14	26.56	5.48	3.83	3.85	22.56	33.86	6.79	5.16	6.20
15	22.68	6.33	4.98	4.30	29.56	33.27	8.79	5.88	3.50
16	24.42	7.58	5.30	8.45	23.88	30.03	8.18	6.84	5.55
Mean	24.67	6.23	4.61	4.88	24.42	32.34	7.74	5.64	5.46
1957									
1	24.28	8.34	8.53	3.05	32.35	32.74	5.96	7.50	7.00
2	26.65	7.91	9.75	4.70	32.20	32.37	5.50	6.71	7.45
3	27.81	6.13	7.88	5.15	30.20	37.10	6.50	8.75	7.25
4	22.51	6.88	8.34	3.80	31.95	34.44	6.25	6.21	8.25
5	27.56	8.22	8.81	5.45	31.20	32.97	6.32	6.96	10.05
6	25.97	4.06	5.78	4.40	25.40	36.04	6.11	6.61	6.40
7	27.44	5.78	5.97	3.60	27.35	32.52	6.07	6.89	5.70
8	26.04	4.97	8.41	4.75	34.20	32.95	6.04	5.93	7.75
9	27.23	4.97	6.38	4.85	25.05	32.88	5.25	5.36	7.70
10	27.38	4.44	5.78	2.80	24.70	36.59	6.96	7.86	8.40
12	26.42	5.88	9.16	3.55	28.60	34.37	5.86	5.90	8.35
13	21.84	5.31	7.56	2.95	28.90	32.15	6.82	6.50	7.25
14	26.79	9.19	10.09	7.55	31.65	34.67	7.56	7.86	--
15	24.75	4.66	6.19	6.15	26.05	30.20	6.07	7.46	8.55
16	26.26	5.38	7.22	4.95	28.85	33.30	5.82	7.00	7.60
Mean	25.93	6.14	7.72	4.51	29.24	33.69	6.21	6.90	7.18