SELECTED CHARACTERISTICS OF USDA CHOICE AND GOOD BEEF RIB STEAKS

by

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INTRODUCTION

Current U.S. Department of Agriculture (USDA) beef grading standards went into effect on February 23, 1976. They should mean leaner beef being available than was available under the 1965 standards, and usually less grain fed to cattle. Changes from the 1965 standards were: (1) all graded beef is graded for both quality (palatability) and yield (percentage of edible meat cuts), (2) slightly leaner beef now qualifies for U.S. Prime and U.S. Choice grades, (3) the U.S. Good grade is more restricted, and (4) conformation is no longer a factor in determining the quality grade (National Live Stock and Meat Board, 1976).

Under the 1976 USDA grading standards, marbling requirements for U.S. Prime and Choice beef are slightly lower than they were under the 1965 standards. All 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 (Fig. 1). 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 will remain 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; Gilpin et al., 1965; Goll et al., 1965 and Walter et al., 1965).

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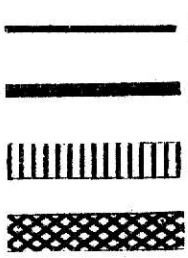
Fig. 1 - Changes in the relationship between marbling, maturity and quality grade (Nelson and Van Arsdall, 1974).



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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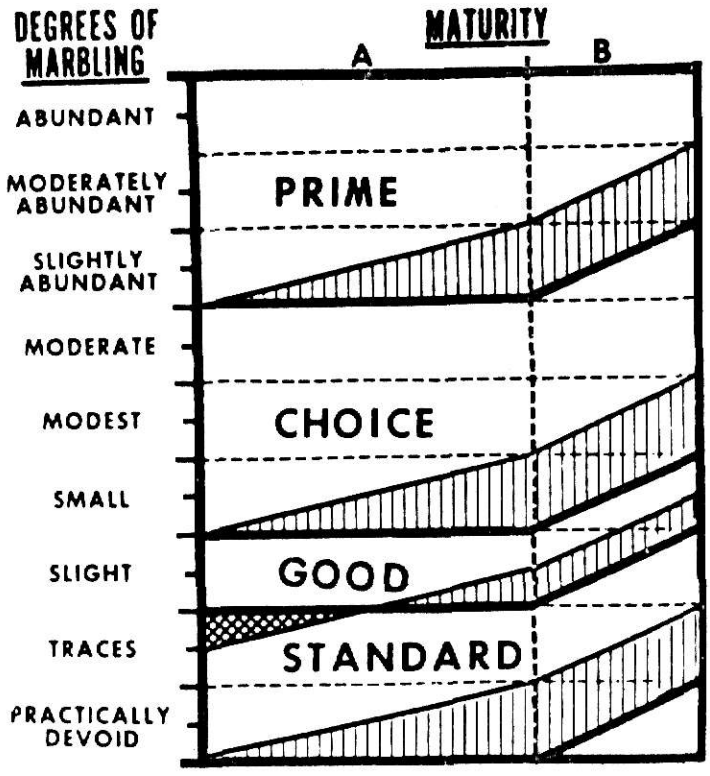
CHANGES IN THE RELATIONSHIP BETWEEN MARBLING, MATURITY, AND QUALITY GRADE



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 forage 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. 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 the 1965 and 1976 USDA standards and Canadian beef grading standards. They reported that from the standpoint of predicting palatability, the 1976 USDA standards did not offer any significant improvement over the previous standards.

Information is needed on the characteristics of beef graded under the 1976 USDA standards. This study identified selected characteristics related to eating quality of rib steaks from U.S. Choice and U.S. Good beef carcasses. Tenderness (panel scores and Warner-Bratzler shear values), juiciness, flavor, water holding capacity, ether extract, total moisture, cooking time and cooking losses were measured.

REVIEW OF LITERATURE

USDA quality grading

The federal grading system was first created in 1927 to provide a uniform system for buying and selling livestock and meat. Grading standards were established to identify characteristics that generally are indicative of differences in palatability, and thus value, and to create an economic incentive for farmers and ranchers to produce high quality livestock. The National Live Stock and Meat Board (1976) referred to grading as "the broad standards by which beef industry people guide themselves when eyeing cattle on the hoof or beef on the rail." U.S. grades provide the consumer with a guide to identify quality levels of meat (National Live Stock and Meat Board, 1976).

The USDA periodically has modified the grading system to reflect changes in industry and consumer demand. The first revision, in 1939, established "marbling and maturity as principal factors for evaluating differences in lean quality and to reflect the premises that an increase in marbling benefits palatability and that advancing maturity has a deleterious effect on palatability" (Carpentar et al., 1977).

1965 grading standards

USDA grades for beef adopted in 1965 provided for two kinds of grading--quality and yield. Quality grading is the traditional grading system that began in 1927. There are eight USDA quality grades for beef: Prime, Choice, Good, Standard, Commercial, Utility, Cutter and Canner, which are intended to be indicators of juiciness, tenderness and flavor. Paul (1972) said that "grade designations can be thought of in a statis-

tical sense as higher grades representing higher probability, but not certainty that the meat will be more flavorful, tender and juicy."

Three general factors on which the original quality grading standards were based are: (1) conformation or shape of the animal, (2) finish--quality and distribution of exterior fat and (3) quality--age of the animal, firmness and texture of the flesh, distribution of intramuscular fat and color of the lean (National Live Stock and Meat Board, 1976).

Yield grade is an estimate of the ratio of edible lean to fat and bone. Yield grades are numbered from 1 to 5 with 5 representing the highest percentage of trim or waste. Yield grading was established to encourage producers to adopt livestock management programs that would yield lean, meaty animals (National Live Stock and Meat Board, 1976).

The quality grade is a subjective and visual appraisal of factors that influence the eating quality of meat. Yield grade, on the other hand, is based on a mathematical formula, and is calculated on the basis of hot carcass weight, area of rib eye (LD muscle), thickness of fat over the rib eye and estimated percentage of fat around the kidney (Rust, 1962). The dual grading system (both quality and yield grade) classifies beef carcasses according to their market value, and discriminates against carcasses that contain a high proportion of fat to muscle (Rust, 1962). Both quality grading and yield grading were voluntary under the 1965 system of grading.

1976 grading standards

Marbling standards of 1965 appeared unnecessary and expensive, so on February 23, 1976, revised standards for federal meat grading went into effect. Changes from 1965 standards are relatively minor, but they reflect

changes in the production of beef and in the long run will benefit the consumer (National Live Stock and Meat Board, 1976).

Under the 1965 grading system, a carcass had to have more marbling as the animal got older to meet the criteria for a given U.S. grade. Because of new genetic developments, production and feeding improvements and crosses of cattle breeds, marbling requirement has been reduced (National Live Stock and Meat Board, 1976). Changes made in the grading system have potential for increasing the efficiency of beef production, thereby reducing expenditures throughout the marketing chain (Nelson and Van Arsdall, 1974).

Primary changes from the 1965 grading standards include (1) a change in the compensation of marbling for increased maturity (for cattle less than 42 months of age); that is slightly leaner beef now qualifies for U.S. Prime and U.S. Choice grades, (2) a decrease in the maximum maturity (from 48 to 42 months) for carcasses in the "young" beef grades, (3) the U.S. Good grade is more restricted, (4) conformation is no longer a factor in determining the quality grade and (5) all graded beef is graded for both quality (palatability) and yield (percentage of edible meat cuts), Carpenter et al., 1977. The 1976 grading system still is set up on a voluntary basis.

Limited research has been conducted to evaluate the 1976 standards. In fact, no references were found for research on beef graded after February 23, 1976. From the viewpoint of predicting the palatability of beef graded under the proposed 1976 standards, some researchers indicated that the 1976 standards do not offer any significant improvement over the 1965 standards (Garcia - de - Siles et al., 1977; Skelley et al., 1976 and Campion et al., 1976). The beef industry will not be able 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.

Relation of marbling to palatability

Quality grades are intended to be indicators of the flavor, tenderness and juiciness of beef. The extent to which they reflect this, however, is questionable. Although there has been considerable research on the role of fat in determining the palatability characteristics of meat, the results often are conflicting. There are different opinions concerning the effect of fat (marbling) on palatability characteristics.

Gilpin et al. (1965) suggested that there were discrepancies among the findings of various workers, because there were inconsistencies in the experiments; such things as different methods of cooking, end point temperature and the muscle or cut of meat used. When meat is heated, the neutral fat melts out of the fat cells. This flow of fat increases the distribution of fat throughout the lean tissue, and may be a factor contributing to the apparent relationship between marbling and juiciness (Paul, 1972). The lubricating quality of fat may affect the ease with which meat is masticated and swallowed. This, too, may be a contributing factor in the marbling/palatability question.

Marbling was defined by Henrickson (1965) as the intramuscular fat that contributes to meat quality. Marbling consists of small streaks of fat deposited along the blood vessels within the muscle and is a part of the intramuscular lipid (Paul, 1972). Although marbling is the popular term used synonomously with intramuscular fat, marbling in the strictest sense of the word refers only to that fat that appears visible to the unaided eye on cut meat surfaces. Intramuscular fat includes the visible fat and also microscopic deposits of fat within the muscle cells (Blumer, 1963).

The feeding regimen of the animal plays a role in determining the amount of fat present. The composition and caloric level of the feed control the rate and quantity of fat deposition (Blumer, 1963). The amount of fat deposition also is influenced by factors such as heredity, stage of growth, sex, hormones and exercise. The types of fat and fatty acids present in the fat depots and the location and extent of those fat deposits varies with the species of the animal (Paul, 1972).

When beef is quality graded, marbling is evaluated on a scale of 1 to 9, which ranges from very abundant (1) to traces of marbling (9). The marbling score is subjective and is assessed on the longissimus dorsi muscle at the 12/13th rib. Marbling is one of the most important criteria for evaluating beef quality, and yet no truly objective and satisfactory method for scoring marbling exists (Blumer et al., 1962).

Relation of marbling to tenderness

"Tenderness of meat is a complex sensation. It is determined principally by the mechanical strength of the muscle fibers and connective tissues. However, the sensation of tenderness or toughness also may be influenced by the juiciness of the meat, the water holding capacity of the proteins and the amount and distribution of fat" (Matz, 1962). Tenderness generally is measured in two ways, by sensory evaluation and by shear force. Sensory tenderness refers to softness to tongue and cheek, softness to tooth pressure, ease of fragmentation, mealiness of muscle fibers, adhesion between muscle fibers and presence of connective tissue (Cover et al., 1962). Taste panel scores are a reflection of the panel members' psychological and physiological response to the effect of doneness on the composite components of tenderness, juiciness and flavor and their interrelationships (Parrish et al., 1973).

Shear force generally is measured by the Warner-Bratzler (WB) shearing apparatus with a 11.25 kg (25 lb) or 22.72 kg (50 lb) dynamometer. WB shear values reflect only the physical force necessary to shear through muscle fibers.

Hostetler et al. (1936) found that marbling was not an important factor in tenderness of beef. Ramsbottom et al. (1945) also reported that there was no relationship between the amount of fat within the muscle and the shear value of raw or cooked beef. Breidenstein et al. (1968) and Wellington and Stouffer (1959) theorized that factors other than marbling must have a greater influence on muscle tenderness than marbling per se. Paul (1962) stated that beef can vary in tenderness even when marbling and maturity are the same.

Tuma et al. (1962) concluded that marbling levels did not influence the tenderness of meat as measured by a taste panel. Their work was confirmed by Goll et al. (1965), Romans et al. (1965), Walter et al. (1965), Breidenstein et al. (1968) and Norris et al. (1971).

In contrast to the studies cited above, Covington et al. (1970) found that steaks from moderately marbled carcasses were more tender than those from carcasses with less marbling. The difference in shear force between carcasses with the two levels of marbling was small (0.37 kg), but consistent. Gilpin et al. (1965) found that steaks from highly marbled carcasses were only slightly more tender than those with less marbling, and attributed the difference in panel scores mainly to the cut of meat and the internal degree of doneness.

In a study of the influence of carcass maturity and marbling on the physical and chemical characteristics of beef (Romans et al., 1965), there appeared to be no significant interactions between maturity and marbling. However, shear force and taste panel score means seemed to indicate

that marbling may have had an influence on tenderness in cattle of older maturity groups. Henrickson and Moore (1965) found that the fat content of the muscle was relatively unimportant in animals under 20 months of age, but that it did play a role in the tenderness, juiciness and flavor of older animals. Field et al. (1966) found that the WB shear values were not affected by marbling when age was held constant. Norris et al. (1971) found that palatability scores and WB shear values were not affected by either marbling or maturity.

Apparently there is little relationship between marbling and maturity of the bovine animal. There seems to be some relationship between maturity and tenderness; as the animal ages, tenderness decreases, but the extent of the relationship between marbling and tenderness still is questionable.

Fat may influence tenderness scores of a taste panel, perhaps because it provides liquid and creates a desirable mouth feel during mastication. Consequently, taste panel results may not always agree with shear values. For example, Moody et al. (1970) reported that meat with a fine marbling texture was more tender than coarsely marbled meat as determined by WB shear, but there was no difference in sensory tenderness or flavor, juiciness and overall acceptability. Similar differences in taste panel scores and WB shear values were obtained by Tuma et al. (1962). According to Paul (1972) "the action of marbling if and when it influences tenderness may also be one of diluting or separating connective tissue fibers and thereby making them more susceptible to alteration (breakdown) by heat."

Relation of marbling to juiciness and flavor

Juiciness can be defined as the liquid detectable during the chewing of a bite of meat. According to Blumer (1963) it is not possible to separate

the quality of juiciness from the flavor of meat because the flavor compounds are present in both liquid and solid portions of meat tissue. Palatability is agreeableness to the taste and involves the complex of sensations resulting from the stimulation of the senses of odor, taste and feel plus the ease of mastication (Blumer, 1963).

Williams (1968) pointed out that at the time of his writing, despite all of the research on the subject, there were no chemical or physical methods or combination of methods by which the palatability of meat could be assessed, so taste panels must be used. That still is true. Trained taste panels seem to be more reliable than consumer taste panels as a means of determining effects of marbling on palatability (Blumer, 1963).

Romans et al. (1965) reported that meat with moderate amounts of marbling was juicier than that with a slight amount of intramuscular fat. Parrish (1974) reported that both juiciness and flavor of abundantly marbled steaks were improved from that of steaks with lesser levels of marbling, but not by maturity. Kropf and Graf (1959) showed a relationship between subcutaneous and intramuscular fat with flavor. As the fat levels increased, the flavor "desirability" increased. Henrickson (1964) and Blumer (1963) agreed that fat contributed more to the flavor of the meat than to tenderness. Henrickson (1965) indicated that 8 to 9% fat in steaks and roasts was adequate for good flavor, but that there was little change in overall palatability as the percentage of fat increased beyond the 9% level. Campion et al. (1976) found that the palatability of rib steaks was "acceptable" when the LD muscle contained 2.9% fat, but below that level, palatability characteristics were less "desirable".

Doty and Pierce (1961) found a relationship between marbling and juiciness below the moderate level of marbling. Gilpin et al. (1965) found that highly

marbled steaks were only slightly more juicy and flavorful than those with less marbling. They attributed the difference to the cut of meat and the internal (end point) temperature.

In contrast, Tuma et al. (1962) found that flavor and juiciness were not related significantly to the level of marbling. The work of Goll et al. (1965) and Norris et al. (1971) supported the findings of Tuma.

MATERIALS AND METHODS

Meat used

Six U.S. Choice and six U.S. Good fresh, unfrozen wholesale ribs (8.6 to 16.8 kg) were purchased from a wholesale packing company and delivered to the Meats Laboratory at Kansas State University (Fig. 2). The quality grade, yield grade, number of days aged, hot carcass weight and chilled carcass weight were recorded for each rib (Table 4, p. 59, Appendix). Marbling was scored at the loin end of the wholesale rib (at the interface of the 12/13th rib). The thickness of the subcutaneous fat over the rib also was measured at the loin end (Fig. 3).

Rib bones, vertebrae, scapula and ligamentum nuchae were removed from the wholesale rib. Boneless rib ends were 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 (Fig. 4). Steaks, either 3.0 or 1.3 cm thick, were cut from the boned rib (Fig. 5). The tail of each steak was trimmed to 2.5 cm from the lateral edge of the LD muscle. The 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 steaks were recorded; the area of the rib eye was traced and measured with a compensating polar planimeter. Individual

Fig. 2 - Wholesale ribs before boning. A, U.S. Choice; B, U.S. Good.

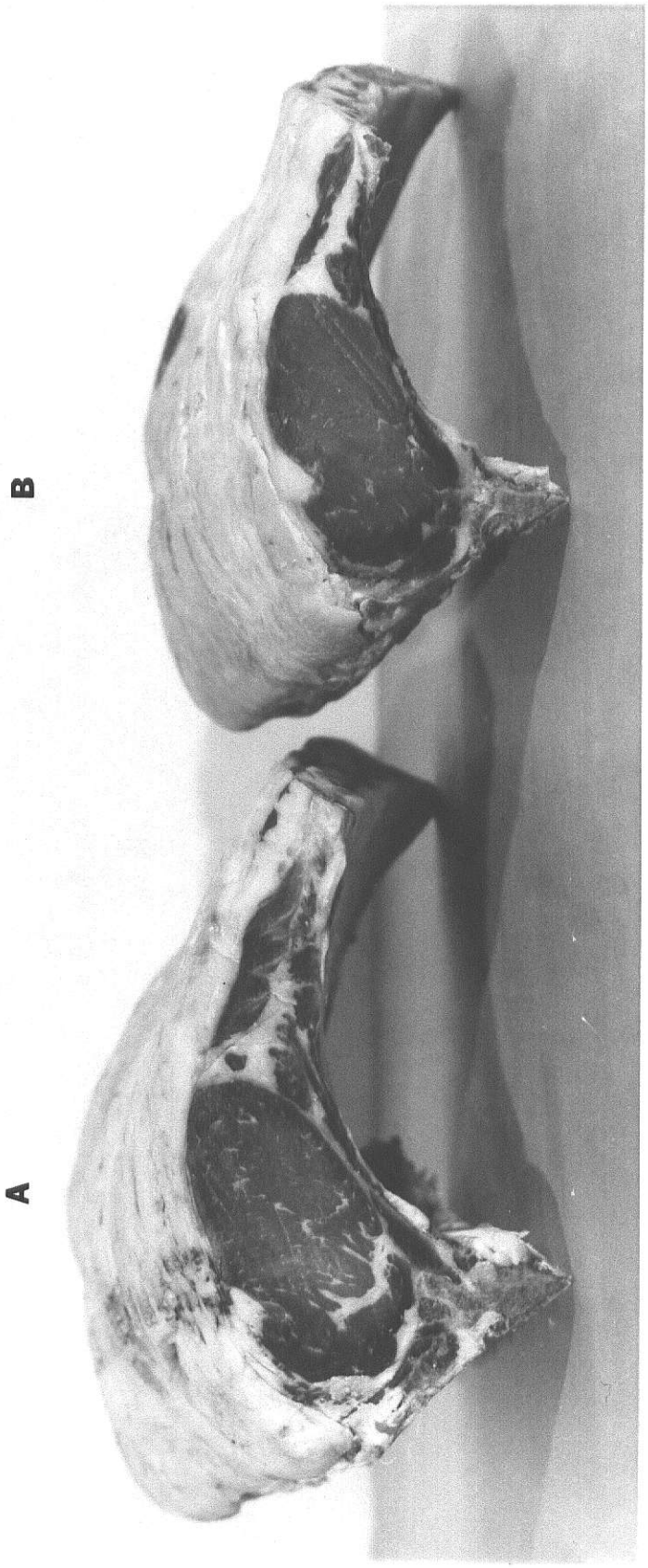

B
A

Fig. 3 - Location for measuring thickness of subcutaneous fat over the rib, loin end (Romans and Ziegler, 1966).

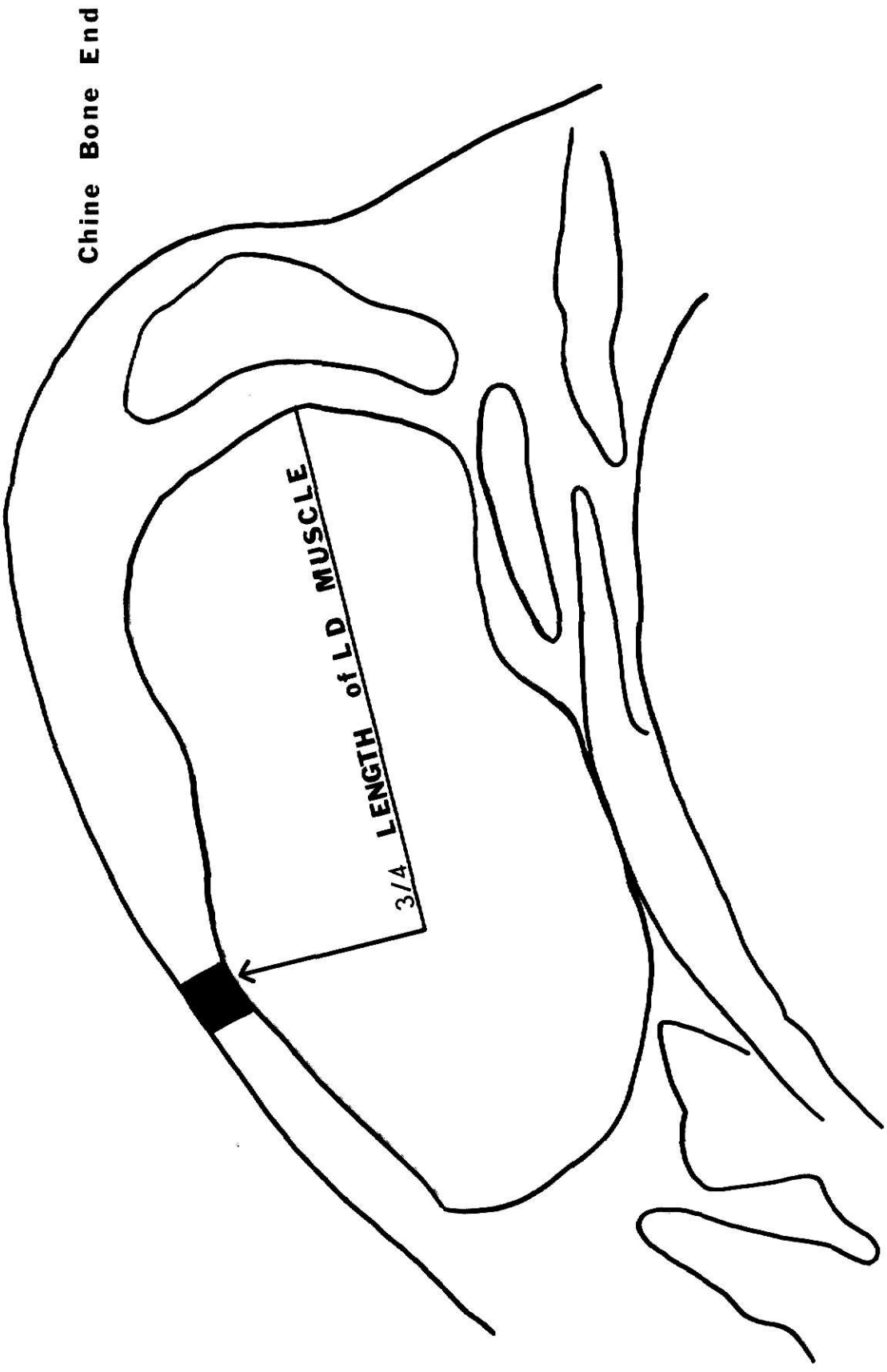

Chine Bone End
3/4 LENGTH of LD MUSCLE

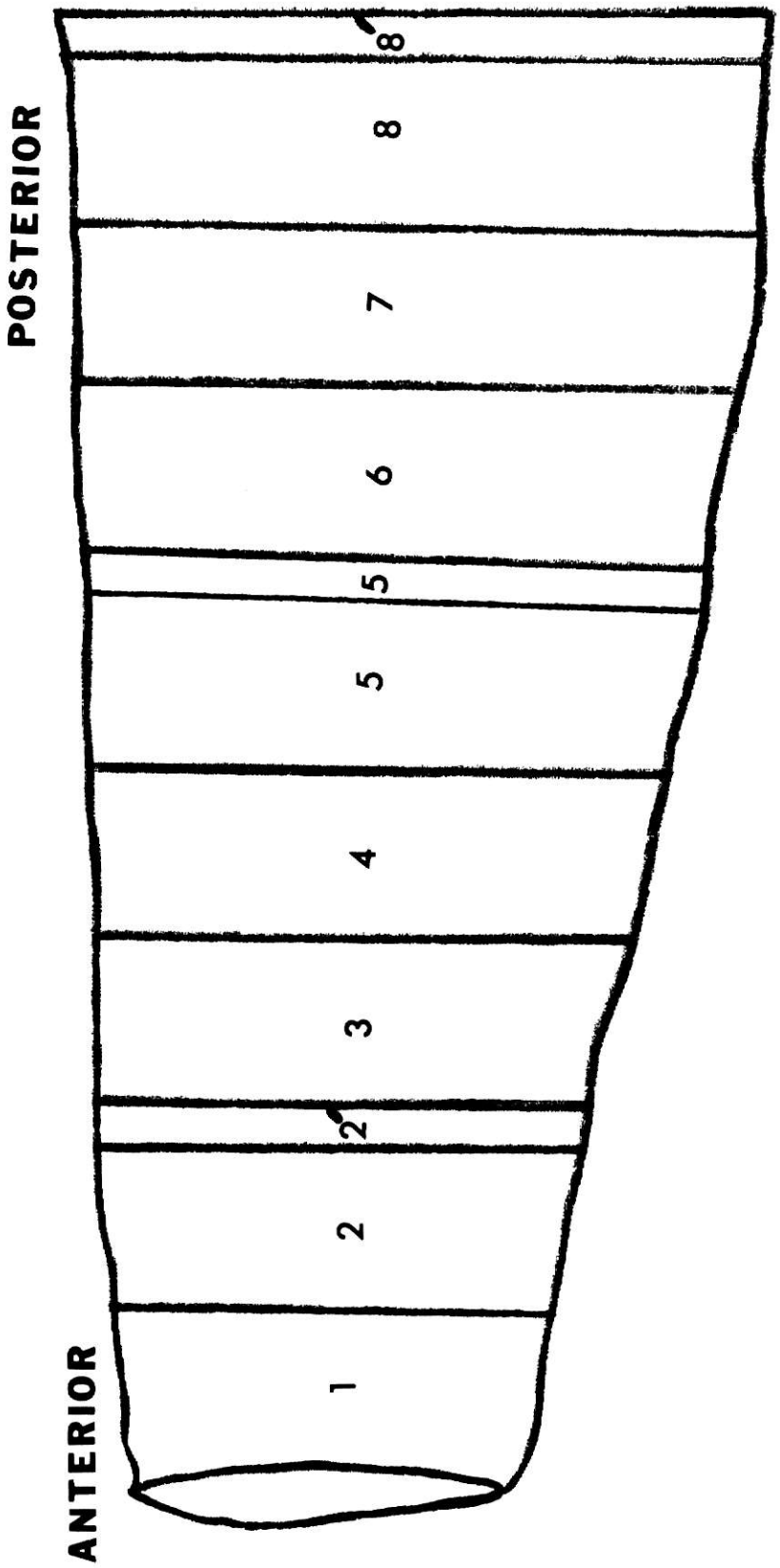
Fig. 4 - Primal rib after boning and trimming.


U. S. CHOICE
U. S. GOOD
PRIMAL RIB-
AFTER BONING

Fig. 5-Plan for sampling the wholesale rib.

1 through 8 - rib steaks, 3.8 cm thick

2', 5', 8' - steaks approximately 1.3 cm thick for analysis of raw muscle tissue (ether extract, total moisture, pH)


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

steaks were wrapped in aluminum foil (gauge 0.0015), labeled and frozen in a walk-in freezer at -26°C for approximately 20 hours, then stored in an upright household freezer at -18° to -24°C for 6 to 16 days.

Experimental design and cooking

Before each of 24 evaluation periods, four steaks (two U.S. Choice and two U.S. Good) were selected randomly according to a split plot design with 6 replications (Table 1). Steaks were thawed at room temperature (22° to 26°C) for four hours, then in the refrigerator (approximately 4°C) for 20 hours.

The boneless beef rib steaks were cooked by modified roasting. Each steak was placed on a wire rack 12.7 cm high (Fig. 6), and a thermometer (-20° to 100°C) 14.1 cm in length with a small bulb approximately 0.5 cm in diameter was inserted with the bulb in the geometric center of the LD muscle. Six thermometers were checked by placing them in a pan of cool tap water which was brought to boiling. The four thermometers that read 98°C when the water was boiling were used for this experiment. The initial temperature of the meat was recorded, and 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 losses based on the weight of the thawed, raw steak were calculated.

Sensory evaluation

Flavor, tenderness and juiciness of cores of cooked meat 1.3 cm in diameter and 3 cm in length (Fig. 7) were evaluated by a 6-member laboratory panel using a 5 to 1 point intensity scale (Form I, p. 57, Appendix) with 5 indicating the most intense rare beef flavor or the greatest tenderness or juiciness, and a score of 1 representing the lowest intensity for each

Table 1 - Experimental design for cooking and evaluating rib steaks

Evaluation period	Replication	Steak number	
		Choice	Good
1	I	2	4
		7	5
2		3	3
		5	6
3		1	2
		6	8
4		4	1
		8	7
5	II	1	4
		7	5
6		2	2
		3	8
7		4	1
		8	7
8		5	3
		6	6
9	III	6	1
		8	5
10		3	2
		7	8
11		2	3
		5	4
12		1	6
		4	7
13	IV	4	3
		7	5
14		1	1
		6	2
15		3	6
		5	8
16		2	4
		8	7

Table 1 - (Concluded)

Evaluation period	Replication	Steak number	
		Choice	Good
17	V	3	1
		5	7
18		4	5
		8	8
19		1	2
		6	4
20		2	3
		7	6
21	VI	6	4
		7	6
22		3	1
		5	3
23		1	2
		2	8
24		4	5
		8	7

Fig. 6 - Steak placed on rack for cooking by modified roasting in an electric rotary hearth oven.

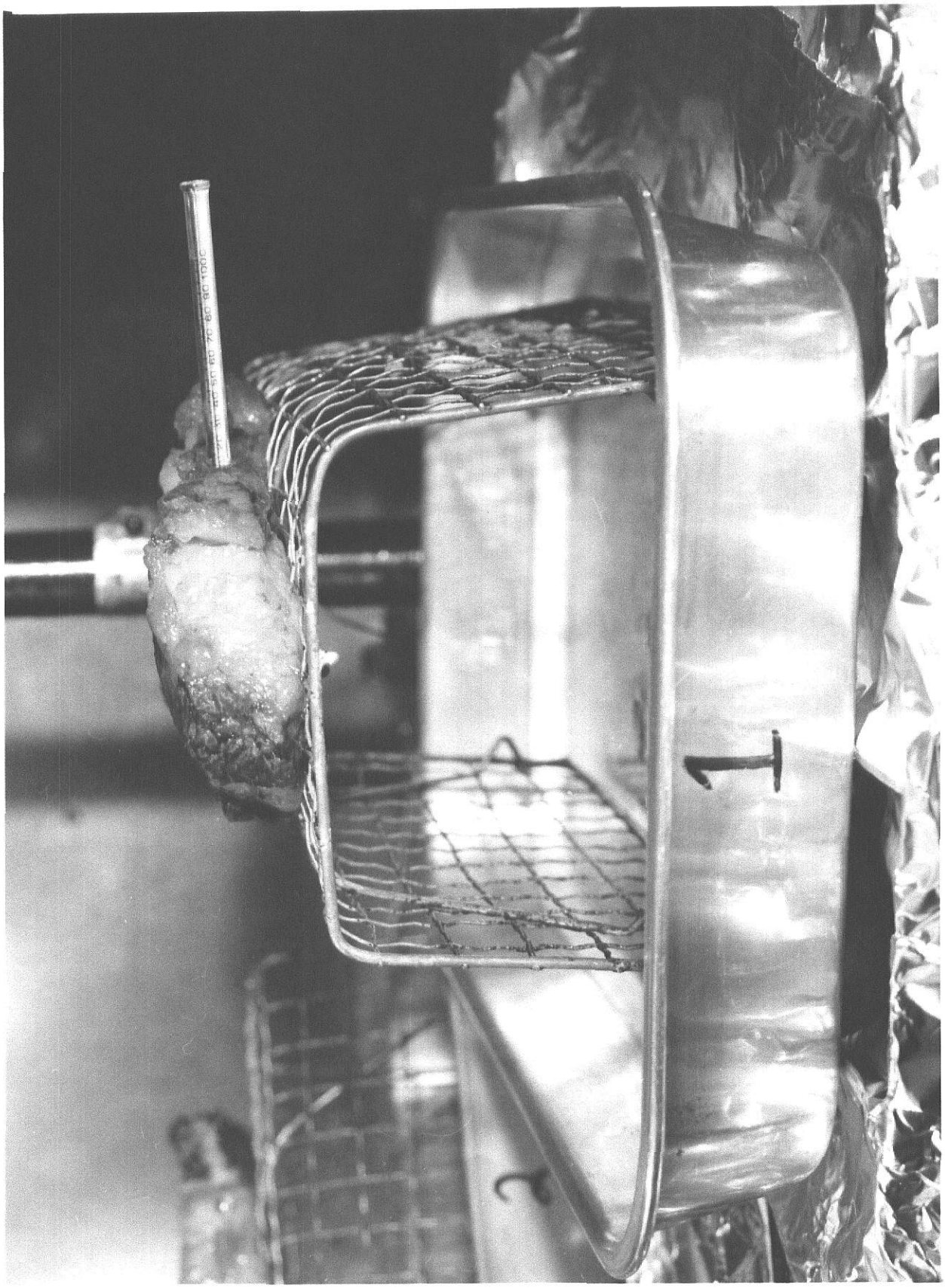


Fig. 7 - Plan for sampling the cooked rib steak (Longissimus dorsi).

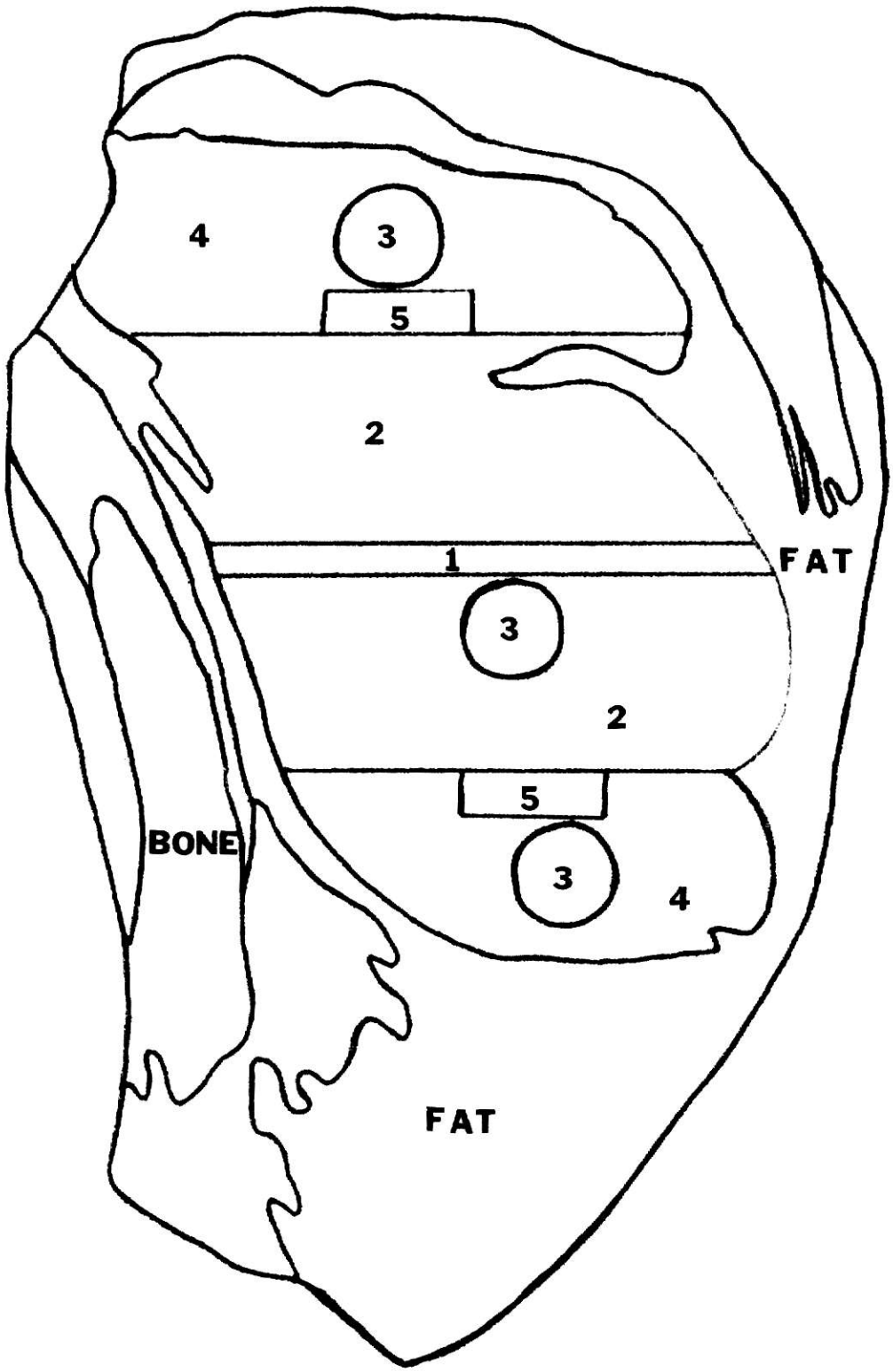
1 - Thermometer hole

2 - Sensory evaluation

3 - Shear cores and water holding capacity

4 - Total moisture, ether extract

5 - Histological evaluation


4
3
5
2
1
FAT
3
2
5
BONE
3
4
FAT

sensory characteristic. Instructions for evaluation (Form II, p. 58, Appendix) were given each panel member during preliminary work.

Cores 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.

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 dynamometer. Cores were taken from the dorsal, medial and lateral positions of the LD muscle (Fig. 7). Triplicate measurements were made on each core and averaged for the overall shear value.

Water holding capacity

Water holding capacity (WHC) of the cooked meat was measured as described by Miller and Harrison (1965) on 0.3-g samples taken from the center of cores used for shear values (Fig. 7). This is a press method in which the expressible-liquid index is calculated as a ratio of the area of pressed muscle to the area of expressed liquid. Unity arbitrarily is assumed as the maximum expressible-liquid index for any particular sample of meat, and the relative WHC expressed as: 1.0 - (expressible-liquid index). Since the magnitude of the expressible-liquid index is inversely related to the amount of liquid expressed from the sample, the larger the value for WHC, the greater the amount of liquid expressed.

pH

Duplicate pH measurements were made on slurries of ground, raw or cooked muscle using a Horizon Digital pH meter. For each slurry, 5 g ground muscle (Fig. 7) 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 pH reading was taken. The pH meter was standardized against a buffer of pH 6.86.

Total moisture and ether extract

Percentage total moisture was determined for cooked muscle in the C. W. Brabender Semi-automatic Moisture Tester. Duplicate 10-g samples of cooked muscle were dried at 121°C for 60 minutes. Percentage ether extract and total moisture in both raw and cooked meat were measured by the analytical laboratory of the Department of Animal Sciences and Industry using modified AOAC methods (AOAC, 1976).

Statistical analyses

Data for each measurement were analyzed by analysis of variance for a split plot design (Table 2). Least significant differences at the 5% level of probability were calculated when F-values attributable to steak position were significant.

Table 2 - Analyses of variance for selected measurements of beef rib steaks

Measurement	Source of variation and DF					
	Grade (G)	Steak Position (S)	G x S	Error A (rep/grade)	Error B (residual)	Total
Rib eye area Length, width, thickness Initial weight Cooking time	1	7	7	10	70	95
Cooking losses: total, volatile, drip	1	7	7	10	68	93
Cooked muscle pH Total moisture Water holding capacity Ether extract Warner-Bratzler shear Sensory scores	1	7	7	10	70	95
Raw muscle pH	1	2	2	6	12	23
Total moisture Ether extract	1	2	2	10	20	35

RESULTS AND DISCUSSION

Effect of grade

None of the measurements were affected significantly by grade (Table 3). Mean rib eye area, initial weight of rib steaks and ether extract from raw muscle were slightly greater for U.S. Choice than for U.S. Good.

The slightly larger rib eye area of U.S. Choice steaks than that for U.S. Good steaks follows the slight difference in mean yield grade between the two quality grades. Area of rib eye is one factor used to calculate yield grade (Rust, 1962); the mean yield grade for U.S. Choice carcasses was 3.0; for U.S. Good carcasses it was 2.7. From the practical viewpoint, there was no difference in yield grade between the quality grades.

The average weight of the wholesale rib was greater for ribs cut from U.S. Choice carcasses than for that from U.S. Good carcasses (Table 4, p. 59, Appendix). Therefore, it would be expected that the mean initial weight of U.S. Choice steaks would be greater than that for U.S. Good steaks.

Since grade is determined partially by the amount and distribution of intramuscular fat (marbling), steaks cut from U.S. Choice carcasses would be expected to have a greater amount of intramuscular fat than those cut from U.S. Good carcasses. Ether extract values for raw bovine LD muscle, therefore, should tend to be and were greater for muscle from U.S. Choice carcasses than for those from U.S. Good carcasses.

Effect of steak position

Rib eye area, length of rib steak, thaw loss, total and drip cooking losses, Warner-Bratzler shear values, percentage total moisture in raw and cooked muscle, ether extract from raw and cooked muscle and sensory tenderness scores were affected significantly by steak position (Table 5, p. 61, Appendix).

Table 3 - Means, standard errors and F-values for selected measurements by grade

Measurements	Grade: U.S. Choice[a] $\bar{x}$	U.S. Choice[a] $s_{\bar{x}}$	U.S. Good[a] $\bar{x}$	U.S. Good[a] $s_{\bar{x}}$	F-value
Rib eye area, sq cm	65.2	±0.6	61.0	±0.6	0.34
Length of steak, cm	17.0	±0.1	16.7	±0.1	0.31
Width of steak, cm	8.7	±0.06	8.6	±0.06	0.01
Thickness of steak, cm	2.9	±0.03	3.0	±0.03	3.11
Initial weight, g	374.5	±6.02	360.9	±6.02	0.17
Steak thaw loss, %	0.9	±0.07	1.1	±0.07	0.32
Cooking time, min	32.4	±0.6	32.6	±0.6	0.01
Cooking losses, %					
Total	12.1	±0.2	12.3	±0.2	0.04
Volatile	8.6	±0.2	8.9	±0.2	0.57
Drip	3.5	±0.1	3.4	±0.1	0.05
pH					
Raw, n = 12	5.44	±0.008	5.48	±0.008	1.14
Cocked, n = 48	5.57	±0.01	5.60	±0.01	0.68
Warner-Bratzler shear					
kg/1.3-cm core	2.1	±0.04	2.2	±0.04	0.28
Total moisture, %					
Raw (AOAC), n = 18	71.0	±0.5	73.3	±0.5	2.56
Cooked, n = 48					
AOAC	65.3	±0.3	64.9	±0.3	0.08
Brabender	65.8	±0.3	65.8	±0.3	0.004
Ether extract, %					
Raw, n = 18	5.6	±0.4	4.9	±0.4	0.50
Cooked, n = 48	9.7	±0.3	9.7	±0.3	0.0
Water holding capacity[b]	0.55	±0.01	0.56	±0.01	0.04
Sensory scores, 5-1[c]					
Flavor	4.4	±0.04	4.2	±0.04	1.21
Juiciness	4.3	±0.05	4.3	±0.05	0.14
Tenderness	4.5	±0.04	4.4	±0.04	0.82

[a] Data for all steak positions combined

[b] 1.0 - (expressible liquid index); the larger the value, the greater the amount of liquid expressed

[c] 5, (rich rare beef flavor, juicy or tender); 1, (no beef flavor, dry or tough)

Although differences among positions were statistically significant, usually they were small (Figs. 8-12).

For area of rib eye, each steak position differed from every other position, except between positions 6 and 7. Position 1 (anterior end) had the smallest value; whereas, position 8 (posterior end) had the largest value, indicating that the area of rib eye increased ($P < 0.05$) from the anterior to the posterior end of the wholesale rib (Fig. 8).

Differences in length of steaks differed ($P < 0.01$) among eight positions in the wholesale rib. Although steaks from position 1 were shorter ($P < 0.05$) than steaks in all other positions, those differences were small (Fig. 8), and they could be partially attributable to the accuracy attained when measuring length. The LSD ($P < 0.05$) for position effect was only 0.53 cm. The initial weight of the steaks was not affected by steak position (Table 5, p. 61, Appendix).

Steak thaw loss was negligible, 1.25% or less (Fig. 9), and was not affected significantly by grade (Table 3).

Percentage total and drip cooking losses of steaks increased slightly from the anterior to the posterior end of the wholesale rib (Fig. 9), and were greatest for positions 6 and 8. For total cooking loss, the only significant difference between positions was between positions 5 and 6. Differences between positions 1 and 2 and between 6 and 1, 2, 3, 4 were significant ($P < 0.05$) for drip cooking loss.

Although Warner-Bratzler shear values were affected ($P < 0.01$) by steak position, the difference between mean values was never greater than 0.3 kg/1.3-cm core. Steaks in positions 3, 5, 6 and 8 had the lowest values (2.0 cm/1.3-cm core), indicating that they were more tender than those in positions 1, 2 and 4. Differences between positions 2 and 3, between 3 and 4, and between 4 and positions 5, 6 and 8 were significant ($P < 0.05$), Fig. 10.

Fig. 8 - Means for area of rib eye (sq cm) and length (cm) of steaks by steak position. Data for U.S. Choice and U.S. Good grades were combined. Least significant difference ($P < 0.05$): rib eye = 3.29, length = 0.53

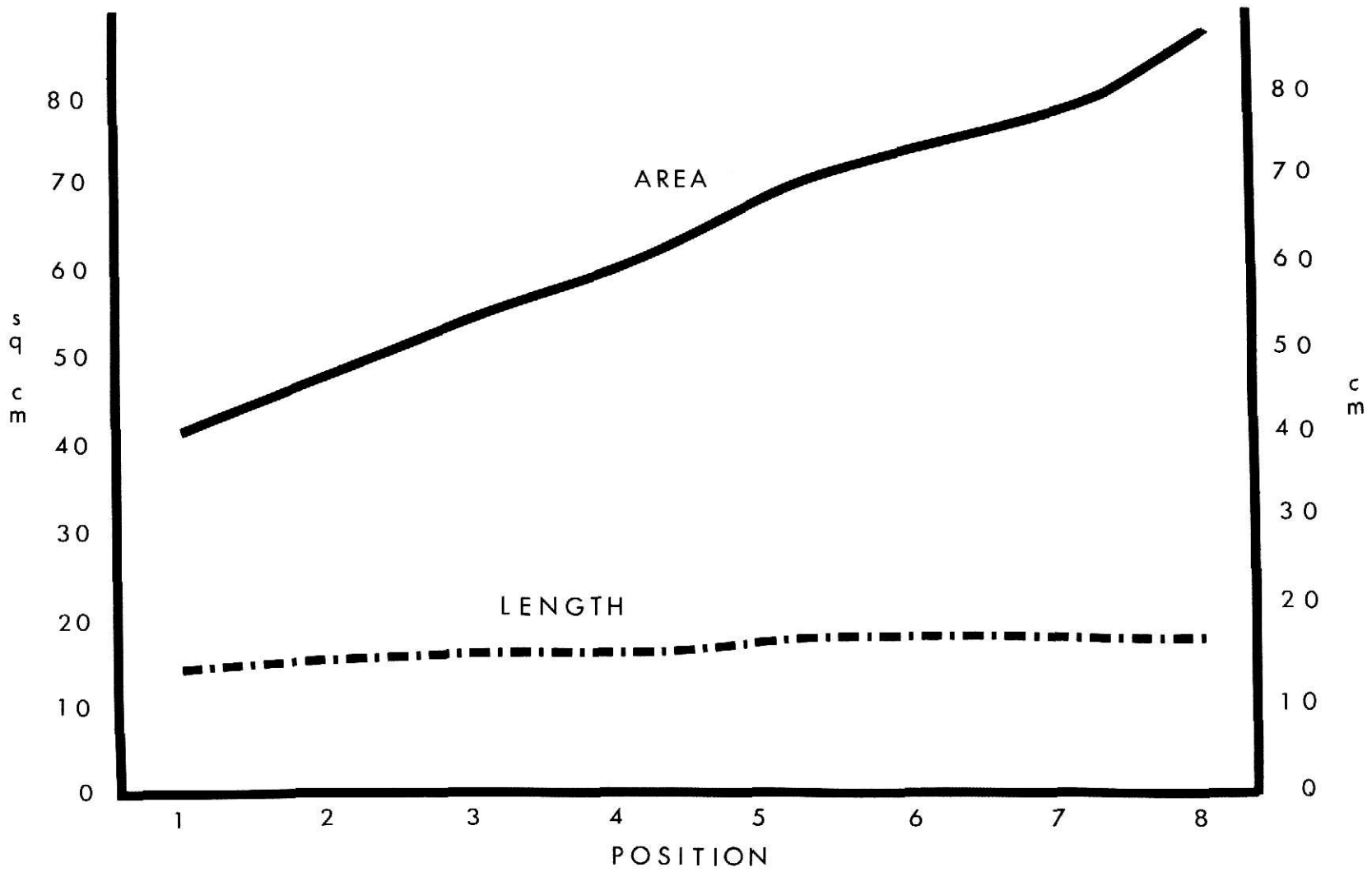

AREA
LENGTH
sq cm
cm
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
POSITION

Fig. 9 -- Means for percentage thaw loss, total cooking loss and drip cooking loss by steak position. Data for U.S. Choice and U.S. Good grades were combined. Least significant difference ($P < 0.05$): thaw loss = 0.45, total cooking loss = 1.29, drip cooking loss = 0.84

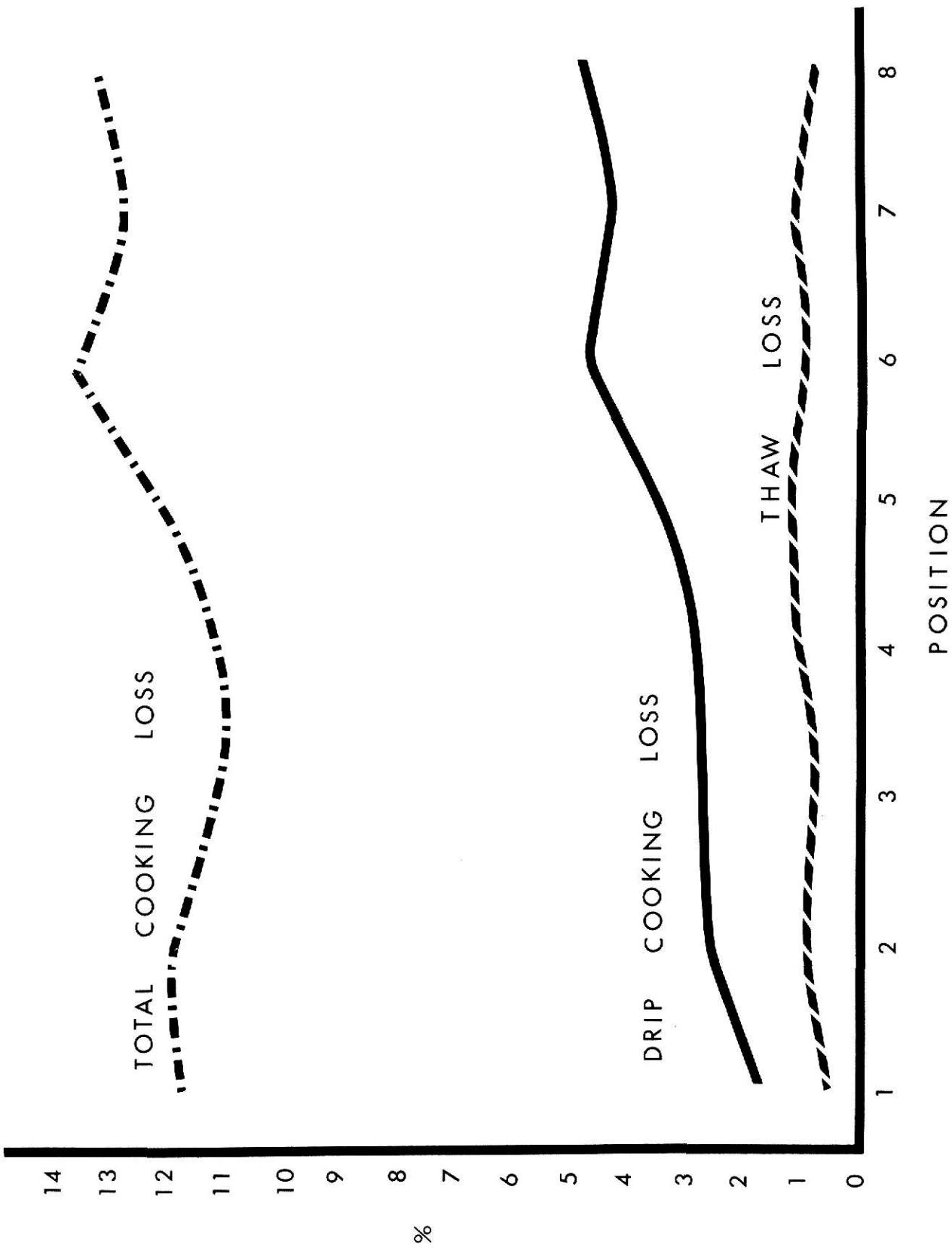

TOTAL COOKING LOSS
DRIP COOKING LOSS
THAW LOSS
%
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1
2
3
4
5
6
7
8
POSITION

Fig. 10 - Means for Warner-Bratzler shear values (kg/1.3 cm core) and sensory tenderness scores (5 - tender, 1 - tough) by steak position. Data for U.S. Choice and U.S. Good grades were combined. Least significant difference ($P < 0.05$): Warner-Bratzler shear = 0.23, tenderness = 0.20

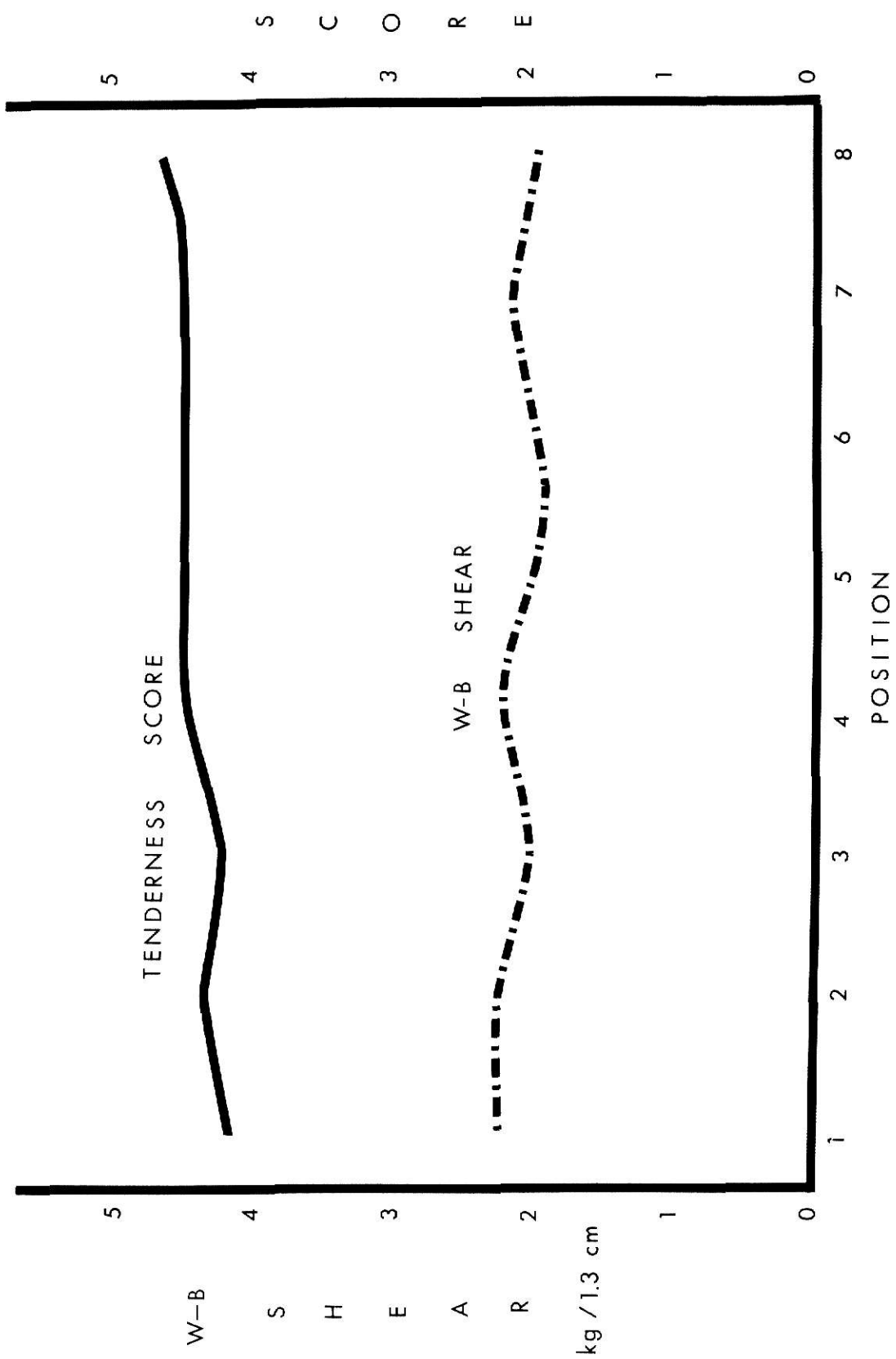

TENDERNESS SCORE
W-B SHEAR
W-B SHEAR kg / 1.3 cm
TENDERNESS SCORE
POSITION
0
1
2
3
4
5
6
7
8

Fig. 11 - Means for percentage total moisture of raw and cooked muscle (AOAC) by steak position. Data for raw muscle were taken from positions 2', 5' and 8'. Data for U.S. Choice and U.S. Good grades were combined. Least significant difference ($P < 0.05$): raw = 1.83, cooked = 1.94

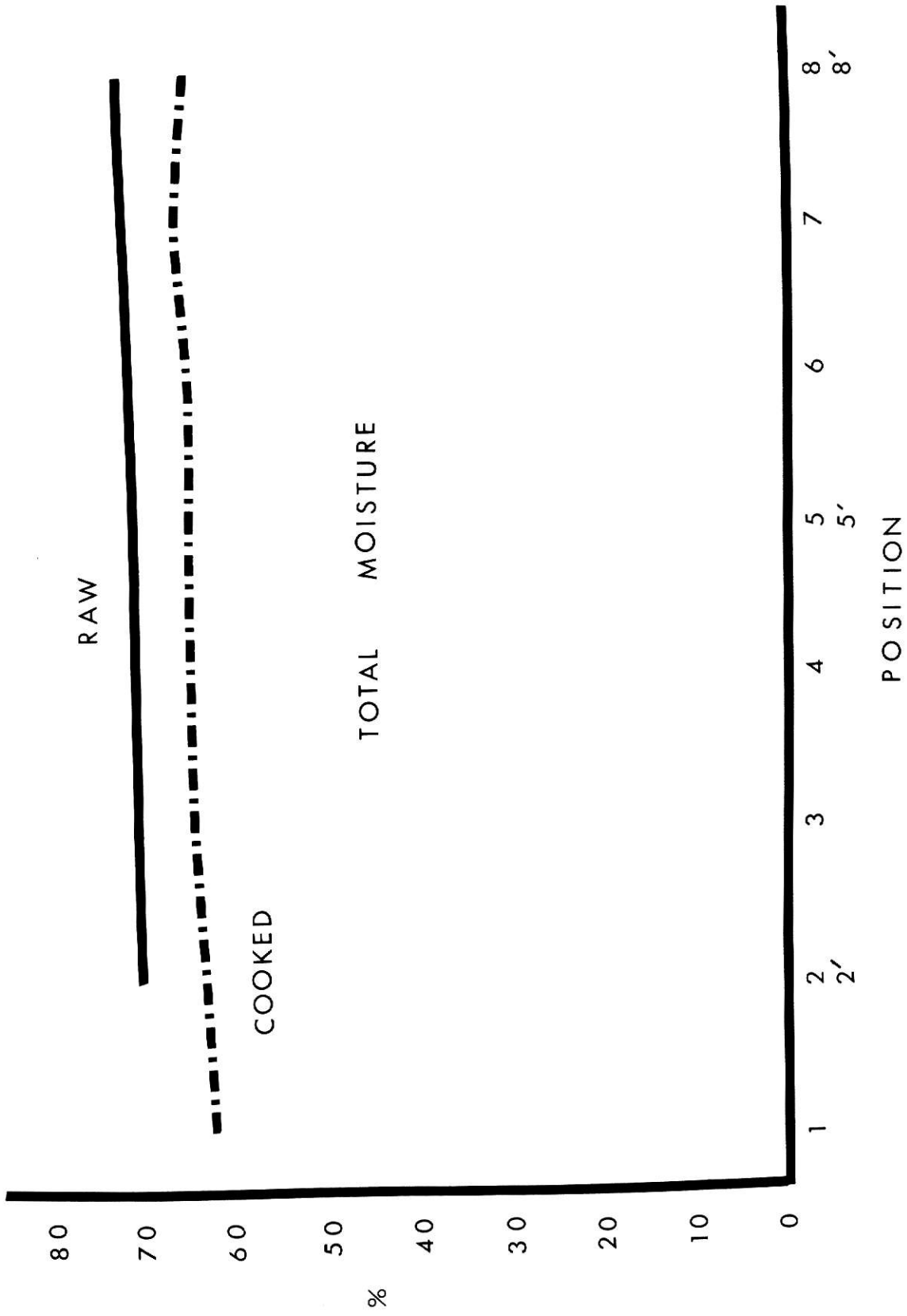
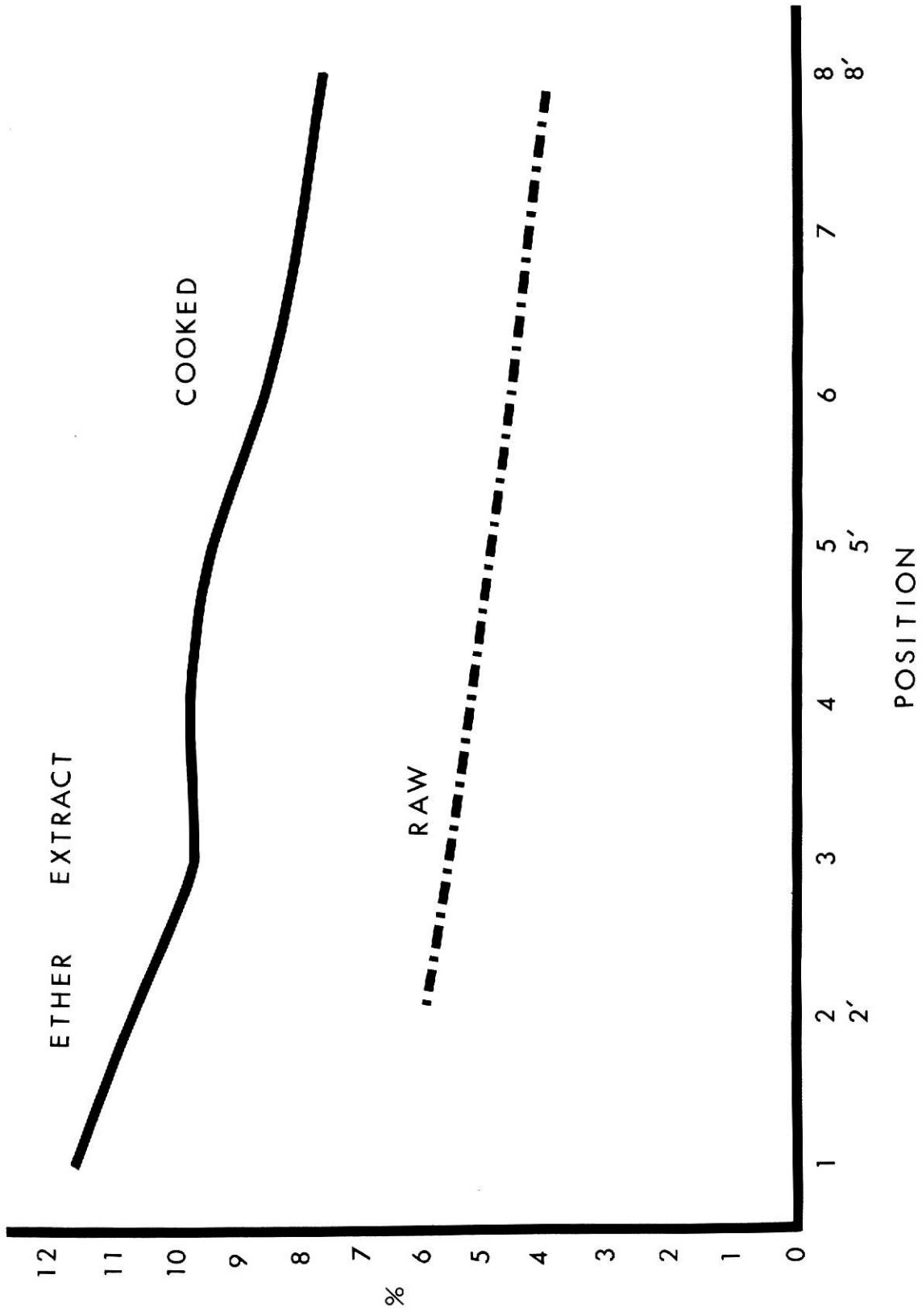

RAW
COOKED
TOTAL MOISTURE
%
80
70
60
50
40
30
20
10
0
1
2
2′
3
4
5
5′
6
7
8
8′
POSITION

Fig. 12 - Means for percentage ether extract of raw and cooked muscle by steak position. Data for U.S. Choice and U.S. Good grades were combined. Data for raw muscle were taken from positions 2', 5' and 8'. Least significant difference ($P < 0.05$): raw = 1.21, cooked = 1.83


ETHER EXTRACT
COOKED
RAW
%
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
2′
3
4
5
5′
6
7
8
8′
POSITION

For sensory tenderness scores, differences were significant ($P < 0.05$) between these positions: 1 and 2, 4, 5, 6, 7, 8; 2-3, 8; 3-4, 6, 7, 8; 8-4, 5, 6, 7. LSD ($P < 0.05$, 0.20) between means for sensory tenderness scores indicated that tenderness increased from the anterior to the posterior end of the bovine LD muscle (Fig. 10). Other investigators reported variations in tenderness within the LD muscle. Ramsbottom et al. (1945) found that bovine 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. Romans et al. (1965) reported that when evaluated by a taste panel, steaks adjacent to the 9th thoracic vertebra were slightly more tender than those adjacent to the 11th thoracic vertebra, but those differences in taste panel scores were not statistically significant. Henrickson and Mjoseth (1964) found that steaks cut from the 9th thoracic vertebra of the wholesale rib were more ($P < 0.01$) tender than those from the 11th thoracic vertebra when measured by the Warner-Bratzler shear.

Percentage total moisture in raw muscle and cooked steaks was affected significantly by steak position, but differences between specific positions were extremely small (Fig. 11). Percentage total moisture of raw LD muscle increased ($P < 0.05$) between positions 2' and 5'. For cooked steaks, percentage total moisture of the LD muscle increased ($P < 0.05$) between position 1 and all other steak positions, except position 2, where the increase was not great enough to be significant. Also, total moisture was greater ($P < 0.05$) for steaks in position 7 than it was for steaks in any other position, as determined by both the Brabender and AOAC methods, LSD ($P < 0.05$, 1.94, AOAC; 1.69, Brabender) between mean values for total moisture of steaks indicated that steaks cut from the posterior end of the wholesale rib had a greater ($P < 0.05$) percentage of moisture than steaks from the anterior end. That was true for both raw and cooked LD muscle (Fig. 11).

Total moisture for cooked steaks was determined in the C. W. Brabender Semi-automatic Moisture Tester and by the AOAC method. Data obtained by the two methods were similar; values for the same sample never differed between methods by more than 1.4%.

Steak position affected ($P < 0.05$) percentage ether extract from both raw and cooked muscle. Differences were significant ($P < 0.05$) between positions 2' and 8' (raw muscle), between 1 and 3, 5, 6, 7 or 8, and between 2 and 6, 7 or 8 (cooked muscle). Position 1 (anterior end) had the highest value and position 8 (posterior end) had the lowest value, indicating that percentage ether extract decreased from the anterior to the posterior end of the LD muscle (Fig. 12). Similarly, Doty and Pierce (1961) observed that muscle at the 7th/8th rib interface contained a higher percentage of intramuscular fat than muscle from the 9th to 12th rib section. 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. Cook et al. (1964) also reported differences ($P < 0.01$) in ether-extractable lipid among anatomical positions within the bovine LD muscle. Satorius and Child (1938) studied differences among beef roasts from the 7-8th, 9-10th and 11-12th ribs. Ether extract was higher in 7-8th ribs than in 9-10th or 11-12th ribs. They concluded that for work involving only physical properties, i.e. press fluid, tenderness and cooking losses, the 7-8th and 9-10th ribs can be used as comparable cuts, but if chemical analyses are involved, none of the three cuts (7-8th, 9-10th, 11-12th ribs) are comparable.

Effect of cooking

Data for ether extract, pH and total moisture were not analyzed statistically for differences between raw and cooked muscle. However, means for

raw and cooked muscle tissue in Table 3 indicate that raw muscle had a slightly lower pH (0.12 or 0.13 units) than cooked tissue. Bendall (1946) reported a shift in pH to the alkaline side when beef was cooked at 100°C for 1 hour. This shift is a reflection of the molecular changes undergone by the proteins during coagulation. The loss of carbon dioxide during cooking also may contribute to this change in pH.

Raw muscle had slightly less ether extractable lipid (approximately 4 - 5%) than cooked tissue (Table 3). Wooseley and Paul (1969) reported that less crude fat was extracted from raw, lean muscle than from cooked muscle. They explained that denaturation of protein caused by heating and the release of lipid previously bound with protein made the lipid in cooked muscle more accessible to solvent extraction than was lipid in raw muscle.

As expected, raw tissue had a higher percentage (6-12%) of total moisture than cooked muscle.

SUMMARY

This study identified selected characteristics related to the eating quality of beef rib steaks from U.S. Choice and U.S. Good carcasses. Cooking time, cooking losses, sensory characteristics, ether extract, total moisture and pH were measured. Also, differences between the two grades for area of rib eye and for length and width of the steaks were studied. Steaks were cooked to an internal temperature of 60°C by modified roasting at 177°C.

Data were analyzed by analyses of variance for a split plot design, and least significant differences at the 5% level were calculated when F-values for effects of steak positions (anterior to posterior) of the wholesale rib were significant.

None of the measurements used to evaluate the steaks were affected significantly by grade. Rib eye area, length of rib steak, total and drip cooking losses, Warner-Bratzler shear values, sensory tenderness scores, percentage total moisture in raw and cooked muscle and ether extract from raw and cooked muscle were affected significantly by position of steaks in wholesale ribs, but generally, differences between specific positions were small.

Irrespective of grade, changes from the anterior to the posterior of the rib were: (a) rib eye area increased; (b) length of rib steak increased; (c) total and drip cooking losses increased; (d) Warner-Bratzler shear values decreased; (e) sensory tenderness scores increased; (f) percentage total moisture increased and (g) percentage ether extract decreased.

CONCLUSIONS

1. In general, selected physical and sensory characteristics of beef rib steaks do not differ significantly between steaks from U.S. Choice and U.S. Good carcasses.

2. Differences among steaks that are attributable to position in the wholesale rib from carcasses graded U.S. Choice and U.S. Good are small, but statistically significant. This confirms the importance of randomly assigning experimental treatments to steaks in the various positions in wholesale ribs.

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APPENDIX

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

For sensory evaluation, each judge is to select two cubes of meat at random from each double boiler. Use one cube for assessing flavor and juiciness, and 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 the 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. cube of meat before swallowing. Chew until the cube is masticated completely, then swallow. Record a score of 5 to 1 that describes your impression of the tenderness of the cube. Refer to the score card for descriptive terms for 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 4, 35 to 45 times, a score of 3; 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 sample and/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 4 - Selected characteristics of wholesale rib cuts

Characteristic	Rib number	U.S. Grade: Choice	U.S. Grade: Good
Marbling score[a]	I	small+	slight+
	II	small	small
	III	small+	small-
	IV	small	slight
	V	small+	slight
	VI	modest-	slight+
Carcass weight, kg			
Hot	I	290.0	307.0
	II	266.0	278.0
	III	343.0	353.0
	IV	344.0	237.0
	V	347.0	314.0
	VI	234.0	232.0
	Avg	304.0	287.0
Chilled	I	286.0	304.0
	II	264.0	275.0
	III	337.0	349.0
	IV	339.0	235.0
	V	341.0	310.0
	VI	229.0	228.0
	Avg	299.0	284.0
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
	Avg	13.72	13.44

Table 4 - (Concluded)

Characteristic	Rib number	U.S. Grade	
		Choice	Good
Aging time, days	I	6.0	6.0
	II	12.0	8.0
	III	12.0	9.0
	IV	13.0	8.0
	V	6.0	6.0
	VI	8.0	9.0
	Avg	9.5	7.7
Yield grade	I	3.0	3.0
	II	2.0	2.0
	III	3.0	3.0
	IV	2.0	2.0
	V	4.0	3.0
	VI	4.0	3.0
	Avg	3.0	2.7
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
	Avg	0.97	0.90

[a] 6=modest, 7=small, 8=slight, (USDA, AMS. June 1976)

Table 5 - Means, standard error, F-values and LSD's for selected measurements by steak position

Measurements		Position[a] 1	2	3	4	5	6	7	8	F-value	LSD
Rib eye area, sq cm	$\bar{x}$	41.7	47.7	54.6	60.0	68.1	73.5	76.6	83.0	154.58**	3.29
	$s_{\bar{x}}$	± 1.17	± 1.17	± 1.17	± 1.17	± 1.17	± 1.17	± 1.17	± 1.17		
Length of steak, cm	$\bar{x}$	16.0	16.5	16.7	16.7	17.1	17.5	17.2	17.2	6.35**	0.53
	$s_{\bar{x}}$	± 0.19	± 0.19	± 0.19	± 0.19	± 0.19	± 0.19	± 0.19	± 0.19		
Width of steak, cm	$\bar{x}$	8.5	8.5	8.6	8.7	8.8	8.9	8.7	8.4	1.91	
	$s_{\bar{x}}$	± 0.11	± 0.11	± 0.11	± 0.11	± 0.11	± 0.11	± 0.11	± 0.11		
Thickness of steak, cm	$\bar{x}$	3.0	2.9	2.9	3.0	2.9	3.0	2.9	2.9	0.97	
	$s_{\bar{x}}$	± 0.05	± 0.05	± 0.05	± 0.05	± 0.05	± 0.05	± 0.05	± 0.05		
Initial weight, g	$\bar{x}$	358.1	343.4	386.2	368.7	373.8	391.5	359.8	360.0	1.73	
	$s_{\bar{x}}$	±12.04	±12.04	±12.04	±12.04	±12.04	±12.04	±12.04	±12.04		
Steak thaw loss, %	$\bar{x}$	0.70	1.02	0.94	1.10	1.25	0.97	1.14	0.86	2.38*	0.45
	$s_{\bar{x}}$	± 0.11	± 0.16	± 0.12	± 0.12	± 0.11	± 0.12	± 0.11	± 0.11		
Cooking time, min	$\bar{x}$	35.1	35.7	34.0	31.2	32.0	34.0	31.1	31.0	1.92	
	$s_{\bar{x}}$	± 1.16	± 1.16	± 1.16	± 1.16	± 1.16	± 1.16	± 1.16	± 1.16		

Table 5 -(continued)

Measurements		Position[a] 1	2	3	4	5	6	7	8	F-value	LSD
Cooking losses, %											
Total	$\bar{x}$	11.9	12.2	11.2	11.2	12.0	13.5	12.6	13.1	3.48**	1.29
	$s_{\bar{x}}$	± 0.44	± 0.44	± 0.44	± 0.44	± 0.46	± 0.44	± 0.46	± 0.44		
Volatile	$\bar{x}$	10.0	9.4	8.5	8.4	8.6	8.7	8.2	8.2	1.94	
	$s_{\bar{x}}$	± 0.45	± 0.45	± 0.45	± 0.45	± 0.47	± 0.45	± 0.47	± 0.45		
Drip	$\bar{x}$	1.9	2.8	2.8	2.8	3.4	4.7	4.3	4.7	13.31**	0.84
	$s_{\bar{x}}$	± 0.29	± 0.29	± 0.29	± 0.29	± 0.30	± 0.29	± 0.30	± 0.29		
pH											
Raw	$\bar{x}$		5.47			5.45			5.46	1.44	
	$s_{\bar{x}}$		± 0.01			± 0.01			± 0.01		
Cooked	$\bar{x}$	5.60	5.60	5.57	5.56	5.58	5.58	5.60	5.59	1.03	
	$s_{\bar{x}}$	± 0.01	± 0.01	± 0.01	± 0.01	± 0.01	± 0.01	± 0.01	± 0.01		
Warner-Bratzler shear, kg/1.3-cm core	$\bar{x}$	2.3	2.3	2.0	2.3	2.0	2.0	2.2	2.0	3.03**	0.23
	$s_{\bar{x}}$	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08		
Total moisture, %											
Raw (AOAC)	$\bar{x}$		70.8			72.7			73.0	3.58**	1.83
	$s_{\bar{x}}$		± 0.65			± 0.65			± 0.65		

Table 5 -(continued)

Measurements		Position[a] 1	2	3	4	5	6	7	8	F-value	LSD
Total moisture, %											
Cooked (AOAC)	$\bar{x}$	63.2	63.9	65.5	65.5	65.3	65.5	66.6	65.5	2.37*	1.94
	$s_{\bar{x}}$	± 0.69	± 0.69	± 0.69	± 0.69	± 0.69	± 0.69	± 0.69	± 0.69		
Brabender	$\bar{x}$	64.6	64.4	66.1	65.3	66.5	66.4	67.2	66.8	2.82*	1.69
	$s_{\bar{x}}$	± 0.60	± 0.60	± 0.60	± 0.60	± 0.60	± 0.60	± 0.60	± 0.60		
Ether extract, %											
Raw	$\bar{x}$		6.2			5.1			4.3	4.94**	1.21
	$s_{\bar{x}}$		± 0.43			± 0.43			± 0.43		
Cooked	$\bar{x}$	11.9	11.0	9.9	10.1	9.7	8.7	8.2	7.8	4.50**	1.83
	$s_{\bar{x}}$	± 0.65	± 0.65	± 0.65	± 0.65	± 0.65	± 0.65	± 0.65	± 0.65		
Water holding capacity[b]	$\bar{x}$	0.56	0.55	0.58	0.55	0.54	0.58	0.58	0.51	1.36	
	$s_{\bar{x}}$	± 0.02	± 0.02	± 0.02	± 0.02	± 0.02	± 0.02	± 0.02	± 0.02		
Sensory scores, 5 - 1[c]	$\bar{x}$	4.4	4.1	4.3	4.3	4.3	4.2	4.2	4.4	1.31	
Flavor	$s_{\bar{x}}$	± 0.09	± 0.09	± 0.09	± 0.09	± 0.09	± 0.09	± 0.09	± 0.09		

Table 5 - (concluded)

Measurements		Position[a] 1	2	3	4	5	6	7	8	F-value	LSD
Sensory scores, 5 - 1[c]											
Juiciness	$\bar{x}$	4.4	4.1	4.4	4.5	4.3	4.1	4.2	4.3	1.90	
	$s_{\bar{x}}$	±0.10	± 0.10	± 0.10	± 0.10	± 0.10	± 0.10	± 0.10	± 0.10		
Tenderness	$\bar{x}$	4.2	4.4	4.2	4.5	4.5	4.5	4.5	4.7	4.77**	0.20
	$s_{\bar{x}}$	±0.07	± 0.07	± 0.07	± 0.07	± 0.07	± 0.07	± 0.07	± 0.07		

[a] Data for U.S. Choice and U.S. good grades combined

[b] 1.0 - (expressible liquid index); the larger the value, the greater the amount of liquid expressed

[c] 5, (rich rare beef flavor, juicy or tender); 1, (no beef flavor, dry or tough)

*, $P < 0.05$

**, $P < 0.01$

Table 6 - Rib eye area of beef rib steaks, sq. cm.

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	46.3	42.2
	2	58.5	44.4
	3	65.3	53.9
	4	67.8	61.2
	5	81.5	68.8
	6	86.7	69.8
	7	89.6	74.1
	8	95.5	83.4
	Avg	73.9	62.2
II	1	38.1	44.4
	2	43.7	51.5
	3	51.3	58.8
	4	55.4	64.1
	5	61.3	77.9
	6	62.8	80.3
	7	65.3	83.4
	8	72.3	88.1
	Avg	56.3	68.6
III	1	41.3	23.8
	2	41.9	41.1
	3	57.1	51.4
	4	60.1	60.9
	5	65.1	69.1
	6	74.2	75.5
	7	81.9	77.9
	8	79.8	81.5
	Avg	62.7	60.1

Table 6 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	69.6	42.2
	2	81.2	45.8
	3	84.5	50.5
	4	91.2	55.2
	5	91.5	66.4
	6	96.7	73.3
	7	105.6	72.0
	8	107.7	80.6
	Avg	91.0	60.7
V	1	44.4	38.4
	2	48.8	44.3
	3	53.9	52.3
	4	61.6	55.3
	5	72.6	63.8
	6	81.5	73.2
	7	83.0	72.2
	8	92.0	88.1
	Avg	67.2	60.9
VI	1	29.1	40.5
	2	28.1	42.6
	3	33.5	42.3
	4	37.3	49.6
	5	38.2	60.8
	6	46.5	61.0
	7	51.6	62.4
	8	57.8	69.2
	Avg	40.3	53.5

Table 7 - Length of beef rib steaks, cm

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	17.0	16.0
	2	18.0	16.5
	3	18.0	17.5
	4	18.0	17.5
	5	18.0	17.5
	6	19.0	17.5
	7	19.0	17.5
	8	19.5	17.4
	Avg	18.3	17.1
II	1	16.0	15.5
	2	16.3	15.5
	3	16.4	17.0
	4	15.4	15.9
	5	15.8	17.2
	6	16.0	18.8
	7	15.5	17.7
	8	16.0	17.3
	Avg	15.9	17.1
III	1	18.0	15.0
	2	16.5	16.2
	3	17.9	17.5
	4	17.8	18.0
	5	18.0	18.3
	6	18.8	18.4
	7	17.6	18.5
	8	17.0	17.5
	Avg	17.7	17.4

Table 7 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	17.8	16.5
	2	17.5	15.0
	3	18.0	15.5
	4	17.5	16.5
	5	19.1	16.5
	6	18.9	16.0
	7	19.0	16.0
	8	20.5	16.0
	Avg	18.5	16.0
V	1	15.5	16.0
	2	16.7	16.0
	3	16.0	16.5
	4	17.0	16.5
	5	17.0	16.0
	6	17.5	16.2
	7	17.5	16.0
	8	17.0	17.0
	Avg	16.8	16.3
VI	1	14.5	14.5
	2	14.5	17.0
	3	14.5	15.5
	4	15.0	15.5
	5	15.5	16.5
	6	16.0	17.0
	7	14.5	17.3
	8	15.5	16.5
	Avg	15.0	16.2

Table 8 - Width of beef rib steaks, cm

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	9.0	8.0
	2	8.5	8.5
	3	9.5	7.5
	4	9.5	8.0
	5	9.5	8.0
	6	9.5	8.0
	7	9.0	8.0
	8	9.5	8.0
	Avg	9.2	8.0
II	1	8.6	8.0
	2	7.7	9.0
	3	8.0	9.5
	4	7.8	9.5
	5	8.2	9.4
	6	7.4	9.6
	7	7.5	9.0
	8	7.0	9.5
	Avg	7.8	9.2
III	1	9.0	8.6
	2	8.0	9.5
	3	8.6	8.8
	4	8.6	9.0
	5	8.6	9.2
	6	8.8	9.6
	7	9.0	9.2
	8	7.5	8.7
	Avg	8.5	9.1

Table 8 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	9.3	8.0
	2	9.0	8.2
	3	9.0	8.2
	4	9.3	8.3
	5	9.2	8.5
	6	9.3	9.0
	7	9.0	7.8
	8	8.8	8.2
	Avg	9.1	8.3
V	1	9.3	9.0
	2	9.5	9.0
	3	11.0	8.8
	4	9.5	9.4
	5	10.0	8.8
	6	10.0	9.0
	7	10.0	10.0
	8	9.5	8.5
	Avg	9.8	9.1
VI	1	7.0	8.0
	2	7.5	8.0
	3	7.2	7.5
	4	7.5	8.3
	5	7.5	8.5
	6	7.8	8.7
	7	7.8	8.3
	8	8.0	8.2
	Avg	7.5	8.2

Table 9 - Thickness of beef rib steaks, cm

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	3.0	3.0
	2	3.0	3.0
	3	3.0	3.0
	4	3.0	3.0
	5	2.8	3.0
	6	3.3	3.3
	7	2.5	2.5
	8	3.0	3.0
	Avg	2.9	3.0
II	1	3.0	2.7
	2	2.9	3.0
	3	2.9	2.7
	4	3.0	3.0
	5	2.9	2.9
	6	2.8	3.0
	7	3.0	3.1
	8	2.9	3.0
	Avg	2.9	2.9
III	1	2.8	2.9
	2	2.8	3.1
	3	3.0	2.9
	4	3.0	3.0
	5	3.0	2.9
	6	3.0	2.9
	7	3.0	2.9
	8	3.0	2.9
	Avg	2.9	2.9

Table 9 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	3.0	3.5
	2	2.8	2.9
	3	2.8	2.9
	4	2.8	3.0
	5	2.8	3.0
	6	3.0	3.0
	7	3.0	2.9
	8	3.0	2.9
	Avg	2.9	3.0
V	1	2.8	3.0
	2	3.0	3.0
	3	2.9	3.0
	4	2.8	3.0
	5	3.0	3.2
	6	3.0	3.0
	7	3.0	3.0
	8	3.0	2.6
	Avg	2.9	3.0
VI	1	3.5	2.9
	2	2.8	2.8
	3	3.0	3.0
	4	2.9	3.0
	5	2.8	3.0
	6	2.8	3.0
	7	2.7	2.7
	8	2.5	2.7
	Avg	2.9	2.9

Table 10 - Initial weight of beef rib steaks, g

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	457.0	345.0
	2	447.0	343.0
	3	465.0	383.0
	4	432.0	369.0
	5	395.0	374.0
	6	497.0	428.0
	7	426.0	328.0
	8	533.0	377.0
	Avg	456.5	368.4
II	1	378.0	325.0
	2	317.0	371.0
	3	356.0	482.0
	4	336.0	416.0
	5	341.0	391.0
	6	303.0	433.0
	7	317.0	447.0
	8	300.0	526.0
	Avg	331.0	423.9
III	1	408.0	297.0
	2	288.0	357.0
	3	458.0	376.0
	4	333.0	418.0
	5	407.0	378.0
	6	390.0	417.0
	7	371.0	411.0
	8	266.0	355.0
	Avg	365.0	376.1

Table 10 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	412.0	384.0
	2	472.0	272.0
	3	390.0	296.0
	4	443.0	349.0
	5	481.0	297.0
	6	459.0	337.0
	7	436.0	257.0
	8	423.0	322.0
	Avg	439.5	314.2
V	1	307.0	390.0
	2	353.0	335.0
	3	465.0	368.0
	4	363.0	333.0
	5	400.0	379.0
	6	435.0	383.0
	7	419.0	330.0
	8	393.0	275.0
	Avg	392.0	349.1
VI	1	264.0	333.0
	2	252.0	314.0
	3	270.0	326.0
	4	272.0	361.0
	5	263.0	380.0
	6	263.0	353.0
	7	264.0	312.0
	8	254.0	295.0
	Avg	262.7	334.2

Table 11 - Cooking time for beef rib steaks, min.

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	41	36
	2	36	37
	3	35	33
	4	38	36
	5	35	34
	6	42	39
	7	37	34
	8	46	39
	Avg	39	36
II	1	35	35
	2	27	33
	3	35	40
	4	29	37
	5	29	32
	6	28	32
	7	33	32
	8	29	39
	Avg	31	35
III	1	37	30
	2	27	33
	3	38	32
	4	26	32
	5	35	29
	6	35	35
	7	30	30
	8	24	29
	Avg	32	31

Table 11 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	32	30
	2	38	27
	3	31	29
	4	34	33
	5	35	27
	6	32	30
	7	35	23
	8	31	33
	Avg	34	29
V	1	29	37
	2	32	33
	3	39	36
	4	25	26
	5	31	37
	6	38	37
	7	37	25
	8	28	23
	Avg	32	31
VI	1	35	44
	2	28	34
	3	26	34
	4	29	29
	5	31	34
	6	27	33
	7	23	26
	8	23	27
	Avg	28	33

Table 12 - Percentage total cooking loss of beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	12.9	11.1
	2	11.2	13.5
	3	8.8	8.4
	4	13.4	11.5
	5	12.9	12.2
	6	15.0	14.2
	7	14.1	14.6
	8	14.1	16.0
	Avg	12.8	12.7
II	1	10.3	11.8
	2	9.1	11.7
	3	11.8	12.4
	4	9.0	11.2
	5	10.0	10.6
	6	12.3	13.4
	7	13.0	10.9
	8	15.3	12.5
	Avg	11.3	11.8
III	1	11.9	13.3
	2	11.3	14.6
	3	13.0	12.9
	4	9.2	13.5
	5	12.4	12.9
	6	13.5	14.5
	7	12.0	12.3
	8	11.7	15.1
	Avg	11.9	13.6

Table 12 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	11.2	8.4
	2	13.7	9.5
	3	11.7	8.1
	4	12.8	12.5
	5	11.6	9.7
	6	12.8	9.8
	7	14.4	10.5
	8	13.1	12.2
	Avg	12.7	10.1
V	1	11.5	13.8
	2	12.4	14.5
	3	14.1	14.1
	4	8.8	12.6
	5	11.2	14.8
	6	14.7	15.9
	7	--	13.0
	8	11.0	12.7
	Avg	12.0	13.9
VI	1	13.3	13.3
	2	11.9	12.7
	3	8.6	10.8
	4	10.8	8.7
	5	14.7	--
	6	13.0	12.6
	7	12.2	10.7
	8	11.6	11.6
	Avg	12.0	11.5

Table 13 - Percentage volatile cooking loss of beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	10.0	8.2
	2	8.2	9.1
	3	6.8	5.5
	4	9.7	8.5
	5	8.8	7.9
	6	9.7	7.3
	7	8.6	9.9
	8	8.4	12.6
	Avg	8.8	8.6
II	1	8.2	11.7
	2	6.3	9.0
	3	8.4	10.5
	4	6.6	10.2
	5	7.1	9.0
	6	8.6	8.2
	7	9.2	7.7
	8	8.7	8.8
	Avg	7.9	9.4
III	1	11.4	9.2
	2	9.2	10.1
	3	10.4	8.9
	4	6.4	8.7
	5	9.2	8.6
	6	8.9	8.2
	7	8.7	6.9
	8	3.0	8.7
	Avg	8.4	8.7

Table 13 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	8.3	7.3
	2	11.2	8.0
	3	9.1	8.1
	4	9.6	10.2
	5	8.4	7.7
	6	8.4	8.0
	7	9.5	8.1
	8	10.0	8.1
	Avg	9.3	8.2
V	1	10.3	10.5
	2	9.6	10.4
	3	10.3	9.7
	4	7.1	8.4
	5	8.5	10.5
	6	10.3	10.4
	7	--	6.8
	8	8.2	7.2
	Avg	9.2	9.2
VI	1	12.1	12.6
	2	10.2	11.9
	3	5.2	8.6
	4	8.2	7.3
	5	8.5	—
	6	8.8	8.0
	7	6.8	7.2
	8	6.8	8.2
	Avg	8.3	9.1

Table 14 - Percentage drip loss of beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	2.9	3.0
	2	3.0	4.4
	3	2.0	3.0
	4	3.8	3.0
	5	4.1	4.3
	6	5.2	6.9
	7	5.5	4.7
	8	5.7	3.5
	Avg	4.0	4.1
II	1	2.1	0.3
	2	2.8	2.7
	3	3.4	1.9
	4	2.4	1.0
	5	2.9	1.6
	6	3.6	5.2
	7	3.8	3.2
	8	6.7	3.6
	Avg	3.5	2.4
III	1	0.5	4.0
	2	2.1	4.5
	3	2.6	4.0
	4	2.8	4.8
	5	3.2	4.3
	6	4.7	6.2
	7	3.3	5.4
	8	8.7	4.5
	Avg	3.5	4.7

Table 14 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	2.9	1.0
	2	2.6	1.5
	3	2.6	0.0
	4	3.2	2.3
	5	3.2	2.0
	6	4.4	1.8
	7	4.9	2.3
	8	3.1	4.1
	Avg	3.4	1.9
V	1	1.3	3.3
	2	2.8	4.2
	3	3.9	4.3
	4	1.6	4.2
	5	2.7	4.3
	6	4.4	5.5
	7	--	6.2
	8	2.8	5.4
	Avg	2.8	4.7
VI	1	1.1	0.6
	2	1.6	1.0
	3	3.4	2.2
	4	2.6	1.4
	5	6.2	--
	6	4.2	4.6
	7	5.3	3.5
	8	4.8	3.4
	Avg	3.7	2.4

Table 15 - pH of raw beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	2'	--	--
	5'	--	--
	8'	--	--
	Avg	--	--
II	2'	--	--
	5'	--	--
	8'	--	--
	Avg	--	--
III	2'	5.5	5.6
	5'	5.4	5.5
	8'	5.5	5.5
	Avg	5.5	5.5
IV	2'	5.4	5.5
	5'	5.4	5.5
	8'	5.4	5.5
	Avg	5.4	5.5
V	2'	5.5	5.5
	5'	5.5	5.5
	8'	5.5	5.5
	Avg	5.5	5.5
VI	2'	5.4	5.4
	5'	5.4	5.4
	8'	5.4	5.4
	Avg	5.4	5.4

Table 16 - pH of cooked beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	5.6	5.6
	2	5.6	5.6
	3	5.6	5.6
	4	5.6	5.6
	5	5.6	5.6
	6	5.7	5.6
	7	5.7	5.6
	8	5.6	5.6
	Avg	5.6	5.6
II	1	5.6	5.6
	2	5.6	5.6
	3	5.6	5.6
	4	5.5	5.6
	5	5.5	5.6
	6	5.6	5.6
	7	5.6	5.6
	8	5.6	5.6
	Avg	5.6	5.6
III	1	5.5	5.7
	2	5.5	5.6
	3	5.5	5.6
	4	5.4	5.6
	5	5.5	5.6
	6	5.4	5.6
	7	5.7	5.5
	8	5.5	5.5
	Avg	5.5	5.6

Table 16 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	5.5	5.6
	2	5.6	5.6
	3	5.5	5.6
	4	5.5	5.6
	5	5.5	5.6
	6	5.5	5.6
	7	5.5	5.6
	8	5.5	5.5
	Avg	5.5	5.6
V	1	5.6	5.6
	2	5.6	5.6
	3	5.5	5.6
	4	5.4	5.6
	5	5.6	5.6
	6	5.6	5.5
	7	5.6	5.5
	8	5.6	5.7
	Avg	5.6	5.6
VI	1	5.7	5.6
	2	5.7	5.6
	3	5.6	5.6
	4	5.7	5.6
	5	5.7	5.6
	6	5.6	5.7
	7	5.7	5.6
	8	5.7	5.7
	Avg	5.7	5.6

Table 17 - Warner-Bratzler shear values, kg/1.3-cm core

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	2.8	3.8
	2	2.5	3.4
	3	2.3	2.6
	4	3.1	3.1
	5	2.0	2.2
	6	2.3	3.0
	7	1.9	2.7
	8	2.3	2.5
	Avg	2.4	2.9
II	1	2.2	2.2
	2	2.1	2.1
	3	1.5	1.8
	4	2.3	2.3
	5	2.1	2.3
	6	2.0	1.8
	7	1.8	2.3
	8	1.9	2.5
	Avg	2.0	2.2
III	1	1.8	2.6
	2	2.6	2.6
	3	1.7	2.7
	4	2.1	2.3
	5	1.8	2.0
	6	1.7	2.3
	7	2.0	2.5
	8	1.9	2.2
	Avg	2.0	2.4

Table 17 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	2.0	1.4
	2	2.0	1.4
	3	1.7	1.3
	4	1.7	2.0
	5	1.6	1.5
	6	1.7	1.3
	7	1.9	1.5
	8	1.4	1.4
	Avg	1.8	1.5
V	1	2.1	2.3
	2	2.3	2.2
	3	2.2	2.4
	4	2.3	2.5
	5	2.2	2.1
	6	1.9	2.0
	7	2.5	2.9
	8	2.8	1.8
	Avg	2.3	2.3
VI	1	2.3	2.0
	2	2.6	1.6
	3	2.0	2.3
	4	2.3	1.9
	5	2.0	2.2
	6	1.9	1.9
	7	2.1	1.8
	8	1.8	2.0
	Avg	2.1	2.0

Table 18 - Percentage total moisture of raw beef steaks, AOAC

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	2'	60.2	71.0
	5'	64.1	71.6
	8'	72.7	72.1
	Avg	65.7	71.6
II	2'	71.2	72.6
	5'	73.2	72.2
	8'	73.5	73.8
	Avg	72.6	72.9
III	2'	71.4	68.8
	5'	72.2	72.1
	8'	70.4	71.6
	Avg	71.3	70.8
IV	2'	66.2	75.2
	5'	74.6	78.1
	8'	71.8	75.0
	Avg	70.8	76.1
V	2'	72.4	73.1
	5'	72.5	73.1
	8'	70.5	74.8
	Avg	71.8	73.7
VI	2'	72.7	74.4
	5'	73.9	75.0
	8'	75.3	75.1
	Avg	74.0	74.8

Table 1º - Percentage total moisture of cooked beef rib steaks, AOAC

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	60.5	62.7
	2	63.2	61.9
	3	64.8	66.2
	4	63.0	63.3
	5	65.0	62.0
	6	64.1	54.7
	7	65.8	63.4
	8	64.0	63.4
	Avg	63.8	62.2
II	1	66.4	63.0
	2	63.7	63.7
	3	65.4	63.7
	4	66.4	61.7
	5	62.7	65.2
	6	65.1	66.6
	7	65.0	66.4
	8	65.3	65.0
	Avg	65.0	64.4
III	1	64.6	56.2
	2	64.9	59.5
	3	62.9	61.9
	4	66.2	63.3
	5	67.7	57.2
	6	66.0	64.7
	7	66.0	66.3
	8	64.6	62.2
	Avg	65.4	61.4

Table 19 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	66.5	68.6
	2	68.9	69.1
	3	68.1	70.0
	4	68.0	72.5
	5	70.8	75.0
	6	68.7	71.1
	7	72.0	65.0
	8	69.2	66.4
	Avg	69.0	69.7
V	1	64.5	64.3
	2	62.3	60.8
	3	66.0	64.0
	4	63.9	67.5
	5	63.2	64.3
	6	66.4	65.2
	7	67.0	71.9
	8	65.3	66.8
	Avg	64.8	65.6
VI	1	57.0	64.3
	2	64.3	64.4
	3	67.2	65.8
	4	60.8	69.1
	5	64.5	66.6
	6	67.1	66.2
	7	64.3	66.1
	8	66.3	67.9
	Avg	63.9	66.3

Table 20-Percentage total moisture of cooked beef rib steaks, Brabender

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	62.8	64.7
	2	64.8	61.9
	3	67.7	68.2
	4	64.5	63.8
	5	65.7	63.5
	6	65.5	66.2
	7	65.6	64.0
	8	65.7	65.1
	Avg	65.3	64.7
II	1	68.4	65.2
	2	64.8	67.1
	3	67.1	64.1
	4	68.6	64.8
	5	63.8	66.6
	6	66.5	66.7
	7	66.1	66.1
	8	68.0	65.8
	Avg	66.7	65.8
III	1	64.9	55.6
	2	63.9	60.0
	3	62.6	61.0
	4	65.5	63.5
	5	65.2	65.5
	6	67.3	65.2
	7	64.5	66.9
	8	66.8	62.8
	Avg	65.1	62.6

Table 20 -(Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	67.7	69.0
	2	65.2	69.4
	3	66.5	70.5
	4	64.0	69.8
	5	68.1	69.0
	6	66.2	69.2
	7	69.3	67.4
	8	67.6	69.0
	Avg	66.8	69.2
V	1	67.1	67.3
	2	63.3	61.9
	3	67.5	65.8
	4	66.5	66.2
	5	66.6	64.4
	6	66.3	64.9
	7	68.0	71.6
	8	66.6	67.7
	Avg	66.5	66.2
VI	1	59.2	62.8
	2	65.4	65.6
	3	64.8	67.9
	4	58.8	67.8
	5	64.5	63.5
	6	65.8	66.8
	7	68.1	68.4
	8	67.3	69.3
	Avg	64.2	66.5

Table 21 - Ether extract of raw beef rib steaks, AOAC

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	2'	10.4	5.3
	5'	10.7	4.7
	8'	4.4	4.0
	Avg	8.5	4.7
II	2'	4.9	5.1
	5'	3.7	5.6
	8'	3.1	3.9
	Avg	3.9	4.9
III	2'	5.5	11.0
	5'	4.8	5.2
	8'	6.5	6.3
	Avg	5.6	7.5
IV	2'	5.2	3.1
	5'	4.3	2.5
	8'	5.2	2.8
	Avg	4.9	2.8
V	2'	4.5	5.0
	5'	3.7	5.1
	8'	4.5	2.3
	Avg	4.2	4.1
VI	2'	8.4	6.4
	5'	6.2	5.2
	8'	4.2	4.8
	Avg	6.3	5.5

Table 22- Ether extract for cooked beef rib steaks, AOAC

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	12.5	10.9
	2	9.0	12.5
	3	7.3	5.0
	4	10.4	10.2
	5	8.4	11.8
	6	8.9	9.7
	7	7.7	8.6
	8	7.6	7.3
	Avg	9.0	9.5
II	1	6.5	12.6
	2	12.2	10.3
	3	8.4	13.6
	4	7.6	13.0
	5	11.6	9.7
	6	8.1	8.8
	7	8.4	10.6
	8	7.6	8.7
	Avg	8.8	10.9
III	1	11.4	21.6
	2	10.0	15.6
	3	12.2	14.9
	4	10.5	14.2
	5	9.4	8.4
	6	7.5	10.8
	7	7.5	8.5
	8	8.4	11.5
	Avg	9.6	13.2

Table 22 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	10.1	8.1
	2	7.5	7.0
	3	8.1	6.0
	4	8.3	5.8
	5	10.1	6.8
	6	8.5	4.9
	7	4.8	8.3
	8	8.3	6.7
	Avg	8.2	6.7
V	1	8.6	7.1
	2	12.0	13.6
	3	7.0	12.9
	4	7.1	9.0
	5	9.1	9.2
	6	7.3	9.0
	7	7.0	3.3
	8	6.6	6.1
	Avg	8.1	8.8
VI	1	21.5	12.2
	2	12.8	9.3
	3	13.8	9.6
	4	16.8	7.8
	5	14.5	7.5
	6	9.9	10.8
	7	15.5	8.0
	8	9.6	5.5
	Avg	14.3	8.8

Table 23 - Water holding capacity[a] of beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	0.48	0.55
	2	0.60	0.51
	3	0.59	0.61
	4	0.52	0.69
	5	0.60	0.54
	6	0.59	0.56
	7	0.65	0.56
	8	0.47	0.50
	Avg	0.56	0.57
II	1	0.54	0.56
	2	0.53	0.59
	3	0.56	0.54
	4	0.47	0.59
	5	0.51	0.50
	6	0.56	0.57
	7	0.58	0.55
	8	0.53	0.54
	Avg	0.54	0.56
III	1	0.53	0.54
	2	0.40	0.51
	3	0.56	0.48
	4	0.60	0.32
	5	0.52	0.44
	6	0.59	0.57
	7	0.59	0.47
	8	0.60	0.52
	Avg	0.55	0.48

Table 23 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	0.54	0.50
	2	0.52	0.63
	3	0.56	0.51
	4	0.54	0.62
	5	0.55	0.39
	6	0.60	0.38
	7	0.39	0.66
	8	0.44	0.50
	Avg	0.52	0.52
V	1	0.53	0.57
	2	0.59	0.59
	3	0.67	0.66
	4	0.43	0.54
	5	0.58	0.53
	6	0.64	0.63
	7	0.56	0.60
	8	0.30	0.46
	Avg	0.54	0.57
VI	1	0.65	0.71
	2	0.63	0.49
	3	0.56	0.65
	4	0.68	0.63
	5	0.57	0.73
	6	0.61	0.63
	7	0.64	0.67
	8	0.56	0.67
	Avg	0.61	0.65

[a] 1.0 - (expressible liquid index); the larger the value, the greater the amount of liquid expressed.

Table 24- Flavor scores[a] for beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	4.4	3.4
	2	3.9	3.6
	3	4.3	3.7
	4	4.3	4.0
	5	3.7	3.7
	6	4.1	3.9
	7	4.0	3.4
	8	4.6	4.0
	Avg	4.2	3.7
II	1	4.7	4.0
	2	4.2	4.2
	3	3.7	4.3
	4	4.3	4.6
	5	4.6	3.9
	6	3.6	4.4
	7	4.1	4.1
	8	4.3	4.2
	Avg	4.2	4.2
III	1	4.5	4.7
	2	4.0	4.6
	3	5.0	4.4
	4	4.8	3.9
	5	5.0	4.3
	6	4.5	4.0
	7	4.4	4.3
	8	4.3	4.4
	Avg	4.6	4.3

Table 24 -(Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	4.9	4.6
	2	4.6	4.0
	3	4.6	4.3
	4	4.3	4.6
	5	4.6	3.4
	6	4.9	3.9
	7	4.6	4.1
	8	4.6	4.4
	Avg	4.6	4.2
V	1	4.7	4.7
	2	4.7	4.5
	3	4.3	4.5
	4	4.0	4.2
	5	4.5	4.8
	6	4.5	4.3
	7	4.0	4.5
	8	4.2	4.8
	Avg	4.4	4.5
VI	1	4.3	4.2
	2	3.7	3.8
	3	4.3	4.5
	4	4.4	4.6
	5	4.5	4.6
	6	4.5	4.4
	7	4.6	4.4
	8	4.6	4.7
	Avg	4.4	4.4

[a]Scale 1-no beef flavor--5-rich rare beef flavor

Table 25 - Juiciness scores[a] for beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	4.7	3.6
	2	4.3	3.6
	3	4.7	3.1
	4	4.3	3.9
	5	4.0	3.4
	6	3.7	4.0
	7	3.9	3.7
	8	4.4	4.3
	Avg	4.3	3.7
II	1	4.7	3.9
	2	4.3	4.0
	3	3.7	4.0
	4	4.6	4.6
	5	3.9	4.0
	6	3.4	4.3
	7	4.1	3.9
	8	3.7	4.0
	Avg	4.1	4.1
III	1	4.8	4.2
	2	4.0	4.6
	3	4.7	4.4
	4	4.8	4.3
	5	4.6	4.5
	6	4.5	4.2
	7	4.1	4.3
	8	4.3	4.1
	Avg	4.5	4.3

Table 25--(Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	4.7	4.9
	2	4.4	4.4
	3	4.3	4.9
	4	4.1	4.7
	5	4.9	4.0
	6	4.6	3.7
	7	4.7	4.1
	8	4.6	4.3
	Avg	4.5	4.4
V	1	4.2	4.5
	2	3.8	4.3
	3	4.3	4.8
	4	4.0	4.7
	5	3.8	4.8
	6	4.3	4.3
	7	4.0	4.8
	8	4.2	4.4
	Avg	4.1	4.6
VI	1	4.3	4.0
	2	3.8	3.5
	3	4.7	4.7
	4	4.9	5.0
	5	4.7	5.0
	6	4.3	4.4
	7	4.4	4.4
	8	4.9	4.8
	Avg	4.5	4.5

[a]Scale 1-Dry--5-Juicy

Table 26-Tenderness scores[a] for beef rib steaks

Rib number	Steak number	U.S. Grade	
		Choice	Good
I	1	4.1	4.1
	2	4.3	4.1
	3	4.1	3.3
	4	4.3	4.1
	5	4.3	4.0
	6	4.3	3.9
	7	4.4	3.9
	8	4.7	4.4
	Avg	4.3	4.0
II	1	4.6	4.0
	2	4.5	4.5
	3	4.5	4.7
	4	4.6	4.4
	5	4.9	4.1
	6	4.6	4.1
	7	4.7	4.0
	8	4.9	4.0
	Avg	4.7	4.2
III	1	4.3	3.8
	2	4.4	3.9
	3	4.7	3.6
	4	4.7	3.9
	5	4.7	4.2
	6	4.8	4.2
	7	4.7	4.0
	8	4.8	4.0
	Avg	4.6	4.0

Table 26 - (Concluded)

Rib number	Steak number	U.S. Grade	
		Choice	Good
IV	1	4.6	5.0
	2	4.6	5.0
	3	4.9	4.9
	4	4.7	4.7
	5	4.7	4.7
	6	4.7	4.9
	7	4.9	4.9
	8	4.9	5.0
	Avg	4.8	4.9
V	1	4.3	4.3
	2	4.2	4.8
	3	4.3	4.2
	4	4.4	4.7
	5	4.7	4.6
	6	4.7	4.5
	7	4.5	4.5
	8	4.6	5.0
	Avg	4.5	4.6
VI	1	3.3	4.0
	2	4.0	4.8
	3	3.1	4.0
	4	4.4	4.6
	5	4.7	4.1
	6	4.8	4.6
	7	4.6	4.9
	8	4.9	5.0
	Avg	4.2	4.5

[a]Scale 1-Tough--5-Tender

Table 27 - Mean squares, F-values and levels of probability for objective and sensory measurements

Source of variation	DF	MS	F-value
Measurements			
Rib eye area, sq cm			
Grade[a]	1	421.68	0.34
Steak position[b]	7	2553.04	154.58**
G x S	7	13.32	0.81
Error A	10	1254.65	75.97
Error B	70	16.52	
Length of steak, cm			
Grade[a]	1	2.87	0.31
Steak position[b]	7	2.79	6.35**
G x S	7	0.26	0.59
Error A	10	9.30	21.21
Error B	70	0.44	
Width of steak, cm			
Grade[a]	1	0.04	0.01
Steak position[b]	7	0.29	1.91
G x S	7	0.26	1.70
Error A	10	4.36	28.86
Error B	70	0.15	
Thickness of steak, cm			
Grade[a]	1	0.04	3.11
Steak position[b]	7	0.03	0.97
G x S	7	0.008	0.27
Error A	10	0.01	0.40
Error B	70	0.03	
Initial weight, g			
Grade[a]	1	4395.62	0.17
Steak position[b]	7	3005.33	1.73
G x S	7	648.96	0.37
Error A	10	26400.86	15.19
Error B	70	1738.34	
Steak thaw loss, %			
Grade[a]	1	0.17	0.32
Steak position[b]	7	0.24	2.38*
G x S	7	0.28	2.80*
Error A	10	0.54	5.26
Error B	43	0.10	

Table 27 -(continued)

Source of variation	DF	MS	F-value
Cooking time, min			
Grade[a]	1	0.84	0.01
Steak position[b]	7	30.96	1.92
G x S	7	7.65	0.47
Error A	10	80.70	5.0
Error B	70	16.17	
Cooking losses, %			
Total			
Grade[a]	1	0.39	0.04
Steak position[b]	7	7.98	3.48**
G x S	7	1.60	0.70
Error A	10	9.42	4.11
Error B	68	2.29	
Volatile			
Grade[a]	1	1.12	0.57
Steak position[b]	7	4.70	1.94
G x S	7	1.88	0.78
Error A	10	1.97	0.82
Error B	68	2.42	
Drip			
Grade[a]	1	0.38	0.05
Steak position[b]	7	13.04	13.31**
G x S	7	1.15	1.18
Error A	10	6.91	7.05
Error B	68	0.98	
pH			
Raw			
Grade[a]	1	0.01	1.14
Steak position[b]	2	0.001	1.44
G x S	2	0.0004	0.48
Error A	6	0.009	10.10
Error B	12	0.0009	
Cooked			
Grade[a]	1	0.01	0.68
Steak position[b]	7	0.003	1.03
G x S	7	0.006	2.24*
Error A	10	0.02	7.32
Error B	70	0.002	
Warner-Bratzler shear, kg/1.3 cm core			
Grade[a]	1	0.32	0.28
Steak position[b]	7	0.24	3.03**
G x S	7	0.05	0.65
Error A	10	1.13	14.17
Error B	70	0.08	

Table 27 - (continued)

Source of variation	DF	MS	F-value
Total moisture, %			
Raw (AOAC)			
Grade[a]	1	46.24	2.56
Steak position[b]	2	18.25	3.58**
G x S	2	3.66	0.72
Error A	10	18.08	3.55
Error B	20	5.09	
Cooked (AOAC)			
Grade[a]	1	3.80	0.08
Steak position[b]	7	13.70	2.37*
G x S	7	2.63	0.46
Error A	10	50.88	8.80
Error B	70	5.78	
Brabender			
Grade[a]	1	0.09	0.004
Steak position[b]	7	12.07	2.82*
G x S	7	1.35	0.32
Error A	10	23.43	5.47
Error B	70	4.29	
Ether extract, %			
Raw			
Grade[a]	1	3.93	0.50
Steak position[b]	2	10.91	4.94**
G x S	2	0.09	0.04
Error A	10	7.87	3.56
Error B	20	2.21	
Cooked			
Grade[a]	1	0.001	0.0
Steak position[b]	7	23.16	4.50**
G x S	7	2.14	0.42
Error A	10	41.21	8.01
Error B	70	5.15	
Water holding capacity[c]			
Grade[a]	1	0.001	0.04
Steak position[b]	7	0.007	1.36
G x S	7	0.003	0.55
Error A	10	0.017	3.20
Error B	70	0.005	
Sensory scores, 5-1[d]			
Flavor			
Grade[a]	1	0.57	1.21
Steak position[b]	7	0.11	1.31
G x S	7	0.05	0.59
Error A	10	0.47	5.41
Error B	70	0.09	

Table 27 - (concluded)

Source of variation	DF	MS	F-value
Sensory scores, 5-1[d]			
Juiciness			
Grade[a]	1	0.08	0.14
Steak position[b]	7	0.22	1.90
G x S	7	0.06	0.51
Error A	10	0.60	5.22
Error B	70	0.11	
Tenderness			
Grade[a]	1	0.59	0.82
Steak position[b]	7	0.32	4.77**
G x S	7	0.10	1.44
Error A	10	0.72	10.65
Error B	70	0.07	

[a]Data for all steak position sombined

[b]Data for U.S. Choice and U.S. Good grades combined

[c]1.0 - (expressible liquid index); the larger the value, the greater the amount of liquid expressed

[d]5, (rich rare beef flavor, juicy or tender);

1, (no beef flavor, dry or tough)

*, $P<0.05$

**, $P<0.01$

Table 28 - F-values required for significance at the 5 and 1% levels of probability for certain combinations of degrees of freedom

Level of probability	DF	F-value
* P < 0.05	1,6	5.99
** P < 0.01	1.6	13.74
* P < 0.05	1,10	4.96
** P < 0.01	1,10	10.04
* P < 0.05	2,12	3.88
** P < 0.01	2,12	6.93
* P < 0.05	2,20	3.49
** P < 0.01	2,20	5.85
* P < 0.05	7,43	2.23
** P < 0.01	7,43	3.07
* P < 0.05	7,68	2.14
** P < 0.01	7,68	2.91
* P < 0.05	7,70	2.14
** P < 0.01	7,70	2.91

SELECTED CHARACTERISTICS OF USDA CHOICE AND GOOD BEEF RIB STEAKS

by

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B.A., Marycrest College, 1976

AN ABSTRACT OF A MASTER'S THESIS

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Current USDA beef grading standards went into effect on February 23, 1976. Those standards should provide slightly leaner beef in U.S. Prime and U.S. Choice grades than was available in those grades under the 1965 standards. U.S. Good beef now should be lean, but relatively tender with a more consistent eating quality than that formerly available. From the viewpoint of palatability, some researchers predicted that the 1976 standards will not offer significant improvements over the 1965 standards.

This study identified selected characteristics related to the eating quality of beef rib steaks from U.S. Choice and U.S. Good carcasses. Cooking time, cooking losses, sensory characteristics, ether extract, total moisture and pH were measured. Also, differences between the two grades for area of rib eye and for length and width of the steaks were studied. Steaks were cooked to an internal temperature of 60°C by modified roasting at 177°C.

Data were analyzed by analyses of variance for a split plot design, and least significant differences at the 5% level were calculated when F-values for effects of steak positions (anterior to posterior) in the wholesale rib were significant.

None of the measurements used to evaluate the steaks were affected significantly by grade. Rib eye area, length of rib steak, total and drip cooking losses, Warner-Bratzler shear values, sensory tenderness scores, percentage total moisture in raw and cooked muscle and ether extract from raw and cooked muscle were affected significantly ($P < 0.05$ or $P < 0.01$) by position of steaks in wholesale ribs.

Irrespective of grade, changes from the anterior to the posterior of the rib were (a) rib eye area increased; (b) length of rib steak increased; (c) total and drip cooking losses increased; (d) Warner-Bratzler shear values decreased; (e) sensory tenderness scores increased; (f) percentage total moisture increased and (g) percentage ether extract decreased.

In general, selected physical and sensory characteristics of beef rib steaks do not differ significantly between steaks from U.S. Choice and U.S. Good carcasses. Differences among steaks that are attributable to position in the wholesale rib from carcasses graded U.S. Choice and U.S. Good are small, but statistically significant. This confirms the importance of randomly assigning experimental treatments to steaks in the various positions in wholesale ribs.