A STUDY OF TENDERNESS VARIATION IN CERTAIN BOVINE MUSCLES

By

JOHN H. MJOSETH

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1951

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1962

A STUDY OF TENDERNESS VARIATION IN CERTAIN BOVINE MUSCLES

Thesis Approved:

R. L. Henrickson
Thesis Adviser

Lowell S. Watts

Joe M. Bowman

Robert MacVicar
Dean of the Graduate School

ACKNOWLEDGMENT

The author wishes to express appreciation to Dr. R. L. Henrickson, Professor of Animal Husbandry, for guidance, assistance and encouragement rendered during this assignment at the university.

Special recognition is accorded to Mrs. Ruby Eager Moore for assistance in the chemical and statistical analysis portion of the study and to the graduate assistants for helpful and timely suggestions.

The author is indebted to his family for their noteworthy encouragement and understanding throughout this program of graduate study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF PLATES

LIST OF FIGURES

INTRODUCTION

Tenderness is recognized as the most desirable quality attribute of meat. Although the problem of tender beef for consumers has been extensively investigated by basic and applied scientists, the knowledge is still incomplete. Tenderness of beef has been attributed to a wide variety of factors: genetic, environmental (exercise, feed and stress), physiological (age), chemical (post-mortem changes), histological and anatomical (connective tissue, muscle fiber diameter and muscle bundle size), processing (cutting, freezing, cooking, and coring) and method of evaluation (mechanical, sensory, chemical).

Variation in tenderness exists not only among carcasses, but among different muscles of a single carcass. Proof of acceptance of this belief lies in the United States Army's Military Specification (Proposed) for boneless, frozen, fabricated beef (seven categories). Muscles known to contain certain types of connective tissue (collagen and elastin) are prepared for serving by the moist heat method of cookery. Cuts from other muscles are prepared by braising, broiling or boiling with the method being determined primarily by the potential tenderness of the specific cut.

Investigations of meat tenderness are similar to other types of research in that the sample material should be uniform in composition and representative of the population from which it was selected. Much work has been done on certain muscles and findings have been based upon

observations of one or more positions of a muscle without taking into account the inherent variation.

This study was undertaken to determine the variation in tenderness within two muscles of the bovine species, the longissimus dorsi and the semitendinosus. The longissimus dorsi, "loin eye" muscle, has long been a primary muscle for meat investigations, primarily due to its great size (length and width), economic importance and ease of removal from the carcass. Less work has been done on the semitendinosus, "eye of the round". Whether the reluctance to use this particular muscle is due to the relatively smaller size, lesser value or more difficulty encountered in removal is not known.

The major objectives of this study were to determine the variation in tenderness, chemical composition, pH, and cooking loss between and within the longissimus dorsi and semitendinosus muscles of the beef animal.

REVIEW OF LITERATURE

The information reported here will be confined, in general, (1) to the variation within and among muscles, and (2) to the present status of knowledge relative to the effect of chemical composition. The review will not be confined to bovine muscles, but will include other investigations involving swine and poultry in an effort to draw on all the existing knowledge.

Muscle Variation

Ginger (1957) summed up the prevalent attitude of some investigators when she stressed the importance of beginning with a uniform sample of meat when imposing experimental treatments, such as aging, freezing and storing for varying periods. The author reported on studies utilizing the longissimus dorsi and the semimembranosus muscles. Position difference in the semimembranosus muscle reportedly had an F value of 4.16** (1% level). The longissimus dorsi muscle was reportedly most tender in the anterior portion and least tender in the center portion. The author felt that the longissimus dorsi muscle presented fewer problems of design for tenderness studies due to its length and width and was, therefore, more useful than the semimembranosus muscle. In later work, Ginger (1958) reported on work accomplished on the semimembranosus, semitendinosus and biceps femoris by taste panel observation and shear measurements for the biceps femoris and semimembranosus. All muscles varied

significantly in tenderness throughout their length. The biceps femoris and semitendinosus had less abrupt changes than the semimembranosus. The anterior half of the biceps femoris and the posterior half of the semitendinosus were quite uniform in taste panel tenderness ratings. The author felt that the biceps femoris and the semitendinosus, being more uniform in tenderness than the semimembranosus, were the muscles to utilize in research. The muscles used in the test were from U. S. Good rounds and were removed from 48 to 72 hours post-mortem.

Sartorius and Child (1938) conducted a tenderness and chemical composition study with beef and pork rib and loin roasts. Results using beef indicated that no significant variation in tenderness existed between the 7-8th, 9-10th and 11-12th rib roasts when only the physical properties of tenderness were measured. Differences in tenderness of the pork loin roasts (loins were divided between the thoracic and lumbar vertebrae with four vertebrae per roast) were minimized by rotating the order of utilization between rib and loin ends.

Ramsbottom, Strandine and Koonz (1945) performed tenderness variation studies on 25 muscles from each of three heifer carcasses grading U. S. Good. The longissimus dorsi muscle was more tender at the posterior and middle than at the anterior end. Shear force readings in pounds were for the posterior, 8.3 ± 0.8; middle, 8.3 ± 0.9; anterior, 10.7 ± 1.4.

Bray and Vail (1942) reported on tenderness variation within muscles of six 700 pound Hereford steers and butcher-type hogs weighing approximately 250 pounds. The investigation revealed that in beef, (1) considerable variation in tenderness existed among animals, (2) the posterior portion of the short loin was more tender than the anterior

portion, (3) the greatest variation existed among cores taken from the longissimus dorsi muscle, and (4) the right side of the carcass was found to be significantly more tender than the left (no explanation given); in pork, (1) considerable variation in tenderness existed among animals and (2) representative samples were difficult to obtain from the posterior portion of the loin.

Eighteen beef short loins were utilized in a test conducted by Blakeslee and Miller (1948) in an effort to determine tenderness values of several different grades of beef. Roasts from the longissimus dorsi muscles were cooked by the oven technique at 350° F to an internal temperature of 136° F. Short loins were found to be less tender at the rib end (corresponding to the middle portion of the entire longissimus dorsi muscle) than at the porterhouse end (corresponding to the posterior portion of the longissimus dorsi muscle). Positions of steaks were not keyed to any particular vertebra, but were taken from four separate locations, posterior to anterior.

Hiner and Hankins (1950) reported on a comprehensive tenderness study utilizing nine muscles (including the longissimus dorsi and semitendinosus muscle) of beef animals varying widely in age. The larger muscles of the round, semimembranosus, semitendinosus and biceps femoris did not differ significantly in tenderness.

Deatherage and Harsham (1947) discounted side to side and within longissimus dorsi muscle variation in efforts to explain irregularity of tenderness/aging time curves. The authors based their belief upon a lack of demonstrated side to side and end to end variation of the longissimus dorsi muscle.

Weir (1953) reported on variation in tenderness of the longissimus

dorsi muscle, right and left, from six hogs slaughtered following uniform handling conditions. The longissimus dorsi muscles right and left were cut into eight equal portions. Samples from each side were cooked in a single testing period by means of a forced-air-circulation oven until an internal muscle temperature of 76.7° C (170° F) was reached. Shear force was measured on one-inch cores by the Warner-Bratzler shear strength apparatus. The results indicated that the anterior and posterior portions of the longissimus dorsi muscle were more tender than the center region. Highly significant differences were found to exist between individually compared locations.

Mackey and Oliver (1954) also reported variation among positions of the same muscle, as well as between muscles and animals. The longissimus dorsi muscle of swine was chosen for its length and size, enabling the investigators to procure as many as 18 or more fairly good size chops. The authors were attempting to establish the degree of uniformity in the longissimus dorsi muscle or the existing gradient so that one would be able to select samples anywhere along the length of the loin and be assured of a representative sample. One section of the experiment, using 54 fresh loin chops showed an analysis of variance for shear force as follows:

Source	df	MS
Total	53	
Animals	2	810.11**
Position	17	14.62**
Error	34	4.93

**Significant at 1% level

Low, non-significant "r" values, .29, .41 and .40, indicated that there was no significant linear trend between chop number and shear strength. The chop differences, as determined by analysis of variance for cooking loss and shear strength, were reportedly due to fluctuation among chops rather than to linear trends. Cooking loss was reported as a linear trend, increasing from rib to loin end for two of the three animals. The results led the authors to conclude that positional effects as detected by experimentation on pork loins could be controlled by an appropriate experimental design.

Paul and Bratzler (1955a) found that the adductor muscle was the most tender in a comparison study between the adductor and semimembranosus muscles of beef. The anterior and center portions of the semimembranosus were the most tender while the posterior was the least tender.

Crown (1953) felt that the inherent cost of material for meat investigations would require one to choose a location representative of the entire carcass in terms of carcass quality. Results from this work indicated that the 12th rib portion of the longissimus dorsi muscle was highly correlated with the previously used 9-10-11th rib cut in determining carcass quality.

Christians (1962) reported that longissimus dorsi muscle steaks from the 12th rib location were more tender than those from the 8th or 9th rib section.

Chemical Composition

Fat Content:

Mackintosh, Hall and Vail (1936) reported that increased finish rendered meat more tender and that the grade and marbling of the carcass

seemed to be related to tenderness. Eighty-one test animals were divided into five groups: mature steers; yearling steers; yearling steers full fed dry lot; yearling steers full fed on pasture; and yearling steers, pasture only. Yearling steers full fed on dry lot possessed the lowest shear force (pounds), highest carcass grade and marbling grade. The authors felt that the Warner-Bratzler shear instrument was an acceptable substitute for the palatability committee when the quality of tenderness alone was being measured.

Contradictory results of previously reported data were later published by Branaman, Hankins and Alexander (1936). Twelve heifers and 12 steers were slaughtered each year for three years in an experiment to determine the importance and influence of finish. The tenderness attribute of beef definitely was not influenced by increased carcass finish.

Hankins and Ellis (1939) reported on a series of tests utilizing 728 cattle. The correlation coefficient was -.108 $\pm$ .025 for the longissimus dorsi muscle of the 9-10-11th rib cut between tenderness and percent fat (ether extract). An "r" value of 0.22 $\pm$ .02 was reported for the entire edible portion of the 9-10-11th rib cut between percent fat (ether extract) and tenderness of the longissimus dorsi muscle. A separate test using 69 cattle of mixed breeding, fed grain and roughage in dry lot, 9-18 months old, revealed an "r" value of -0.07 $\pm$ .08 between the same two factors (percent fat/shear) of the longissimus dorsi muscle. The authors concluded that since none of the correlation coefficients were even moderately high and that inconsistency existed in sign, that variations in tenderness were probably caused by factors other than fatness.

Ramsbottom and Strandine (1948) removed 50 of the larger muscles from three U. S. Good carcasses for a chemical composition and tenderness investigation. The muscles varied widely in fat content with the intercostal muscles having an average fat content of 18.1 percent and the carpi radialis having 1.5 percent fat. The longissimus dorsi and semitendinosus muscles had an average of 6.3 and 2.6 percent fat respectively. Average fat content of all 50 muscles was 5.7 percent.

Cover, King and Butler (1958) performed tenderness studies on the longissimus dorsi muscle from 203 steers in an effort to determine the relationship between carcass grades and fatness to tenderness. Fatness was measured by percent separable fat (finish) and ether extract (marbling). Tenderness was measured organoleptically (taste panel) and mechanically (Warner-Bratzler shear instrument). Low correlation coefficients, inconsistent to sign, were obtained for tenderness rating with separable fat, percent ether extract and carcass grade. The authors concluded that more reliable methods for detecting the tenderness quality of beef were required in view of the fact that carcass grades were designed to classify carcass attributes other than tenderness.

Contradictory results were reported by Palmer et al. (1959) when they found highly significant correlations between marbling and ether extract, taste panel and shear force value in the longissimus dorsi muscle. Highly significant correlations were also obtained between grade and marbling, ether extract, taste panel tenderness and shear force values. Short loin steaks from 536 carcasses, removed 48-72 hours post-mortem, were used in the test.

Walker and Henrickson (1960) reported on percent fat and tenderness values (Warner-Bratzler shear instrument) of the longissimus dorsi

muscle steaks keyed to individual vertebra positions. Results indicated that the anterior end of the muscle was slightly more tender than the posterior end, while the fat content increased from the 13th thoracic vertebra to the 5th lumbar vertebra.

Wierbicki et al., (1956) in tests conducted on 32 animals reported no significant relationship between intramuscular fat and tenderness. The authors felt that intramuscular fat was a sex characteristic rather than a mark of tenderness.

Carpenter et al., (1961) investigated intramuscular fat distribution in the longissimus dorsi of paired pork loins. Samples were keyed to adjoining vertebra with 7th, 13th thoracic and 6th lumbar vertebra utilized separately and the remaining portions forming a composite sample. The 6th lumbar vertebra position in both heavy and light groups was found to contain a significantly higher percentage of fat than the other two positions. The 13th thoracic vertebra position contained the least amount of fat in each case. The authors felt their results tended to support McMeekan (1940).

Husaini et al., (1950a) originally reported a very significant correlation ("r" = +.66) between carcass grade and tenderness. A low but significant correlation ("r" = +.47) existed between marbling and tenderness. The test material consisted of 20 animals which represented wide variations in market grade. Other pertinent information concerning the animals was unobtainable. Later work by Husaini et al., (1950b) refuted the earlier conclusion of a significant correlation between carcass grade and tenderness.

Average fat content of longissimus dorsi and semitendinosus muscles in a test on light muscles from four animals was reported as

2.48 percent and 2.10 percent respectively by Swift and Berman (1959).

Hydrogen Ion Concentration (pH):

Winkler (1939) in conjunction with developing a tenderness measuring device similar to the wooden jaw type of Volodkevich conducted tests on beef and pork muscle injected with solutions of lactic acid and/or ammonia to vary the pH levels. The author felt that definite conclusions should not be drawn on the effect of pH on tenderness due to the limited nature of the experiment. However, the pH and maximum toughness were slightly lower for beef than pork. There was an indication of greater variability in tenderness of beef than of pork with samples at the same pH and from the same animals. Hydrolysis of connective tissue around the fiber bundles was discounted as a primary factor in tenderness.

Husaini et al., (1950a) reported no relationship between tenderness and pH of shortloin steaks from animals with wide grade variation. Average pH value for steaks was 5.53 ± .25. Steaks were aged 14 days at 3.5° C (38° F).

Slightly different results were described by Paul et al., (1952) when they found the six day pH value of semitendinosus and biceps femoris steaks removed from two Prime, two Good and two Commercial carcasses to measure 5.48. Other average readings indicated a decreasing trend with increased storage time. The changes were zero hours, pH 6.68; five hours, pH 6.50; 12 hours, pH 6.3; 24 hours, pH 5.90; 48-53 hours, pH 5.55; and 144-149 hours, pH 5.48.

Wierbicki et al., (1954) reported that the pH of muscle dropped from 7.3-7.4 in the living animal to 5.4-5.6 in the carcass within 48 hours after slaughter and was due to muscle metabolism changing from an

aerobic to an anaerobic state. The drop in pH was reportedly concurrent with the disappearance of adenosine triphosphate (ATP), appearance of lactic acid and inorganic phosphate. Although no direct relationship could be shown, pH and increasing tenderness may be indirectly related. The authors doubted if pH was the primary factor causing increases in tenderness with post-mortem aging.

In a continuation of tests begun in Study I, Paul and Bratzler (1955b) utilized the longissimus dorsi muscle of the previously mentioned carcasses plus longissimus dorsi muscles from two commercial grade cows. The pH was determined on every fourth steak of each muscle. Animal differences in pH values were the only significant values obtained. Average pH values for the six groups ranged from a high of 5.80 to a low of 5.22. The pH differences due to storage, handling and position were not significant. The authors felt that two days of cold storage was adequate to complete the initial drop in pH normally observed in beef after slaughter, while nine days was not sufficiently long enough to cause the slight rise in pH due to increased storage periods observed by Wierbicki et al., (1954).

A correlation of $-0.892 \pm .056$ (P.01) between pH and protein content of eight muscles was reported by Swift and Berman (1959). The longissimus dorsi and semitendinosus muscles had pH values of 5.33 and 5.50 respectively. Overall pH range of eight muscles was 5.50 to 5.79. Additional work by Swift, Berman and Lockett (1960) substantiated their previous work. Correlation of -0.804 ± 0.097** (5% level of significance) between pH and protein content was reported in the second study. Residual glycogen content was largest in muscles attaining the lowest pH values. These same muscles originally contained the largest glycogen

stores.

In a series of tests to determine the relationship between pH and early post-morten tenderness of turkeys, Dodge and Stadelman (1960) reported "r" values of 0.82**, 0.71** and 0.89** for experiments III, IV and V, respectively. The investigators felt that tests on beef carcasses had not yielded significant correlation values between pH and tenderness due to tests not commencing early enough after slaughter.

The primary importance of pH is its relationship with pork processing shrinkage was the conclusion developed by Kauffman et al., (1961). They further reported that muscles which were darker, drier and firmer had relatively higher pH values and shrank less during curing and cooking. These same muscles were more tender and juicy in comparison to pale soft muscles.

The pH values of 50 muscles as reported by Ramsbottom and Strandine (1948) ranged from 5.5 to 6.0 with a mean of 5.7. The longissimus dorsi and the semitendinosus muscles had pH values of 5.70 and 5.50 respectively.

Moisture Content:

Ramsbottom and Strandine (1948) found moisture content varied widely in the 50 muscles of three U. S. Good carcasses. Moisture content ranged from 62.5 percent in the intercostal muscles to 76 percent in the carpi radialis. Moisture content was 72.9 and 73.4 percent for the longissimus dorsi and semitendinosus muscles with 72.2 percent moisture as the overall average for all muscles.

Bramblett et al., (1959) reported moisture content varied from 70.0 percent for the biceps femoris to 74.5 percent for the adductor. Average moisture percent for five raw muscles was given as 72.9 percent. Moisture

content for the semitendinosus muscle at 63° C (145° F) was 73.4 percent (raw) and 69.1 percent (cooked). At 68° C (154° F), moisture content was 73.8 percent (raw) and 66.4 percent (cooked).

Strandine, Koonz and Ramsbottom (1949) reported no positive correlation between tenderness and any of the proximate analyses (fat, protein, water) or pH on 12 different chicken muscles. The authors felt that the chief causes of variation in tenderness were not chemical in nature, but were rather due to differences in the structure and arrangement of the elements both within and outside the muscle fibers.

Swift and Berman (1959) noted that the longissimus dorsi and semitendinosus muscles had 74.15 percent and 74.20 percent moisture in a test of eight muscles from four animals.

Wierbicki et al., (1956) reported moisture averaged 67.03 percent ± 2.19 in a group of six heifers utilized in an investigation involving post-mortem and tenderness changes.

EXPERIMENTAL PROCEDURE

I. Materials

Twelve seventeen-month old Hereford heifers sired by purebred Hereford bulls and out of grade Hereford dams were utilized in the study. The heifers were from a group of cows on a dam nutritional level study conducted by the university. The heifers, originally divided into "high" and "low" level dam nutrition groups, were combined and treated as one uniform sample. Treatment of the heifers from birth to slaughter was identical.

II. Methods

A. Slaughter

The animals were slaughtered in four separate groups at the Oklahoma State Agricultural Experiment Station abattoir during the summer of 1961. Slaughter procedure was in accord with that recommended by the Fourth Annual Reciprocal Meat Conference of 1951. Carcasses were initially chilled to 34° F for 48 hours. All carcasses were split 24 hours after slaughter and ribbed after 48 hours, just prior to being graded by a Federal grader. Cattle and carcass data are presented in Table I. The left side of each carcass was utilized in the study, while the right side provided material for another investigation.

TABLE I

LIVE AND CARCASS DATA FROM INDIVIDUAL HEIFERS

Item	Animal Number 1	2	4	5	6	7	11	12	13	14	15	16	Mean
Age (Days)	511	514	506	525	521	511	498	513	519	519	512	509	513
Live Weight	574	667	723	885	831	698	907	895	755	795	792	778	775
Car. Wt. (Hot)	352.5	406.5	448.0	562.0	528.0	431.0	605.5	576.5	479.0	499.5	493.0	474.0	488.0
Car. Wt. (Chilled)	347.0	397.5	440.5	553.0	519.5	424.5	596.0	567.0	467.0	488.5	487.0	467.0	479.5
Dressing Percent	60.4	59.6	60.9	62.5	62.5	60.8	65.7	63.4	61.8	61.5	61.5	60.0	61.7
Side Weight (R)	176.0	196.0	220.5	280.0	261.0	213.0	299.0	285.0	232.0	247.0	242.0	236.5	240.7
Side Weight (L)	171.0	201.5	220.0	273.0	258.5	211.5	297.0	282.0	235.0	241.5	245.5	230.5	238.9
Car. Grade	G -	G -	Ch	Ch -	Ch +	G +	Ch +	Ch -	Ch -	G	Ch -	G +	
Grade Score[1]	7	7	11	10	12	9	12	10	10	8	10	9	10.4
Marbling Score[2]	3	4	7	5	7	5	7	5	5	4	6	5	5.2
Slaughter Date[3]	7/15	7/29	8/10	9/5	9/5	9/5	7/15	7/15	7/29	7/29	8/10	8/10	

[1]Grade Score: Choice +, 12; Choice, 11; Choice -, 10; Good +, 9; Good, 8; Good -, 7.

[2]Marbling Score: Extremely abundant, 12; very abundant, 11; abundant, 10; moderately abundant, 9; slightly abundant, 8; moderate, 7; modest, 6; small, 5; slight, 4; traces, 3; practially devoid, 2; devoid, 1.

[3]Slaughter Date: All dates cited are 1961.

B. Muscle Removal

The longissimus dorsi and semitendinosus muscles were removed as soon as possible after the carcasses were graded. Each cut was made perpendicular to the dorsal surface between the 5th and 6th thoracic vertebra and again between the 6th lumbar and 1st sacral vertebra. The whole section was then weighed, tagged with identifying information and taken to the cutting room.

The semitendinosus muscle was carefully excised from the round, freed of excess fat and ragged ends, weighed and tagged. Beginning at the origin (pelvic end), the semitendinosus muscle was cut into steaks and numbered in the following manner: steak 1, one-inch thick; steak 2, two-inches thick; and continuing toward the insertion end of the muscle, alternating a one-inch thick steak with a two-inch steak. Steaks numbered 1, 3, 5, and 7, one-inch thick steaks, were used for proximate analysis; while steaks numbered 2, 4 and 6, two-inch thick, were utilized in the shear force test. The semitendinosus steaks were taken to the 34° F cold storage room after cutting.

The longissimus dorsi muscle was cut in the following manner: one-inch thick steaks for proximate analysis beginning with the 6th thoracic vertebra were cut alternately with two-inch thick steaks for shear force test. The first steak for shear force was opposite the 7th thoracic vertebra. Each succeeding steak for proximate analysis and shear force was numbered according to its thoracic or lumbar vertebra location. Steaks numbered 6, 8, 10, 12 (thoracic), and 1, 3 and 5 (lumbar) were used for proximate analysis. Steaks 7, 9, 11, 13 (thoracic), and 2, 4 and 6 (lumbar) were used in the shear force test. The longissimus dorsi steaks were cut using a band saw with the fat and bone

accompanying each steak being removed by hand.

C. Hydrogen Ion Concentration

Steaks were individually identified by tags bearing the following data: animal number, steak location, muscle and study number. The pH readings were taken with a hydrogen ion meter, a Beckman zeromatic line operated instrument using a single surface electrode and a thermal compensator electrode. Three separate readings were taken and reported as an average. Steaks were kept covered and stored at 34° F prior to and after pH readings were taken in an attempt to minimize the variation that might occur due to temperature and humidity changes.

D. Wrapping, Freezing and Storage

All steaks were individually wrapped in .0015 gauge aluminum foil, identified in the previously described manner and placed in a quick freeze room (-20° F) for 12 hours. Steaks were then removed and stored in a small locker at -20° F until utilized. Storage time averaged 13 days between slaughter and shear test and 98 days between slaughter and proximate analysis.

E. Cooking

Steaks were removed from -20° F storage 12 hours prior to cooking and placed into a 34° F cooler for thawing. Some freezer drip loss was evident during the thawing period. No attempt was made to measure this separate from cooking loss.

A Toastmaster automatic fry kettle, model N2115, 230 volt A. C. (Plate I, 1) was filled with approximately three gallons (15 pounds) of a commercially available hydrogenated vegetable shortening. Each

group of steaks (steaks from three carcasses) were cooked in fresh shortening. The fat was preheated to 275° F and this temperature maintained through use of a Taylor deep fat thermometer, model number 5913, calibrated from 100° F to 520° F.

Four steaks were removed from the 34° F cooler just prior to cooking. Drip adhering to the steaks was removed by blotting with paper towels. Steaks were then weighed by use of a Harvard Trip Balance to the nearest 0.5 gram and tagged for identification purposes. A Weston steak thermometer, model 2261, 5.5 inch stem, calibrated from 0° F to 220° F, was inserted into the most central position of the steak (height, width and depth) for use in recording internal temperature. The steaks were then placed into numbered wire baskets (Plate I, 1), which facilitated identification and allowed the thermometer to be viewed throughout the cooking phase. Initial pre-cooked temperature of the steaks ranged from 40° F to 50° F. Two-inch thick steaks from the longissimus dorsi muscle required approximately 20 minutes cooking time to reach an internal temperature of 150° F, while two-inch steaks from the semitendinosus muscle normally required less time. When the correct internal temperature (150° F) was reached, the steaks were removed from the deep fat fryer and placed on individual plates. The steaks were then reweighed and data recorded (Figure 1). Difference between raw and cooked weight was recorded as percent cooking loss of the original or precooked weight. Individual steak cooking times were recorded.

F. Coring and Shearing

Considerable difficulty has been experienced in obtaining uniform individual cores for shear force determinations. A tendency for the

hour glass or concave shape was especially exhibited in cores from the longissimus dorsi muscle, but less frequently in the semitendinosus muscle (Plate III, 2). This condition is practially unavoidable, especially when the hand coring method is followed on medium to rare steaks.

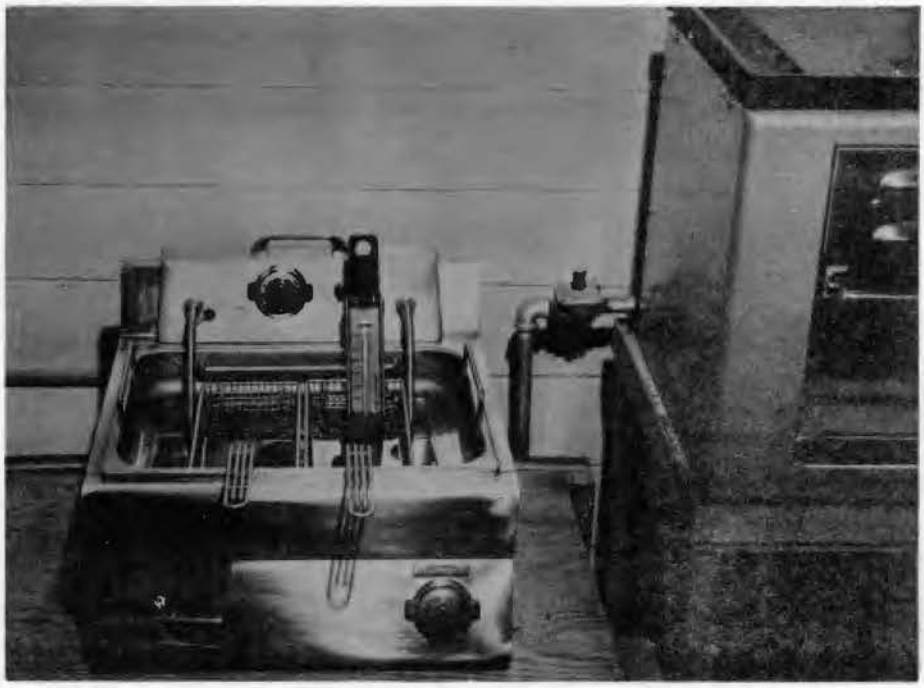
In order to develop a technique to overcome this lack of core uniformity, a Black and Decker one-fourth inch utility drill, 115 volts A. C., 2.0 amps, 2,000 RPM and a Black and Decker drill stand, type 3, were utilized (Plate II). A metal rod attachment (2.0" X 1.0") was machined to the following proportions:

shaft	0.8" X $\frac{1}{4}$"
body	1.2" X 1.0"

Two metal projections, 0.1 of an inch in diameter, extending 0.14 of an inch perpendicular, 180° apart, 0.7 of an inch distant from the terminal end (furthest end away from the shaft) were affixed to the body of the metal male insert. A standard one-inch diameter borer was milled with two recesses in the thickened end to receive the two metal projections. The projections on the male insert hold the borer to the modified "chuck" device during operation and allow the borer to be detached for core removal and cleaning (Plate III, 1). Use of the coring device provided more uniform diameter cores as illustrated in Plate III, 2.

The longissimus dorsi muscle shear steaks were positioned on a 5/8 inch plywood cutting board immediately after reweighing, and the dorsal, medial and lateral cores were taken by use of the powered coring device. The cores of meat were removed from the borer and immediately reinserted into the original cavity of the steak in order to minimize temperature variation. Semitendinosus muscle shear steaks were cored in a similar manner except the three cores had to be removed in somewhat of a circular

PLATE I



1. Deep Fat Fryer With Wire Baskets

2. Warner-Bratzler Shear Instrument

COOKING DATA

Date_____ Project Number_____

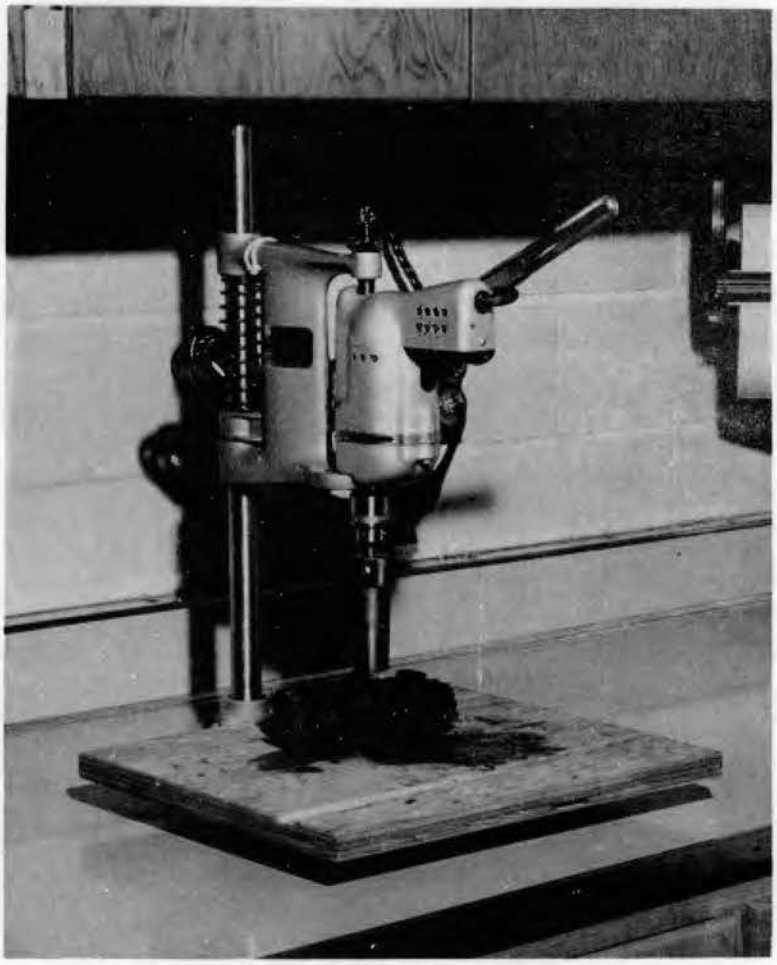
Muscle_____ Side_____ Aged: 14 Days_____ 48 Hours_____

Sample No.	____	____	____	____	____	____	____	____
Precooked Wt.	____	____	____	____	____	____	____	____
Cooked Wt.	____	____	____	____	____	____	____	____
Cooking Loss	____	____	____	____	____	____	____	____
% Cooking Loss	____	____	____	____	____	____	____	____
Cooking Time	____	____	____	____	____	____	____	____
Cooking Temp.	____	____	____	____	____	____	____	____
Beginning	____	____	____	____	____	____	____	____
Middle	____	____	____	____	____	____	____	____
End	____	____	____	____	____	____	____	____
Oven Temp.	____	____	____	____	____	____	____	____
Beginning	____	____	____	____	____	____	____	____
Middle	____	____	____	____	____	____	____	____
End	____	____	____	____	____	____	____	____

Remarks:

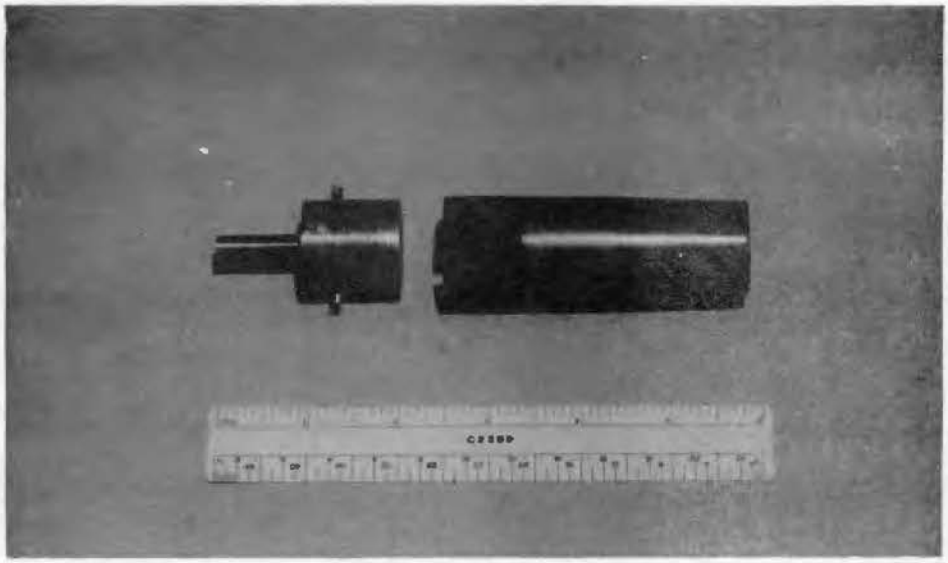
Figure 1. Cooking Data Sheet

PLATE II



Modified Coring Device Ready For Use

P L A T E III



1. Modified Chuck Device and Borer

2. A Comparison of Cores Obtained by Machine and Hand Operation

pattern due to muscle configuration.

Each core was then sheared three times using the Warner-Bratzler shear, (Plate I, 2). Shear force was recorded in pounds on previously prepared data sheets (Figure 2).

G. Chemical

Samples for proximate analysis stored at -20° F were removed, unwrapped, trimmed of excess fat and obvious connective tissue, cut into one-half inch cubes and homogenized by use of a Waring blender to a consistency of thick paste. A tendency for the intra-muscular fat (marbling) to separate out and adhere to the sides of the blender was obviated by blending the samples in a semi-frozen state. Samples were then placed into four-ounce sample jars, identified in the manner previously described and stored at -20° F.

Fat Determination:

Chemical composition was determined by a modification of the proximate analysis procedure by Berman (1960) and is described as follows: fat was determined by use of Paley-Babcock bottles in which the meat sample was digested with a 1:1 mixture of perchloric acid (60%) and glacial acetic acid (99.7%). Duplicate 9.0 gram samples were weighed on a Mettler analytical balance, type H_5 and placed directly into the Paley-Babcock bottles. Thirty c. c. of the acid mixture was added and the solution placed into a 100° C water bath for 30 to 60 minutes or until no particles of the homogenized material could be discerned. Additional acid was added to bring the level of the fluid up in the calibrated neck. The bottles and mixture were then centrifuged for two minutes, then allowed to stand in a 70° C water bath for 15 minutes. Approximately

SHEAR DATA

Date_____ Project Number_____

Muscle_____ Side_____ Aged: 14 Days_____ 48 Hours_____

Sample No.									
Dorsal	1.								
	2.								
	3.								
Total									
Average									
Medial	1.								
	2.								
	3.								
Total									
Average									
Lateral	1.								
	2.								
	3.								
Total									
Average									
Grand Total									
Average									

Remarks:

Figure 2. Shear Data Sheet

one-half ml. of acid mixture was drained down the wall of the calibrated neck which permitted the percent fat to be read directly and easily. The minimum calibration of the Paley-Babcock bottles is 0.2 percent, and was likewise the arbitrarily set maximum allowable fat deviation between duplicate samples. Duplicate samples that differed by more than 0.2 percent were rerun. Only slight difficulty was experienced in obtaining a clear and definite interface (separation) between fat and solution.

Moisture Determination:

Duplicate two gram portions of the recently stirred homogenized meat samples were each weighed and placed into previously tared porcelain crucibles. The samples were then placed into an electric laboratory oven, 115 volts A. C. at 105° C for a period of eight hours. After cooling in a dessicator, the crucibles containing the sample were weighed and the moisture content calculated.

Ash Determination:

Dried samples from previously conducted moisture determinations were introduced into an electric furnace maintained at 510° C for a period of 12 hours. Samples were characterized by a white ash at the end of the ashing period. All samples were cooled in a dessicator, reweighed and percent ash calculated. The porcelain crucibles were rinsed with 12 N HCl, washed, dried and stored in a dessicator prior to use in an attempt to standardize their true weights.

Protein Determination:

Percent protein was obtained by combining averages of the three previously determined variables; percent fat, ash and moisture, for

each location and subtracting from the total or 100 percent.

RESULTS AND DISCUSSION

The longissimus dorsi and semitendinosus muscles demonstrated variation in tenderness, chemical composition, pH and cooking loss both among carcasses and within muscles to varying degrees.

The data demonstrating this variation was primarily resolved by the Analysis of Variance method. Mean values and standard deviation of the means were determined for carcasses and positions. The discussion and tables are separated into (1) longissimus dorsi muscle variations and (2) semitendinosus muscle variations.

Longissimus dorsi Muscle Variations

Shear:

The longissimus dorsi muscle demonstrated a tenderness trend from the 7th to the 11th thoracic vertebrae which was accompanied by the lowest standard deviations. The greatest resistance to shear was at the 13th thoracic vertebra with standard deviations increasing from the 2nd to the 6th lumbar vertebrae positions. Carcass variation, as demonstrated by a mean square (MS) value of 49.32, exerted a greater influence upon tenderness than position variation, MS value of 21.64 (Table II). The results agree essentially with work performed by Blakeslee and Miller (1948), Weir (1953), Ginger (1957), Walker and Henrickson (1961), and is contrary to work accomplished by Ramsbottom, Strandine and Koonz (1945), Hiner and Hankins (1950) and Christians (1962).

TABLE II

VARIATION IN SHEAR FORCE OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2] 7	9	11	13	2	4	6	Mean	St. Dev.
1	17.28	19.90	17.80	18.28	17.66	13.61	15.44	17.14	2.0
2	12.11	10.16	14.21	12.96	10.94	10.24	9.80	11.49	1.7
4	14.67	16.62	20.07	21.74	19.28	22.69	20.04	19.30	2.8
5	17.23	17.64	17.65	18.93	17.49	13.78	15.36	16.87	1.7
6	14.94	12.97	17.38	18.07	17.58	17.85	18.00	16.68	2.0
7	14.37	12.51	17.39	19.08	18.57	16.90	16.61	16.49	2.3
11	16.57	15.19	16.83	14.94	18.70	17.91	12.85	16.14	2.0
12	17.25	17.74	19.42	18.36	19.82	22.83	28.79	20.60	4.0
13	14.35	13.08	16.61	18.63	16.22	22.62	8.67	15.74	4.4
14	15.07	15.25	18.66	20.39	15.79	18.77	18.04	17.42	2.1
15	19.12	18.83	20.92	24.41	24.14	19.51	24.50	21.63	2.6
16	15.96	14.89	20.77	23.02	19.52	19.12	23.77	19.58	3.4
Mean	15.74	15.40	18.14	19.07	17.98	17.99	17.66	17.43	
St. Dev.	1.9	2.9	1.9	3.2	3.1	3.9	6.0		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	1,055.03		
Carcass	11	542.48	49.32	8.50**
Position	6	129.83	21.64	3.73*
Error	66	382.72	5.799	

*P $<$ 0.05

**P $<$ 0.01

Fat:

The fat content (intramuscular) of the muscle exhibited a different trend, highest at the 6th thoracic and 5th lumbar vertebrae positions, and lowest at the 1st lumbar vertebra position. Standard deviations followed this same trend, highest at either end (6th thoracic and 5th lumbar vertebrae) and lowest at the 12th thoracic vertebra. Carcass variation again exerted a greater influence upon percent of fat with a MS value of 21.08 than position variation having a MS value of 8.04 (Table III).

Hydrogen Ion Concentration:

The pH values of steaks used for the proximate analysis, Table IV, and those used for the shear force are shown in Tables XIX and XX, Appendix. No particular gradient was detected for pH values along the length of the muscle. Carcass and position MS values were 0.199 and 0.035 respectively. Standard deviations were extremely uniform throughout the length of the muscle. The range of pH values for the longissimus dorsi muscle ranged from 5.15 to 5.90 (Table XXII) and compares favorably with that reported by Paul and Bratzler (1955).

Moisture:

Percent moisture in the longissimus dorsi muscle varied both among carcasses and within steak positions with MS values of 14.68 and 5.51 respectively. There was a slightly higher percentage of moisture in the center portion of the muscle with a gradual decrease toward either end. Lowest percent moisture (70.6) was found to be at the 5th lumbar vertebra position, which likewise contained the greatest percent of fat (7.2) (Table V).

TABLE III

VARIATION IN PERCENT FAT OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2] 6	8	10	12	1	3	5	Mean	St. Dev.
1	2.5	2.2	2.1	2.9	2.9	4.0	3.2	2.8	0.7
2	3.9	4.3	3.8	3.2	2.3	4.0	6.4	4.0	1.3
4	8.6	7.2	7.3	6.7	7.1	8.8	13.7	8.5	2.4
5	8.4	7.0	6.3	6.2	6.0	8.2	10.[illegible]	7.4	1.5
6	7.2	7.0	7.3	7.5	7.2	7.1	6.9	7.2	0.2
7	6.3	5.2	6.3	4.4	4.1	4.2	4.1	4.9	1.0
11	10.0	5.2	6.8	5.5	5.7	7.9	8.2	7.0	1.8
12	6.1	5.0	5.3	6.0	5.2	5.9	6.8	5.8	0.6
13	6.8	7.1	5.3	4.2	4.1	5.9	6.6	5.7	1.2
14	3.6	4.2	3.4	3.2	2.7	3.1	4.1	3.5	0.5
15	5.8	4.7	4.5	6.1	4.6	6.2	6.1	5.4	0.8
16	6.1	6.7	7.1	6.5	4.6	7.5	10.3	7.0	1.7
Mean	6.3	5.5	5.5	5.2	4.7	6.1	7.2	5.8	
St. Dev.	2.2	1.6	1.7	1.5	1.6	1.9	3.0		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	352.07		
Carcass	11	231.87	21.08	19.34**
Position	6	48.23	8.04	7.38**
Error	66	71.97	1.09	

**P $<$ 0.01

TABLE IV

VARIATION IN pH OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2] 6	8	10	12	1	3	5	Mean	St. Dev.
1	5.48	5.39	5.39	5.23	5.32	5.30	5.27	5.34	0.08
2	5.67	5.54	5.39	5.41	5.39	5.41	5.49	5.47	0.10
4	5.80	5.60	5.73	5.65	5.63	5.85	5.67	5.70	0.10
5	5.47	5.48	5.27	5.26	5.23	5.38	5.33	5.35	0.10
6	5.52	5.43	5.28	5.17	5.32	5.24	5.40	5.34	0.10
7	5.41	5.33	5.37	5.33	5.33	5.28	5.35	5.34	0.04
11	5.41	5.20	5.40	5.26	5.23	5.18	5.40	5.30	0.10
12	5.43	5.33	5.45	5.44	5.58	5.42	5.50	5.45	0.08
13	5.67	5.65	5.58	5.42	5.53	5.52	5.53	5.56	0.08
14	5.60	5.45	5.50	5.49	5.31	5.43	5.43	5.46	0.09
15	5.83	5.77	5.70	5.78	5.68	5.77	5.80	5.76	0.05
16	5.85	5.82	5.65	5.80	5.70	5.70	5.63	5.74	0.09
Mean	5.60	5.50	5.48	5.44	5.44	5.46	5.48	5.48	
St. Dev.	0.20	0.20	0.20	0.20	0.20	0.20	0.20		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	2.75		
Carcass	11	2.19	0.199	36.89**
Position	6	0.213	0.035	6.59**
Error	66	0.356	0.0054	

**P $<$ 0.01

TABLE V

VARIATION IN PERCENT MOISTURE OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2] 6	8	10	12	1	3	5	Mean	St. Dev.
1	74.9	74.9	74.1	74.2	74.0	73.8	74.1	74.29	0.44
2	73.8	73.5	73.9	73.5	73.9	73.6	70.9	73.30	1.20
4	70.4	70.5	71.0	71.0	70.8	70.1	65.6	69.91	1.90
5	69.6	71.1	71.5	71.3	71.5	70.3	68.6	70.56	1.10
6	70.6	72.0	70.9	71.4	71.3	71.0	71.0	71.17	0.45
7	72.0	72.4	71.6	73.8	75.3	73.2	73.5	73.11	1.30
11	70.2	72.4	71.4	72.5	71.9	70.3	69.4	71.16	1.20
12	72.2	72.9	71.9	72.8	72.3	71.7	71.1	72.13	0.63
13	71.7	71.5	72.6	72.7	73.3	71.5	70.9	72.03	0.85
14	74.6	73.2	73.2	73.8	74.4	74.5	73.1	73.83	0.67
15	71.9	72.5	72.6	70.6	72.8	71.0	71.2	71.80	0.87
16	71.3	69.9	69.9	70.3	71.9	69.1	68.1	70.71	1.30
Mean	71.9	72.2	72.1	72.3	72.8	71.7	70.6	71.95	
St. Dev.	1.7	1.4	1.3	1.4	1.4	1.7	2.4		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	242.49		
Carcass	11	161.50	14.68	20.22**
Position	6	33.08	5.51	7.59**
Error	66	47.91	0.726	

**P $\angle$ 0.01

Ash:

Only slight minor differences were noted in the ash content of the steaks. Carcass variation had a MS value of 0.017 while position variation was non-significant. Standard deviations were minor in nature and did not indicate any particular trend (Table VI).

Protein:

Percent protein was greatest at the 1st lumbar vertebra and declined both anteriorly and posteriorly. Carcass variation was evident by a MS value of 1.55 while position variation had a MS value of 0.68 (Table VII).

Cooking Loss:

Percent cooking loss was greatest at the 4th lumbar vertebra and decreased posteriorly and generally anteriorly to a low of 31.1 percent at the 6th thoracic vertebra position. Carcass and position variation had MS values of 15.18 and 24.26 respectively (Table VIII). Mean values for all the variables are contained in Table IX.

Semitendinosus Muscle Variations

Shear:

The semitendinosus muscle was most tender in the center portion with the highest shear rating at the origin (pelvic region) followed by the insertion (shank region). Variation in shear force due to carcass effect had a MS value of 14.80 which was considerably less than the position MS value of 23.76 (Table X). This trend is contradictory to results observed in the longissimus dorsi muscle. Standard deviations were fairly uniform in the shear steaks with the smallest standard deviation corresponding

TABLE VI

VARIATION IN PERCENT ASH OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2] 6	8	10	12	1	3	5	Mean	St. Dev.
1	1.09	1.03	1.17	1.04	1.13	0.94	1.04	1.06	0.08
2	1.07	1.08	1.07	1.25	1.04	1.04	1.03	1.08	0.08
4	0.90	0.99	0.97	1.21	0.91	0.87	0.95	0.97	0.10
5	0.95	1.00	1.17	1.07	1.05	1.05	0.83	1.02	0.10
6	1.02	1.13	1.09	0.90	0.99	0.87	1.10	1.01	0.10
7	1.05	1.04	0.89	1.06	0.91	0.81	1.00	0.97	0.09
11	0.91	1.01	1.01	1.00	1.00	0.79	0.86	0.94	0.09
12	1.00	0.89	1.06	1.11	1.09	0.98	1.11	1.03	0.08
13	1.01	0.77	0.72	0.97	0.93	1.05	1.02	0.92	0.20
14	0.96	1.01	1.15	1.09	1.01	1.07	1.06	1.05	0.02
15	0.99	1.10	1.04	0.95	1.03	1.02	0.90	1.00	0.02
16	1.01	1.10	1.06	0.97	1.13	0.94	0.98	1.03	0.07
Mean	1.00	1.01	1.03	1.05	1.02	0.95	1.00	1.00	
St. Dev.	0.06	0.10	0.14	0.10	0.08	0.10	0.10		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	0.781		
Carcass	11	0.184	0.017	2.12*
Position	6	0.074	0.012	1.57NS
Error	66	0.522	0.008	

*P $\leq$ 0.05

TABLE VII

VARIATION IN PERCENT PROTEIN OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1,2]

Carcass Number	Vertebra Position[3] 6	8	10	12	1	3	5	Mean	St. Dev.
1	21.50	21.85	22.62	21.84	21.97	21.27	21.62	21.81	0.43
2	21.36	21.10	21.27	22.05	22.72	21.41	21.63	21.65	0.57
4	20.08	21.33	20.70	21.07	21.24	20.23	19.71	20.62	0.63
5	21.07	20.94	21.04	21.42	21.41	20.49	20.59	20.99	0.36
6	21.16	19.92	20.75	20.17	20.56	21.04	21.02	20.66	0.44
7	20.67	21.37	21.18	20.73	19.65	21.78	21.42	20.97	0.70
11	18.87	21.37	20.82	21.04	21.43	21.03	21.50	20.87	0.90
12	20.67	21.18	21.71	20.13	21.38	21.42	21.02	21.07	0.53
13	20.48	20.64	21.38	22.12	21.65	21.54	21.48	21.33	0.58
14	20.80	21.63	22.27	21.88	21.87	21.38	21.77	21.66	0.46
15	21.33	21.71	21.88	22.34	21.59	21.75	21.77	21.77	0.30
16	21.59	22.32	21.99	22.23	22.38	22.43	20.64	21.94	0.65
Mean	20.80	21.28	21.47	21.42	21.49	21.31	21.18	21.28	
St. Dev.	0.80	0.60	0.60	0.80	0.80	0.60	0.60		

[1]Protein determined by difference.
[2]Hereford heifers 17 months of age grading good to choice.
[3]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	40.59		
Carcass	11	17.10	1.55	5.28**
Position	6	4.09	0.68	2.32*
Error	66	19.41	0.294	

*P $\leq$ 0.05

**P $\leq$ 0.01

TABLE VIII

VARIATION IN PERCENT COOKING LOSS OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2] 7	9	11	13	2	4	6	Mean	St. Dev.
1	30.6	28.9	35.6	37.0	37.3	39.7	37.7	35.26	4.00
2	27.4	25.2	35.7	34.3	31.0	34.1	34.5	31.70	4.00
4	32.5	35.0	34.8	37.1	34.4	37.8	33.0	34.90	2.00
5	30.7	29.9	31.2	34.1	34.1	37.6	34.1	33.10	2.70
6	36.7	36.1	36.9	36.2	36.4	32.5	33.7	35.50	1.70
7	25.5	34.0	38.2	37.4	33.9	34.6	36.9	34.36	4.30
11	30.1	36.7	30.3	34.0	32.2	31.9	26.7	31.70	3.20
12	34.6	35.2	28.6	37.3	36.7	35.7	35.6	34.81	2.89
13	36.3	34.1	20.5	22.3	33.6	38.4	36.3	31.60	7.20
14	31.1	34.1	36.8	34.6	33.2	36.4	32.0	34.00	2.10
15	30.7	34.8	29.5	34.7	37.5	35.1	28.5	33.00	3.40
16	26.5	28.5	35.9	34.5	32.6	29.7	37.6	32.19	4.10
Mean	31.1	32.7	32.8	34.5	34.4	35.3	33.9	33.52	
St. Dev.	3.6	3.6	5.1	4.1	2.1	3.0	3.4		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	83	1,168.75		
Carcass	11	166.94	15.18	1.17NS
Position	6	145.57	24.26	1.87NS
Error	66	856.24	12.97	

TABLE IX

MEAN VALUES OF SEVEN VARIABLES FOR THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Variable	Vertebra Position 6	7	8	9	10	11	12	13	1	2	3	4	5	6	Mean
Shear (lbs.)		15.7		15.4		18.1		19.1		18.0		18.0		17.7	17.4
Fat (%)	6.3		5.5		5.5		5.2		4.7		6.1		7.2		5.8
pH	5.60	5.54	5.50	5.43	5.48	5.41	5.44	5.38	5.44	5.41	5.46	5.45	5.48	5.49	5.46
Moisture (%)	71.9		72.2		72.1		72.3		72.8		71.7		70.6		72.0
Ash (%)	1.00		1.01		1.03		1.05		1.02		0.95		1.00		1.00
Protein (%)	20.8		21.3		21.5		21.4		21.5		21.3		21.2		21.3
Cooking Loss (%)		31.1		32.7		32.8		34.5		34.4		35.3		33.9	33.5

[1] Hereford heifers 17 months of age grading good to choice.

TABLE X

VARIATION IN SHEAR FORCE OF THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2] 2	4	6	Mean	St. Dev.
1	19.71	16.19	17.77	17.89	1.8
2	17.78	16.97	17.11	17.29	0.4
4	20.71	16.91	20.17	19.26	2.1
5	24.57	18.78	24.73	22.69	3.4
6	23.58	19.28	20.10	20.99	2.3
7	19.27	21.02	19.61	19.97	0.9
11	21.46	15.59	17.99	18.35	3.0
12	24.67	21.23	22.98	22.96	1.7
13	22.53	18.57	19.62	20.24	2.0
14	19.08	17.63	20.38	19.03	1.4
15	25.56	23.12	25.32	24.67	1.3
16	19.91	20.49	22.54	20.98	1.4
Mean	21.57	18.82	20.69	20.36	
St. Dev.	2.6	2.3	2.7		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	35	255.96		
Carcass	11	162.81	14.80	7.15**
Position	2	47.52	23.76	11.48**
Error	22	45.63	2.07	

**P $<$ 0.01

to the most tender central steak.

Fat:

The fat content (intramuscular) exhibited an anterior to posterior trend with highest percentage of fat at the 5th steak position and decreasing to the least amount of fat in the most posterior steak. The carcass influence was again less than that exerted by the position effect with MS values of 3.97 and 14.32 respectively (Table XI). Standard deviations were fairly uniform with smallest variation at the origin and insertion ends. Standard deviations were identical for the center two steaks which likewise had the greatest percent of fat.

Hydrogen Ion Concentration:

No trend was observed in the pH values of steaks from various locations within the muscle. The carcass influence had a MS value of 0.040 while the position effect MS value was 0.002 (Table XII). Standard deviations were extremely uniform for all steak positions. The composite pH values with the Analysis of Variance are contained in Tables XX and XXI, Appendix.

Moisture:

Percent moisture was greatest at either extremity (origin and insertion) and least at the middle two steak positions. Positional effect with a MS value of 10.51 exerted much greater influence than carcass effect with a MS value of 1.99 (Table XIII).

Ash:

Minor, non-significant, differences were observed both for carcass and position effect with MS values of 0.011 and 0.007 respectively

TABLE XI

VARIATION IN PERCENT FAT OF THE SEMITENTINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2] 1	3	5	7	Mean	St. Dev.
1	2.1	3.8	3.2	1.6	2.7	1.0
2	3.1	4.3	4.5	3.0	3.7	0.8
4	4.5	6.5	7.5	3.6	5.5	1.8
5	4.0	4.8	4.6	2.6	3.9	1.0
6	3.5	4.2	4.2	2.1	3.5	1.0
7	1.8	3.3	5.1	2.0	3.1	1.5
11	5.1	7.0	6.0	3.1	5.3	1.7
12	3.0	6.0	6.3	2.8	4.5	1.9
13	2.2	5.3	5.3	1.2	3.5	2.1
14	2.2	3.3	3.1	1.9	2.6	0.7
15	2.0	2.2	4.8	1.9	2.7	1.4
16	4.0	2.6	2.0	3.1	2.9	0.9
Mean	3.1	4.4	4.7	2.4	3.7	
St. Dev.	1.1	1.5	1.5	0.7		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	47	112.63		
Carcass	11	43.65	3.97	5.03**
Position	3	42.96	14.32	18.13**
Error	33	26.02	0.79	

**P $\leq$ 0.01

TABLE XII

VARIATION IN pH OF THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2] 1	3	5	7	Mean	St. Dev.
1	5.20	5.22	5.30	5.32	5.26	0.06
2	5.50	5.50	5.44	5.53	5.49	0.03
4	5.50	5.43	5.40	5.50	5.46	0.05
5	5.46	5.38	5.32	5.39	5.39	0.05
6	5.28	5.40	5.37	5.41	5.37	0.02
7	5.43	5.41	5.39	5.34	5.39	0.04
11	5.37	5.33	5.28	5.29	5.32	0.04
12	5.25	5.31	5.24	5.27	5.27	0.03
13	5.58	5.48	5.56	5.58	5.55	0.04
14	5.53	5.49	5.50	5.22	5.44	0.20
15	5.48	5.40	5.53	5.53	5.49	0.02
16	5.63	5.50	5.57	5.53	5.56	0.05
Mean	5.43	5.40	5.41	5.41	5.41	
St. Dev.	0.10	0.09	0.10	0.10		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	47	0.588		
Carcass	11	0.443	0.040	9.57**
Position	3	0.007	0.002	0.55NS
Error	33	0.138	0.004	

**P $<$ 0.01

TABLE XIII

VARIATION IN PERCENT MOISTURE OF THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2] 1	3	5	7	Mean	St. Dev.
1	75.3	73.3	74.9	75.6	74.78	1.00
2	73.7	73.6	73.6	75.0	73.98	0.69
4	73.5	71.8	71.3	74.0	72.65	1.30
5	73.6	73.4	72.4	75.1	73.62	1.10
6	73.6	73.4	73.4	76.1	74.12	1.30
7	74.7	74.1	72.2	75.7	74.18	1.47
11	72.7	71.4	71.9	74.5	73.62	1.35
12	74.1	72.2	72.2	74.7	73.30	1.29
13	75.3	73.1	72.7	75.8	74.22	1.55
14	74.5	73.8	74.5	76.1	74.72	0.97
15	74.8	73.8	73.1	74.0	73.92	0.70
16	72.2	72.8	74.6	73.7	73.32	1.05
Mean	74.0	73.1	73.1	75.0	73.79	
St. Dev.	0.97	0.85	1.16	0.85		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	47	72.47		
Carcass	11	21.95	1.99	3.47**
Position	3	31.53	10.51	18.27**
Error	33	18.99	0.575	

**P $\angle$ 0.01

(Table XIV).

Protein:

Percent protein, highest at the first steak position, decreased slightly in an anterior to posterior direction to the 5th steak position where it then increased slightly to the last steak. Carcass variation, with a MS value of 1.19 demonstrated a slightly greater influence than position variation, MS value of 0.87 (Table XV). The 3rd steak position exhibited a slightly higher standard deviation than the other three positions.

Cooking Loss:

Percent cooking loss was greatest in the center steak position and decreased slightly toward both the origin and the insertion ends of the muscle. Position effect with a MS value of 1.62 had little influence on cooking loss while carcass effect had a MS value of 35.27 (Table XVI). Mean values for variables are contained in Table XVII.

Fewer semitendinosus muscle steaks were available for investigation than the longissimus dorsi muscle due to the former's shorter length. This may be partially overcome by reducing steak thickness by one-half for both the proximate analysis and shear force steaks.

A summary of "F" values for seven variables of the longissimus dorsi and semitendinosus muscles is contained in Table XVIII. Higher values due to carcass effect rather than position effect were obtained for the longissimus dorsi muscle. The reverse was true for the shear force, fat and moisture content of the semitendinosus muscle.

TABLE XIV

VARIATION IN PERCENT ASH OF THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2] 1	3	5	7	Mean	St. Dev.
1	1.02	0.96	0.97	1.12	1.02	0.07
2	1.16	1.00	1.17	1.08	1.10	0.08
4	0.99	1.12	1.04	1.14	1.07	0.07
5	1.11	1.06	1.18	1.12	1.12	0.05
6	1.00	1.20	0.94	1.08	1.06	0.10
7	1.01	1.08	0.94	1.08	1.03	0.07
11	1.07	1.11	1.02	1.15	1.09	0.06
12	1.06	0.92	0.91	1.13	1.01	0.10
13	1.15	1.00	1.18	1.18	1.13	0.08
14	0.91	1.15	0.90	0.97	0.98	0.10
15	0.96	1.25	1.20	1.19	1.15	0.10
16	1.11	1.03	1.11	0.90	1.04	0.10
Mean	1.05	1.07	1.05	1.10	1.07	
St. Dev.	0.08	0.10	0.10	0.08		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	47	0.418		
Carcass	11	0.123	0.011	1.34NS
Position	3	0.020	0.007	0.80NS
Error	33	0.275	0.008	

TABLE XV

VARIATION IN PERCENT PROTEIN OF THE SEMITENDINOSUS MUSCLE OF BEEF[1,2]

Carcass Number	Steak Position[3] 1	3	5	7	Mean	St. Dev.
1	21.58	21.90	20.98	21.65	21.53	0.40
2	22.09	21.10	20.77	20.97	21.23	0.58
4	21.03	20.59	20.15	21.28	20.76	0.50
5	21.32	20.79	21.87	21.18	21.29	0.45
6	21.90	21.20	21.42	20.72	21.31	0.50
7	22.53	21.51	21.75	21.26	21.76	0.54
11	21.10	20.48	21.11	21.21	20.98	0.33
12	21.82	20.85	20.59	21.39	21.16	0.55
13	21.34	20.65	20.86	21.79	21.16	0.51
14	22.40	21.80	21.47	21.00	21.67	0.59
15	22.24	22.75	20.94	22.91	22.21	0.90
16	22.69	23.58	22.30	22.28	22.71	0.61
Mean	21.84	21.43	21.18	21.47	21.48	
St. Dev.	0.57	0.95	0.60	0.62		

[1]Protein determined by difference.
[2]Hereford heifers 17 months of age grading good to choice.
[3]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	47	24.10		
Carcass	11	13.07	1.19	4.66**
Position	3	2.60	0.87	3.41*
Error	33	8.42	0.255	

*P $\leq$ 0.05

**P $\leq$ 0.01

TABLE XVI

VARIATION IN PERCENT COOKING LOSS OF THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2] 2	4	6	Mean	St. Dev.
1	29.7	27.1	26.0	27.6	1.9
2	31.4	25.1	26.8	27.8	3.2
4	30.7	24.8	30.4	28.6	3.4
5	37.7	37.4	38.2	37.8	0.4
6	36.6	38.5	39.0	38.0	1.3
7	31.0	29.2	35.5	31.9	3.2
11	34.1	35.6	27.3	32.3	4.5
12	25.3	36.4	31.5	31.1	5.5
13	32.2	33.6	30.4	32.1	1.6
14	33.3	38.7	31.5	34.5	3.8
15	29.5	36.2	36.4	34.0	3.9
16	32.1	29.4	32.5	31.3	1.7
Mean	31.97	32.67	32.13	32.25	
St. Dev.	3.3	5.2	4.4		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.

Analysis of Variance

Source	df	SS	MS	F-Test
Total	35	633.91		
Carcass	11	387.99	35.27	3.20**
Position	2	3.23	1.62	0.15NS
Error	22	242.69	11.03	

**P $<$ 0.01

TABLE XVII

MEAN VALUES OF SEVEN VARIABLES FOR THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Variable	Steak Position 1	2	3	4	5	6	7	Mean
Shear (lbs.)		21.6		18.8		20.7		20.4
Fat (%)	3.1		4.4		4.7		2.4	3.7
pH	5.43	5.41	5.40	5.39	5.41	5.40	5.41	5.41
Moisture (%)	74.0		73.1		73.1		75.0	73.8
Ash (%)	1.05		1.07		1.05		1.10	1.07
Protein (%)	21.8		21.4		21.2		21.5	21.5
Cooking Loss (%)		32.00		32.7		32.1		32.2

[1]Hereford heifers 17 months of age grading good to choice.

TABLE XVIII

"F" VALUE SUMMARY FOR SEVEN VARIABLES OF THE LONGISSIMUS DORSI AND SEMITENDINOSUS MUSCLES OF BEEF[1]

Variable	Carcass[2]		Position[2]	
	Ld	St	Ld	St
Shear (lbs.)	8.50**	7.15**	3.73*	11.48**
Fat (%)	19.34**	5.03**	7.38**	18.13**
pH	36.89**	9.57**	6.59**	0.54NS
pH (composite)	70.83**	14.67**	6.60**	0.43NS
Moisture (%)	20.22**	3.47**	7.59**	18.27**
Ash (%)	2.12*	1.34NS	1.57NS	0.80NS
Protein (%)	5.28**	4.65**	2.31*	3.40*
Cooking Loss (%)	1.17NS	3.20**	1.87NS	0.15NS

[1]Hereford heifers 17 months of age grading good to choice.

[2]Longissimus dorsi (Ld), Semitendinosus (St).

*P $\leq$ 0.05

**P $\leq$ 0.01

NS - Non-Significance

SUMMARY

Two muscles, the longissimus dorsi and the semitendinosus, from the left side of 12 Hereford heifer carcasses were studied to determine the variation in tenderness, gross chemical composition, pH and cooking loss due to carcass and position effect.

The amount of variation accounted for by carcass differences in the longissimus dorsi muscle was greater for all variables except cooking loss than that accounted for by steak position. Six out of eight of the variables exhibited highly significant differences ($P < 0.01$) among carcasses. Percent of ash was the only variable significantly different ($P < 0.05$), while percent cooking loss was the only non-significant variable. This would indicate that factors such as marbling score, carcass grade, weight, and sex are relatively poor indicators of uniformity in tenderness and/or chemical composition.

The position variation, while exerting less influence than carcass effect, did show highly significant differences ($P < 0.01$) for percent fat, pH and percent moisture. Position effect for shear force and percent protein was significantly different ($P < 0.05$), whereas percent ash and percent cooking loss were non-significant variables.

The reverse was true in the semitendinosus muscle with position effect exerting a greater influence than carcass effect. Shear force, percent fat and percent moisture varied more due to position than to carcass influence. Percent ash, pH, percent cooking loss, and composite

pH were non-significant for position effect, while the longissimus dorsi muscle had only percent ash and percent cooking loss as non-significant variables for position effect.

Variation due to carcass effect of the semitendinosus muscle was highly significant ($P \leq 0.01$) in seven of eight variables. Percent ash was the only non-significant variable.

The results indicate that the posterior portion of the longissimus dorsi muscle of beef may be the best suited for tenderness studies in which animal variation is of prime importance. Position variation of the longissimus dorsi muscle was highly significant in many cases, but the position effect of the semitendinosus muscle was much greater for important variables such as shear force, percent fat and percent moisture.

The longissimus dorsi muscle's 13th thoracic and 1st lumbar vertebrae region may offer researchers a challenging opportunity for improvement in tenderness and fat deposition. This site contained the least percent of fat (intramuscular) and had the greatest resistance to shear. Sample acquisition does not appear to represent an economical problem due to the proximity of this area to where a carcass is normally ribbed. Improvement in tenderness and fat deposition at this location by utilizing selection techniques may result in corresponding improvement in other regions of the muscle.

The semitendinosus muscle may be of more value than the longissimus dorsi muscle in investigations that subject the sample steaks to various treatments, such as effect of freezing and varying storage periods.

The use of the mechanical coring device, for all practical purposes, eliminated core diameter variation. Uniform diameter of cores was the rule rather than the exception. Modification of the borer and use of

the chuck device with the drill and drillstand permitted economies both in actual coring time and lag time between coring and shearing. This reduction in time in addition to the elimination of core diameter variation may well serve to reduce experimental error due to technique.

CONCLUSIONS

I. That the longissimus dorsi muscle may be more suited for tenderness studies when carcass differences are being determined than the semitendinosus muscle due to the following:

1. Greater uniformity exhibited throughout its length.
2. The possibility of obtaining more samples due to its greater length.

II. That further work be performed utilizing greater number of carcasses.

III. That consideration be given to increasing the number of semitendinosus muscle steaks available for testing by the following:

1. Using one-half inch thick steaks for proximate analysis.
2. Using one-inch thick steaks for shear force determinations.

IV. That further use be made of the mechanical coring device to reduce time lag between coring and shearing in an effort to eliminate variation due to experimental technique.

A SELECTED BIBLIOGRAPHY

Association of Official Agricultural Chemists. Official and Tentative Methods of Analysis. 6th ed. 1945. Association of Official Agricultural Chemists, Washington, D. C.

Bate-Smith, E. C. 1938. Report of the Food Investigation Board. Dept. Sci. Ind. Research. (Brit) (e) 15.

Berman, M. D. 1960. Determination of the proximate and electrolyte content of beef. Food Technol. 14:9.

Blakeslee, L. H., and J. I. Miller. 1948. Shear tenderness tests on beef short loins. J. Animal Sci. 7:517. (Abstract).

Brady, D. E. 1937. Study of the factors influencing tenderness and texture of beef. Proc. Amer. Soc. Animal Prod. 30:246.

Bramblett, V. D., R. L. Hostetler, G. E. Vail, and H. N. Draudt. 1959. Qualities of beef as affected by cooking at very low temperatures for long periods of time. Food Technol. 13:12.

Branaman, G. A., O. G. Hankins, and L. M. Alexander. 1936. The relation of degree of finish in cattle to production and meat flavors. Proc. Amer. Soc. Animal Prod. 295:300.

Bratzler, L. J. 1932. Measuring the tenderness of meat by means of a mechanical shear. M. S. Thesis, Kansas State University.

Bray, R. W., G. E. Vail and D. L. Mackintosh. 1942. Influence of freezing upon tenderness in aged beef. J. Animal Sci. 1:81. (Abstract).

Callow, E. H. 1952. Frozen meat. J. Sci. Food Agr. 3:145.

Carpenter, J. A., R. L. Saffle, and L. D. Kamstra. 1960. Tenderization of beef by pre-rigor infusion of a chelating agent. Food Technol. 15:4.

Carpenter, Z. L., R. W. Bray, E. J. Briskey, and D. H. Traeder. 1961. Intramuscular fat distribution in the longissimus dorsi of paired pork loins. J. Animal Sci. 20:603.

Christians, C. J. 1962. Factors affecting beef carcass traits. Ph. D. Thesis. Oklahoma State University.

Cover, S., O. D. Butler, and T. C. Cartwright. 1956. The relationship of fatness in yearling steers to juiciness and tenderness of broiled and braised steaks. J. Animal Sci. 15:464.

_____, G. T. King, and O. D. Butler. 1958. Effect of carcass grades and fatness on tenderness of meat from steers of known history. Texas Agr. Exp. Bul. 889.

Crown, R. M. 1953. A preliminary study of carcass quality data from the 12th ribs of beef as compared to that of the 9-10-11th rib cuts. J. Animal Sci. 12:901. (Abstract).

Deans, R. J. 1951. A recommended procedure for slaughtering experimental cattle. Reciprocal Meat Conference Proceedings 4:81.

Deatherage, F. E. and A. Harsham. 1947. Relation of tenderness of beef to aging time at 33-35° F. Food Res. 12:2.

Dodge, J. W. and W. J. Stadelman. 1960. Relationship between pH, tenderness and moisture levels during early post-mortem aging of turkey meat. Food Technol. 14:1.

Emerson, J. A., A. M. Pearson, J. A. Hoefer, and L. J. Bratzler. 1961. Carcass characteristics of 100-200 pound hogs. J. Animal Sci. 20:4. (Abstract).

Ginger, B. 1957. Four Symposia: meat processing, nutrition, beef tenderization, irradiation. A. M. I. F. Cir. 35:61.

_____ and C. Weir. 1958. Variations in tenderness within three muscles from beef rounds. Food Res. 23:662.

Hall, J. L., E. E. Latschar, and D. L. Mackintosh. 1944. Characteristics of dark cutting beef. Survey and preliminary investigation. Kansas Agr. Exp. Sta. Tech. Bul. 58.

Hankins, O. G. and N. R. Ellis. 1939. Fat in relation to quantity and quality factors of meat animal carcasses. Proc. Amer. Soc. Animal Prod. 32:314.

_____ and H. W. Titus. 1939. Growth, fattening, and meat production. U. S. Dept. of Agri. Yearbook. 450.

_____ and R. L. Hiner. 1940. Freezing makes beef tenderer. Food Inds. 12:49.

Harrison, D. L., R. Visser, and L. Shirmer. 1959. A resume of the literature related to factors affecting the tenderness of certain beef muscles. Kansas Agr. Exp. Report No. 10.

Hiner, R. L. and O. G. Hankins. 1950. The tenderness of beef in relation to different muscles and age in the animal. J. Animal Sci. 9:347.

Husaini, S. A., F. E. Deatherage, L. E. Kunkle, and H. N. Draudt. 1950a. Studies on meat. I. The biochemistry of beef as related to tenderness. Food Technol. 4:7.

_____, F. E. Deatherage, and L. E. Kunkle. 1950b. Studies on meat. II. Observations on relation of bio-chemical factors to changes in tenderness. Food Technol. 4:9.

Joubert, D. M. 1956. An analysis of factors influencing post natal growth and development of the muscle fiber. J. Agr. Sci. 47:59.

Kauffman, R. G., Z. L. Carpenter, R. W. Bray, and W. G. Hoekstra. 1961. pH of chilled, aged and cooked pork as related to quality. J. Animal Sci. 20:4. (Abstract).

Lehmann, K. B. 1907. Studies of the toughness of meat and its causes. Arch. Hyg. 63:134.

Lowe, B. 1955. Experimental Cookery. 4th Ed. John Wiley and Son, Inc., New York, p. 216.

Mackey, A. O. and A. W. Oliver. 1954. Sampling pork loin for cooking tests. Food Res. 19:298.

Mackintosh, D. L., J. L. Hall, and G. E. Vail. 1936. Some observations pertaining to tenderness of meat. Proc. Amer. Soc. Animal Prod. 29:285.

McMeekan, C. P. 1940. Growth and development in the pig with special reference to carcass quality characters. J. Agr. Sci. 30:276.

Palmer, A. Z., J. W. Carpenter, R. L. Alsmeyer, H. L. Champman, and W. G. Kirk. 1959. Simple correlations between carcass grade, marbling, ether extract of loin eye, and beef tenderness. J. Animal Sci. 17:1153. (Abstract).

Paul, P., L. J. Bratzler, E. D. Farwell, and K. Knight. 1952. Studies on tenderness of beef. I. Rate of heat penetration. Food Res. 17:504.

_____ and L. J. Bratzler. 1955a. Studies on tenderness of beef. II. Varying storage times and conditions. Food Res. 20:626.

_____ and L. J. Bratzler. 1955b. Studies on tenderness of beef. III. Size of shear cores: end to end variations in the semimembranosus and adductor. Food Res. 20:635.

Ramsbottom, J. M., E. J. Strandine, and C. H. Koonz. 1945. Comparative tenderness of representative beef muscles. Food Res. 10:497.

_____ and E. J. Strandine. 1948. Comparative tenderness and identification of muscles in wholesale beef cuts. Food Res. 13:4.

Satorius, M. J. and A. M. Child. 1938. Problems in meat research. I. Four comparable cuts from one animal. II. Reliability of judges' scores. Food Res. 3:627.

Snedecor, G. W. 1956. Statistical Methods. 5th Ed. The Iowa State College Press, Ames, Iowa.

Strandine, E. J., C. H. Koonz, and J. M. Ramsbottom. 1949. A study of variations in muscles of beef and chicken. J. Animal Sci. 8:483.

Swift, C. E. and M. D. Berman. 1959. Factors affecting the water retention of beef. I. Variations in composition and properties among eight muscles. Food Technol. 13:7.

_____, M. D. Berman and C. Lockett. 1960. Factors affecting the water retention of beef. II. Variation in some pH determinants among eight muscles. Food Technol. 14:2.

Walker, M. and R. L. Henrickson. 1960. Unpublished data. Oklahoma Agri. Exp. Sta.

Wang, H., E. Rasch, and V. Bates. 1954. Histological observations on fat loci and distribution in cooked beef. Food Res. 19:314.

Weir, C. E. 1953. The variation in tenderness in the longissimus dorsi muscle of pork. Food Technol. 7:12.

Wellington, G. H. and J. R. Stouffer. 1959. Beef marbling, its estimation and influence on tenderness and juiciness. Cornell Univ. Agri. Exp. Sta. Bul. 941.

Wierbicki, E., L. E. Kunkle, V. R. Cahill, and F. E. Deatherage. 1954. The relation of tenderness to protein alteration during post-mortem aging. Food Technol. 8:11.

_____, L. E. Kunkle, V. R. Cahill, and F. E. Deatherage. 1956. Post-mortem changes in meat and their possible relation to tenderness together with some comparisons of meat from heifers, bulls, steers and diethylstilbesterol treated bulls and steers. Food Technol. 10:2.

Winkler, C. A. 1939. Tenderness of meat. I. A recording apparatus for its estimation and relation between pH and tenderness. Can. J. Research 17:8.

Wismer-Pedersen, J. 1959. Quality of pork in relation to rate of pH change post-mortem. Food Res. 24:711.

A P P E N D I X

TABLE XIX

COMPOSITE pH VALUES OF THE LONGISSIMUS DORSI MUSCLE OF BEEF[1]

Carcass Number	Vertebra Position[2,3]														Mean	St. Dev.
	6	7	8	9	10	11	12	13	1	2	3	4	5	6		
1	5.48	5.41	5.39	5.41	5.39	5.16	5.23	5.15	5.32	5.30	5.30	5.32	5.27	5.19	5.31	0.10
2	5.67	5.59	5.54	5.25	5.39	5.43	5.41	5.31	5.39	5.45	5.41	5.43	5.49	5.50	5.45	0.10
4	5.80	5.82	5.60	5.73	5.73	5.50	5.65	5.77	5.63	5.67	5.85	5.62	5.67	5.85	5.71	0.10
5	5.47	5.47	5.48	5.20	5.27	5.30	5.26	5.26	5.23	4.22	5.38	5.35	5.33	5.37	5.33	0.10
6	5.52	5.23	5.43	5.40	5.28	5.24	5.17	5.20	5.32	5.22	5.24	5.33	5.40	5.33	5.28	0.10
7	5.41	5.49	5.33	5.27	5.37	5.23	5.33	5.36	5.33	5.24	5.28	5.30	5.35	5.30	5.33	0.07
11	5.41	5.33	5.20	5.22	5.40	5.26	5.26	5.17	5.23	5.30	5.18	5.34	5.40	5.38	5.29	0.09
12	5.43	5.28	5.33	5.30	5.45	5.37	5.44	5.30	5.58	5.32	5.42	5.50	5.50	5.54	5.41	0.10
13	5.67	5.60	5.65	5.47	5.58	5.37	5.42	5.36	5.53	5.51	5.52	5.47	5.53	5.49	5.51	0.09
14	5.60	5.58	5.45	5.49	5.50	5.40	5.49	5.30	5.31	5.40	5.43	5.40	5.43	5.53	5.45	0.09
15	5.83	5.88	5.77	5.67	5.70	5.73	5.78	5.70	5.68	5.57	5.77	5.67	5.80	5.67	5.73	0.08
16	5.85	5.77	5.82	5.70	5.65	5.90	5.80	5.68	5.70	5.67	5.70	5.70	5.63	5.72	5.74	0.08
Mean	5.60	5.54	5.50	5.43	5.48	5.41	5.44	5.38	5.44	5.41	5.46	5.45	5.48	5.49	5.46	
St. Dev.	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.10	0.20	0.20		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from anterior to posterior.
[3]Includes pH values for shear steaks number 7, 9, 11, 13, 2, 4, and 6.

TABLE XX

ANALYSIS OF VARIANCE FOR COMPOSITE pH VALUES OF TWO MUSCLES OF BEEF[1]

Longissimus dorsi				
Source	df	SS	MS	F-Test
Total	167	5.87		
Carcass	11	4.53	0.412	70.83**
Position	13	0.500	0.038	6.60**
Error	142	0.832	0.006	

Semitendinosus				
Source	df	SS	MS	F-Test
Total	83	1.09		
Carcass	11	0.762	0.693	14.67**
Position	6	0.012	0.002	0.43NS
Error	66	0.312	0.005	

[1]Hereford heifers 17 months of age grading good to choice.

**P $<$ 0.01

TABLE XXI

COMPOSITE pH VALUES OF THE SEMITENDINOSUS MUSCLE OF BEEF[1]

Carcass Number	Steak Position[2,3]							Mean	St. Dev.
	1	2	3	4	5	6	7		
1	5.20	5.12	5.22	5.28	5.30	5.27	5.32	5.24	0.20
2	5.50	5.56	5.50	5.50	5.44	5.52	5.53	5.51	0.04
4	5.50	5.55	5.43	5.63	5.40	5.47	5.50	5.50	0.08
5	5.46	5.31	5.38	5.35	5.32	5.35	5.39	5.37	0.05
6	5.28	5.27	5.40	5.33	5.37	5.42	5.41	5.35	0.06
7	5.43	5.38	5.41	5.35	5.39	5.27	5.34	5.37	0.05
11	5.37	5.33	5.33	5.24	5.28	5.30	5.29	5.31	0.04
12	5.25	5.35	5.31	5.23	5.24	5.32	5.27	5.28	0.05
13	5.58	5.48	5.48	5.31	5.56	5.54	5.58	5.50	0.10
14	5.53	5.55	5.49	5.54	5.50	5.45	5.22	5.47	0.10
15	5.48	5.53	5.40	5.47	5.53	5.47	5.53	5.49	0.05
16	5.63	5.50	5.50	5.47	5.57	5.43	5.53	5.52	0.07
Mean	5.43	5.41	5.40	5.39	5.41	5.40	5.41	5.41	
St. Dev.	0.10	0.22	0.09	0.10	0.10	0.09	0.10		

[1]Hereford heifers 17 months of age grading good to choice.
[2]Steaks were cut from origin to insertion.
[3]Includes pH values for shear steaks number 2, 4, and 6.

TABLE XXII

RANGES FOR SEVEN VARIABLES IN LONGISSIMUS DORSI AND SEMITENDINOSUS STEAKS[1]

Variables	No. of Steaks[2] Ld	St	Ranges Longissimus dorsi	Semitendinosus
Shear Force (lbs.)	84	36	8.67 - 28.79	15.59 - 25.56
Fat (%)	84	48	2.10 - 13.7	1.20 - 7.50
Moisture (%)	84	48	65.6 - 75.3	71.30 - 75.3
Ash (%)	84	48	0.72 - 1.21	0.90 - 1.25
Protein (%)	84	48	18.87 - 22.72	20.15 - 23.58
Cooking Loss (%)	84	36	20.5 - 39.7	24.8 - 39.0
Composite pH	168	84	5.15 - 5.90	5.12 - 5.63

[1]Includes steaks from 12 Hereford heifers 17 months of age grading good to choice.

[2]Longissimus dorsi (Ld), Semitendinosus (St).

VITA

JOHN HOWARD MJOSETH

Candidate for the Degree of

Master of Science

Thesis: A STUDY OF TENDERNESS VARIATION IN CERTAIN BOVINE MUSCLES

Major Field: Meats Science

Biographical:

Personal Data: Born November 22, 1927, at Fort Worth, Texas, the eldest son of Bernard Cook and Eva Nelson Mjoseth. Married to Claudene Ferrell on June 7, 1951.

Education: Attended grade school in Forth Worth, Texas. Graduated from Arlington Heights High School, Fort Worth, in 1945. Attended Texas Agricultural and Mechanical College, Tarleton State College; received the Bachelor of Science degree from Oklahoma State University with a major in Animal Husbandry in August, 1951. Military education includes: Battery Officer's Course, The Artillery School, Fort Sill, Oklahoma; Company Grade Officer's Course, Petroleum Analysis Course and Associate Advanced Officer's Course at the Quartermaster School, Fort Lee, Virginia. Assigned to Civilian Student Detachment, Headquarters, Fourth U. S. Army with duty station Oklahoma State University in August, 1960 to May, 1962.

Professional Experience: Entered the United States Army from college in 1951 and now holds rank of captain in the United States Army Quartermaster Corps. Overseas assignments have been Korea 1952-1953 and Federal Republic of West Germany 1956-1959.