A STUDY OF VARIOUS CHEMICAL AND HISTOLOGICAL CHARACTERISTICS OF BEEF MUSCLE AND THEIR RELATIONSHIPS TO PALATABILITY

by

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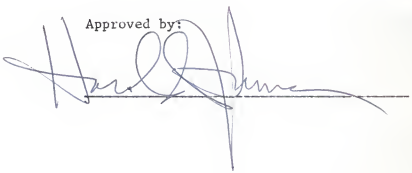

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

INTRODUCTION

Beef quality, which is still determined by visual appraisal, is used as an indicator of tenderness and the consumer demands a consistently tender product. However, the validity of using marbling and maturity as the two major predictors of quality has been challenged.

Changes in management and shorter feeding periods have resulted in younger slaughter cattle than in the past which emphasizes the need for new research to re-evaluate the maturity-marbling relationship.

The revised Federal grade standards of 1965 reflected the latest research information available regarding the effect of maturity on beef palatability. The rate of increase in required marbling to offset increasing maturity was changed by reducing the minimum marbling permitted for more mature block beef carcasses.

There is still a need for additional information on the effect of the 12-36 month ages (A-B maturity) on tenderness because most of our block beef comes from this age range.

Studies by meat researchers are continually being conducted to provide the merchandiser and consumer with more precise and objective methods for quality determination. Various histological measurements and chemical analysis as predictors of beef tenderness now appear promising.

The objectives of this study were to provide further information on the maturity and marbling relationship by evaluating the following: (1) limited maturity and marbling levels as associated with tenderness; and (2) the anatomical location effect on various histological and chemical factors and their relationship to tenderness.

REVIEW OF LITERATURE

Maturity

Chronological age and physiological maturity are not synonymous although they frequently are used as such by researchers and industry. Chronological age is determined by the calendar age of the animal while the physiological age (maturity) of carcass beef is determined by the visual characteristics of bone, cartilage and muscle. Blumer (1963) stated that although this subjective evaluation is less accurate than desired it recognizes that carcasses differ with respect to the influence of sex, nutrition and other biological factors.

Brady (1937); Hiner and Hankins (1950); Hiner et al (1955) and Tuma et al (1963) have indicated that when beef from a wide range in chronological age (2 1/2 months to old cows) was used, tenderness decreased as animal age increased. This was not found to be true by other workers, Nelson et al (1930) and Ritchey and Hostetler (1964), using meat from carcasses typical of cattle slaughtered for block beef (12-42 months). Both of these concepts were supported by Field (1966). He reported that when you compare beef from extreme age differences (one year to old cows) tenderness would decrease as age increased, but when cattle from the block beef slaughter age (300-699 days of age in his study) were used, no significant tenderness effects due to age were present.

Alsmeyer et al (1959) conducted a study involving 502 cattle varying in ages from 5-30 months. They observed, within the devoid, slight, small and modest degrees of marbling, positive but nonsignificant relationships between tenderness and animal age at slaughter. Also, they found an increase in age, as such, was not associated with a decrease in tenderness.

Palmer (1963), studying the effect of age, used 538 calves, steers,

heifers, cows and bulls from 5-99 months of age (average of 19.9 months) representing the major beef breeds and various crosses of these breeds. He found that (with a few exceptions) all correlations between age and tenderness, within the various degrees of marbling, lacked significance and were often inconsistent to sign.

Moe et al (1964) observed that chronological age was not related to sensory evaluations when the maturity range was limited (yearlings). Walter et al (1965) observed that wide extremes in maturity influenced the eating quality of beef more than the wide extremes in marbling. They found no differences between A and B maturity levels for tenderness (before the new grade standards of 1965).

Romans et al (1965) studied A, B, C and D physiological maturity levels (prior to the 1965 grade standards) and two marbling levels (slight and moderate) and found that neither maturity, marbling, nor core location had a significant effect on tenderness as determined by the Warner-Bratzler shear, even though a trend for the more mature carcasses to be less tender was present. However, they concluded, "the commonly accepted hypotheses that marbling and maturity tend to counterbalance one another with regard to their effects on beef tenderness was not clearly evident in the maturity and marbling levels studied". Walter et al (1963) discovered the same trends while studying A, B and F maturity. Tuma et al (1962a) reported that both tenderness evaluations, Warner-Bratzler shear and taste panel, revealed a greater decrease in tenderness between the 18 and 42 month age groups than between the 42 and 90 month old groups. Therefore, they suggested that animal age may be more critical with regard to tenderness at a point between 18-42 months of age. Simone et al (1959) indicated this critical age for tenderness may fall in the range of 18-20 months.

Many unanswered questions regarding these two factors and their interrelationships with other quality factors remain for further investigation.

Marbling

Blumer (1963) in a review article stated that a reasonable estimate of 1-36% (average of 5%) of the variation in panel tenderness values could be explained by marbling. Barbella et al (1939); Wanderstock and Miller (1948); Husaini et al (1950) and Batterman et al (1952) (utilizing ages from young calves to old cows) indicated differences in tenderness, caused by marbling, to be very small and often nonsignificant. Cover et al (1956) in a study using 38 yearling steers stated that tenderness scores were more closely correlated with other "fatness" measures. They reported that the correlation between the degree of marbling and the Warner-Bratzler shear score was -.22 which was nonsignificant.

Branaman et al (1936) detected no relationship between marbling and tenderness. They did, however, observe that flavor and juiciness tended to increase with an increase in marbling. Cover et al (1956), (1958) using 203 beef carcasses of variable but known histories have found significant, although low, correlation coefficients between ether extract in muscle and the various palatability characteristics.

A study by Gilpin et al (1965), involving the 9-10-11 rib cuts from 20 carcasses varying in weight and marbling, reported that the degree of marbling for an individual steak did not always coincide with the marbling score for the carcass from which it was taken. They further asserted that marbling varied between adjacent steaks. Therefore, they concluded that the variation of marbling within a muscle, coupled with its poor association with intra-muscular fat, indicated that marbling may be inadequate as an index of carcass

quality. Furthermore, they found that steaks from highly marbled carcasses to be scored only slightly more tender, juicy and more flavorful than steaks with low marbling.

Walter et al (1965) found that nearly 85% of the variation in ether extract was due to marbling (r=0.92). This indicated that subjective marbling values were in close agreement with objective measurements. They found no differences in ether extract or moisture between the left and right sides but did find that tenderness decreased with advancing maturity (A, B and F). Tenderness was, however, not significantly affected by marbling. In view of the wide range of marbling (6 marbling scores) in their study, they stated that some effect of marbling on tenderness should have been detected.

Tuma et al (1962a) in a study with 18, 42 and 90 month age groups observed that the marbling levels used (slight and slightly abundant) did not significantly influence the tenderness of the longissimus steaks as evaluated by the taste panel. However, the shear values were significantly ($P<0.05$) lower (or more tender) for steaks from the slightly abundant marbled carcasses.

Many studies have been made to determine just how the moisture-ether extract relationship is related to meat tenderness. Lush (1926) indicated that the percent of "true" fat in fatty tissue increases as an animal becomes fatter and the percentage of other constituents (mainly water) of the fatty tissue decreases. Gilpin et al (1965), employing high and low degrees of marbling in 15-26 month old cattle observed that the moisture in the longissimus muscle of high marbled carcasses was less than in low marbled carcasses. They also found that the marbling score of the rib steak was associated with the percent of moisture in the muscle (r=-.75) and that 65% of the variation in percent ether extract was associated with moisture in the muscle. In a similar study by Walter et al (1965), using A, B and F maturity groups and 6 marbling scores,

the percent water decreased as the percent ether extract and marbling scores increased. Although moisture was not significantly influenced by carcass maturity, the means did decrease slightly with advancing maturity.

Romans et al (1965) found the "moderate" marbling group had significantly more fat and less moisture than the "slight" level of marbling.

Tuma et al (1961a) found that muscle from 6 month old calves had a greater moisture content than 90 month old cows. Goll et al (1963) also reported younger animals to have more moisture than mature animals. Walter et al (1965) stated that on a fat-free basis the moisture content changes very little after an animal reaches 15-18 months of age.

Protein and Ash

Romans et al (1965) disclosed that the percent protein for the A maturity group was significantly lower than for the B, C and D maturity groups. Tuma et al (1962b), using animals selected for a constant marbling level, reported that moisture, protein and fat content did not differ significantly among the age groups of 18, 42 and 90 month old animals.

Water Holding Capacity

Research has indicated that the water holding capacity of meat may influence its flavor, juiciness and tenderness. Water holding capacity may be defined as the ability of meat to hold fast its own or added water during application of any force (pressing, heating, chewing, grinding, etc.).

Wierbicki (1956) stated that all properties of meat of prime importance to the processor and consumer are primarily related to the water holding capacity of the meat protein.

Swift (1959) found the moisture to protein ratio to be directly related to water retention. Hamm (1960) suggested the amount of water bound to the tissues,

rather than the amount of expressible juice, may be related to juiciness of meat. Hamm (1960) and Moe et al (1964) found that water holding capacity was not significantly related to the percent protein.

Hamm (1959) indicated that water holding capacity of muscle is the interaction between the proteins and water. He explained that water is a dipole (negative charge of oxygen and positive charge of hydrogen that do not coincide); therefore, water is a molecular magnet. This magnet is then attracted by all kinds of polar groups in the protein. Not all charged groups, however, may bind water. Groups that compensate their charges by an inter-molecular or intra-molecular salt cross-linkage are not available for dipole water molecules. Therefore, only the net charge of protein has an influence on the water holding capacity. Consequently, water holding capacity is not determined by the amount of protein but the condition of the protein present.

Gaddis et al (1950) noted that possibly the juiciness-palatability factor is not influenced as much by amount of juice as by chemical composition of muscle. They also noted that fat added flavor, which stimulated saliva and increased the impression of juiciness during the chewing process.

Moe et al (1964) estimated water holding capacity by the following three methods: (1) a modification of the expressible moisture determination of Hamm (1956); (2) procedure similar to above but using 1000 gram balance weight on plexiglass plates; and (3) modification of the method of Wierbicki et al (1957). He found that water holding capacity was not strongly related to moisture, protein or fat content of meat.

Previously the press method had been used to determine the amount of expressible juice in meat and its relationship to panel tenderness or juiciness. Gaddis et al (1950) used amount of expressed juice from a 50-100 gram meat sample as an indicator of juiciness and found the relationships were generally

quite poor. Wierbicki and Deatherage (1958) used a modification of the Grau and Hamm (1953) filter paper technique for determining water holding capacity. Both were an attempt to measure the same characteristics.

Tuma et al (1962a) obtained the water holding capacity from the longissimus muscle of cattle 6, 18, 42 and 90 months of age by using a Carver Press and a modified version of the Wierbicki and Deatherage filter paper technique (1958). They found the moisture ring to meat ring ratios were divided into two distinct pairs. The 6 month and 18 month age ratios were much smaller than those for the 42 month and 90 month old animals, with little differences noted in the moisture ring areas. The correlation coefficients between moisture ring area and panel tenderness were low, but all negative, thus indicating that those samples with the smallest moisture areas (more bound water) were the most tender.

Core Location

Conflicting results seem to prevail among researchers as to the "within" muscle core location effect of tenderness. Alsmeyer et al (1965) found the beef longissimus muscle to be more tender at the dorsal location when he was comparing the effects of the STE (slice tenderness evaluator) and Warner-Bratzler shear methods. Tuma et al (1962a) partially disagreed with this by reporting a study using 33 Herefords varying in age from 6 month old calves to 90 month old cows. They stated, "the dorsal to lateral decrease in fiber diameter was prevalent for both 48 hour and 14 day postmortem samples studied. If tenderness and shear are closely related, the shear value would likely decrease laterally however, the reverse was true for the 14 day postmortem samples". They did find, for the 48 hour samples, that the dorsal position had the lowest shear value.

Walter et al (1965), using the longissimus muscle with considerable range

in marbling score, compared the cross-section position effect (medial, intermediate and lateral) and found the lateral to be significantly less tender.

Howard (1966) in a study comparing Holstein to Angus steers found the longissimus muscle from Holstein steers to be less tender than that of the Angus steers and the medial position to be less tender than the lateral position in both breeds.

Romans et al (1965) perceived no significant longissimus muscle core location (medial, central and lateral) differences in shear tenderness for the four maturity groups (A, B, C and D) which they studied.

Ramsbottom et al (1945) and Cover and Hostetler (1960) have reported that the same beef muscles do not always respond alike to shear forces even when cooked the same way.

Brady (1937); Ramsbottom et al (1946) and Tuma et al (1962), have reported that shear force values and tenderness vary from one area to another within a muscle.

Fiber Diameter

Early attempts to classify tenderness were based on the theory that it could be explained on the basis of histological appearance. Brady (1937) conducted a histology-tenderness study using triceps brachi, longissimus dorsi, adductor and semimembranoses muscles from 7 mature grade Holstein cows. He found a significant difference in fiber diameters for steers and cows ($58.5 \pm 1.8\mu$ and $70.8 \pm 1.8\mu$ respectively), but no differences were observed in the diameters of the fibers from the different muscles studied. The relationship between fiber diameter and tenderness was low, although large fibers were significantly correlated with less tender beef. This was verified later by Hiner et al (1953) when they reported that as age increased, fiber diameter increased.

Their study was conducted using ages ranging from 10 week old calves to 9 year old cows and they stated that there was a significant fiber diameter-tenderness relationship, that is, as fiber diameter increased in size tenderness decreased correspondingly.

An investigation by Tuma et al (1962a) using 33 Herefords from five different age groups (6-42 months) disclosed a gradual increase in fiber diameter for the longissimus muscle with increasing age. Their study indicated that the larger the fiber diameter, the higher the shear force when the data is uncorrected for animal age. They stated however, that when the effect of age was removed, the correlations varied from -.22 to 0.47 for fiber diameter and shear force within any one age group. They also observed a waviness of the muscle fibers in 40% of the samples (range of waviness within the samples 0-85%) with a predominance for animals 18 months and older. In addition to these factors, they found a statistically significant ($P<.005$) "position effect" (dorsal, medial and lateral) for fiber diameters of the longissimus dorsi muscle. The averages were 68.1, 65.1 and 62.2 microns for the dorsal, medial and lateral respectively.

Joubert (1956) reported muscle fiber diameter to be more closely associated with muscle weight ($r=.86$) than age of animal ($r=.75$), live weight ($r=.83$) or carcass weight ($r=.76$).

Swanson (1965) performed a study with both right and left ribs and short loins from five good grade carcasses weighing 500-600 pounds. He studied both position and location effects and found that a great deal of variation existed in muscle fiber size both among different positions along the longissimus dorsi muscle and among different locations within each position. He felt the results indicated that studies pertaining to muscle fiber diameter or meat texture should carefully consider sampling procedures. He also discovered large and

significant differences in the longissimus muscle fiber size among animals of the same weight and grade.

Romans et al (1965) revealed fiber diameter to be larger in muscles with moderate amounts of marbling than for those with a slight amount. They reported a trend toward larger fiber diameters from the longissimus muscle of the more mature carcasses (A, B, C and D maturity groups), but fiber diameter was not significantly correlated with tenderness.

Even though there have been numerous studies conducted to determine the relationship between fiber diameter, age and tenderness, it seems quite evident that further research should be conducted to establish more substantial data.

Sarcomere Length

Sarcomere length, used as a measure of muscle contraction, was suggested to be related to beef tenderness by Locker (1960). The sarcomere length is only a gross indicator of the molecular changes occuring in the actin and myosin filaments of the muscle fiber. It was shown, however, to be related to tenderness by Herring et al (1965) in a study with contracted vs. stretched muscles. They found short sarcomere lengths, as compared to long (1.8μ vs. 3.5μ), were less tender. They indicated that the extremely long sarcomeres may be particularly significant in relation to ultimate tenderness in view of the structural changes which may be involved.

Ramsbottom et al (1945) and Herring et al (1965) were in reasonable agreement when they reported that those muscles which increased in sarcomere length and had a corresponding decrease in fiber diameter also tended to show a decrease in shear force. Herring et al (1965), in a study using 12 bovine muscles from sides horizontally placed and vertically suspended, found a simple correlation of -.28 ($P<.01$) between sarcomere length and tenderness as measured by

the Warner-Bratzler shear. When the effect between muscle variation was removed, the correlation was -.46, indicating that sarcomere length was a factor affecting shear force.

An investigation conducted by Howard (1966), using the longissimus muscle from 20 Angus and 20 Holstein steers weighing approximately 1000 pounds, compared the relationship of sarcomere length to other known predictors of tenderness. He reported that breed and muscle position were highly significant sources of variance for sarcomere length measurements. The Holstein muscles had shorter sarcomeres than Angus muscles; the medial positions (1.79μ) in the muscles had shorter sarcomeres than the lateral positions (1.95μ). In Angus carcasses, long sarcomeres also appeared in the lateral muscle position. None of the other variables, i.e. percent moisture, ether extract, were related to sarcomere length in the lateral position. For the medial position, increased moisture, decreased extractable fat (correlation of .49 and -.46 respectively) and minimal press fluid loss, were related to long sarcomeres. For Holstein carcasses the chronological age-sarcomere correlation indicated that as the animal grew older the sarcomeres became shorter.

A step-wise multiple correlation and regression analysis were used to rank the variables in order of their usefulness in prediction equations to specifically determine the usefulness of sarcomere length as a predictor of tenderness. Sarcomere length ranked high when observed by itself, but it was not useful for either medial or lateral positions of both Holstein and Angus carcasses when other carcass variables were added. Howard (1966) also found that when comparing sarcomere length to shear resistance for all locations of the longissimus muscle, very small (0.13μ) differences in contractile state were associated with marked differences in tenderness.

Although the average sarcomere length is a gross indication of molecular

arrangements within the myofibril, it does represent a simple, objective method of estimating the degree of muscle contraction. Further investigation is needed to determine its value within the age range of typical block beef.

MATERIALS AND METHODS

Materials

The longissimus muscle from both left and right wholesale rib cuts of 60 steer carcasses (500-950 pounds) was used in this study. Carcasses were selected from the three U.S.D.A. physiological age groups $A^{-}A^{o}$, $A^{+}B^{-}$, and $B^{o}B^{+}$ (which will be referred to as A, AB and B respectively) and corresponds to the chronological ages of approximately 12-18, 18-30 and 30-38 months respectively. "Small" and "moderate" levels of marbling were selected for each group.

The two marbling levels were represented equally within each maturity group of 40 ribs. Thus, the experiment was a two X three factorial design as illustrated in Table I. Also in this table there is an identification of the average grade represented in each cell.

TABLE I

EXPERIMENTAL DESIGN

Marbling Levels	Maturity Levels[1]						
	A		AB		B		Total
	R	L	R	L	R	L	R L
	Choice[2]		Choice Good		Good		
Small	10	10	10	10	10	10	60
	Choice		Choice		Choice Good		
Moderate	10	10	10	10	10	10	60
Totals	40		40		40		

1 = using U.S.D.A. criteria
2 = estimated grade for each cell
R = right side L = left side

The beef ribs used as the experimental material were purchased from two packers (Mauer-Neurer & Co. of Kansas City, Kansas and Armour & Co. of Emporia, Kansas). All selections were made by a project associate and the author for those carcasses typical in all respects for each of the three maturity groups and two marbling levels studied. More than 6000 carcasses were examined over a three month period from January 1967 through March 1967 in order to fill the cells of the design.

Sample Selection

The degree of maturity was determined by the amount of bone ossification and color of lean as defined by the Federal Grading Service (1965). Plate I, shows the location of specific points on the carcass where the degree of bone ossification was observed. The first (topmost) arrow indicates the sacral vertebrae; the second and third arrows indicate the spinal processes in the anterior-lumbar and posterior-thoracic regions, respectively. The fourth arrow shows the location in the rib cage; the fifth arrow identifies the sternum.

Plates II, III and IV illustrate the typical bone and cartilage structure for each of the three maturity groups studied. The photographs on plate II show close-up views of the sacral vertebrae of the three maturity groups studied. The youthfulness of the A maturity carcasses is shown in Fig. 1 by the distinct division of the vertebrae and the white cartilagenous tips. In Fig. 2 the vertebrae are beginning to fuse together which is typical of group 2 or intermediate (AB) maturity because physiological maturity is increasing. Figure 3 shows complete ossification in the sacral region and is typical of the oldest maturity group studied.

PLATE I

PLATE II

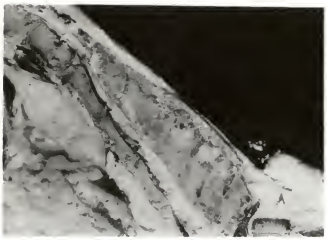

Fig. 3

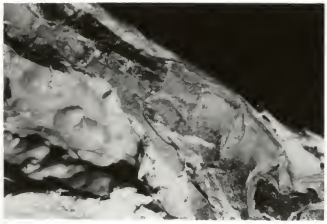

Fig. 2

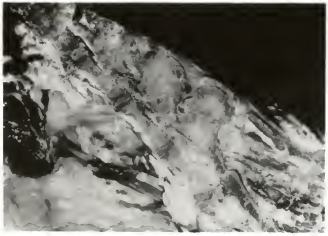

Fig. 1

Plate III shows the spinous process or chine bones in the lumbar region. Figure 1 shows soft, pearly white cartilages called "buttons" which are typical of the A maturity group. As the maturity increased to AB maturity, a progressive hardening and grainy appearance of these buttons occurs (Fig. 2) called cartilage ossification. Further ossification as seen in Fig. 3 is typical of the B maturity group. This same sequence of events occurs in the rib buttons also, and may be seen in plate IV, Fig. 1, Fig. 2 and Fig. 3 respectively.

With the maturity groups studied there was little observable variation in color or texture of lean.

Nine levels of marbling are specified by the U.S.D.A. Grading Standards (1965). They are: (1) practically devoid (2) traces (3) slight (4) small (5) modest (6) moderate (7) slightly abundant (8) moderately abundant and (9) abundant. This study involved the small (number 4) and moderate (number 6) levels of marbling. Cross sectional photographs taken of the longissimus muscle between the 12th and 13th ribs, as shown in plate V, Fig. 2 and 3, illustrate the marbling levels studied. The combination of these marbling levels and the maturity groups produced carcasses that graded choice and good.

Maturity and marbling were the main selection criteria used. Color of lean was observed but was only used as a "sample elimination factor" if it did not conform to the typical color for a maturity group.

Methods

Samples were removed from the wholesale ribs of the left and right sides of the carcasses and cut at locations as shown in plate V, Fig. 1. The anterior half of the longissimus muscle adjacent to the 12th thoracic vertebrae referred to as sample 12, and all of the longissimus muscle adjacent to the 9th thoracic

PLATE III

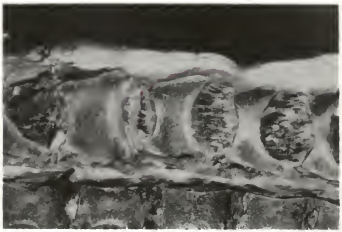

Fig. 3

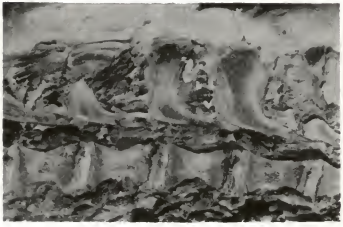

Fig. 2

Fig. 1

PLATE IV

Fig. 3

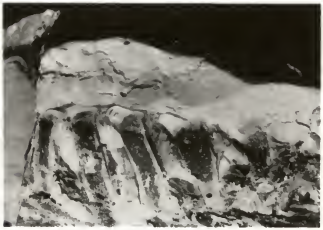

Fig. 2

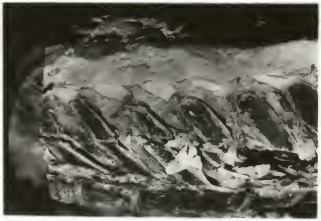

Fig. 1

PLATE V

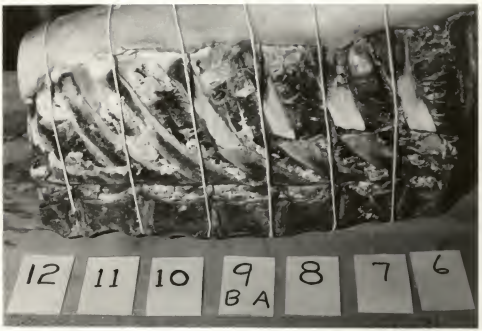

Fig. 1

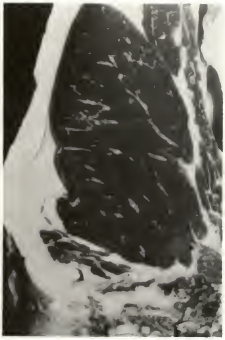

Fig. 2

Fig. 3

vertebrae referred to as sample 9, were used in collecting the data for this study. These ribs were then divided into 2-inch steaks (except sample 12 which was 1-inch) by ruler measurement, starting from the posterior of the rib, and then removing the steak with a hand saw and steak knife. Sample 9 was divided into two 1-inch steaks and identified as 9A and 9B.

Chemical Analysis

The 1-inch thick longissimus muscle from the sample 12 was divided into three sections (medial, central and lateral) as shown in plate VI, Fig. 1. Each section was homogenized in a Waring blender to a paste consistency and used for proximate analysis as determined by the standard A.O.A.C. (1960) methods, for nitrogen (Kjeldahl), ether extract (Soxhlet), ash (muffle furnace) and dry matter (vacuum oven).

Histological

The muscle fibers for sarcomere length determination came from the 9B steak sample as shown in plate VI, Fig. 2. Three 1/2-inch cores were taken from the medial, central and lateral positions, from location B, and combined to make a representative sample. The sarcomeres were extracted from the muscle fibers using the method listed in appendix A. The sarcomeres were then measured with a Bausch and Lomb phase contrast microscope using the oil immersion objective lens, 970 magnification, and an eyepiece micrometer. Twenty-five sarcomeres were measured to obtain an average value for each sample, then converted to microns. The fiber diameters were also measured from the 9B steak sample shown on plate VI, Fig. 2. Three 1/2-inch cores were taken from the medial, central and lateral positions at location A. Location C was taken for later use in another study. The muscle fibers were separated by the procedure listed in appendix B and then measured with an eyepiece micrometer in a Bausch and Lomb

PLATE VI

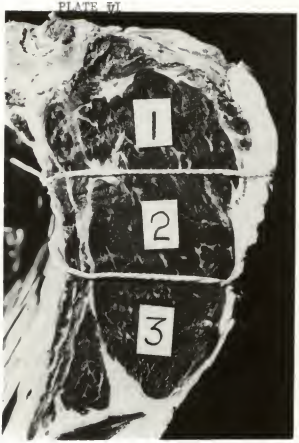

Fig. 1

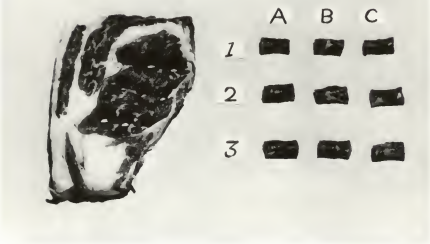

Fig. 2

microscope at 100 X. A total of 50 fibers were measured for each sample and the average diameter determined, then converted to microns.

Also, the number of contracted or wavy and non-contracted or straight fibers were obtained by counting the number of each found in 13 fields for every sample.

Water Holding Capacity

Material for the water holding capacity was obtained from the remaining longissimus muscle of steak sample 9B. The centrifuge method of Wierbicki (1958) was modified and is outlined in appendix C. The results were converted to the "actual percentage water retained" by the sample rather than "water extracted".

Cookery and Shear Evaluation

The 1-inch steaks used for the Warner-Bratzler shear tenderness evaluation were obtained from steak sample 9A which had been wrapped and then stored in a -23.5°C. freezer until needed for the cooking phase. The steaks were then removed from the freezer and thawed in a 3.3°C. cooler until they became pliable (about 12-14 hours). They were then broiled to an internal temperature of 65.5°C. in a rotary gas oven pre-heated to 176.6°C. This required an average cooking time of 38 minutes. The internal temperature was determined by the use of glass thermometers with precautions taken to keep their tips located in the center of each steak.

Three 1-inch cores as shown in plate VII, Fig. 1 (medial=1, central=2, and lateral=3) were removed after the steaks had cooled to an internal temperature of 58.8°C. The average of two shears on each core, as determined by the Warner-Bratzler shear as shown on plate VII, Fig. 2, were recorded for use in the statistical analysis.

EXPLANATION OF PLATE VII

Fig. 1 - Core position for shear values, Fig. 2 - Warner-Bratzler shear, slicing a core.

PLATE VII

Fig. 1

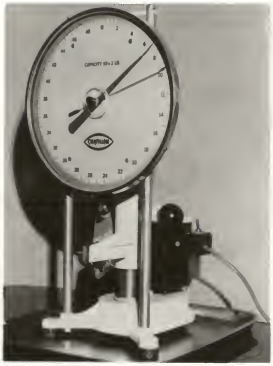

Fig. 2

Statistical Analysis

The data collected were placed on key punch cards. Analysis of variance was computed first, then the desired simple correlation coefficients were obtained. The Duncan's multiple range test was conducted when the differences between three or more values were desired.

RESULTS AND DISCUSSION

Shear

It has been accepted by researchers that animals are bilaterally symmetrical although industry personnel have felt that there were side differences, particularly for marbling and tenderness. There were no significant shear force differences between the right and left sides in this study (Table II).

Contrary to the assumption that increased maturity means decreased tenderness, there were no significant shear force differences for the longissimus steaks between the three maturity groups studied (Table II). This agrees with work by Romans et al (1965).

Although other researchers report that the tenderness-marbling relationship is often small and nonsignificant, this study indicates that steaks from the "moderate" marbled carcasses were significantly more tender than those from the "small" marbled carcasses. This might indicate that even though both can give choice carcasses there could be a tenderness difference. These results are shown in Table II.

Shear values from the lateral cores indicate that they are significantly less tender than those from the medial or central cores; thus, supporting the tenderness-marbling relationship previously mentioned, since the lateral position had significantly lower ether extract values than the other positions (Table VIII).

Fiber Diameter

The increase in fiber diameter means from 62.58 to 65.54 to 69.60 microns with advancing maturity was of significant magnitude. These differences are similar to the ones obtained by Hiner et al (1953) and Tuma et al (1963) even

though they used chronological age rather than physiological maturity. However, as opposed to their findings, fiber diameter in this study as in Romans et al (1965) was not found to be significantly associated with tenderness. This, probably, was due to the difference in the range of maturity groups evaluated.

Fiber diameter became greater as maturity increased. This increase might possibly be explained by the larger ether extract (nonsignificant) values obtained as maturity advanced, even though the subjective marbling levels remained constant; therefore, indicating that non-observable lipid may be deposited within the fiber as the carcass maturity increases.

Percent Waviness of Fiber

The proportion of wavy fibers was measured as a possible indication of the degree of contraction of the muscle, the theory being that the greater the proportion of wavy fibers the more contracted and less tender the muscle. There were no significant differences found between the percent wavy fibers for the maturity, side or marbling groups studied (Table IV). This was probably due to the within sample variation (0-70%). There was a slight difference observed for the maturity groups, with the youngest group having fewer wavy fibers than either the intermediate or older group. This is in agreement with the work of Tuma et al (1962). It may also be noted that the smaller marbling level, which was also less tender, displayed a greater degree of waviness than the moderate marbling level; thus, possibly indicating a relationship between waviness of fibers, marbling level and tenderness.

TABLE II

SHEAR FORCE MEANS AND STANDARD DEVIATIONS FOR SIDE, MARBLING, MATURITY AND CORE POSITIONS (Kg)

Side		Marbling		Maturity[a]			Position[a]		
Left	Right	Small	Mod.	A	AB	B	Med.	Cent.	Lat.
8.18[1]	8.21	8.38	8.01*	8.20	8.31	8.07	7.91	7.93	8.74
1.50[2]	1.56	1.57	1.47	1.71	1.52	1.33	1.39	1.45	1.60

1=Means
2=Standard Deviations
a=Values underscored were not significantly different ($P<.05$) by Duncan's multiple range test
*=$P<.05$ sig. level

TABLE III

FIBER DIAMETER MEANS AND STANDARD DEVIATIONS OF THE LONGISSIMUS MUSCLE FOR THE LEFT AND RIGHT SIDES, THREE MATURITY GROUPS AND TWO MARBLING LEVELS[a]

Side		Maturity[b]			Marbling	
Left	Right	A	AB	B	Small	Mod.
65.99[1]	65.82	62.58	65.54	69.60	64.62	67.20
7.22[2]	11.31	12.02	6.29	7.92	10.76	7.80

1=Means
2=Standard Deviations
a=Measurements are in microns
b=Duncan's multiple range $P<.05$ all means significantly different

TABLE IV

THE PERCENT WAVY FIBER MEANS AND STANDARD DEVIATIONS FROM LONGISSIMUS MUSCLE OF LEFT AND RIGHT SIDES, THREE MATURITY GROUPS AND TWO MARBLING LEVELS

Side		Maturity			Marbling	
Left	Right	A	AB	B	Small	Mod.
13.05[1]	12.75	10.64	14.34	13.72	13.38	12.43
12.95[2]	11.60	11.56	12.50	12.61	13.03	11.48

1=Means
2=Standard Deviations

Sarcomere Length

Sarcomere length has been related to tenderness (longer length more tender). However, in this study there were no significant sarcomere length differences noted for the sides, maturity groups or marbling levels observed. Correspondingly, nonsignificant tenderness difference resulted. The means show a trend for sarcomere length to decrease as maturity increased (Table V) and as fiber diameter increased (Table III) however, the standard deviations indicate a lot of overlap. Howard (1966) also indicated that as the animal grew older the sarcomeres became shorter.

Water Holding Capacity

The water holding capacity, as shown in Table VI, remained practically constant for all of the maturity groups and marbling levels studied. Even though found to be nonsignificant, there is an indication from the data that the right side had slightly less water holding capacity than the left.

A maturity, marbling interaction for water holding capacity was observed for the samples studied. As the maturity increased for the small level of

marbling, the water holding capacity increased, however, as the maturity increased for the moderate marbling level, the water holding capacity decreased (Table VII).

TABLE V

MEANS AND STANDARD DEVIATIONS FOR SARCOMERE LENGTH FROM LONGISSIMUS MUSCLE OF LEFT AND RIGHT SIDES, THREE MATURITY GROUPS AND TWO MARBLING LEVELS[a]

Side		Maturity			Marbling	
Left	Right	A	AB	B	Small	Mod.
2.08[1]	2.06	2.08	2.07	2.06	2.06	2.08
.10[2]	.15	.07	.13	.17	.15	.10

a=Measured in microns
1=Means
2=Standard Deviations

TABLE VI

THE WATER HOLDING CAPACITY MEANS AND STANDARD DEVIATIONS OF THE LONGISSIMUS MUSCLE OF LEFT AND RIGHT SIDES, THREE MATURITY GROUPS AND TWO MARBLING LEVELS[a]

Side		Maturity			Marbling	
Left	Right	A	AB	B	Small	Mod.
70.34[1]	68.63	69.20	69.32	69.44	69.48	69.49
4.52[2]	6.29	7.81	3.78	4.18	6.41	4.50

a=Measured in percent
1=Means
2=Standard Deviations

TABLE VII

THE MATURITY MARBLING INTERACTION
FOR WATER HOLDING CAPACITY

Maturity	Marbling	
	Small	Moderate
A	67.53[1]	70.88
AB	69.07	69.57
B	71.86	68.02

1=Means - expressed as percent water retained by sample

CHEMICAL COMPOSITION

Protein

There was a small decrease in protein noted with increasing animal maturity (Table VIII) and the right side contained slightly less protein than the left (Table IX). However, both trends were nonsignificant.

As the ether extract values increase, the percent of protein correspondingly decreases therefore, the "small" level of marbling exhibited a significantly higher level of protein than the "moderate" level (Table IX). This is further supported by the negative correlations found to exist between the protein and ether extract levels. A significant muscle position effect was also observed, as indicated by a decreasing protein content for the lateral, medial and central positions respectively (Table VIII).

Ether Extract

Ether extract values were significantly greater for B maturity than A maturity even though an attempt was made to hold constant by using the subjective evaluation of marbling score. This suggests that marbling may not be a good

indicator, as maturity increases, of ether extract content of the muscle (Table VIII). The "moderate" marbling level had significantly more ether extract than the "small" marbling level, as would be expected (Table IX). Both medial and central muscle positions had significantly more ether extract than the lateral position; there were no significant differences between the medial and central positions (Table VIII).

TABLE VIII

THE MATURITY AND POSITION MEANS FOR THE PROXIMATE ANALYSIS OF THE LONGISSIMUS MUSCLE[a]

	Maturity			Position		
	A	AB	B	Med.	Cent.	Lat.
Protein[1]	76.46	76.33	75.45	75.56	74.56	78.12
Ether Extract[1]	19.37	19.60	20.82	20.99	21.23	17.56
Moisture[2]	71.79	71.39	71.11	71.06	71.03	72.19
Dry Matter	28.23	28.62	28.89	28.97	28.96	27.81
Ash[1]	3.77	3.76	3.70	3.70	3.67	3.85

a=significant at P<.05 level by Duncan's test - means underscored by the same line are not significantly different
1=dry weight bases
2=expressed as the actual percent water retained

Moisture

No evident side difference for moisture content was found (Table IX). The "small" marbling level had significantly more moisture than the "moderate" marbling level (Table IX) due to an increase in ether extract and decrease in moisture content relationship.

The moisture content decreased progressively as maturity increased since

ether extract increased with maturity. The youngest maturity group had significantly more moisture than the intermediate or the older group, probably due to a higher protein content (a positive correlation of 0.78 existed between protein and moisture). Differences however, were not present between the intermediate or older maturity groups (Table VIII). This corresponds with work by Tuma et al (1963) and Goll et al (1963).

TABLE IX

THE SIDE AND MARBLING MEANS FOR THE PROXIMATE ANALYSIS OF THE LONGISSIMUS MUSCLE

	Side		Marbling	
	Left	Right	Small	Moderate
Protein	76.36	75.79	78.61*	73.54
Ether Extract	19.59	20.26	17.16	22.69*
Moisture	71.52	71.34	72.17*	70.69
Dry Matter	28.49	28.67	27.83	29.33*
Ash	3.76	3.72	3.88*	3.60

*=Significant at $P<.05$ level (F-test)

Ash

Actual maturity or side differences were not observed for ash content (Table VIII). The "small" level of marbling did have significantly more ash than the "moderate" level (Table IX).

The lateral muscle position had significantly more ash content than either the medial or central position and the medial position had a slightly higher ash content than the central position (Table VIII). It was found in this study, as in other investigations, that the percent protein and ash increase and

decrease together.

CORRELATION COEFFICIENTS

Significant positive correlations were observed for pooled data for all longissimus muscle positions between protein X moisture (r=0.78) and protein X ash (r=0.68) (Table X). This indicates that moisture and ash increase as protein content increases for all positions studied. However, the opposite relationship (as indicated by the negative correlations) was found to be true when ether extract was correlated with protein (-.85), moisture (-.44) and ash (-.62) (Table X). Dry matter increased as ether extract increased for all positions.

When protein was correlated with water holding capacity, fiber diameter and waviness of fibers, for the three muscle positions, no significant relationships were found to exist. There was a significant correlation, but very low, between protein X sarcomere length and protein X shear force value. A correlation of r=-.27 indicated that shear values decrease as ether extract increases (Table XII).

No conclusive explanation can be offered for the negative correlation found between sarcomere length and moisture content (Table IX); except that as ether extract becomes greater, fiber diameter gives the same response and moisture decreases. Therefore, the relationship of increased fiber diameter to decreased sarcomere length would exist.

Ash content was negatively correlated with water holding capacity, fiber diameter and sarcomere length and was found to be positively correlated with waviness of fiber and shear values. The correlation between protein and ash content was low (+.68) but highly significant. This was probably due to the relationship between protein and ash (Table X).

Shear values were negatively related to water holding capacity, fiber

diameter and sarcomere length (Table XVI). However, this table also shows that the percent waviness of fibers increased as shear values increased, shown by a positive (r=0.45) relationship between these two variables. This would indicate that the percent waviness of fibers do have some affect on tenderness of muscle.

TABLE X

CORRELATION COEFFICIENTS COMPARING THE PROXIMATE ANALYSIS FACTORS FOR THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES[a]

	Position	Ash	Moisture	Dry Matter	Ether Extract
	Medial	+.556	+.839	-.691	-.888
Protein	Central	+.498	+.697	-.550	-.848
	Lateral	+.396	+.786	-.495	-.811
	Pooled	+.680	+.780	-.504	-.849
	Medial	-.706	-.619	+.761	
Ether Extract	Central	-.684	-.475	+.736	
	Lateral	-.592	-.467	+.612	
	Pooled	-.624	-.443	+.717	
	Medial	-.630	-.607		
Dry Matter	Central	-.666	-.407		
	Lateral	-.507	-.467		
	Pooled	-.371	-.277		
	Medial	+.322			
Moisture	Central	+.184			
	Lateral	+.128			
	Pooled	+.554			

a=All values significant at $P<.05$ level

TABLE XI

CORRELATION COEFFICIENTS COMPARING PROTEIN WITH VARIOUS PHYSICAL AND HISTOLOGICAL FACTORS AT THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES

	Position			
	Medial	Central	Lateral	Pooled
Water Holding Capacity	+.008	+.074	+.035	+.039
Fiber Diameter	-.090	-.022	+.016	-.034
Waviness of Fiber	+.022	+.135	+.189	+.123
Sarcomere	-.194	-.229*	-.348**	-.353**
Shear	+.273**	+.249*	+.266**	+.290**

*=P<.05 sig. level
**=P<.01 sig. level

TABLE XII

CORRELATION COEFFICIENTS COMPARING ETHER EXTRACT WITH VARIOUS PHYSICAL AND HISTOLOGICAL FACTORS AT THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES

	Position			
	Medial	Central	Lateral	Pooled
Water Holding Capacity	+.054	+.006	-.014	_.027
Fiber Diameter	+.089	+.015	+.070	+.069
Waviness of Fiber	-.046	-.149	-.200*	-.134
Sarcomere	-.028	-.051	+.209	+.021
Shear	-.346**	-.263**	-.328**	-.268**

*=P<.05 sig. level
**=P<.01 sig. level

TABLE XIII

CORRELATION COEFFICIENTS COMPARING DRY MATTER WITH VARIOUS PHYSICAL AND HISTOLOGICAL FACTORS AT THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES

	Position			
	Medial	Central	Lateral	Pooled
Water Holding Capacity	-.015	-.008	-.036	-.025
Fiber Diameter	+.130	+.024	+.048	+.089
Waviness of Fiber	+.070	-.018	+.018	+.029
Sarcomere	+.004	+.036	+.106	+.099
Shear	-.191	-.163	-.153	-.119

TABLE XIV

CORRELATION COEFFICIENTS COMPARING MOISTURE WITH VARIOUS PHYSICAL AND HISTOLOGICAL FACTORS AT THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES

	Position			
	Medial	Central	Lateral	Pooled
Water Holding Capacity	+.093	+.140	+.175	+.162
Fiber Diameter	-.072	+.053	+.026	-.043
Waviness of Fiber	-.053	+.034	+.020	.000
Sarcomere	-.530*	-.619**	-.905**	-.677**
Shear	+.088	+.066	+.050	+.194

*=P<.05 sig. level
**=P<.01 sig. level

TABLE XV

CORRELATION COEFFICIENTS COMPARING ASH WITH VARIOUS PHYSICAL AND HISTOLOGICAL FACTORS AT THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES

	Position			
	Medial	Central	Lateral	Pooled
Water Holding Capacity	-.129	-.073	-.091	-.016
Fiber Diameter	-.272*	-.068	-.067	-.077
Waviness of Fiber	+.112	+.117	+.182	+.168
Sarcomere	-.004	-.039	-.113	-.101
Shear	+.173	+.116	+.269**	+.273**

*=P<.05 sig. level
**=P<.01 sig. level

TABLE XVI

CORRELATION COEFFICIENTS COMPARING SHEAR VALUES WITH VARIOUS PHYSICAL AND HISTOLOGICAL FACTORS AT THREE POSITIONS OF THE LONGISSIMUS MUSCLE OF BEEF CARCASSES

	Position			
	Medial	Central	Lateral	Pooled
Water Holding Capacity	-.071	-.024	-.011	-.013
Fiber Diameter	-.106	-.016	-.073	-.061
Waviness of Fiber	+.363*	+.398*	+.392*	+.451*
Sarcomere	-.177	-.241*	-.111	-.164

*=P<.05 sig. level

SUMMARY

Longissimus muscle from the left and right wholesale rib cuts of 60 steer carcasses (500-950 pounds) were used in this study. Carcasses were selected for the two marbling levels of "small" and "moderate" and from the physiological age (maturity) groups of $A^{-}A^{o}$, $A^{+}B^{-}$, and $B^{o}B^{+}$, therefore, giving a 2 X 3 factorial design.

The histological and chemical tenderness factors studied, i.e., fiber diameter, percent wavy fibers, sarcomere length, water holding capacity and proximate analysis were evaluated for the sides, maturity and marbling levels studied.

Warner-Bratzler shear force values showed no significant differences between sides or among maturity groups. However, the "moderately" marbled steaks recorded significantly lower shear force values than the "small".

Sarcomere length varied only slightly for the side, maturity or marbling levels studied.

Fiber diameter was not affected by side but tended to be greater for the "moderate" marbling level and significantly ($P<.05$) increased in size as maturity increased even though it was found not to be associated with tenderness.

Percent wavy fibers was not significantly related to the maturity, side or marbling levels although the youngest maturity group had fewer wavy fibers. Water holding capacity showed only small differences for marbling, side or maturity however, a marbling-maturity interaction was present.

Protein and moisture content were significantly ($P<.05$) greater for the lateral position. Ether extract was correspondingly less for the lateral position. It increased though as maturity advanced while protein and moisture declined.

Correlations for protein with ether extract, moisture and ash were -.85, 0.78 and 0.68 respectively. Higher shear values were found in samples with a greater proportion of wavy fibers (r=0.45) and correlation of 0.29 and -.27 were present for protein and ether extract with shear values.

TABLE XVII

CARCASS INFORMATION

Carcass Number	Hot Carcass Weight (Kg)	Maturity Group	Marbling Level
001	241	AB	Small
002	357	AB	Moderate
003	317	AB	Moderate
004	341	AB	Small
005	380	A	Small
006	283	A	Small
007	303	AB	Moderate
008	378	AB	Small
009	326	B	Moderate
010	318	B	Moderate
011	287	B	Small
012	438	B	Moderate
013	286	A	Small
014	314	B	Moderate
015	321	AB	Moderate
016	286	B	Small
017	344	AB	Moderate
018	345	AB	Moderate
019	290	AB	Small
020	254	AB	Small
021	381	B	Small
022	268	B	Moderate
023	249	B	Moderate
024	366	AB	Small
025	337	AB	Small
026	308	AB	Small
027	272	A	Small
028	308	A	Small
029	296	A	Small
030	267	A	Small

Carcass Number	Hot Carcass Weight (Kg)	Maturity Group	Marbling Level
031	377	A	Small
032	297	A	Moderate
033	302	A	Small
034	266	A	Small
035	335	A	Moderate
036	351	AB	Moderate
037	347	AB	Moderate
038	354	B	Moderate
039	309	B	Small
040	336	B	Small
041	324	B	Small
042	317	B	Small
043	315	AB	Moderate
044	299	AB	Small
045	261	AB	Small
046	313	AB	Moderate
047	321	A	Moderate
048	323	A	Moderate
049	297	A	Moderate
050	279	A	Moderate
051	325	A	Moderate
052	348	B	Small
053	375	B	Small
054	312	B	Small
055	338	B	Moderate
056	331	B	Moderate
057	362	B	Moderate
058	367	A	Moderate
059	347	A	Moderate
060	384	A	Moderate

TABLE XVIII

MATURITY AND MARBLING MEANS AND
STANDARD DEVIATIONS FOR FAT THICKNESS
AND RIB EYE AREA OF THE LONGISSIMUS MUSCLE

	Maturity			Marbling	
	A	AB	B	Small	Mod.
Fat Thickness[a]					
Means	1.56	1.43	1.62	1.37	1.70
S.D.[1]	.12	.13	.13	.09	.11
Rib Eye Area[b]					
Means	70.2	72.3	77.6	73.1	73.6
S.D.[1]	1.8	2.6	2.3	2.3	2.6

a=Fat thickness measured in (cm)
b=Rib eye area measured in (cm^2)
1=Standard deviation

TABLE XIX

SIDE, MATURITY AND MARBLING MEANS
AND STANDARD DEVIATIONS FOR RIB WEIGHT
OF THE LONGISSIMUS MUSCLE[a]

Side		Maturity			Marbling	
Left	Right	A	AB	B	Small	Mod.
14.44[1]	13.97	13.77	14.12	14.72	13.82	14.59
1.77[2]	1.79	1.74	1.65	1.88	1.87	1.63

a=Weights in (Kg)
1=Means
2=Standard deviations

APPENDIX A

SARCOMERE EXTRACTION

Reference: Locker, R.L. 1960. Degree of muscular contraction as a factor in tenderness of beef. Food Res. 25:304.

Procedure

1. Place sample in 3.3°C. cooler for period not longer than 12 hours.
2. Combine sample with 50 ml of .02 M Kcl solution.
3. Mix in Waring blender for one minute at slow speed.
4. Place one drop of homogenate on slide.
5. Place cover slip on slide and seal with paraffin.
6. Measure sarcomere length (distance between Z-discs) with a phase contrast scope.

APPENDIX B

FIBER DIAMETER

Reference: Tuma, H.J., J.H. Venable, P.R. Wuthier and R.C. Hendrickson. 1962a. Relationship of fiber diameter to tenderness and meatiness as influenced by bovine age. J. Animal Sci. 21:33.

Procedure

1. Place representative sample in jar containing fixing solution.
2. Remove from solution after 48 hours and slice 1/8-inch section from each core in sample.
3. Place in Waring blender and add 50 ml of solution.
4. Blend at slow speed (about 50 on rheostat) for 30 seconds.
5. Pour part of contents onto petri dish and observe through scope at 100x.

Notes

The fixing solution is prepared as follows:

40% formalin	10cc
Dist. water	90cc
Na Acetate	2gm
NaCl	2gm

APPENDIX C

WATER HOLDING CAPACITY

Reference: Wierbicki, E., L.E. Kunkle and F.E. Deatherage. 1958. Determination of W.H.C. of fresh meats. J. Agr. Food Chem. 6:387.

Procedure

1. Weigh 25 gm of thoroughly ground and mixed beef. Put in tube and close with rubber stopper and glass capillary tube which acts as a vent. (Run in duplicate.)
2. Immerse in a water bath to a depth of about 9/10 of the tube length for 30 minutes.
3. Water bath temperature is 70°C.
4. After heating, immerse for 10 minutes in water at room temperature (20-25°C.).
5. Centrifuge for 10 minutes at 170 X gravity (1000 R.P.M.).
6. Read directly the amount of juice on the tube.
7. Compute percentage moisture loss by using the formula:

$$\% \text{ moisture} = \frac{(\text{ml juice})\ (F)}{\text{grams of moisture in sample}} \times 100$$

F=0.951 at 64°C.
F=0.951 - .004 at 70°C.

Note

After each use, wash with hot soapy water and rinse with distilled water and acetone and dry in drying oven.

Precision

When heating is carried out at 70°C., duplications usually agree to .1 ml of juice per 25 grams of meat.

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A STUDY OF VARIOUS CHEMICAL AND HISTOLOGICAL CHARACTERISTICS OF BEEF MUSCLE AND THEIR RELATIONSHIPS TO PALATABILITY

by

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ABSTRACT

Both wholesale rib cuts of 60 steer carcasses ranging from 500-950 pounds were selected from the physiological age (maturity) groups of $A^{-}A^{o}$, $A^{+}B^{-}$, and $B^{o}B^{+}$ to study the effects of the marbling levels, "small" and "moderate", as determined at the longissimus muscle, on histological and chemical traits and tenderness.

Sides and maturity groups showed no significant Warner-Bratzler shear differences, however, the "moderately" marbled steaks recorded significantly lower shear force value than the "small" marbled steaks. Fiber diameter significantly increased with advancing maturity, mean values of 62.6-69.6 microns, and was greater for the "moderate" marbling level. It was not affected by side nor was it found to be associated with tenderness. Sarcomere length means of 2.06-2.08 microns varied only slightly for the side, maturity or marbling levels studied.

The wavy or contracted fiber means ranging from 10.6-12.7 percent, were not significantly different for the side, marbling or maturities studied, although the youngest maturity group did tend to have fewer wavy fibers. Increased shear values were found in samples with a greater proportion of wavy fibers ($r=0.45$). Only small differences between marbling, sides, maturity and water holding capacity were found even though a marbling-maturity interaction was present. Correlations between shear value versus sarcomere length, water holding capacity and fiber diameter were -.16, -.01 and -.06 respectively.

Protein and moisture content were significantly ($P<.05$) greater for the lateral position while ether extract was correspondingly less. However, ether extract was found to increase with advancing maturity. Correlations for protein with ether extract, moisture and ash were -.85, 0.78 and 0.68 respectively.