HISTOLOGICAL CHARACTERISTICS OF USDA CHOICE AND USDA GOOD BEEF RIB STEAKS

by

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TABLE OF CONTENTS

INTRODUCTION 1

REVIEW OF LITERATURE 3

USDA beef carcass quality grades 3

Major components of beef grades 4

1976 standards of grading 5

Reflection on changes in 1976 beef grades . . . 8

Gross structure of muscle tissue 10

Muscle fibers 10

Connective tissue 10

Adipose tissue 11

Relationship of selected histological characteristics of bovine muscle and marbling to tenderness, juiciness or ether extract 11

Fiber diameter 11

Fat quantity and distribution 13

Marbling 13

MATERIALS AND METHODS 15

Meat used 15

Experimental design and cooking 18

Histological measurements 23

Samples 23

Preparation of slides 23

Evaluation 26

Statistical analyses 30

RESULTS AND DISCUSSION. 32
Effect of grade 32
Effect of steak position 36
Effect of cooking. 38
Relationships between selected measurements. 43
SUMMARY 45
CONCLUSIONS 47
REFERENCES 48
ACKNOWLEDGMENTS 53
APPENDIX 54

INTRODUCTION

Current USDA beef grading standards went into effect on February 23, 1976. Those standards will mean that slightly leaner beef will qualify for each grade classification than under the 1965 standards, and less grain will be fed to cattle.

Under 1976 USDA grading standards, marbling requirements for U.S. Prime and Choice beef are slightly lower than they were under the 1965 standards. All of the beef that previously qualified for U.S. Prime still qualifies for that grade, and all that previously qualified for U.S. Choice still qualifies for U.S. Choice, except for a small portion that now qualifies for U.S. Prime. Some of the beef formerly in "top" Good grade now will grade U.S. Choice. U.S. Good beef should have a consistent eating quality for those who prefer lean, but relatively tender beef (National Live Stock and Meat Board, 1976).

Previous standards required increased marbling to compensate for increased age of cattle. Now the minimum amount of marbling specified for cattle nine months old remains unchanged through 30 months of age. Research revealed that tenderness, juiciness and flavor are not affected significantly by the maturing process of animals under 30 months of age (Norris et al., 1971; Covington et al., 1970; McBee and Wiles 1967; Lawrie, 1966; Gilpin et al., 1965; Goll et al., 1965 and Walter et al., 1965).

Production and feeding practices in the past few years,

including new genetic developments and crosses of cattle breeds, have reduced the marbling in bovine muscle. Because of those changes, and since so many beef animals now reach market weight at less than 24 months of age, the previously higher marbling requirements are regarded as wasteful (National Live Stock and Meat Board, 1976).

Schupp et al. (1976) studied the acceptance of foraged finished and limited grain finished beef. They reported that forage finished beef has a yellower fat and a greater proportion of lean to fat than grain finished beef. A consumer taste panel indicated that both forage finished and grain finished beef are acceptable.

Skelly et al. (1976) and Campion et al. (1976) published data for characteristics of beef based on estimates of the 1976 carcass grading standards as first proposed in 1974. Campion et al. (1976) concluded that with adoption of the new grading standards, it is unlikely that consumers could discern differences in palatability associated with the particular grade of beef they are accustomed to eating.

Garcia-de-Siles et al. (1977) compared the effectiveness of 1965 and 1976 USDA standards and the Canadian system for grading beef carcasses. They reported that from the viewpoint of predicting palatability, the 1976 USDA standards did not offer any significant improvement over the 1965 standards, and that as far as carcass fatness was concerned, 1976 standards offered only slight improvement.

Information is needed on the characteristics of beef

graded according to 1976 standards. Data for this study include histological characteristics of beef rib steaks from USDA Good and USDA Choice beef carcasses. Data for other characteristics of the same steaks were available to study the relationship of ether extract, tenderness and juiciness to histological characteristics of rib steaks within each grade.

REVIEW OF LITERATURE

USDA beef carcass quality grades

Nationally recognized standards for grading of livestock and meat were promulgated in 1926 (Carpenter et al., 1977). Those standards provided the basis for grading when a voluntary beef grading and stamping service was begun in May, 1927 (Paul, 1972; USDA, 1976).

Before establishment of grade standards, there was no uniform system for identifying livestock according to expected palatability characteristics. With promulgation of the standards, meat packers and retailers adopted use of them as an aid in obtaining consistent product for customers in the quantity food preparation and food service industries. Soon retailers began to promote the fact that their product met Federal Standards of quality; in merchandizing beef they stressed the consistency of U.S. grades (Carpenter et al., 1977). Now most fed beef is examined for grade, though not

always grade marked. Both Government and private agencies report price by USDA grades, and most livestock and meat transactions involve USDA grades in price negotiation (Nelson and Van Arsdall, 1974).

Since the grading standards were first introduced, USDA has modified periodically the names and specifications for various grades to reflect changes in production and processing practices and in consumer demands. Such revisions have been made every 7 to 10 years (Paul, 1972; Carpenter et al., 1977).

Major components of beef grades. Quality and yield grades are the bases used to identify two important factors that affect beef acceptance and value, namely: (1) eating quality (tenderness, juiciness and flavor), and (2) yield of saleable meat (Carpenter et al., 1977). There are eight quality grades (Prime, Choice, Good, Standard, Commercial, Utility, Cutter and Canner) included in the 1976 USDA beef grading standards (USDA, 1976).

Quality grading standards involve carcass characteristics related to palatability such as maturity, marbling, texture, firmness and color (Carpenter et al., 1977). Specifications for marbling and maturity were established in 1939 with the first revision of beef grading standards. They reflected the premises that increase in marbling enhances palatability and that advancing maturity has a deleterious effect on palatability (Carpenter et al., 1977).

Maturity is determined by evaluating the size, shape and ossification of the bones and cartilages, and the color and

texture of the lean meat. Marbling is the fat within the muscle and is evaluated for the ribeye between the 12th and 13th ribs. Texture refers to the apparent fineness or coarseness of the meat in the ribeye. Firmness refers to the relative firmness or softness of the meat in the ribeye. Color of the meat in the ribeye is used as an indicator of maturity or physiological age.

Five numerical USDA yield grades, developed in 1965, are used to identify carcasses and certain wholesale cuts for their relative yields of retail cuts or cutability. Yield Grade 1 carcasses have the highest yield of retail cuts; Yield Grade 5 carcasses, the lowest yield (Carpenter et al., 1977). The yield grade of a beef carcass is determined by considering: (1) the amount of external fat, (2) the amount of kidney, pelvic and heart fat, (3) the area of the ribeye muscle and (4) the hot carcass weight (USDA, 1976).

1976 standards of grading. Several changes from the 1965 standards were incorporated into the carcass beef quality grading standards of 1976. They were made to reduce the variation in palatability within each grade and to better identify value differences in beef carcasses (USDA, 1976).

Figure 1 presents the 1965 and 1976 standards indicating relationships among marbling, maturity and quality grade. Under the 1976 standards, marbling requirements for Good grade are narrowed to include only carcasses with slight amounts of marbling. Within A maturity (approximately 9 to 30 months of age), minimum marbling requirements for Prime,

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Figure 1-Changes in the relationship between marbling, maturity and quality grade (Nelson and Van Arsdall, 1974).

Marbling requirements for 1965 standards

Marbling requirements for 1976 standards

Areas that indicate change to the next higher grade

Area that indicates change from Good to Standard

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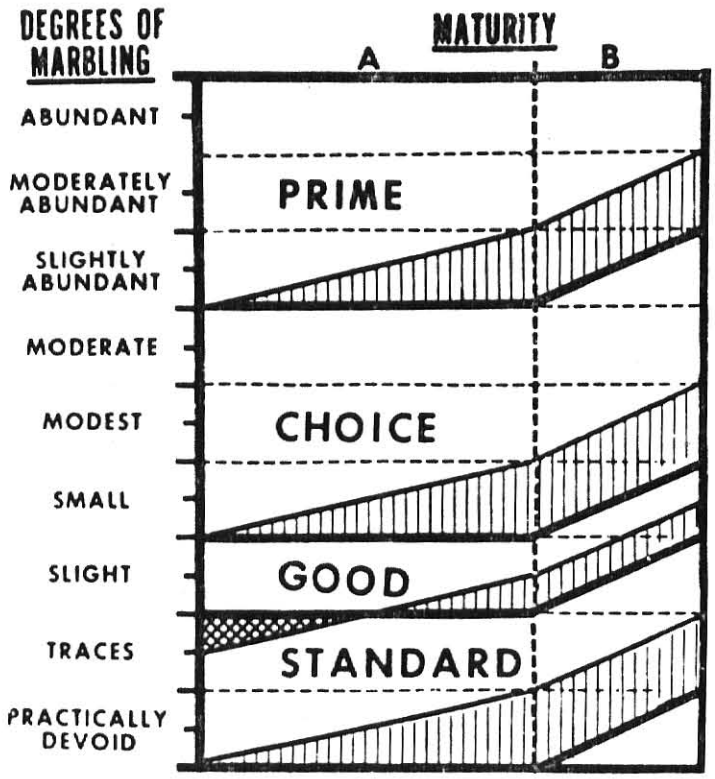
DEGREES OF MARBLING
MATURITY
A
B
ABUNDANT
MODERATELY ABUNDANT
SLIGHTLY ABUNDANT
MODERATE
MODEST
SMALL
SLIGHT
TRACES
PRACTICALLY DEVOID
PRIME
CHOICE
GOOD
STANDARD

Choice, Good and Standard grades do not increase with increasing maturity. For B maturity and older carcasses, increases in marbling are required with increases in maturity, but minimum marbling is decreased by one degree, e.g., for Choice grade, the marbling requirement is reduced from a modest to a small amount. Under the 1976 beef grading standards, conformation was eliminated from the factors used in determining the quality grade. If graded, carcasses must be graded for both quality and yield.

Reflection on changes in 1976 beef grades. Although limited reaserch has been conducted to evaluate the 1976 standards, Nelson and Van Arsdall (1974) stated that the 1976 standards may increase the efficiency of beef production. Those authors also indicated that the greatest impact of the grading change would be on the Good and Choice grades, which have accounted for about 90% of all beef offically grade marked by USDA in recent years.

Campion et al. (1976) studied the distribution of carcasses within quality grades under the 1965 and 1976 grading standards. Using the 1965 and 1976 standards, the percentage of carcasses that graded Choice or better was 58 and 68, respectively. Thus, an increase of 10% in carcasses graded Choice or better would be realized in switching to the 1976 standards.

The percentage of estimated grain-fed beef graded U.S. Prime, Choice and Good from 1966 to 1976 was reported. From 1975 to 1976 there was a 14.8% increase in Prime and Choice

carcasses (Anonymous, 1977).

Carpenter et al. (1977) reported some disagreement among purveyors regarding acceptability of the 1976 Choice beef. Some purveyers believed that the 1976 standards make the Choice grade meaningless, and others reported no difficulty in merchandising beef from the new U.S. Choice grade to their customers. Some observers believe that the Choice grade will break down into a two-tier pricing system as buyers agree to pay a premium to assure a supply of beef from the higher portion of the grade.

In considering consumers' acceptance of the new grades, Carpenter et al. (1977) stated that some purveyers said that consumers would revolt at having to pay the same price for what they think is less valuable meat, e.g., the previous "top" Good grade now is graded U.S. Choice. However, the American National Cattlemen's Association predicted that as cattle feeding times were shortened, 1976 grades would translate into savings of 3 to 5 ¢ per pound for consumers.

From the viewpoint of predicting palatability, some researchers indicated that the 1976 standards did not offer any significant improvement over the 1965 standards (Garcia-de-Siles et al., 1977; Skelley et al., 1976 and Campion et al., 1976).

Carpenter et al. (1977) concluded that most predictions about effects of grade changes on the U.S. beef industry have not materialized. They stated that the beef industry will be unable to assess the effectiveness of the revised

beef grading standards until there is a reversal of current production trends. Cattle feeders must market shorter-fed cattle before the industry will know the extent to which the new grades are acceptable to consumers, retail chains and purveyors.

Gross structure of muscle tissue

Meat is composed of straited voluntary muscles with the individual muscles being made up of muscle fibers, connective tissue and adipose tissue (Paul, 1972).

Muscle fibers. The muscle fiber is a long, cylindrical multinucleated cell. Diameters of fibers vary (from 10 to 100 μ or more) within the muscle, between muscles, with age and with degree of activity of the animal. The outer membrane of the muscle fiber is known as the sarcolemma. Individual muscle fibers are enclosed by extremely thin networks of connective tissue called the endomysium, which holds the fibers together in bundles. Muscle fiber bundles are bounded by larger sheets of connective tissue, the perimysium. The outer layer of connective tissue surrounding the entire muscle is called the epimysium (Cassens, 1971; Meyer, 1968).

Connective tissue. Connective tissue is composed of collagen, elastic and reticular fibers and ground substance. Collagen fibers are distributed widely in muscle. Fibers in loose collagenous tissue run in all directions; they may be straight or wavy, and consist of fibrils grouped parallel to

each other in bundles. Although the fibers branch considerably, the fibrils do not. Elastic connective tissue fibers are homogeneous instead of fibrillar and are thinner than collagenous fibers. They run in various directions and branch freely; they are straight when in natural position, but when teased onto a microscopic slide they may appear wavy or spiral. Collagenous and elastic connective tissue fibers are embedded in a homogeneous material or ground substance that varies from a fluid to a gel-like consistency (Harrison et al., 1959).

Adipose tissue. Some researchers consider that adipose tissue is a specialized type of connective tissue containing large deposits of fat (Meyer, 1968). The adipose cell mass is laid down during the early stages of life, and the number of fat cells does not change, but the size of the cell does (Sheldon, 1969). Fat cells that accumulate in large numbers and crowd out other tissue are designated as adipose tissue (Paul, 1972). In addition to deposition in adipose tissue, fat cells also may be scattered throughout or in groups in loose connective tissue (Meyer, 1968) or between muscle fibers.

Relationship of selected histological characteristics of bovine muscle and marbling to tenderness, juiciness or ether extract

Fiber diameter. Tenderness of meat has been attributed to many factors (Paul, 1972). The "diameter" of muscle fibers is regarded as being partly responsible for tenderness

of muscle (Hiner et al., 1953).

Ramsbottom et al. (1945) cited the work of Moran and Smith (1929) which indicated that a small muscle fiber diameter and small primary and secondary bundles were associated with tender muscle.

Brady (1937) observed a low relationship (r = 0.22) between raw fiber diameter and tenderness of aged beef and a moderate relationship (r = 0.53) between fiber diameter and tenderness of cooked beef. Large muscle fibers tended to indicate toughness. Hiner et al. (1953) found a curvilinear relationship (r = 0.83) between fiber diameter and tenderness in nine cuts from animals ranging in age from 10 weeks to 9 years. Tenderness and fiber diameter were associated more closely in the mature carcasses (r = 0.77) than in the younger, immature carcasses (r = 0.50). Tuma et al. (1962) found that with increasing animal age, fiber diameter increased, and tenderness of muscle decreased.

Carpenter et al. (1963) reported that with an increase in maximum muscle fiber diameter, there was a decrease in taste-panel tenderness scores on cooked porcine longissimus dorsi muscle. Conversely, Romans et al. (1965) and Covington et al. (1970) reported that fiber diameter was not correlated significantly with tenderness of bovine longissimus dorsi muscle.

Herring et al. (1965) reported that fiber diameter of the carcass was related to shear force (r = 0.73**), an objective measurement of tenderness. As fiber diameter

increased, the shear force increased.

Fat quantity and distribution. Reports in the literature concerning the relationship of tenderness, juiciness or ether extract to histological estimates of fat quantity and distribution are limited.

In a histological study, Wang et al. (1954) observed the fat loci and distribution in cooked beef. They concluded that it is the distribution of fat rather than the quantity that affects tenderness; the amount of "linear fat" in raw samples correlated well with panel tenderness scores for cooked samples. They also observed that the total quantity of fat in a muscle was related closely to juiciness.

According to Covington et al. (1970), ether extract is a crude measure of lipid material. The lipid distribution within muscle varies and precise measure of this trait possibly may be more important in studying eating quality of muscle than total lipid quantity.

Moody (1967) reported that histological estimated fat content of the longissimus dorsi muscle increased as marbling level increased. Although histological estimates gave higher values, they compared well with ether extract scores.

Marbling. In a review of effect of marbling on palatability of meat, Blumer (1963) concluded that the variance in tenderness accountable to marbling would be about 5%. Doty and Pierce (1961) and McBee and Wiles (1967) reported a close relationship between marbling and tenderness.

Some workers reported a slight relationship between

marbling and tenderness. Gilpin et al. (1965) found that steaks from highly marbled carcasses scored slightly more tender than steaks from carcasses of low marbling levels. Goll et al. (1965) found that a fine texture and an even distribution of marbling were associated with tenderness. Tuma et al. (1962) noted that the association between marbling and tenderness varied with animal age. Marbling level did not affect tenderness of steaks from 18-month old animals; whereas, more tender steaks from the 42- and 90- month old animals were found among higher marbling levels.

Other reports (Romans et al., 1965 and Walter et al., 1965) indicated low and nonsignificant relationship between tenderness and marbling score. Norris et al. (1971) reported that panel scores for tenderness and Warner-Bratzler shear value were not affected by level of marbling in bovine longissimus dorsi muscle.

Reports have indicated variation concerning the relationship of juiciness to the amount of marbling in a piece of meat. Goll et al. (1965) found that juiciness was not affected by marbling level. In a review of the relationship of marbling to palatability, Blumer (1963) estimated that about 16% of the variance in juiciness could be attributed to fat content. Whereas, Gilpin et al. (1965) stated that about 20% of the variation in juiciness scores was associated with percentage fat. A direct, linear relationship between marbling and juiciness was found by McBee and Wiles (1967). Steaks from moderately marbled ribs were juicier than those

from slightly marbled carcasses (Romans et al., 1965).

Several studies were reported that showed a high and significant correlation between ether extract (moisture free basis) and subjective marbling scores (Kropf and Graf, 1959; McBee and Wiles, 1967; Walter et al., 1965; Moody, 1967 and Romans et al., 1965). Walter et al. (1965) reported that nearly 85% of the variation in ether extract could be accounted for by marbling. Marbling level was related to water content and fat (Romans et al., 1965); higher levels of marbling exhibited more fat and less moisture content.

MATERIALS AND METHODS

Meat used

Six USDA Choice and six USDA Good fresh, unfrozen wholesale ribs (8.6 to 16.8 kg, Fig. 2) were purchased from a wholesale packing company in western Kansas and delivered to the Meats Laboratory at Kansas State University.

The USDA quality grade, yield grade, number of days aged, hot carcass weight and chilled carcass weight were recorded for each rib (Table 7, Appendix, p. 55). Marbling was scored at the loin end of the wholesale rib (the interface of the 12/13th rib). Thickness of the subcutaneous fat over the rib also was measured at the loin end (Table 7, Appendix, p. 56). Rib bones, vertebrae, scapula, and ligamentum nuchae were removed from the wholesale rib. Boneless rib ends were

Figure 2-Wholesale ribs of USDA Choice grade and USDA Good grade beef.

A USDA Choice rib

B USDA Good rib

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A
B

removed on a line approximately 10.2 cm from the lateral edge of the anterior end of the longissimus dorsi (LD) muscle and 2.5 cm from the lateral edge of the posterior end of the LD muscle.

Steaks, either 3.0 cm or 1.3 cm in thickness, were cut from the boneless rib (Fig. 3). The tail of each steak was trimmed to 2.5 cm from the lateral edge of the LD muscle. Subcutaneous fat on steaks containing no trapezius muscle was trimmed to 0.6 cm. When present, the trapezius muscle was removed and the spinalis dorsi was left intact.

Weights and dimensions of the 3.0 cm thick steaks were recorded. The area of the rib eye was traced and measured with a polar planimeter. Individual rib steaks were wrapped in aluminum foil (guage 0.0015), and coded.

The 3.0 cm thick steaks were frozen in a walk-in freezer at -15°C for approximately 20 hours, then stored in an upright household freezer at -18 to -24°C for 6 to 16 days.

The 1.3 cm thick steaks were used for analysis of raw meat. Samples for each raw meat measurement were removed from unfrozen steaks immediately after they were cut.

Experimental design and cooking

Before each of 24 evaluation periods, four steaks (two U.S. Choice and two U.S. Good) selected randomly according to the experimental design (Table 1) were defrosted in the foil wrap four hours at room temperature (22 to 26°C) and 20 hours in a refrigerator (4°C), then unwrapped and weighed.

Figure 3-Plan for sampling the wholesale rib cut (longissimus dorsi).

1 through 8 - rib steaks, 3.0 cm thick

2', 5', 8' - steaks 1.3 cm thick, for analysis of raw muscle tissue

Histological samples (raw muscle tissue) - 2', 5', 8'

Histological samples (cooked tissue) - 2, 5, 8

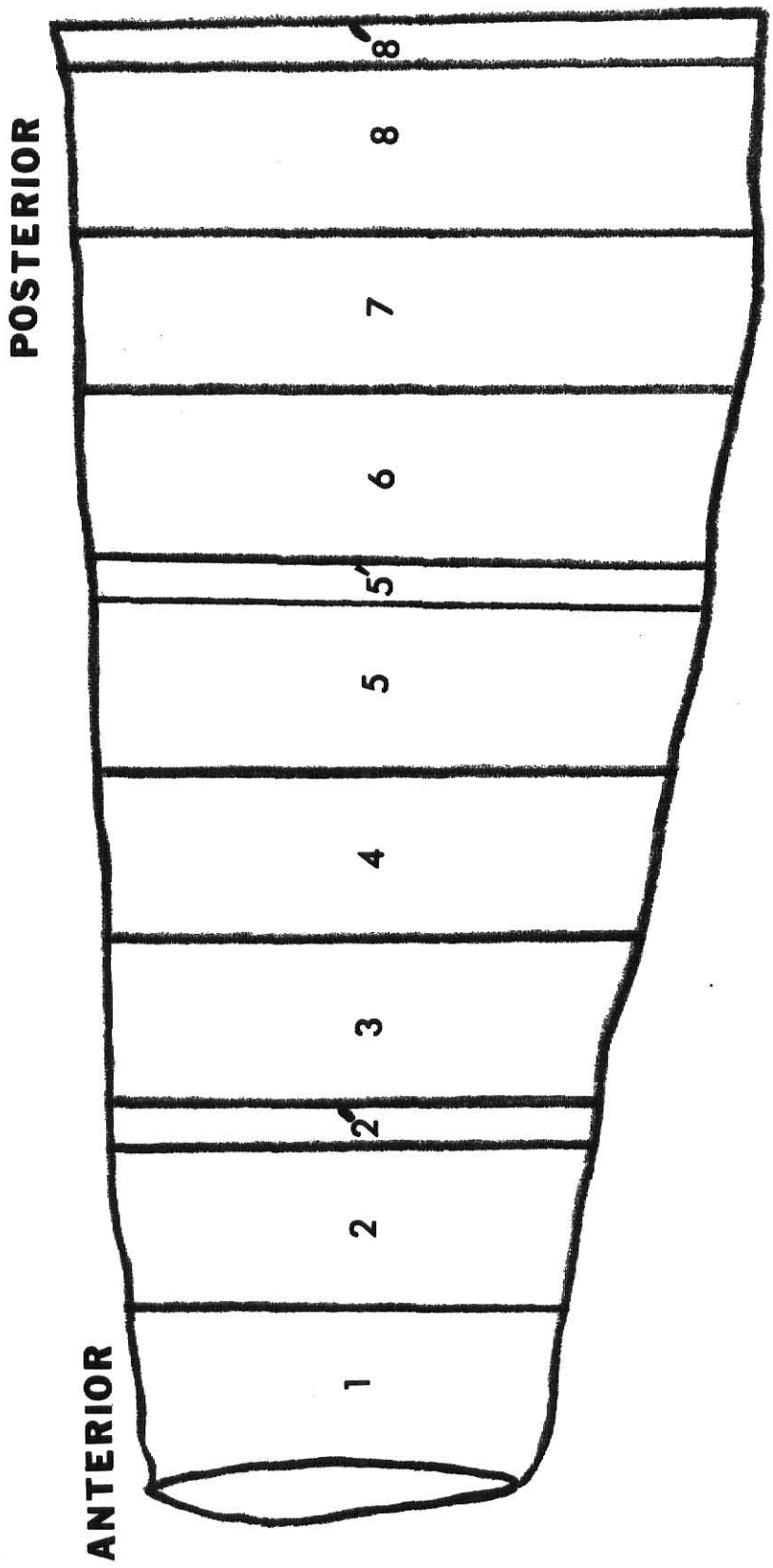

POSTERIOR
ANTERIOR
8
8
7
6
5
5
4
3
2
2
1

Table 1-Experimental design for cooking U.S. Choice and U.S. Good beef rib steaks[a]

Evaluation period	Replication	Steak code[b] Choice	Steak code[b] Good	Evaluation period	Replication	Steak code[b] Choice	Steak code[b] Good
1	I	1002	1904	9	III	3006	3901
		1007	1905			3008	3905
2		1003	1903	10		3003	3902
		1005	1906			3007	3908
3		1001	1902	11		3002	3903
		1006	1908			3005	3904
4		1004	1901	12		3001	3906
		1008	1907			3004	3907
5	II	2001	2904	13	IV	4004	4903
		2007	2905			4007	4905
6		2002	2902	14		4001	4901
		2003	2908			4006	4902
7		2004	2901	15		4003	4906
		2008	2907			4005	4908
8		2005	2903	16		4002	4904
		2006	2906			4008	4907

Table 1-(concluded)

Evaluation period	Replication	Steak code[b] Choice	Steak code[b] Good	Evaluation period	Replication	Steak code[b] Choice	Steak code[b] Good
17	V	5003	5901	21	VI	6006	6904
		5005	5907			6007	6906
18		5004	5905	22		6003	6901
		5008	5908			6005	6903
19		5001	5902	23		6001	6902
		5006	5904			6002	6908
20		5002	5903	24		6004	6905
		5007	5906			6008	6907

[a]Two U.S. Choice and two U.S. Good rib steaks selected randomly within each replication

[b]Interpretation of steak codes:

1st no. = Replication (1-6)

2nd no. = Grade (0 = Choice, 9 = Good)

3rd no. = Steak no. for histological, pH and ether extract measurements (2, 5, 8 for raw samples or "0" for cooked samples)

4th no. = Steak no. (1-8 for cooked samples or "0" for raw samples)

The boneless beef rib steaks were cooked by modified roasting. Each steak was placed on a wire rack 12.7 cm high, and a thermometer (-20 to 100°C) 14.1 cm in length with a small bulb was inserted with the bulb in the geometric center of the LD muscle.

Steaks were cooked in an electric rotary hearth oven at 177°C to an internal temperature of 60°C. Percentages of total, volatile and dripping cooking losses, based on weight of the defrosted steak, were calculated.

Histological measurements

Samples. Histological samples (approximately 1.5 x 1.5 x 0.5 cm) from raw and cooked muscle were removed parallel to the muscle fiber from steaks in positions specified by the sampling plans (Fig. 3 and 4).

Samples were fixed in 10% formalin and physiological saline solution, and held at room temperature (22 to 26°C) for 24 to 32 days. The order of preparing sections for histological study was the same as that followed for cooking the steaks.

Preparation of slides. Each fixed tissue sample was blotted on paper towel, then washed in tap water for 10 minutes. A CTD International Harris Cryostat Microtome was used for sectioning the muscle. Specimens (approximately 1 x 1 x 0.5 cm) were cut parallel with the fibers of each sample. A small amount of Cryoform, an embedding matrix, was placed on the microtome tissue holder. The tissue to be

Figure 4-Plan for sampling the cooked rib steak (longissimus dorsi).

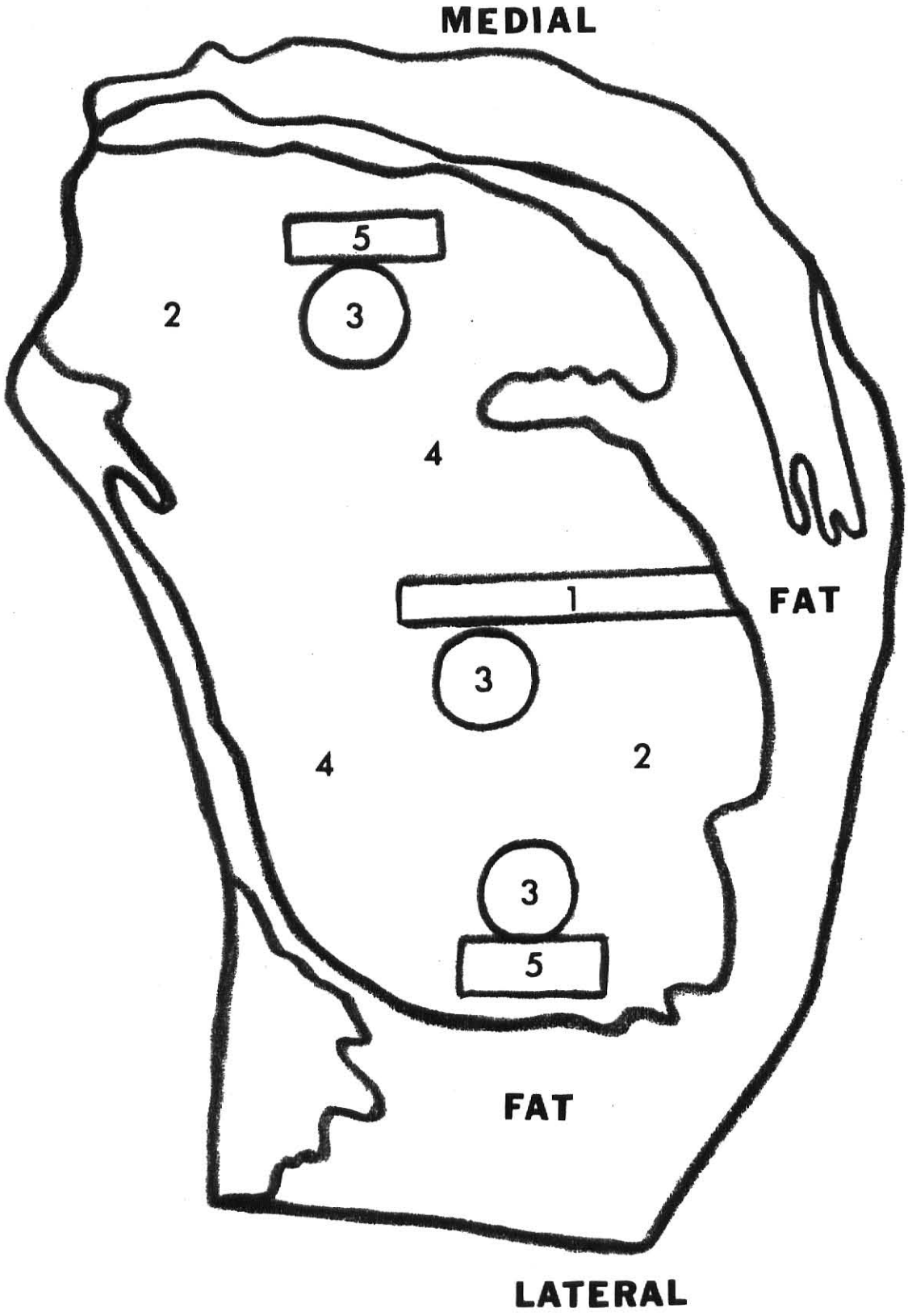
1 Thermometer hole

2 Sensory evaluation samples

3 Shear cores and water-holding capacity

4 Total moisture, pH and ether extract

5 Histological samples


MEDIAL
5
2
3
4
1
FAT
3
4
2
3
5
FAT
LATERAL

sectioned was placed on the cryoform and the holder was inserted into the Cryostat Microtome. A commercial preparation of freon gas, Cryokwik, was used to freeze the tissue before sectioning. Sections, 8 μ thick, were cut longitudinally at a working temperature of -19 to -20°C. Each section was transferred immediately to a slide containing a thin layer of albumin fixative by lightly touching the slide to the section while it was still on the knife blade. At least 15 sections were prepared from each sample.

Sections were stained to differentiate the muscle fibers and fat. Stains used were Alum Hematoxylin for the muscle fibers and Sudan IV for fat. After the section was stained, the cover glass was mounted on the slide with glycerine jelly. Details of staining and mounting procedures are described in the Appendix, p. 57 and 58.

Evaluation. A three-member panel evaluated five sections of muscle tissue per sample for muscle fiber width, relative quantity of fat and fat distribution. For each U.S. grade, each panel member used an ocular micrometer in the eyepiece of the Bausch and Lomb microscope and magnification of 430x to measure the width of three fibers (Forms I and II, Appendix, p. 59 to 61) randomly selected, from each section (36 samples (18 raw tissue, 18 cooked tissue) x 5 sections x 3 fibers = 540 fibers). This procedure provided for the measurement of 810 raw and 810 cooked fibers per grade.

For each grade, quantity and distribution of fat in 540 sections (270 raw tissue, 270 cooked tissue) were estimated

by the three-member panel using a Bausch and Lomb micro-projector. A distance of 59.4 cm between the slide and the surface of plain white paper on which the section was projected gave a magnification of 16.1x. The slide was moved back and forth until the entire section was viewed before judgements for quantity and distribution of fat based on a seven-point intensity scale, were given (Form I, Appendix, p. 59). A score seven represented a large quantity of fat and a score of one represented no fat to a trace of fat.

One person used a Bausch and Lomb microprojector to obtain an objective measurement of the quantity and distribution of fat in 90 sections of each U.S. grade (45 raw tissue, 45 cooked tissue). Each section was projected on graph paper with 20 x 20 squares to the inch (Fig. 5). At a magnification of 16.1x, each squares represented 0.1 sq mm on the section as measured by focusing a Lovins Microslide Field Finder on the graph paper. The area of fat projected in 3,000 squares on the graph paper was colored on the paper. Six randomly selected positions of each section of muscle tissue were measured. The colored squares for the six positions were counted and averaged to obtain the area of fat per 300 sq mm of a section of tissue. Counting was done using an AO Quebec Darkfield Colony Counter or a hand counter.

Tenderness and juiciness scores from a 6-member sensory panel, Warner-Bratzler shear values, pH and ether extract data for the same steaks from which histological samples were taken were provided by colleagues in the laboratory. Methods

Figure 5-Objective evaluation of fat quantity using the microprojector.

A Measurement of squares with field finder

B Measurement of fat area per 3,000 squares on graph paper

A

B

used for those measurements are described in the Appendix, p. 62 to 65.

Statistical analyses

Data for fiber width; fat quantity, panel score; fat distribution, panel score and ether extract were analyzed by analysis of variance (AOV) for a split, split plot design. An unequal subclass AOV for a split, split plot design was used to analyze data for fat quantity, objective score and pH (Table 2). Grades were the main plots, steak position and treatment (raw vs. cooked) as the sub plots.

The AOV for sensory scores and Warner-Bratzler shear values was:

Source of variation	D/F
Grade (G)	1
Error A	10
Steak position (S)	2
G x S	2
Error	20
Total	35

When the analysis of variance for effects of steak position indicated significant differences, least significant differences (LSD) at the 5% level were calculated, e. g., ether extract and tenderness scores.

Also, correlation coefficients were calculated on the basis of grade for selected paired variates:

Table 2-Analysis of variance (AOV) for histological measurements, ether extract and pH

Source of variation	Measurement					
	Fiber width[a]	Fat quantity panel score[a]	Fat quantity objective score[b]	Fat distribution panel score[a]	Ether extract[a]	pH[b]
	Degrees of freedom					
Grade (G)	1	1	1	1	1	1
Error A	10	10	4	10	10	10
Steak position (S)	2	2	2	2	2	2
G x S	2	2	2	2	2	2
Error B	20	20	8	20	20	20
Treatment (T) (raw vs. cooked)	1	1	1	1	1	1
G x T	1	1	1	1	1	1
S x T	2	2	2	2	2	2
G x S x T	2	2	2	2	2	2
Error	30	30	12	30	30	18
Total	71	71	35	71	71	59

[a]Data were analyzed by AOV for a split, split plot design

[b]Data were analyzed by an unequal subclass AOV for a split, split plot design

Fiber width, cooked muscle vs.

Tenderness score

Fat quantity objective score, cooked muscle vs.

Tenderness score

W-B shear value

Juiciness score

Fat distribution panel score, cooked muscle vs.

Tenderness score

W-B shear value

Juiciness score

Ether extract vs.

Tenderness score

Fat quantity panel score

Fat quantity objective score

Fat distribution panel score

RESULTS AND DISCUSSION

Effect of grade

None of the measurements were affected significantly by grade (Table 3). Mean fiber width was only slightly greater for U.S. Good (46.5 μ) than that for U.S. Choice (46.2 μ) bovine LD muscle. Figure 6 shows the similarity in fiber width observed in microscopic sections of tissue from LD muscle representing the two U.S. grades.

One of the 18 samples from U.S. Good bovine LD muscles

Table 3-Means, standard deviations of means and F-values for selected measurements by grade

Measurement	Grade				F-value
	U.S. Choice		U.S. Good		
	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	
Histological measurements[a]					
Fiber width, μ	46.2	±4.5	46.5	±5.8	0.01
Fat quantity					
Panel score[b]	5.1	±0.9	4.9	±1.0	0.94
Objective score[c]	11.6	±6.1	13.1	±7.5	0.11
Fat distribution					
Panel score[d]	4.7	±1.0	4.8	±1.1	0.28
pH[a]	5.51	±0.09	5.54	±0.08	2.29
Ether extract[a,e]	7.6	±3.0	7.2	±3.3	0.36
W-B shear value[f], kg/1.3-cm core	2.1	±0.4	2.1	±0.5	0.00
Sensory score[f,g]					
Tenderness	4.6	±0.3	4.5	±0.4	0.82
Juiciness	4.3	±0.4	4.2	±0.4	0.04

[a]Data for all steak positions and raw and cooked samples combined (n = 36, except for fat quantity objective score, where n = 18 and pH, where n = 30)

[b]Range 7-1 = large to none

[c]Area of fat/300 sq mm of muscle section (16.1x)

[d]Range 7-1 = large droplets to cloudy aggregate

[e]Percentage lipid, moisture free basis

[f]Data for all steak positions and cooked samples combined (n = 18)

[g]Range 5 (tender, juicy) to 1 (tough, dry)

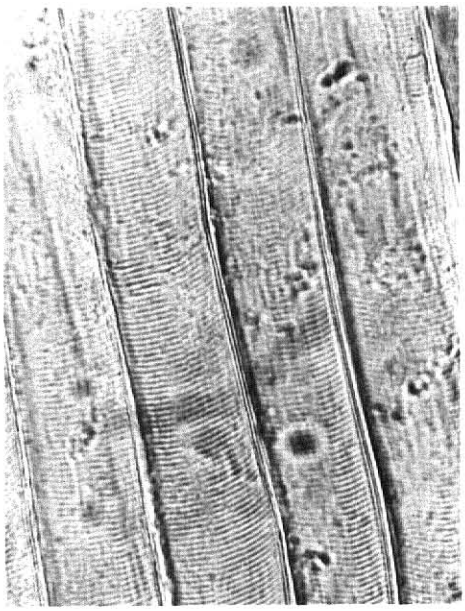
Figure 6-Photomicrographs illustrating fiber width of LD muscls from U.S. Choice and U.S. Good ribs (430x).

A Choice, raw

B Choice, cooked

C Good, raw

D Good, cooked



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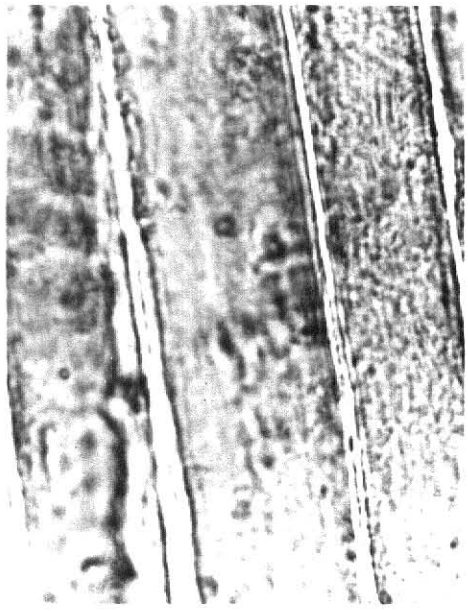

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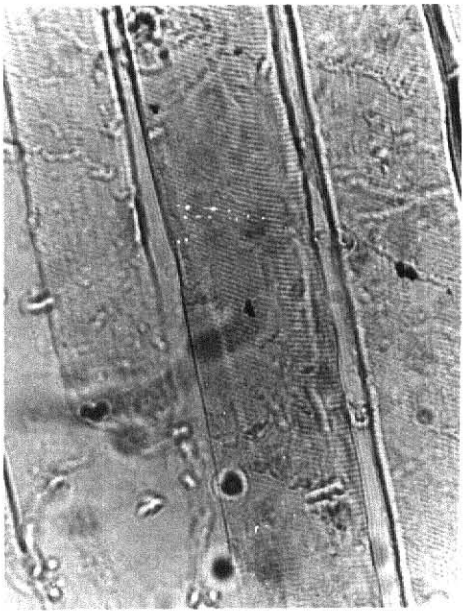

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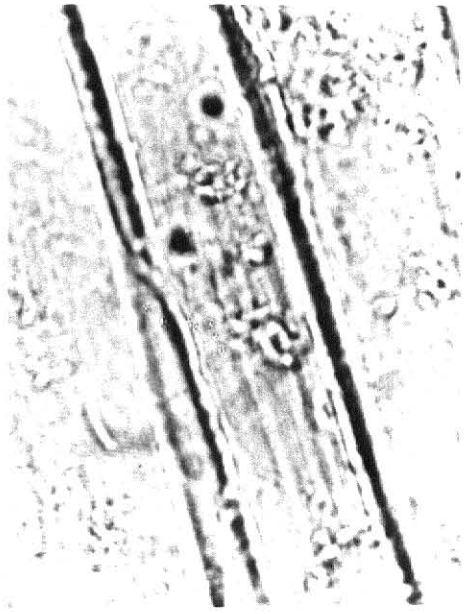


C

that was observed in this study had an average value of 35.2 for fat quantity objective score, which was approximately 2.7 times that of the mean value (13.1). The mean value for fat quantity objective score for U.S. Good obtained with that particular observation omitted was 11.5. This reflected the effect of sampling. Lowe (1948) noted that any microscopic section under scrutiny represents an extremely small area of the entire muscle, and different areas in the same section may vary widely.

Effect of steak position

Ether extract and tenderness scores were affected significantly by steak position (Table 4). Least significant difference ($P < 0.05$) between means indicated that each steak position differed from every other position in percentage ether extract. Position 2 (near the anterior end) had the highest value and position 8 (close to the posterior end) had the lowest value, which indicated that percentage ether extract decreased from the anterior to the posterior end of the bovine rib LD muscle. Similarly, Doty and Pierce (1961) observed that a 7th to 8th rib section of bovine LD muscle contained a higher percentage of intramusclar fat than a 9th to 12th rib section, but differences between the 9th to 10th and the 11th to 12th rib sections were not significant. Lawrie (1961) noted that the intramuscular fat within the 3rd to 5th lumbar section was higher than that found in a corresponding section of the 9th to 11th thoracic vertebra.

Table 4-Means and F-values by steak position

Measurement	Steak position 2	5	8	F-value	$LSD_{0.05}$
Histological measurements[a]					
Fiber width, μ	46.4	46.0	46.6	0.21	
Fat quantity					
Panel score[b]	5.3	5.0	4.6	0.93	
Objective score[c]	13.1	14.8	9.2	3.46	
Fat distribution					
Panel score[d]	4.9	4.8	4.5	0.96	
pH[a]	5.54	5.51	5.53	1.51	
Ether extract[a,e]	8.6	7.4	6.2	10.59***	1.10
W-B shear value[f], kg/1.3-cm core	2.3	2.0	2.0	3.11	
Sensory score[f,g]					
Tenderness	4.4	4.5	4.7	5.46*	0.17
Juiciness	4.1	4.3	4.3	1.44	

[a]Data for both grades and raw and cooked samples combined (n = 24, except for fat quantity objective score, where n = 12 and pH, where n = 20)

[b]Range 7-1 = large to none

[c]Area of fat/300 sq mm of muscle section (16.1x)

[d]Range 7-1 = large droplets to cloudy aggregate

[e]Percentage lipid, moisture free basis

[f]Data for both grades of cooked samples combined (n = 12)

[g]Range 5 (tender, juicy) to 1 (tough, dry)

*, $P < 0.05$; ***, $P < 0.001$

Cook et al. (1964) also reported differences ($P < 0.01$) in ether-extractable lipid among anatomical positions within the bovine LD muscle. The lowest level of intramuscular lipid was proximate to the 11th to 12th thoracic vertebra.

LSD ($P < 0.05$) between means for tenderness scores indicated that tenderness increased from the anterior to the posterior end of bovine LD muscle. Other investigators reported variations in tenderness within the bovine LD muscle. Ramsbottom et al. (1945) found that LD muscle was more tender at the posterior end and in the middle than at the anterior end. However, Ginger (1957) reported that LD muscle was most tender in the anterior portion and least tender in the center portion.

Fiber width, fat quantity panel score and objective score, fat distribution panel score, pH, W-B shear value and juiciness score were not affected significantly by steak position (Table 4).

Effect of cooking

Ether extract, pH and all of the histological measurements except fat quantity objective score were affected significantly by cooking (Table 5). Mean fiber width was smaller ($P < 0.001$) for cooked muscle than that for raw muscle. The percentage decrease in fiber width from raw to cooked tissue (heated to 60°C) was 6.9. Similarly, Reid and Harrison (1971) reported decreases in fiber width of 7.2% for beef semimembranosus muscle heated to 70°C by oven roasting.

Table 5-Means and F-values for raw and cooked samples

Measurement[a]	Raw	Cooked	Change from raw to cooked,%	F-value
Histological measurements				
Fiber width, μ	48.0	44.7	-6.9	25.43***
Fat quantity				
Panel score[b]	4.7	5.2	10.6	4.94*
Objective score[c]	12.2	12.5	2.5	0.01
Fat distribution				
Panel score[d]	5.2	4.2	-19.2	17.00***
pH	5.46	5.59	2.4	31.68***
Ether extract[e]	5.2	9.6	84.6	104.79***

[a]Data for both grades and all steak positions combined (n = 36, except for fat quantity objective score, where n = 18 and pH (raw), where n = 24)

[b]Range 7-1 = large to none

[c]Area of fat/300 sq mm of muscle section (16.1x)

[d]Range 7-1 = large droplets to cloudy aggregate

[e]Percentage lipid, moisture free basis

*, $P < 0.05$; ***, $P < 0.001$

Satorius and Child (1938) reported decreases in fiber diameter of 12 to 16% for beef muscles (LD, triceps brachii and adductor) heated to 58°C by oven roasting, and further decreases during heating to 67°C. Hosteltler and Landmann (1968) heated LD fibers on slides on a microscope stage to 53° - 77°C. They observed decreases of approximately 20 to 25% in muscle fiber diameter. Figure 6 illustrates the differences in fiber width observed in microscopic sections of raw and cooked tissues from LD muscle of both grades.

Mean fat quantity panel score for cooked muscle was higher ($P < 0.05$) than that for raw muscle (Table 5). However, the objective scores did not differ significantly. Mean fat distribution panel score was lower ($P < 0.001$) for cooked muscle than that for raw muscle, which indicated that cooked muscle tended to have smaller droplets of fat than raw tissue. Norris et al. (1971) and Wang et al. (1954) reported similar observations. Figure 7 shows the microprojector images of fat quantity and distribution for both raw and cooked LD muscles from U.S. Choice and U.S. Good ribs. Fat droplets of the cooked muscles were smaller than that of the raw tissues.

Mean values for pH indicated a 2.4% increase ($P < 0.001$) from raw to cooked samples (60°C end point). Increases in pH of 0.4% and 1.1% were observed by Schock et al. (1970) and Vollmar et al. (1976), respectively, for semimembranosus muscle heated to 70°C by oven roasting. Harrison (1947) found that during cooking, five beef muscles in deep fat at 96° to 98°C to 70°C became more (5.1%) alkaline. Also,

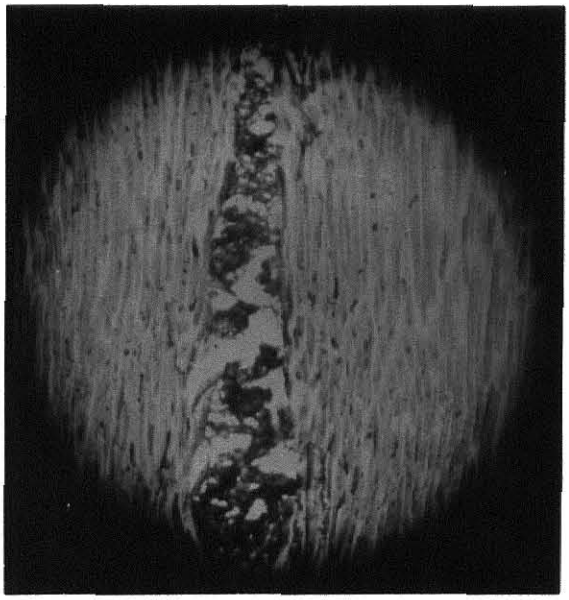
Figure 7-Microprojector images of fat quantity and distribution of U.S. Choice and U.S. Good grades LD muscles.

A Choice, raw

B Choice, cooked

C Good, raw

D Good, cooked



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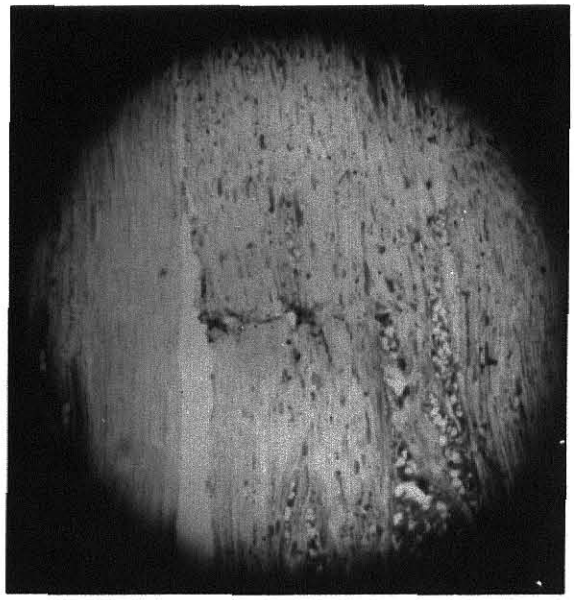

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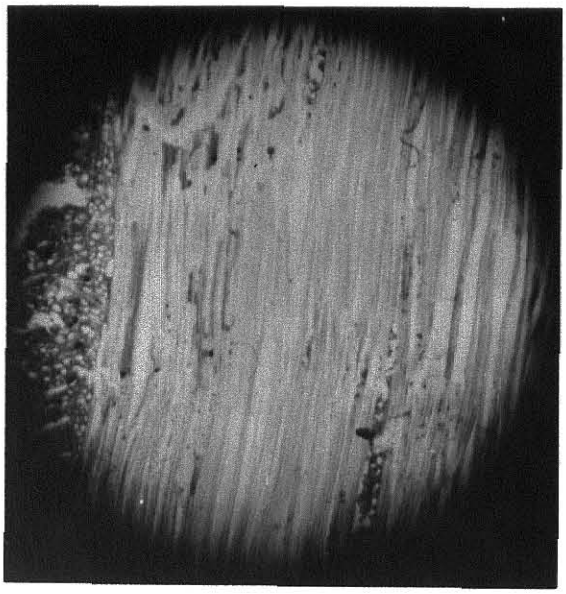

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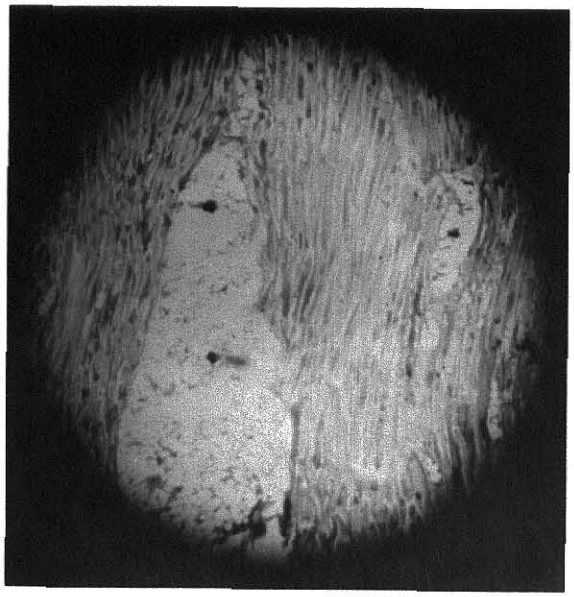

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Bendall (1946) reported a shift in pH (5.1%) to the alkaline side when beef was cooked at 100°C for one hour. Molecular changes under gone by the proteins, such as the formation of free sulfhydryl groups during coagulation, and the loss of carbon dioxide during cooking may contribute to this change in pH.

The mean value for percentage ether extract was higher ($P < 0.001$) for cooked muscle than that for raw muscle. The percentage increase for this measurement from raw to cooked muscle was 84.6. Woolsey and Paul (1969) reported that more crude fat was extracted from cooked than from raw, lean muscle. They explained that heating caused denaturation of protein and subsequent release of lipid previously complexed with protein, so that lipid in cooked muscle was more accessible to both polar and nonpolar solvent extraction than was lipid in raw muscle.

Relationships between selected measurements

Correlation coefficients for selected paired variates on the basis of grade are given in Table 6. Shindell (1964) cited Falkner (1962) and stated that usually a coefficient between 0.00 (no correlation) and 0.39 is considered low, one between 0.40 and 0.79 is moderate, and one above 0.80 is considered high. With those values the plus (+) and minus (-) signs are disregarded. For the data in this study, few significant relationships were obtained between tenderness score, juiciness score or W-B shear value and any of the

Table 6-Correlation coefficients for selected paired variates on the basis of grade

Paired variates	Grade	
	U.S. Choice	U.S. Good
Fiber width, cooked muscle vs.[a]		
Tenderness score	0.02	-0.76**
W-B shear value	0.01	0.45
Fat quantity panel score, cooked muscle vs.[a]		
Tenderness score	-0.19	-0.38
W-B shear value	0.22	0.16
Juiciness score	-0.02	-0.40
Fat quantity objective score, cooked muscle vs.[b]		
Tenderness score	0.06	0.16
W-B shear value	-0.22	-0.50
Juiciness score	0.44	-0.20
Fat distribution panel score, cooked muscle vs.[a]		
Tenderness score	0.35	-0.22
W-B shear value	-0.20	0.06
Juiciness score	-0.01	0.13
Ether extract vs.		
Tenderness score[a]	-0.32	-0.62**
Fat quantity panel score[c]	0.53**	0.43**
Fat quantity objective score[a]	0.17	0.18
Fat distribution panel score[c]	-0.42*	-0.11

[a] D/F = 16; r-value required for a significant relationship: $P < 0.05$, 0.468; $P < 0.01$, 0.59

[b] D/F = 7; r-value required for a significant relationship: $P < 0.05$, 0.666; $P < 0.01$, 0.798

[c] D/F = 34; r-value required for a significant relationship: $P < 0.05$, 0.330; $P < 0.01$, 0.424

*, $P < 0.05$; **, $P < 0.01$

histological measurements. Correlation was moderate (r = -0.76) for fiber width, cooked muscle vs. tenderness score for U.S. Good bovine LD muscle. As fiber width increased, tenderness score decreased.

Correlations (r = -0.32 or -0.62) were low or moderate for ether extract vs. tenderness score, that was in agreement with the results found in effect of steak position (Table 4). Ether extract decreased from the anterior to the posterior end of the bovine LD muscle. However, tenderness scores indicated that tenderness increased from the anterior to the posterior end of the bovine LD muscle. Moderate (r = 0.53 or 0.43) relationships were observed between ether extract and fat quantity panel score for both grades. Coefficients (r = -0.42 or -0.11) were moderate or low for ether extract vs. fat distribution panel score.

SUMMARY

Raw and cooked (heated to 60°C by modified oven roasting) muscle samples from bovine LD muscle representing USDA Choice and USDA Good ribs were used to study the selected histological characteristics of beef rib steaks from the two U.S. grades. Data for other characteristics of the same steaks from which histological samples were taken were provided by colleagues in the laboratory to study the relationship of ether extract, tenderness, juiciness to histological characteristics of rib steaks within each grade. Date were

analyzed by analysis of variance for a split, split plot design, and least significant differences at the 5% level were calculated when F-values for effects of steak position (anterior to posterior of LD muscle) were significant. Correlation coefficients were calculated for selected paired variates on the basis of grade.

Percentage ether extract, histological estimates of fiber width, fat quantity (panel score and objective score), or fat distribution (panel score) did not differ significantly between the two U.S. grades. Percentage ether extract decreased ($P < 0.05$) from the anterior to the posterior end of LD muscle from U.S. Choice or U.S. Good beef ribs. Ether extract, pH and all of the histological measurements, except fat quantity (objective score), were affected significantly by cooking. Raw muscle tended to have wider fibers, less ether-extractable lipid, slightly larger fat droplets and lower pH than cooked tissue. Relationships between ether extract, tenderness or juiciness to any of the histological measurements were low to moderate. Correlation was moderate ($r = -0.76$) for fiber width, cooked muscle, vs. panel tenderness score for U.S. Good bovine LD muscle. As fiber width increased, tenderness decreased. Fat quantity and distribution had little relationship to tenderness or juiciness of U.S. Choice or U.S. Good bovine LD muscle.

CONCLUSIONS

Under the condition of this study, it was concluded that:

1. In general, selected histological characteristics and percentage ether extract do not differ significantly between U.S. Choice and U.S. Good bovine LD muscle.
2. Fat quantity or fat distribution has little relationship to tenderness and juiciness of U.S. Choice or U.S. Good bovine LD muscle.
3. Percentage ether extract decreases ($P < 0.05$) from the anterior to the posterior end of LD muscle from U.S. Choice or U.S. Good beef ribs.
4. Relationships between ether extract, tenderness or juiciness to any of the histological measurements are low to moderate.

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APPENDIX

Table 7-Selected characteristics of wholesale rib cuts

Characteristic	Rib number	U.S. Grade	
		Choice	Good
Marbling score	I	small+	slight+
	II	small	small
	III	small+	small-
	IV	small	slight
	V	small+	slight
	VI	modest-	slight+
Yield grade	I	3	3
	II	2	2
	III	3	3
	IV	2	2
	V	4	3
	VI	4	3
Aging time, days	I	6	6
	II	12	8
	III	12	9
	IV	13	8
	V	6	6
	VI	8	9
Carcass weight, kg			
Hot	I	290	307
	II	266	278
	III	343	353
	IV	344	237
	V	347	314
	VI	234	232

Table 7-(concluded)

Characteristics	Rib number	U.S. Grade	
		Choice	Good
Carcass weight, kg			
Chilled	I	286	304
	II	264	275
	III	337	349
	IV	339	235
	V	341	310
	VI	229	228
Wholesale rib weight, kg	I	15.5	14.5
	II	12.7	13.2
	III	15.0	15.9
	IV	--	--
	V	16.8	14.1
	VI	8.6	9.5
Fat thickness over rib, cm	I	0.5	0.5
	II	0.5	1.0
	III	1.0	2.0
	IV	1.0	0.6
	V	0.8	0.8
	VI	2.0	0.5

STAINING AND MOUNTING PROCEDURES

The following staining procedure[a] was used to stain muscle fibers and fat.

1. Tissue in tap water - dip
2. Stain in Alum Hematoxylin[b] - 1.5 to 2 minutes
3. Rinse in tap water - 1 minute
4. Rinse in tap water - 0.5 minute
5. Rinse in tap water - 0.5 minute
6. Stain in Sudan IV solution[c] -

   1.5 to 2 minutes for raw tissue section

   2.5 to 3 minutes for cooked tissue section
7. Dip in 50% ethyl alcohol
8. Dip in 70% ethyl alcohol
9. Dip in 95% ethyl alcohol
10. Rinse in tap water
11. Rinse in tap water

Muscle fibers stained blue and fat cells stained red.

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[a] Modified from "Microtome-Cryostat Handbook" International Equipment Co., Needham Heights, Mass. 1964.

[b] Manufactured by: Paragon C. & C. Co., Inc. 190 Willow Avenue, Bronx, N. Y. 10454

[c] Formula for Sudan IV solution:

1.0 g Sudan IV
50 ml 70% ethyl alcohol
50 ml acetone

Keep the saturated solution in a tightly stoppered bottle, and filter before using.

Mounting the cover glass

Glycerine jelly was used as the mounting medium. After the sections were stained and the slides were dried with tissue paper, care being taken to avoid damage to the meat section, about two drops of warm glycerine jelly (stored at 37°C in a paraffin warming oven, and heated in a hot-water bath (approximately 70°C) during mounting periods) were dropped onto the section. Then, cover glass was lowered over the section by placing one edge down on the slide and allowing the mounting media to flow under it as the cover glass was lowered over the section. This retarded formation of bubbles in the glycerine jelly. Five sections from each sample were selected for histological evaluation.

Form I. Score Card for Histological Evaluation of USDA Choice and USDA Good Beef Rib Steaks.

Panel Member _____ Code _____ Date_____

Measurement	Section number 1	2	3	4	5	Total	Average
Muscle fibers							
Fiber width, μ							
Fat							
Relative quantity[a]							
Fat distribution[b]							

[a]Quantity

7 - Large
5 - Medium
3 - Small
1 - None or trace

[b]Distribution

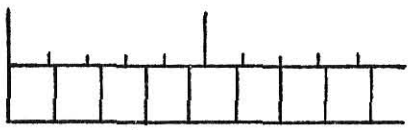
7 - Large droplets
5 - Medium droplets
3 - Small droplets
1 - Cloudy aggregate of fat

Form II. Instructions for Microscopic Measurement of Fiber Width

The virtual image of a tiny scale is engraved on a clear glass disc, the ocular micrometer. Insert this disc into the eyepiece by unscrewing the top lens and inserting the disc into the shelf within the eyepiece. This disc is marked off in equal units with the center further divided into smaller units.

To measure the magnified image, the units on the ocular disc are compared to a stage micrometer. This is a slide with a measurement line divided into 0.01 mm units. To do this, insert the slide on the stage of the microscope under high power (43x objective and 10x eyepiece). Set the Dyna-zoom knob on the microscope at position 1 to give a magnification of 430x. Match a line of the scale on the stage micrometer with a line on the squared scale of the ocular (eyepiece) micrometer. Count the number of ocular and stage units until another line on the ocular matches another line on the stage micrometer.

Example:



7 stage units

6 ocular units

Determine the distance covered by the ocular units. Each unit on the stage micrometer equals 0.01 mm, see slide. There were 7 stage units counted so 0.07 mm is the same measurement as 6 magnified ocular units. Divide the distance in the stage micrometer by the corresponding number of units in the ocular micrometer to determine the actual size of each ocular unit.

Example: 7 stage units = 7 x 0.01 or 0.07 mm

$\frac{0.07}{6}$ = 0.012 mm/ocular unit or

1 ocular unit = 0.012 mm

Replace the stage micrometer with the slide to be studied. The width of the muscle fibers can be obtained by counting the number of units that correspond to the width of a fiber and multiplying that number by the size of the unit of measure.

Example: muscle fiber width = 3 ocular units
3 x 0.012 mm = 0.036 mm for that fiber's width
Covert the mm value to μ by multiplying by 1000.
0.036 mm x 1000 = 36 μ

Notes. Through the center of the eyepiece, the ocular units are further divided into 5 parts. These may be used in measurements for greater accuracy.

The eyepiece can be turned in the tube, thus turning the ocular scale. In this way, fibers can be measured even though they do not lie in a perfectly vertical or horizontal direction.

For each section, select 3 fibers at random, measure, calculate width in μ and record on score sheet.

Once the ocular micrometer has been set up, it should not be removed from the eyepiece of the microscope. If the disc is removed from the eyepiece, the calibrations for unit determinations need to be repeated for each magnification used, because turning the disc over changes the calibration readings.

METHODS OF MEASURING TENDERNESS, JUICINESS, pH AND ETHER EXTRACT

Sensory evaluation

For sensory evaluation, cores of cooked meat 1.3 cm in diameter and 3 cm in length were presented to panel members in the top of half-pint double boilers set over warm water (approximately 50°C) and the entire system was placed on an electric hot tray at low heat (approximately 71°C). All sensory evaluation took place within 15 minutes after preparation of samples. Panel members scored the cores of meat using Forms III & IV (Appendix, p. 64 and 65).

Shear values

Tenderness was measured on the cooked steaks by shearing cores of LD muscle 1.3 cm in diameter on a Warner-Bratzler shearing apparatus with a 11.25 kg dyanmometer. Cores were taken from the lateral, center and medial positions of the LD muscle (Fig. 4). Triplicate measurements were made on each core and averaged for the overall shear value.

pH

Duplicate pH measurements were made on slurries of ground raw and cooked muscle using a Horizon Digital pH meter. For each slurry, 5 g ground muscle (Fig. 4) were blended with 50 ml distilled, deionized water for 2 minutes at high speed in a Waring Blender. The slurry was brought to 25°C, stirred 30 seconds with a magnetic stirrer, and the pH reading was taken. The beaker was turned 180°, the slurry

stirred an additional 15 seconds, and a second reading was taken. The pH meter was standardized against a buffer of pH 6.86.

Ether extract

Percentage ether extract (moisture free basis) in both raw and cooked meat were measured by the analytical laboratory of the Department of Animal Science and Industry using a modified AOAC method (AOAC, 1976).

Form III. Score Card for the Sensory Evaluation of USDA Good and USDA Choice Beef Rib Steaks.

Panel Member _____ Code _____ Date _____

Sample No.	Flavor[a]	Juiciness[b]	Tenderness		Comments
			Chews	Score[c]	
1					
2					
3					
4					

Descriptive terms for scoring:

[a]Flavor

5 Rich rare beef flavor
4 Moderately rich rare beef flavor
3 Slightly rich rare beef flavor
2 Perceptible rare beef flavor
1 No beef flavor

[b]Juiciness

5 Juicy
4 Moderately juicy
3 Neither juicy nor dry
2 Slightly dry
1 Dry

[c]Tenderness

5 Tender
4 Moderately tender
3 Neither tender nor tough
2 Slightly tough
1 Tough

Form IV. Instructions to Judges for Sensory Evaluation of USDA Good and USDA Choice Beef Rib Steaks.

For sensory evaluation, each judge is to select two cores (1.3 cm diam) of meat at random from each double boiler. Use one core for assessing flavor and juiciness, the other for counting the number of chews and evaluating tenderness.

Scoring for flavor and juiciness

Record a score for flavor and another for juiciness within a range of 5 to 1 that describes your impression of the sample. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1. Record a score describing your impression of flavor and juiciness at the beginning of the chewing process.

Scoring for tenderness

Count the number of chews on a 1.3 cm core of meat before swallowing. Chew until the core is masticated completely, then swallow. Record a score of 5 to 1 that describes your impression of the tenderness of the core. Refer to the score card for descriptive terms for the specific scores within the range of 5 to 1.

Use the number of chews to help you standardize your tenderness scores from day to day. Set up for yourself a range of the number of chews for each score from 5 to 1. For example, if you chew from 25 to 35 times, a score of 5; 35 to 45 times, a score of 4; continuing to reduce the score by a given number of increased chews. Each judge sets his own range of chews for a given score.

Comments

Comments about the samples or an explanation of why you gave a particular score to the sample are helpful.

Take your time to score each sample. Water is provided for rinsing your mouth between samples.

Table 8-Mean squares and F-values for fiber width and fat quantity panel scores

Source of variation	D/F	Fiber width		Fat quantity panel score	
		Mean square	F-value	Mean square	F-value
Grade(G)	1	1.361491	0.011	0.740146	0.943
Error A	10	124.058197		0.785137	
Steak position(S)	2	2.461833	0.206	2.497622	2.928
G x S	2	0.081676	0.007	0.823484	0.966
Error B	20	11.924652		0.852887	
Treatment(T) (raw vs. cooked)	1	192.406235	25.433***	3.966736	4.941*
G x T	1	0.516879	0.068	0.040139	0.050
S x T	2	1.193916	0.158	0.619305	0.771
G x S x T	2	0.390493	0.052	1.048468	1.306
Error	30	7.565090		0.802753	
Total	71				

*, $P < 0.05$; ***, $P < 0.001$

Table 9-Mean squares and F-values for fat distribution panel scores and ether extract

Source of Variation	D/F	Fat distribution panel score		Ether extract	
		Mean square	F-value	Mean square	F-value
Grade(G)	1	0.142226	0.280	3.827220	0.358
Error A	10	0.508220		10.678692	
Steak position(S)	2	1.095964	0.963	35.290451	10.587***
G x S	2	1.388446	1.220	2.987201	0.896
Error B	20	1.138054		3.333372	
Treatment(T) (raw vs. cooked)	1	16.819977	16.965***	338.866455	104.787***
G x T	1	0.375553	0.379	0.719998	0.223
S x T	2	0.190413	0.192	1.887207	0.584
G x S x T	2	0.715135	0.721	1.681658	0.520
Error	30	0.991448		3.233859	
Total	71				

***, $P < 0.001$

Table 10-Mean squares and F-values for fat quantity objective score and pH

Source of variation	Fat quantity objective score			pH		
	D/F	Mean square	F-value	D/F	Mean square	F-value
Grade(G)	1	22.562470	0.613	1	0.010208	2.290
Error A	4	36.904703		10	0.004458	
Steak position(S)	2	99.628555	3.461	2	0.002153	1.520
G x S	2	31.205780	1.084	2	0.000903	0.637
Error B	8	28.785477		20	0.001417	
Treatment(T) (raw vs. cooked)	1	0.613598	0.011	1	0.200209	31.687***
G x T	1	10.780272	0.192	1	0.001875	0.297
S x T	2	14.996917	0.268	2	0.000208	0.033
G x S x T	2	113.378433	2.025	2	0.000625	0.099
Error	12	56.001404		18	0.006318	
Total	35			59		

***, $P < 0.001$

Table 11-Mean squares and F-values for tenderness score, juiciness score and W-B shear value

Source of variation	D/F	Tenderness score		Juiciness score		W-B shear value	
		Mean square	F-value	Mean square	F-value	Mean square	F-value
Grade(G)	1	0.187770	0.820	0.010000	0.042	0.000000	0.000
Error A	10	0.229111		0.236222		0.369555	
Steak position(S)	2	0.225282	5.458*	0.221116	1.440	0.298612	3.114
G x S	2	0.258609	6.265**	0.000000	0.000	0.052500	0.548
Error	20	0.041278		0.153555		0.095889	
Total	35						

*, $P < 0.05$; **, $P < 0.01$

Table 12-Fiber width (μ)[a] for U.S. Choice and U.S. Good bovine longissimus dorsi muscles

Replication	Steak number	Grade			
		U.S. Choice		U.S. Good	
		Raw	Cooked	Raw	Cooked
I	2', 2	55.9	47.4	44.0	43.9
	5', 5	47.8	49.9	50.2	44.7
	8', 8	50.6	46.4	50.4	50.3
	mean	51.4	47.9	48.2	46.3
II	2', 2	49.3	44.3	51.4	49.1
	5', 5	49.7	47.4	49.8	50.0
	8', 8	46.8	47.6	52.9	50.8
	mean	48.6	46.4	51.4	50.1
III	2', 2	47.4	47.0	53.8	52.2
	5', 5	49.8	47.6	58.2	54.3
	8', 8	44.6	46.1	53.9	52.2
	mean	47.6	46.9	55.3	52.9
IV	2', 2	49.5	46.2	50.5	38.0
	5', 5	49.0	40.9	42.9	38.1
	8', 8	55.2	46.6	44.7	43.1
	mean	51.2	44.6	46.0	39.7
V	2', 2	46.9	46.5	45.0	43.3
	5', 5	44.8	45.6	38.1	38.3
	8', 8	50.5	44.1	49.8	37.8
	mean	47.4	45.4	44.3	39.8
VI	2', 2	38.1	37.6	45.5	41.4
	5', 5	42.4	34.7	45.7	43.1
	8', 8	40.9	37.8	40.7	34.5
	mean	40.5	36.7	44.0	39.7

[a]Average value for three panel members

Table 13-Fat quantity(panel score[a])[b] for U.S. Choice and U.S. Good bovine longissimus dorsi muscles

Replication	Steak number	Grade			
		U.S. Choice		U.S. Good	
		Raw	Cooked	Raw	Cooked
I	2', 2	4.7	6.1	5.1	5.1
	5', 5	5.7	4.7	3.8	6.5
	8', 8	5.5	5.4	5.7	4.7
	mean	5.3	5.4	4.9	5.4
II	2', 2	4.2	6.1	4.9	6.1
	5', 5	5.8	5.8	5.1	5.1
	8', 8	3.7	5.0	3.0	5.4
	mean	4.6	5.6	4.3	5.5
III	2', 2	3.4	4.6	7.0	4.5
	5', 5	3.5	6.7	5.3	6.6
	8', 8	5.8	4.2	3.0	4.7
	mean	4.2	5.2	5.1	5.3
IV	2', 2	5.5	4.9	3.8	4.6
	5', 5	3.3	5.4	3.7	3.9
	8', 8	4.9	5.0	5.3	4.8
	mean	4.6	5.1	4.3	4.4
V	2', 2	4.7	5.3	5.8	5.4
	5', 5	4.2	4.6	5.8	4.9
	8', 8	5.0	4.5	3.3	4.7
	mean	4.6	4.8	5.0	5.0
VI	2', 2	6.6	6.2	6.2	5.4
	5', 5	5.4	5.7	3.4	5.0
	8', 8	4.5	5.5	3.4	3.8
	mean	5.5	5.8	4.3	4.7

[a]Range 7-1 = large to none

[b]Average value for three panel members

Table 14-Fat quantity(objective score[a]) for U.S. Choice and U.S. Good bovine longissimus dorsi muscles

Replication	Steak number	Grade			
		U.S. Choice		U.S. Good	
		Raw	Cooked	Raw	Cooked
I	2', 2	6.0	13.4	11.6	9.1
	5', 5	15.0	7.0	5.5	18.6
	8', 8	13.3	8.7	14.6	5.1
	mean	11.4	8.7	10.6	10.9
II	2', 2	12.4	21.3	14.2	17.7
	5', 5	23.0	13.5	14.7	12.6
	8', 8	6.5	11.0	5.6	16.3
	mean	14.0	15.3	11.5	15.5
III	2', 2	2.8	6.8	35.2	6.6
	5', 5	8.8	23.8	13.2	22.2
	8', 8	10.1	5.1	7.4	6.3
	mean	7.2	11.7	18.6	11.7

[a]Area of fat/300 sq mm of muscle section (16.1x)

Table 15-Fat distribution[a,b] for U.S. Choice and U.S. Good bovine longissimus dorsi muscles

Replication	Steak number	Grade			
		U.S. Choice		U.S. Good	
		Raw	Cooked	Raw	Cooked
I	2', 2	4.2	3.9	7.0	4.5
	5', 5	6.1	3.7	3.4	3.3
	8', 8	5.3	4.1	6.2	3.3
	mean	5.2	3.9	5.5	3.7
II	2', 2	5.9	5.7	5.0	5.6
	5', 5	6.6	5.0	4.3	4.5
	8', 8	4.1	4.9	3.8	5.3
	mean	5.5	5.2	4.4	5.1
III	2', 2	3.4	3.8	6.2	4.2
	5', 5	5.0	5.0	6.2	6.4
	8', 8	4.5	4.3	4.4	3.7
	mean	4.3	4.4	5.6	4.8
IV	2', 2	6.9	4.1	4.3	4.7
	5', 5	4.0	4.3	4.3	4.6
	8', 8	4.3	4.3	6.2	3.9
	mean	5.1	4.2	4.9	4.4
V	2', 2	4.9	3.4	5.7	4.9
	5', 5	4.9	3.5	7.0	3.9
	8', 8	6.7	4.3	3.7	3.5
	mean	5.5	3.7	5.5	4.1
VI	2', 2	5.6	3.5	6.9	3.7
	5', 5	6.2	3.1	4.2	5.0
	8', 8	5.7	3.4	4.5	3.5
	mean	5.8	3.3	5.2	4.1

[a]Range 7-1 = large droplets to cloudy aggregate

[b]Average value for three panel members

Table 16-Ether extract[a] for U.S. Choice and U.S. Good bovine longissimus dorsi muscles

Replication	Steak number	Grade			
		U.S. Choice		U.S. Good	
		Raw	Cooked	Raw	Cooked
I	2', 2	10.4	9.0	5.3	12.5
	5', 5	10.7	8.4	4.7	11.8
	8', 8	4.4	7.6	4.0	7.3
	mean	8.5	8.3	4.6	10.5
II	2', 2	4.9	12.2	5.1	10.3
	5', 5	3.7	11.6	5.6	9.7
	8', 8	3.1	7.6	3.9	10.9
	mean	3.9	10.5	4.9	10.3
III	2', 2	5.5	10.0	11.0	15.3
	5', 5	4.8	9.4	5.2	8.4
	8', 8	6.5	8.4	6.3	11.5
	mean	5.6	9.3	7.5	11.8
IV	2', 2	5.2	7.5	3.1	7.0
	5', 5	4.3	10.1	2.5	6.8
	8', 8	5.2	8.3	2.8	6.7
	mean	4.9	8.6	2.8	6.8
V	2', 2	4.5	12.0	5.0	13.6
	5', 5	3.7	9.1	5.1	9.2
	8', 8	4.5	6.6	2.3	6.1
	mean	4.2	9.2	4.1	9.6
VI	2', 2	8.4	12.8	6.4	9.3
	5', 5	6.2	14.5	5.2	7.5
	8', 8	4.2	9.6	4.8	5.8
	mean	6.3	12.3	5.5	7.5

[a]Percentage lipid, moisture free basis

Table 17-pH for U.S. Choice and U.S. Good bovine longissimus *dorsi* muscles

Replication	Steak number	Grade			
		U.S. Choice		U.S. Good	
		Raw	Cooked	Raw	Cooked
I	2', 2	--	5.6	--	5.6
	5', 5	--	5.6	--	5.6
	8', 8	--	5.6	--	5.6
	mean		5.6	--	5.6
II	2', 2	--	5.6	--	5.6
	5', 5	--	5.5	--	5.6
	8', 8	--	5.6	--	5.6
	mean		5.6		5.6
III	2', 2	5.5	5.5	5.6	5.6
	5', 5	5.4	5.5	5.5	5.6
	8', 8	5.5	5.5	5.5	5.5
	mean	5.5	5.5	5.5	5.6
IV	2', 2	5.4	5.6	5.5	5.6
	5', 5	5.4	5.5	5.5	5.6
	8', 8	5.4	5.5	5.5	5.5
	mean	5.4	5.5	5.5	5.6
V	2', 2	5.5	5.6	5.5	5.6
	5', 5	5.5	5.6	5.5	5.6
	8', 8	5.5	5.6	5.5	5.7
	mean	5.5	5.6	5.5	5.6
VI	2', 2	5.4	5.7	5.4	5.6
	5', 5	5.4	5.7	5.4	5.6
	8', 8	5.4	5.7	5.4	5.7
	mean	5.4	5.7	5.4	5.6

Table 18-Warner-Bratzler shear values and sensory scores for U.S. Choice and U.S. Good bovine longissimus dorsi muscles

Measurement	Replication	Steak number	Grade	
			U.S. Choice	U.S. Good
W-B shear value, kg/1.3-cm core	I	2	2.5	3.4
		5	2.0	2.2
		8	2.3	2.5
		mean	2.3	2.7
	II	2	2.2	2.1
		5	2.1	2.3
		8	1.9	2.5
		mean	2.1	2.3
	III	2	2.6	2.6
		5	1.8	2.0
		8	1.9	2.2
		mean	2.1	2.3
	IV	2	2.0	1.4
		5	1.6	1.5
		8	1.4	1.4
		mean	1.7	1.4
	V	2	2.3	2.2
		5	2.2	2.1
		8	2.8	1.8
		mean	2.4	2.0
	VI	2	2.6	1.6
		5	2.0	2.2
		8	1.8	2.0
		mean	2.1	1.9

Table 18-(continued)

Measurement	Replication	Steak number	Grade	
			U.S. Choice	U.S. Good
Sensory score[a]				
Tenderness	I	2	4.3	4.1
		5	4.3	4.0
		8	4.7	4.4
		mean	4.4	4.2
	II	2	4.5	4.5
		5	4.9	4.1
		8	4.9	4.0
		mean	4.8	4.2
	III	2	4.4	3.9
		5	4.7	4.2
		8	4.8	4.0
		mean	4.6	4.0
	IV	2	4.6	5.0
		5	4.7	4.7
		8	4.9	5.0
		mean	4.7	4.9
	V	2	4.2	4.8
		5	4.7	4.6
		8	4.9	5.0
		mean	4.5	4.6
	VI	2	4.0	4.8
		5	4.7	4.1
		8	4.9	5.0
		mean	4.5	4.6

Table 18-(concluded)

Measurement	Replication	Steak number	Grade	
			U.S. Choice	U.S. Good
Juiciness	I	2	4.3	3.6
		5	4.0	3.4
		8	4.4	4.3
		mean	4.2	3.8
	II	2	4.3	4.0
		5	3.9	4.0
		8	3.7	4.0
		mean	4.0	4.0
	III	2	4.0	4.6
		5	4.6	4.5
		8	4.3	4.1
		mean	4.3	4.4
	IV	2	4.4	4.4
		5	4.9	4.0
		8	4.6	4.3
		mean	4.6	4.2
	V	2	3.8	4.3
		5	3.8	4.8
		8	4.2	4.4
		mean	3.9	4.5
	VI	2	3.8	3.5
		5	4.7	5.0
		8	4.9	4.8
		mean	4.5	4.4

[a]Range 5 (tender, juicy) to 1 (tough, dry)

HISTOLOGICAL CHARACTERISTICS OF USDA CHOICE AND USDA GOOD BEEF RIB STEAKS

by

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Current USDA beef grading standards went into effect on February 23, 1976. Those standards will mean that slightly leaner beef will qualify for each grade classification than under the 1965 standards, and less grain will be fed to cattle. From the viewpoint of predicting palatability, some researchers indicated that the 1976 standards did not offer significant improvement over the 1965 standards. Information is needed on the characteristics of beef graded according to 1976 standards.

Raw and cooked (heated to 60°C by modified oven roasting) muscle samples from bovine LD muscle representing USDA Choice and USDA Good ribs were used to study selected histological characteristics of the beef rib steaks. Data for other characteristics of the same steaks from which histological samples were taken were provided by colleagues in the laboratory to study the relationship of ether extract, tenderness, and juiciness to histological characteristics of rib steaks within each grade. Data were analyzed by analysis of variance for a split, split plot design, and least significant differences at the 5% level were calculated when F-values for effects of steak position (anterior to posterior of LD muscle) were significant. Correlation coefficients were calculated for selected paired variates on the basis of grade.

Percentage ether extract, histological estimates of fiber width, fat quantity (panel score and objective score), and fat distribution (panel score) did not differ significantly between the two U.S. grades. Percentage ether extract decreased ($P < 0.05$) from the anterior to the posterior end

of LD muscle from U.S. Choice or U.S. Good beef ribs. Ether extract, pH and all of the histological measurements, except fat quantity (objective score), were affected significantly by cooking. Raw muscle tended to have wider fibers, less ether-extractable lipid, slightly larger fat droplets and lower pH than cooked tissue. Relationships between ether extract, tenderness or juiciness to any of the histological measurements were low to moderate. Correlation was moderate ($r = -0.76$) for fiber width, cooked muscle, vs. panel tenderness score for U.S. Good bovine LD muscle. As fiber width increased, tenderness decreased. Fat quantity and distribution had little relationship to tenderness or juiciness of U.S. Choice or U.S. Good bovine LD muscle.